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**Raquel Tsukada Lehmann and Christian Lehmann**

**Maastricht Economic and social Research institute on Innovation and Technology (UNU-MERIT)**
email: info@merit.unu.edu | website: http://www.merit.unu.edu

**Maastricht Graduate School of Governance (MGSoG)**
email: info-governance@maastrichtuniversity.nl | website: http://www.maastrichtuniversity.nl/governance

Boschstraat 24, 6211 AX Maastricht, The Netherlands
Tel: (31) (43) 388 44 00

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# The Impact of Rainwater Harvesting on Household Labor Supply*

Raquel Tsukada Lehmann† Christian Lehmann‡

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**Abstract**

This paper explores the effects of rainwater harvesting (RWH) on aggregate household labor supply in areas prone to droughts. Using a Brazilian survey on rainwater harvesting, we find that having a RWH infrastructure at the homestead increases household wellbeing through three channels: (i) a direct time allocation effect - since households spend less time fetching water from distant sources, the time saved is allocated to other productive activities; (ii) a direct input effect - since water is an essential input for agricultural households and more labor hours are available, the cistern technology may contribute to increase the household's agricultural production. Both direct effects associate the labor-saving technology with an increase in productive labor supply. Finally, there is (iii) an indirect consumption effect - as a consequence of larger production, households can exchange larger quantities of own production against market goods, further increasing the household wellbeing.

**JEL Classification:** I32, I38, L95, Q25
**Keywords:** poverty, access to water, risk coping, labor supply

## 1 Introduction

Mrs. Silva is a household head, mother of three, and a hard-working subsistence farmer. She has never studied finance, nor has she ever had a bank account. But Mrs. Silva

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†Corresponding author. UNU-MERIT and Maastricht University. email: tsukada@merit.unu.edu.

‡Universidade de Brasilia.

knows well the importance of saving from one harvest to another. In her small village, trade has been always more conveniently done in-kind. Perishables, however, cannot be stored for long periods as savings. This made the savings rate historically very low in the community. Banking was, however, not the biggest problem in the village. Water was. But Mrs. Silva now enthusiastically says: “The arrival of the cisterns for rainwater harvesting allowed us to raise chicken, the most valuable asset to get money quickly in the village. We now know that our savings [the chicken] won’t dye of thirst”.[1]

Semi-arid regions across the world have always suffered from a chronic deficit of water supply. In Brazil, the northeastern semi-arid, where Mrs. Silva lives, is a region of about 980.000 $km^2$ and over 22 million inhabitants. It is about 250 days per year without any rain. The lack of safe access to water often reinforces a vicious circle of poverty in such rural areas (UNDP, 2006). It hinders economic development for several reasons. First, there is a health concern and the consequent economic impacts of lower labor productivity due to illnesses. Without access to piped water, households rely on ponds, springs, rivers, and similar unsafe, low-quality water sources. The amount of water supplied by these sources is often insufficient to guarantee basic hygiene, increasing the incidence of water-washed diseases.[2] Moreover, long distances to the water source potentially threaten the physical health of children and women, who carry heavy water loads using their backs, shoulders and hips.

The second reason why poor access to water leads to a vicious cycle of poverty is related to a low human capital accumulation. Cognitive capacities cannot develop properly in the absence of sufficient water consumption (Hoddinott and Kinsey, 2001; Alderman et al., 2006). In addition, in the absence of a sustainable access to water, children may skip classes to help the household on water fetching. Ichino and Moretti (2009) show that menstrual cycle increases female absenteeism in work and further affect gender earning gaps. Lack of sanitation seems to magnify this effect as there are reports of teenage girls who skip classes during their menstrual period, if schools cannot provide proper sanitary facilities with water and privacy. Hence, water deprivation is directly associated with children acquiring less schooling, which reinforces the poverty cycle.

Finally, Dercon (2004) shows that rainfall shocks have a substantial impact on consumption growth, which persists for several years. The damage suffered in a single season tends to propagate its effect during longer consecutive periods. For all the above-mentioned reasons, it is argued that reliable safe water provision could potentially break the vicious cycle of poverty, as suggested by Gamper-Rabindran et al. (2010), Jalan and Ravallion (2003) and Hutton et al. (2006).

[1] Interview with cistern beneficiary in Pernambuco, Brasil. The name is fictitious.

[2] The UN considers the consumption of 20 liters per day as the water poverty line. The definition of safe access to water includes a maximal distance of one kilometer to the water source, apart from the requirements of water quality.

Setting up piped water provision from a utility company is, however, not straightforward. It requires high initial costs and a minimum demand level to cover the operational and infrastructure building costs. For this reason, piped water systems are often unfeasible in rural areas, given the low population density, geographical barriers, or a low purchasing power of residents and its consequent low expectation of full cost recovery.

Rainwater harvesting emerged as a popular low-cost technology for bringing in-house safe water supply to areas not served by a utility company. Modern cisterns are ferrocement tanks build at the homestead, aimed at storing rainwater for primary purposes, such as drinking and cooking (see Figure 4 in the Appendix). Households collect rainwater during the rainy season, and store it for consumption along the dry period. Runoff rainwater is diverted from the rooftop of houses via gutters (made of either bamboos, plastic or metal) into a closed tank. Cisterns can vary from 5 to over 50 cubic meters volume of water storage, depending on the usage purpose, the size of the catchment area and the local potential rainfall. In Brazil, a 16 cubic meter cisterns is able to supply a five-member household with safe drinking water for up to eight months of drought. The average construction cost is US$ 500[3].

Although the use of primitive cisterns dates back from some millennia, the dissemination of the in-house modern cistern technology in Brazil started in 2003 by a civil association called ASA - Articulação Semiárido Brasileiro. Composed of local civil organizations present in nine states of the semi-arid region in Northeast Brazil, ASA implements through the Training and Social Mobilization Programme for Coexistence with the Semi-Arid. This is a series of initiatives that teach households how to cope with the natural prolonged droughts and the arid climate. Their flagship initiative is the Program One Million Cisterns (P1MC) that aims at constructing one million cisterns for the income-poor rural households that lack access to sustainable water sources. The P1MC is financed partly by the federal government of Brazil and partly by other institutions, such as private companies, associations and cooperation agencies.[4] The counterpart provided by the beneficiary household is the labor force for the construction of the cistern – five working days of a bricklayer and a bricklayer's assistant (these could be some experienced household member or some neighbors), and their meals during the working period. Between 2003 and 2013, 550,486 cisterns were constructed.[5]

This paper investigates the impact of having a cistern technology at the homestead on household wellbeing through three channels: time allocation, agricultural production and

[3] At 2006 current prices.

[4] More information available at http://www.asabrasil.org.br.

[5] Data retrieved from the SIGcisternas database, retrieved from http://www.assemae.org.br/palestras/item/download/107_c30d9e49a2a36b8b68c39907b1951588, accessed on 24 June 2015.

increase in consumption/wealth. In the absence of piped water or a cistern technology, the opportunity cost of producing water can be very high for adults: time spent fetching water could be allocated into labor market activities or increase agricultural production for subsistence. Also, water is an essential factor of production in rural areas and its greater availability can allow the expansion of agriculture and livestock raising activities. In this sense, the impact of having access to a closer and reliable water source can be significant in terms of household labor supply.

The paper is structured as follows. Section 2 places the problem within the empirical literature. Section 3 discusses the theoretical relationship between rainwater harvesting and poverty through the channels of labor supply. Section 4 describes our empirical strategy and data. Section 5 presents the findings: we first analyze the wealth differences between households who harvest and those who do not harvest rainwater. Then, we explore the effects of having a cistern on the aggregate time allocation, agricultural production, and livestock raising of households. Section 6 offers some policy implications.

# 2 Problem Statement

Policies of water-supply infrastructure upgrade are usually motivated by health issues. An unintended and less explored effect is that easier access to water increases the effective time endowment of households, allowing more leisure and other productive activities: the labor-supply effect.

Empirical evidence also supports the labor supply effect in the case of rainwater harvesting technology. Lima et al. (2007) show that beneficiaries of the Brazilian program One Million Cisterns (P1MC), which were granted a cistern, have higher welfare than non-recipient neighbor households. A weakness in their methodology, however, is comparing mean outcomes of households with and without cisterns disregarding the non-random assignment of cisterns' placement.

In order to estimate the program's causal effect, we use matching techniques. We also suggest a simple theoretical framework to explain the mechanisms through which rainwater harvesting infrastructure affects household wealth. Three possible channels are investigated: (i) households may increase market labor supply; (ii) households may augment own agricultural production; or (iii) households may increase livestock production. We test the model predictions using a Brazilian household survey on rainwater harvesting collected by FAO/Embrapa in semi-arid regions where the cisterns are being constructed.

The paper adds to the literature on impact evaluation of water supply infrastructure by quantifying the relationship between rainwater harvesting and household labor outcomes. In particular, it provides evidence on rainwater harvesting water supply technology that, to the best of our knowledge, has not yet appeared in the literature. The paper suggests an important channel through which water supply technology might affect household welfare other than the widely explored health effect: the time allocation effect.

# 3 Conceptual Framework

Consider a household producing a composite agricultural good $q$ (e.g. crops, livestock) with production technology:

$$q = w^{\beta_1} t_a^{\beta_2} \tag{1}$$

where $w$ is water and $t_a$ is labor dedicated to production of the agricultural good $q$.

There are two technologies of water supply. The first is rainwater harvesting (in our case, a cistern technology). The second is fetching water from a traditional water source outside the homestead (pond, river, well, etc.) which requires labor supply for fetching water. The water production function is as follows:

$$w = lc + \alpha t_w \tag{2}$$

where $c$ is a dummy that takes the value one if the household possesses a RWH cistern and zero otherwise, and $t_w$ is the time dedicated to fetch water from a distant water source. $l$ is the volume of the cistern (abstracting from stochastic rainfall), such that having a cistern potentially increases the water supply by $l$ liters. We also know that $\partial w / \partial t_w = \alpha$ captures the household's ability to collect water from a distant water source per unit of time. The household's time endowment is standardized to one such that household members either collect water or work on agriculture:

$$t_w + t_a = 1 \tag{3}$$

The household sells its agricultural production in order to purchase a market good $y$ at price $p_y$. The budget constraint of the household is:

$$p_q q = p_y y \tag{4}$$

Finally, the household maximizes a unitary utility function, assumed of a log linear type, such as:

$$U = \gamma \log[y] \tag{5}$$

and subject to (1), (2), (3) and (4).

The First Order Conditions yield the following consumption demand and labor supply:

$$t_w^* = \frac{\alpha\beta_1 - \beta_2 cl}{\alpha(\beta_1 + \beta_2)} \tag{6}$$

$$t_a^* = \frac{\beta_2(\alpha + cl)}{\alpha(\beta_1 + \beta_2)} \tag{7}$$

$$w^* = \frac{\beta_1(\alpha + cl)}{\beta_1 + \beta_2} \tag{8}$$

$$q^* = (\frac{\beta_1(\alpha + cl)}{\beta_1 + \beta_2})^{\beta_1}(\frac{\beta_2(\alpha + cl)}{\alpha(\beta_1 + \beta_2)})^{\beta_2} \tag{9}$$

$$y^* = \frac{p_q}{p_y}(\frac{\beta_1(\alpha + cl)}{\beta_1 + \beta_2})^{\beta_1}(\frac{\beta_2(\alpha + cl)}{\alpha(\beta_1 + \beta_2)})^{\beta_2} \tag{10}$$

### 4.3.1 The effect of the rainwater harvesting technology

Rainwater harvesting technology provides households with water at a lower time requirement. Households can relocate the additional time (previously devoted to water collection) to other productive activities. Hence, we can derive the effect of the rainwater harvesting technology on (6) to (10) as:

$$\frac{\partial t_w^*}{\partial c} = -\frac{\beta_2 l}{\alpha(\beta_1 + \beta_2)} < 0 \tag{11}$$

$$\frac{\partial t_a^*}{\partial c} = \frac{\beta_2 l}{\alpha(\beta_1 + \beta_2)} > 0 \tag{12}$$

$$\frac{\partial w^*}{\partial c} = \frac{\beta_1 l}{\beta_1 + \beta_2} > 0 \tag{13}$$

$$\frac{\partial q^*}{\partial c} = \beta_1 l(\frac{\beta_1(\alpha + cl)}{\beta_1 + \beta_2})^{-1+\beta_1} \frac{\beta_2(\alpha + cl)}{\alpha(\beta_1 + \beta_2)}^{\beta_2} > 0 \tag{14}$$

$$\frac{\partial y^*}{\partial c} = \frac{\partial q^*/\partial c \times p_q}{p_y} > 0 \tag{15}$$

The model predicts that the rainwater harvesting technology increases household utility through the following channels: (i) a time allocation effect – there is a direct impact of the rainwater harvesting technology of fewer labor supply requirement for water collection (Equation 11) and, as the household spends less time fetching water, time can be reallocated to other activities, such as increasing agricultural output (Equation 12); (ii) an input effect – the technology increases the household's water supply (13), and finally (iii) a wealth effect – more water and time inputs allow the household to scale-up agricultural production (14) and, consequently, increase consumption of the market purchased good (15).

# 4 Data and Empirical Strategy

## 4.1 Data

The semi-arid region in the Northeast of Brazil encompasses the northern region of Minas Gerais and the dry savannas of Alagoas, Bahia, Ceara, Paraiba, Pernambuco, Piaui, Rio Grande do Norte and Sergipe states, covering 1,133 municipalities and a population of around 20 million.[6] The semi-arid is one of the most vulnerable and economically disadvantaged regions in Brazil. Weather conditions are characterized by a long dry season during more than six months per year, annual rainfall below 800mm, high temperatures and high rates of soil evapotranspiration. The region has always suffered from chronic deficit in water supply.

The P1MC survey was conducted between August 2005 and October 2006 by the Brazilian Agricultural Research Institute (Embrapa), supported by the Food and Agricultural Organization (FAO) and the Brazilian Ministry of Social Assistance and Fight Against Hunger.[7] The purpose of the survey was to evaluate the correct implementation of the eligibility criteria of cisterns financed by the federal government and evaluate households' perceived social impact of the technology regarding time use, quality of water, health and improvements in quality of life. The survey also served to other (engineering) technical evaluation, such as the assessment of compliance of the constructed cisterns with technical requirements and the need for maintenance and repairs.

For the evaluation of the social impact, a 113-question survey on social, economic, and environmental characteristics was designed. The questionnaire took into consideration the "edaphic-environmental location of the household, conditions of the rural establishment, the characteristics of the household members" and how water was managed and stored in those rural settings (MDS, 2008 p.395). The questionnaire modules containing information on household demographics, consumption, water use, and water management are available at MDS (2008).

Three samples of households participated in the survey: (1) households that received a cistern financed by the Ministry of Social Assistance, (2) households that received a cistern financed by other institutions such as local governments or associations and, (3) non-beneficiary neighbor households – control households living within the same landscape units as the beneficiaries but who had not yet received a cistern by the time of the survey. The sampling method was the following (Lima et al., 2007): the semi-arid region that encompassed the rainwater harvesting program was stratified into eleven strata of landscape units based on geoenvironmental characteristics of the Agro-ecological Zoning

[6] Our dataset, however, represents a much smaller sample, comprised of only rural areas, poor households. The state Alagoas was not surveyed though.

[7] A more comprehensive description of the dataset can be found at the Data Appendix, section **??** in this thesis.

classification of the Northeast of Brazil. The Brazilian semi-arid region contains 110 geoenvironmental units, such that each landscape unit holds a collection of geoenvironmental units. For each stratum, the size of each of the three samples of households, per geoenvironmental unit, was calculated. In total, the samples covered over 80% of the existing geoenvironmental units. Sample 1 finally consisted of 450 households, sample 2 covered 179 households and sample 3, 426 households. Lima et al. (2007, p.414) also note that: "In determining samples 2 and 3 there were no previous surveys or registers that would have allowed for the prior identification of households to be selected. Thus the selection was made in the field by direct consultation with the residents in households of the region embraced by the project."

The information collected from sample 1, beneficiaries financed by the Ministry of Social Assistance, was reduced because several data were already at the national registry maintained by the ministry. These data were, however, not made available to us. Since essential variables would be missing for our analysis, we could only use samples 2 and 3 for our empirical analysis. Some 49 households did not complete the survey interview; they either refused to participate, were absent, the cistern has been closed or not in use, or other reason. We further excluded 36 households, 18 in each sample, that declared to hold land above 50 hectares. That is the threshold according to the Brazilian legislation to be declared a small farmer.[8] Since we are interested in poor households, we do not include in the analysis households with great land possessions that might have been either mistakenly benefited by the program or the information regarding land size was misleadingly taken in the survey. Hence, our effective sample consists of 520 households: 134 households that use a cistern technology to harvest rainwater (the treatment group) and 386 households that do not have a cistern technology (the control group).

Table 1 shows descriptive statistics of households using a cistern technology and those that do not, respectively (before PSM matching). We observe that even though households might have a cistern technology installed, this is not always the main water source for the household. The most prevalent water source is surface water: preferred by 49 percent of households with a cistern and by 52 percent households without a cistern technology. Among households using underground, surface water or other methods as main source, the water transportation or delivery method is most often done by a person with the help of an animal, cart or bicycle. It is important to make a distinction between the water delivery mode as it influences the amount of time spent fetching water. We also observe that the incidence of water collection by persons unaided, i. e. when a person carries water without any mechanical or animal help, is more prevalent among households without a cistern (39 percent) than among those with some rainwater harvesting technology (21 percent). Recall that these are observational data after the technology has been implemented.

[8]Available at http://www.planalto.gov.br/ccivil_03/_ato2004-2006/2006/lei/l11428.htm.

The dwelling characteristics of both groups are similar regarding electricity and durable rooftops. The latter is an important requirement for the installation of the gutters that will divert water from the rooftop into the cistern. Some differences across groups are found in terms of walls and toilets. Some 62 percent of households with a cistern have durable walls versus only 46 percent of households without a cistern. A larger proportion of households holding a cistern also have access to toilets at the homestead, compared to households with no cistern technology.

Regarding demographic characteristics, as expected, there is a larger share of female headed households and elder members in the group of cistern beneficiaries. These were priorization criteria to receive a cistern. Both groups are similar in the average number of children per household. The groups are also similar in regards to poverty status. Some 46 and 48 percent of households rely on social assistance by the government, among cistern beneficiaries and non-beneficiaries respectively.[9] Agriculture is the main source of employment for 69 percent of household heads in households with cisterns and 67 percent of heads in households without a cistern. Almost 30 percent of household heads in both groups have no schooling.

Finally, the set of variables at the bottom of Table 1 captures the local environmental and perceived living conditions at the community level. Households declared whether their communities are characterized by a lack of employment opportunities, health facilities, leisure options, transport facilities and employment opportunities. Recall that control households live in the same localities as cistern beneficiaries. As such, it is not surprising that responses do not differ across groups (with exception to violence perception). This suggests that, despite some households were selected into the treatment while others didn't, households experience the same local environmental living conditions.

## 4.2 Wealth index

In order to test the effect of the rainwater technology on household wealth, we need a measure of $y$ – the purchased market good. We adopt an asset-based approach in the absence of consumption and income data. A wealth index based on household's durable goods and assets holdings is constructed using principal component analysis (PCA).[10]

From an initial set of $n$ correlated variables, PCA generates uncorrelated components. Each component is a linear weighted combination of the initial variables. For example,

[9] The Brazilian social protection programs include: Family Grant Program (*Bolsa Famila*), Continuous Cash Benefit for the elderly and the handicapped (BPC), gas voucher, rural old age retirement pension, ordinary pension or retirement pay, Child Labor Eradication Program (PET).

[10] See Vyas and Kumaranayake (2006) for an overview of PCA and its usage for constructing socio-economics indices.

for a set of variables $x_1$ to $x_n$,

$$PC_1 = a_{11}x_1 + a_{12}x_2 \quad + \quad ... + a_{1n}X_n$$
$$...$$
$$PC_m = a_{m1}x_1 + a_{m2}x_2 \quad + \quad ... + a_{mn}X_n$$

where $a_{mn}$ represents the weight for the $m$th principal component and the $n$th variable.

The weights for each principal component are given by the eigenvectors of the correlation matrix. The variance for each principal component is given by the eigenvalue of the corresponding eigenvector. The components are ordered so that the first component ($PC_1$) explains the largest possible amount of variation in the original data, subject to the constraint that the sum of the squared weights ($a_{11}^2 + a_{12}^2 + ... + a_{1n}^2$) is equal to one. Since the first component explains the largest amount of variance (28 percent), it is used as wealth index for our study.

We use all information about assets available in the dataset: whether the household has a gas stove, telephone, radio/CD-player, refrigerator, sewing machine, bicycle, motorcycle, car, mobile phone, and parabolic antenna. The eigenvalues and explained variance of $PC_1$ to $PC_{10}$ are shown in Table 2. The factor loadings of the first component ($PC_1$) are presented in Table 3.

Table 1: Summary statistics, FAO/Embrapa P1MC survey

| **Variable** | **Cistern** | | | | | **No Cistern** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Mean** | **St.dev.** | **Min** | **Max** | **N** | **Mean** | **St.dev** | **Min** | **Max** | **N** |
| time fetching water (minutes/week) | 174.46 | 157.06 | 1.11 | 630 | 97 | 241.24 | 229.81 | 1.48 | 2100 | 306 |
| main water source: | | | | | | | | | | |
| cistern only | 0.13 | 0.34 | 0 | 1 | 134 | 0 | 0 | 0 | 0 | 386 |
| piped water | 0.06 | 0.24 | 0 | 1 | 134 | 0.06 | 0.25 | 0 | 1 | 386 |
| underground water | 0.25 | 0.44 | 0 | 1 | 134 | 0.37 | 0.48 | 0 | 1 | 386 |
| surface water | 0.49 | 0.5 | 0 | 1 | 134 | 0.52 | 0.5 | 0 | 1 | 386 |
| other water sources | 0.06 | 0.24 | 0 | 1 | 134 | 0.03 | 0.17 | 0 | 1 | 386 |
| water transportation/delivery mode: | | | | | | | | | | |
| person unaided | 0.21 | 0.41 | 0 | 1 | 134 | 0.39 | 0.49 | 0 | 1 | 386 |
| person with help (animal/cart/bicycle) | 0.47 | 0.50 | 0 | 1 | 134 | 0.42 | 0.49 | 0 | 1 | 386 |
| vehicle (truck or car) | 0.16 | 0.37 | 0 | 1 | 134 | 0.09 | 0.29 | 0 | 1 | 386 |
| toilet | 0.66 | 0.47 | 0 | 1 | 133 | 0.41 | 0.49 | 0 | 1 | 385 |
| electricity | 0.71 | 0.45 | 0 | 1 | 133 | 0.74 | 0.44 | 0 | 1 | 381 |
| durable wall | 0.62 | 0.49 | 0 | 1 | 133 | 0.46 | 0.5 | 0 | 1 | 386 |
| durable roof | 0.74 | 0.44 | 0 | 1 | 132 | 0.76 | 0.43 | 0 | 1 | 384 |
| female household head | 0.41 | 0.49 | 0 | 1 | 133 | 0.35 | 0.48 | 0 | 1 | 381 |
| number of children | 1.11 | 1.37 | 0 | 6 | 134 | 1.45 | 1.43 | 0 | 7 | 386 |
| number of elder members | 0.62 | 1.03 | 0 | 6 | 134 | 0.32 | 0.63 | 0 | 4 | 386 |
| household size | 4.25 | 1.93 | 1 | 10 | 134 | 3.94 | 1.87 | 1 | 12 | 386 |
| social assistance beneficiary | 0.46 | 0.5 | 0 | 1 | 134 | 0.48 | 0.5 | 0 | 1 | 386 |
| household head's occupation: | | | | | | | | | | |
| no income from work | 0.07 | 0.26 | 0 | 1 | 134 | 0.08 | 0.26 | 0 | 1 | 386 |
| employee or cooperative worker | 0.04 | 0.21 | 0 | 1 | 134 | 0.07 | 0.26 | 0 | 1 | 386 |
| employer or self employed | 0.16 | 0.37 | 0 | 1 | 134 | 0.15 | 0.36 | 0 | 1 | 386 |
| rural laborer | 0.69 | 0.46 | 0 | 1 | 134 | 0.67 | 0.47 | 0 | 1 | 386 |
| large animals | 0.55 | 0.50 | 0 | 1 | 134 | 0.33 | 0.47 | 0 | 1 | 386 |
| midsized animals | 0.33 | 0.47 | 0 | 1 | 134 | 0.19 | 0.40 | 0 | 1 | 386 |
| small animals | 0.58 | 0.50 | 0 | 1 | 134 | 0.34 | 0.47 | 0 | 1 | 386 |
| household head's education: | | | | | | | | | | |
| no schooling | 0.29 | 0.46 | 0 | 1 | 134 | 0.28 | 0.45 | 0 | 1 | 386 |
| lower primary | 0.57 | 0.5 | 0 | 1 | 134 | 0.48 | 0.5 | 0 | 1 | 386 |
| upper primary | 0.1 | 0.31 | 0 | 1 | 134 | 0.15 | 0.36 | 0 | 1 | 386 |
| secondary | 0.01 | 0.12 | 0 | 1 | 134 | 0.04 | 0.21 | 0 | 1 | 386 |
| higher education | 0 | 0 | 0 | 0 | 134 | 0.01 | 0.11 | 0 | 1 | 386 |
| theft, violence or vandalism | 0.25 | 0.44 | 0 | 1 | 130 | 0.16 | 0.36 | 0 | 1 | 379 |
| lack of schools | 0.12 | 0.33 | 0 | 1 | 131 | 0.14 | 0.35 | 0 | 1 | 380 |
| lack of health facilities | 0.75 | 0.44 | 0 | 1 | 131 | 0.75 | 0.43 | 0 | 1 | 380 |
| lack of leisure opportunities | 0.68 | 0.47 | 0 | 1 | 131 | 0.78 | 0.42 | 0 | 1 | 379 |
| lack of transportation | 0.37 | 0.49 | 0 | 1 | 131 | 0.46 | 0.5 | 0 | 1 | 381 |
| lack of employment opportunities | 0.94 | 0.24 | 0 | 1 | 131 | 0.95 | 0.22 | 0 | 1 | 381 |

Source: FAO/Embrapa P1MC survey. Notes: Water underground refers to tubular well, amazonas type. Surface water refers to water hole, spring, river. Roof – dummy refers to ceramic tiles. Toilet – dummy refers to the existence of toilet facilities either in or outside the house. Wall – dummy refers to brickwork, either plastered or not. Animals – dummy whether the household raises any animals.

Table 2: Principal component analysis of durable assets held by households

| Factor | (Eigenvalue) | Explained variance | Cum. expl. variance |
|---|---|---|---|
| $PC_1$ | 2.81844 | 0.2818 | 0.2818 |
| $PC_2$ | 1.28467 | 0.1285 | 0.4103 |
| $PC_3$ | 1.06025 | 0.1060 | 0.5163 |
| $PC_4$ | 0.91103 | 0.0911 | 0.6074 |
| $PC_5$ | 0.87028 | 0.0870 | 0.6945 |
| $PC_6$ | 0.76355 | 0.0764 | 0.7708 |
| $PC_7$ | 0.69613 | 0.0696 | 0.8404 |
| $PC_8$ | 0.67101 | 0.0671 | 0.9075 |
| $PC_8$ | 0.50032 | 0.0500 | 0.9576 |
| $PC_{10}$ | 0.42432 | 0.0424 | 1.0000 |
| $N$ | 511 | | |

Note: Based on asset holdings reported by households. Source: FAO/Embrapa P1MC survey.

Table 3: Factor loadings of the first principal component for the wealth index calculation

| Variable | Factor Loading |
|---|---|
| gas stove | 0.6398 |
| telephone | 0.7129 |
| radio/CD-player | 0.3079 |
| refrigerator | 0.7402 |
| sewing machine | 0.5135 |
| bicycle | 0.2510 |
| motorcycle | 0.4290 |
| car | 0.3443 |
| mobile phone | 0.3360 |
| parabolic antenna | 0.7183 |
| N | 511 |

### 4.3 Propensity score weighted regression

The data consists of a cross-section. Treatment was not random, as there were eligibility criteria for selecting beneficiaries that would receive a cistern technology.[11] We use propensity score matching (PSM) to pin-down the counterfactual distribution, as it is able to balance the distribution of observed covariates between those households that have a cistern (treatment group) and those that do not have (control group). As ususal, the balancing is based on the predicted probabilities of treatment, in this case, having a cistern (Rosenbaum and Rubin, 1983). Denote $c_i = 1$ if the household has a cistern, and $c_i = 0$ if not. Let $\mathbf{X_i}$ be a vector of exogenous household characteristics (covariates). Treated households are matched to control households on the basis of the propensity score

$$p(x_i) = P(c_i = 1|\mathbf{X_i}) \qquad (0 < p(\mathbf{X_i}) < 1) \tag{16}$$

It is well known PSM relies on the 'conditional independence' or 'strong ignorability' assumption. That is, given $\mathbf{X_i}$, the outcomes are independent of treatment. Matching on propensity scores implies that treatment and control group have the same distribution of observed covariates, eliminating the bias arising from observed heterogeneity. In other words, conditional on the set of characteristics $\mathbf{X_i}$, any observed difference in the outcome is due to the treatment variable, as the subjects in treatment and control only differ with regards to the treatment variable.

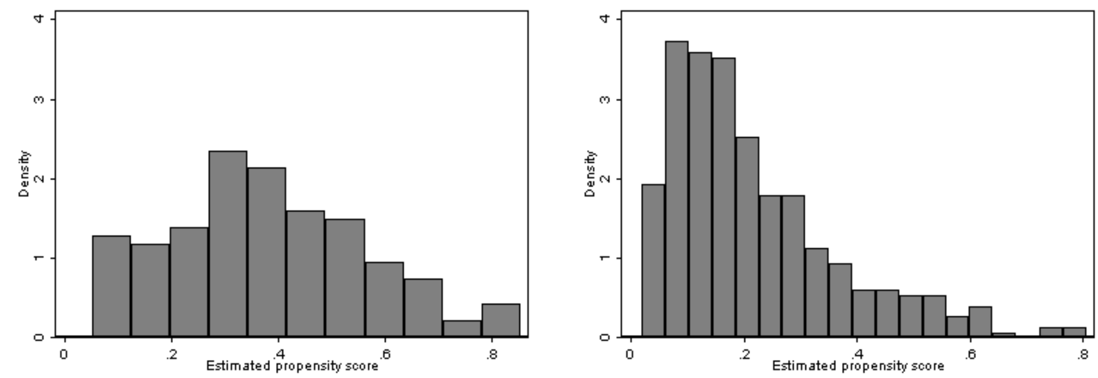
We follow the standard PSM procedure and use the predicted probabilities of a logit model as estimate the propensity score. In an attempt to establish conditional independence we include a large vector of covariates. The latter includes demographic characteristics of the household, dwelling characteristics as well as work and income indicators.

Figure 1 shows the histogram of the estimated propensity scores for treatment and control group. We see that the common support property holds for the entire range of propensity scores of treatment group. That is, we are able to find a match with a sufficiently close propensity score for the entire treated sample.

We conduct balancing tests suggested in Dehejia and Wahba (1999) and Dehejia and Wahba (2002) to check whether the distributions of observable characteristics are similar for the treatment and the control groups with similar propensity scores. We divide the range of estimated propensity scores into blocks, starting with one block consisting of the entire range of propensity scores. Within this block, we test for equality of means of propensity scores between treatment and control group. If we reject the null of equality of means, we divide the block into two blocks and test again for equality of means be-

[11] The priorization criteria to receive a cistern technology financed through the association is: (i) female-headed household, (ii) number of children 0 to 6 years old, (iii) number of children enrolled at school, (iv) number of elder members above 65 years old, and (v) presence of household members with physical or mental disabilities.

Figure 1: Histogram of propensity scores for having a rainwater harvesting labor-saving technology




(a) Treatment group (b) Control group

Note: Propensity for having a cistern technology. Bandwidths defined as the optimal interval that minimizes the differences in household characteristics within a block and maximizes them across blocks. Note that the common support is weak at the lower tail of both distributions. It is also relatively scarce at the top of the distribution, nevertheless observations can be found in both groups.

tween treatment and control group within each of the two blocks. If we reject the null of mean equality for one block, we divide the block again into two blocks. The procedure is repeated until we cannot reject the hypothesis of mean equality of propensity scores for every block. Using this algorithm, we find a total of six blocks. We then test if the means of the exogenous variables are the same within each block. We test for equality of a total of 84 exogenous variables within each block. This makes a total of 504 ($6 \times 84$) T-tests. For 496 of such tests we cannot reject the null hypothesis of equal means between treatment and control groups.

Having obtained an estimate of the propensity score, we then apply the weighted propensity score regression technique (Hirano and Imbens, 2001) to shed light on the effects of the cistern technology on wealth, time spent on water collection, and agricultural production. We estimate the following model:

$$y_i = \alpha_0 + \tau_1 c_i + \alpha \mathbf{Z_i} + u_i \tag{17}$$

where $c_i$ is a dummy if household $i$ has a cistern and $\mathbf{Z_i}$ a vector of eight covariates that failed the propensity score balancing property. To estimate the wealth effect, $y_i$ takes the value of the wealth index. For the time allocation effect regarding water collection, $y_i$ is the time spent on fetching water. The dataset has no information on the time households spent on agriculture, so that it is not possible to calculate directly the time allocation effect regarding agriculture. We use as a proxy the area cultivated, where we have information both for agriculture activities, as well as livestock raising.

Following Hirano and Imbens (2001), the household weights are:

$$\omega = c_i + \frac{(1 - c_i)\hat{p}(\mathbf{X_i})}{1 - \hat{p}(\mathbf{X_i})} \tag{18}$$

such that the weight for the treated household is a unity. $\hat{p}(\mathbf{X_i})$ denotes the estimated propensity score.

As a robustness check, households in the treatment group are matched to those of the control group based on a nearest-neighbor matching estimator. That is, the match $j$ for the $i$th household having a cistern is the one that minimizes $(p(\mathbf{X_i}) - p(\mathbf{X_j}))^2$. We use the nearest five neighbors estimator, which takes the average outcome of the closest five control-group households as the counterfactual for a treated household.

# 5 Results

### 4.5.1 The consumption effect

Our findings suggest a positive impact of the cistern technology on household consumption, as measured by our wealth index. Table 4 shows the parametric estimates of Equation 17. The coefficient on the cistern dummy is positive, statistically significant at the one percent significance level, and robust to different specifications of our model.[12] Figure 2 illustrates this result. The figure shows non-parametric kernel densities (propensity score weighted) of the wealth index for the treatment group (households with a cistern) and the control group (households without a cistern). The wealth density distribution for households owning a cistern (dashed) is shifted rightwards, compared to households not owning a cistern (dotted line).

The specification in (B), Table 4 includes additional covariates in an attempt to capture some possible effects according to the household's main water source. The interaction terms of cistern and those variables was, however, also not statistically significant. The model specification in (C) tried to capture a possible effect of a threshold in household size. It is known that a cistern of 16 $m^3$ was designed to supply a household of up to five members with sufficient water for drinking and cooking to cope with the dry season. The hypothesis, thus, was that cisterns would have a larger impact in smaller households than in large ones. In households larger than 5 members, for instance, a cistern would potentially not be able to provide secure access to water along the entire period. The interaction terms between cistern and household size yield, however, no statistically significant results, hence the hypothesis was not confirmed.

[12] As a robustness check, we apply a nearest-neighbor propensity score matching estimator. The latter confirms the results above. We find a significant impact of cisterns on household wealth: 0.328 (st. error = 0.121) is the average treatment effect of having the technology.

Table 4: Wealth effect of the rainwater harvesting labor-saving technology

| | **wealth (A)** | **wealth (B)** | **wealth (C)** |
|---|---|---|---|
| cistern | 0.382*** | 0.339*** | 0.336*** |
| | (0.11) | (0.10) | (0.10) |
| female head | -0.232** | -0.163 | -0.156 |
| | (0.11) | (0.11) | (0.11) |
| children | 0.025 | -0.063 | -0.043 |
| | (0.04) | (0.06) | (0.05) |
| elder | 0.135** | 0.132** | 0.134** |
| | (0.07) | (0.07) | (0.07) |
| social assistance beneficiary | 0.129 | 0.011 | -0.004 |
| | (0.12) | (0.13) | (0.12) |
| durable wall | 0.644*** | 0.409*** | 0.448*** |
| | (0.11) | (0.13) | (0.13) |
| durable roof | | 0.047 | 0.018 |
| | | (0.12) | (0.11) |
| toilet | | 0.399*** | 0.410*** |
| | | (0.13) | (0.12) |
| main water (piped) | | -0.011 | |
| | | (0.37) | |
| main water (underground) | | -0.142 | |
| | | (0.31) | |
| main water (surface) | | -0.187 | |
| | | (0.32) | |
| main water (other sources) | | -0.317 | |
| | | (0.34) | |
| household size | | 0.115*** | |
| | | (0.04) | |
| household size: 4 or 5 members[1] | | | 0.252* |
| | | | (0.13) |
| household size: 6 or more members[1] | | | 0.512*** |
| | | | (0.17) |
| N | 490 | 476 | 480 |
| R2 | 0.164 | 0.300 | 0.292 |
| F | 10.967 | 7.750 | 8.413 |

Notes: * p<0.10, ** p<0.05, *** p<0.01. Estimated as propensity score weighted OLS regression. Selected variables shown. The control variables *female head, children* and *elder* were used as eligibility/priorization criteria for receiving the cistern. The dummies *social assistance beneficiary* and *durable wall* are covariates that were not well balanced at a few blocks in the pscore estimation. We also control for additional variables in models (B) and (C) such as the head's educational level and variables related to living conditions in the community – lack of schools, health care facilities, leisure options, transportation, employment opportunities, and the perceived safety in terms of violence, crime and vandalism. (1) The baseline category is household size of 1 to 3 members.

In the following we analyze the labor supply effects underlying the increase in consumption caused by the cistern.

### 4.5.2 Labor supply effects

The mechanisms described in Section 3 predict that in rural areas not provided with sustainable water supply household members spend a significant amount of time collecting water from a far distant water source (river, spring, dams). The rainwater captured from a cistern technology installed at the homestead may reduce the demand for water from the distant source and, thus, reduce the time spent fetching water. If the time saved is reallocated to productive activities, the rural household might increase its labor supply to agricultural production and we would observe higher consumption - from either own agricultural production or market purchased goods exchanged by its production.

We estimate Equation 17 using as dependent variables the weekly time spent collecting water, area dedicated to agriculture, area dedicated to raising livestock, and the probability of a household to raise small, mid-sized and large animals. The latter are proxies for the time spent on agriculture and livestock, as those information were not collected in the survey. Table 5 presents our results.[13]

Table 5: Time use, agricultural production and livestock production effects of the rainwater harvesting labor-saving technology

| | **Propensity Score Weighted Regression** | **St.error** |
|---|---|---|
| **Time use effect:** | | |
| Time spent fetching water (in minutes/week) | -69.97*** | 24.33 |
| Time fetching water, water transported by unaided person | -70.07** | 33.68 |
| Time fetching water, transported by person with help | -57.51* | 31.72 |
| Time fetching water, transported by vehicle | -102.98* | 50.24 |
| **Agricultural production effect:** | | |
| Cultivated area (in hectare) | 0.923 | 1.24 |
| **Livestock production effect:** | | |
| Area dedicated to raising livestock (in hectare) | 5.298*** | 1.83 |
| Probability of raising small animals | 0.643** | 0.29 |
| Probability of raising midsized animals | 0.190 | 0.30 |
| Probability of raising large animals | 0.131 | 0.29 |

Notes: * p<0.10, ** p<0.05, *** p<0.01. Controls included. For full regression results, see Tables 6, 7 and 8 in the Appendix.

Table 5 above reports the cistern labor supply effects only: time use, agricultural production and livestock production effects. The full regression results are presented in

[13] As a robustness check we report the results of the nearest neighbor propensity score matching estimator in parenthesis.

Tables 6, 7 and 8 in the Appendix. Having a cistern technology reduces the time spent on water collection by about 69 minutes per week per household. Since there can be significant differences in the average time spent on water collection depending on the water transportation mode, we also estimated the time use effect by subsamples according to the household water transportation mode. The results show a significant decline of 70 minutes per week on water collection for households that transport water without some sort of technical help, a decline of 57 minutes per week for those households that transport water with some sort of technical help, and a decline of 103 minutes per week for households that receive water delivered by water trucks or other vehicles. Note, however, that the sample size for the latter is small.

We found no significant agricultural production effect in the data. There is apparently no difference in the cultivated area between households that have and those that do not have a cistern technology. This could be due to limited amount of water that the cistern is able to provide: 16 cubic meters in full capacity might not be sufficient to encourage households to increase their agricultural production.[14] In that case, the input effect as discussed in Equation (14) is rather tiny or inexistent, given the amount of water provided by the cistern. Another possibility is that the amount of time saved with the technology is so small that households do not allocate it to agriculture; they prefer to perhaps increase household chores or leisure. This calls for an extension of our theoretical model including other household activities. Our data, however, does not allow such investigation.

In line with the qualitative evidence collected and depicted in the introduction of this paper, we find that the cistern has a significant effect on livestock production. The area dedicated to livestock raising is larger for households holding a cistern, according to the propensity score weighted estimates. Robustness checks using nearest neighbor matching, however, show no significant difference in area dedicated to livestock production. The most convincing empirical evidence is the effect of the cistern on the probability of a household to raise small animals (chicken). A cistern increases by about 64 percent the chance of households raising such small livestock. The result is robust to a nearest neighbor matching exercise, but the magnitude of the effect becomes smaller: the average treatment effect on the treated is an increase in 11.9 percent (0.1189, standard error 0.63). The probability of raising midsized and large animals is not affected by a cistern technology. This also reinforces the idea that the water provided by the cistern is not sufficient for large investments in production, it is mostly enough for drinking and

[14] A second initiative implemented by ASA is the Programa Uma Terra e Duas Aguas (P1+2). That is a complementary program to the P1MC in which rural households also receive a larger cistern, of 52m$^3$ capacity of storage, to collect rainwater for agricultural production. The 16m$^3$ cistern would provide exclusively water for cooking and drinking purposes, collected from the rooftop catchment area. The larger cistern would serve for irrigation purposes, having a large and sloped cement-made layer catchment area built above the soil.

cooking purposes and perhaps for small livestock raising.

## 6 Concluding Remarks

This paper argues that rainwater harvesting has an important effect on household wellbeing through increased consumption and labor supply effects. A cistern technology allows savings in time previously devoted to water collection. It also increases the available water supply of households. The channels underlying the wealth effect, an increase in consumption caused by the cistern, are explained by a reallocation of the household labor supply across tasks – what we called the time use effect –, as well as an augmented quantity of clean water – the input effect. The positive (input) supply shock of water, despite mild in quantity, made possible the household decision to invest in small livestock in the Brazilian rural areas studied in this paper.

Qualitative evidence shows that households perceive the cistern as a shock coping mechanism used to smooth consumption during the droughts. The investment in water sensitive assets such as livestock becomes less risky. Semi-structured interviews conducted with beneficiaries in the state of Pernambuco, in Brazil, revealed that raising small livestock has indeed caused a great improvement in insurance levels of those households, as they lack easy access to formal insurance instruments for not having collateral. This evidence was confirmed by the quantitative analysis that found an increased probability of households to raise small livestock (poultry) when they have access to a cistern technology.

Small scale agriculture and livestock raising play indeed an important role for household subsistence in rural areas. Agriculture and livestock outputs can be either consumed or bartered at local markets. They improve the household nutritional intake and surpluses are a complementary source of income. Livestock also supply an insurance mechanism against shocks, particularly in the absence of formal financial institutions or lack of collateral (Deaton, 1991). Small farmer households usually hold buffer stock (e.g. grains) to smooth consumption when hit by droughts, disease or other shocks that affect the consumption (Angelucci and De Giorgi, 2009). While small animals are a source of liquidity to households, quickly traded by essential goods to sustain livelihood, when properly feed and given to drink they are also a better investment than grain stocks, as they are less susceptible to perish.

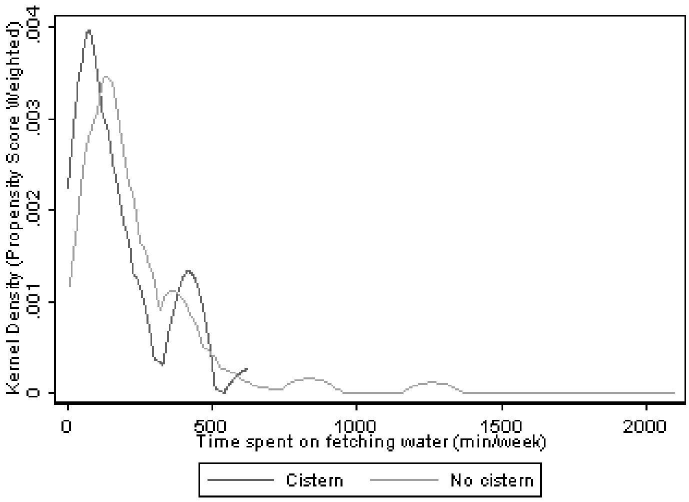
From the above, we draw an important policy implications of rainwater harvesting interventions in drought prone areas: the benefits of water labor-saving technology must be evaluated in a broader perspective. Since the impact of adopting such technologies go beyond an increase in water supply for the household, in the sense that several mechanisms affect the household wellbeing, all possible channels should be considered when designing the policy intervention. For instance, the impact on the time constraint of households, access to financial and saving instruments, local technologies commonly adopted for resilience to shocks in consumption. We know that cost-benefit analyses are decisive for an policy intervention to take place. Undertaking an extended analysis that encompasses some of the above-mentioned dimensions would be useful in revealing the benefits accrued by the labor-saving technology and supporting its implementation.

Moreover, this paper has investigated the labor supply effects in terms of reallocation of time from water collection toward agriculture and livestock activities. We acknowledge that it would be also interesting and important to analyze the direct effect of having a cistern on the time dedicated to paid labor market (small trade activities, agricultural labor to neighboring farms, lower seasonal migration). Data on these were, however, not available in our survey. It is also essential to include housework activities and leisure in an extension of the theoretical model here introduced, and bring them to data.

Further topics also remain to be explored. For instance, the health impacts of being provided with clean rainwater and training on health and hygiene, women empowerment and changes intra-household bargaining following the adoption of cisterns, human capital accumulation once children would spend lower time fetching water, ownership sense by the construction of the cisterns with the labor force and some resources put down by the households, and the long run impact of professional training of masons and health community leaders after the P1MC program has been implemented in a community. These are additional effects, not mentioned in this paper, that are wide spread anecdotal evidence from the P1MC program in Brazil. As part of the program, elected women in the communities were trained as health advisers in water treatment and employed as community leaders to teach and monitor neighbor households on proper water maintenance of the cisterns. This might have brought positive health externalities for the community, as well as the empowerment of those selected women both in intrahousehold relations, as well as inter households within the community. Moreover, communities were brought together by construction of the cisterns: neighbors would provide labor force, and the beneficiary household was responsible for providing meals for all workers during the construction period. Men had the intrinsic incentive to help in the construction of their neighbors' cisterns both from the perspective of asking for water in emergencies, as well as having labor-force when their time to receive the cistern finally arrived. These men developed some skills as bricklayer and there is anecdotal evidence that several continued in this profession.

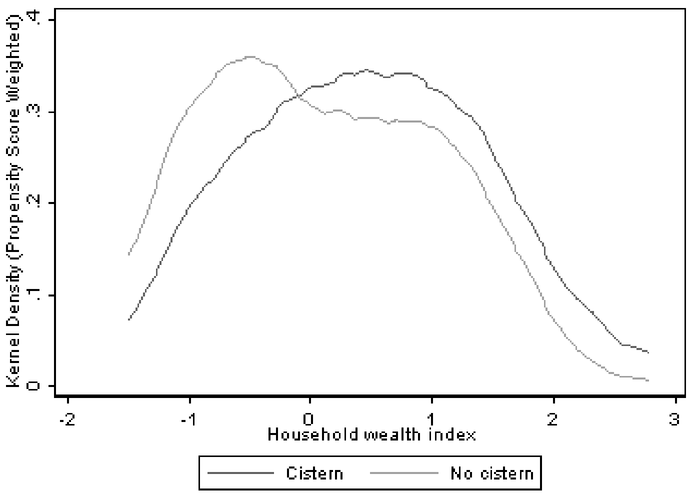
# A Appendix: Propensity Score Matching

Figure 2: Kernel densities of time spent on water collection per week




Source: FAO/Embrapa P1MC survey, restricted sample.

Figure 3: Kernel densities of the wealth index, propensity score weighted




Source: FAO/Embrapa P1MC survey, restricted sample.

# B Appendix: A visual representation of a cistern technology

Figure 4: A rooftop cistern in a Brazilian semi-arid household

Credits: Raquel T. Lehmann and M. Christian Lehmann. Cumaru, Pernambuco, Brazil, 2009.

# C Appendix: Detailed Regression Results

Table 6: Labor supply effect of the labor-supply technology on weekly time collecting water, by water transportation mode

| | All transport modes | | Person unaided | | Person with help | | Vehicle | |
|---|---|---|---|---|---|---|---|---|
| | (A) | (B) | (A1) | (B1) | (A2) | (B2) | (A3) | (B3) |
| cistern | -66.442*** | -69.969*** | -95.316** | -70.068** | -51.615 | -57.511* | -27.870 | -102.979* |
| | (25.41) | (24.33) | (38.15) | (33.68) | (33.21) | (31.64) | (36.63) | (50.24) |
| female head | -17.680 | -0.871 | -66.435* | -69.172 | 7.825 | 39.380 | 5.594 | 24.742 |
| | (24.90) | (26.03) | (39.22) | (43.74) | (33.40) | (38.20) | (37.48) | (62.72) |
| children | 5.537 | -5.079 | 35.798 | 11.623 | -7.516 | -17.515 | -3.649 | 19.479 |
| | (15.18) | (13.62) | (32.94) | (20.63) | (13.75) | (17.38) | (10.42) | (39.39) |
| elder | -12.317 | -24.698** | -10.311 | -18.842 | -16.577 | -31.654 | -2.437 | 6.053 |
| | (10.65) | (12.28) | (15.13) | (16.04) | (18.41) | (20.66) | (11.02) | (38.72) |
| social assistance beneficiary | 10.078 | -6.851 | 5.841 | -30.347 | 4.835 | -13.986 | -28.594 | -20.300 |
| | (26.71) | (28.56) | (43.83) | (44.66) | (39.63) | (37.86) | (26.33) | (41.41) |
| durable walls | -21.944 | 1.744 | 12.790 | -21.395 | -9.180 | 11.872 | -90.804 | -61.425 |
| | (24.50) | (28.67) | (44.95) | (45.64) | (32.59) | (37.12) | (78.98) | (116.80) |
| durable roof | | 17.860 | | -21.825 | | 44.485 | | 44.153 |
| | | (34.86) | | (49.01) | | (44.39) | | (195.86) |
| toilet | | -54.402** | | -65.369 | | -32.506 | | -66.350 |
| | | (26.17) | | (53.19) | | (36.88) | | (91.79) |
| main water (underground) | | . | | . | | . | | -76.656 |
| | | . | | . | | . | | (73.49) |
| main water (surface) | | 21.977 | | 77.426 | | -15.479 | | . |
| | | (29.12) | | (55.56) | | (36.41) | | . |
| main water (other sources) | | 46.016 | | 9.345 | | 14.487 | | -281.838 |
| | | (51.02) | | (68.19) | | (74.70) | | (169.76) |
| household size | | 16.084 | | 28.401 | | 10.830 | | -11.916 |
| | | (11.76) | | (24.42) | | (10.92) | | (13.07) |
| constant | 253.427*** | 273.005*** | 220.134*** | 340.139** | 281.880*** | 269.625** | 190.704** | 194.365 |
| | (31.14) | (88.36) | (46.07) | (131.10) | (48.10) | (115.35) | (78.30) | (289.55) |
| N | 378 | 373 | 159 | 156 | 183 | 183 | 36 | 34 |
| R2 | 0.042 | 0.116 | 0.170 | 0.363 | 0.023 | 0.106 | 0.150 | 0.654 |
| F | 1.902 | 2.038 | 3.630 | 2.697 | 0.504 | 1.840 | 1.179 | . |

Notes: * p<0.10, ** p<0.05, *** p<0.01. Estimated by propensity score weighted OLS regression. Dependent variable: minutes per week spent on water collection. Subsample of households that do not use piped water or cistern-only as the main water source. These did not respond to the survey question regarding time spent on water collection. Selected variables shown. The control variables *female head, children* and *elder* were used as eligibility/priorization criteria for receiving the cistern. The dummies *social assistance beneficiary* and *durable walls* are covariates that were not well balanced at a few blocks in the pscore estimation. We also control for additional variables in models (B), (B1), (B2) and (B3) such as the head's educational level and variables related to living conditions in the community – lack of schools, health care facilities, leisure options, transportation, employment opportunities, and the perceived safety in terms of violence, crime and vandalism.

Table 7: Labor supply effect of the labor-saving technology on livestock production

| | **Dedicated area (A)** | **Dedicated area (B)** | **Dedicated area (C)** | **Small animals (D)** | **Midsized animals (E)** | **Large animals (F)** |
|---|---|---|---|---|---|---|
| cistern | 4.831*** | 5.298*** | 5.212*** | 0.643** | 0.190 | 0.131 |
| | (1.73) | (1.83) | (1.74) | (0.29) | (0.30) | (0.29) |
| female head | -5.269*** | -5.091*** | -4.935*** | 0.117 | -0.632** | -0.716** |
| | (1.77) | (1.83) | (1.81) | (0.29) | (0.32) | (0.30) |
| children | -1.122 | -3.316*** | -2.805*** | -0.285** | -0.352** | -0.227 |
| | (0.69) | (0.86) | (0.84) | (0.14) | (0.15) | (0.14) |
| elder | 2.966*** | 1.761* | 2.114** | 0.191 | -0.059 | 0.398** |
| | (0.95) | (0.96) | (0.96) | (0.17) | (0.16) | (0.18) |
| cash transfer beneficiary | 1.041 | -1.276 | -0.820 | -0.048 | -0.144 | -0.332 |
| | (1.82) | (1.92) | (1.93) | (0.32) | (0.33) | (0.33) |
| dwall | 4.899*** | 3.129 | 3.446* | -0.730** | -0.035 | -0.169 |
| | (1.74) | (2.04) | (1.99) | (0.34) | (0.35) | (0.34) |
| droof | | 2.884 | 3.096 | 0.668* | 0.393 | 0.703* |
| | | (2.26) | (2.18) | (0.39) | (0.42) | (0.40) |
| dtoilet | | 3.119 | 2.744 | -0.208 | 0.375 | 0.325 |
| | | (2.02) | (2.04) | (0.33) | (0.35) | (0.34) |
| main water (piped) | | -2.639 | | 0.144 | -0.037 | -0.869 |
| | | (5.61) | | (0.85) | (0.95) | (0.87) |
| main water (underground) | | -0.279 | | 0.310 | 0.331 | -0.734 |
| | | (3.64) | | (0.62) | (0.70) | (0.64) |
| main water (surface) | | -1.648 | | 0.562 | 0.312 | -0.506 |
| | | (3.55) | | (0.61) | (0.68) | (0.63) |
| main water (other sources) | | 0.239 | | 0.840 | 0.480 | -0.332 |
| | | (5.53) | | (0.87) | (0.92) | (0.86) |
| household size | | 2.457*** | | 0.271*** | 0.227** | 0.265*** |
| | | (0.59) | | (0.09) | (0.10) | (0.10) |
| household size: 1 to 3 members[1] | | | -9.623*** | | | |
| | | | (2.85) | | | |
| household size: 4 or 5 members[1] | | | -7.826*** | | | |
| | | | (2.39) | | | |
| N | 402 | 393 | 394 | 479 | 479 | 479 |
| N unconstrained | 187 | 185 | 185 | | | |
| R2 | 0.021 | 0.039 | 0.037 | 0.092 | 0.073 | 0.124 |

Notes: * p<0.10, ** p<0.05, *** p<0.01. Models (A) to (C) estimated by tobit propensity score weighted regression, models (D) to (F) estimated by logit propensity score weighted regression. Selected variables shown. The control variables *female head, children* and *elder* were used as eligibility/priorization criteria for receiving the cistern. The dummies *social assistance beneficiary* and *durable wall* are covariates that were not well balanced at a few blocks in the pscore estimation. We also control for additional variables in models (B) to (F) such as the head's educational level and variables related to living conditions in the community – lack of schools, health care facilities, leisure options, transportation, employment opportunities, and the perceived safety in terms of violence, crime and vandalism. Small animals are chicken, midsized animals are pigs and sheep, large animals are goats and cattle. (1) The baseline category is household size of 6 or more members.

Table 8: Labor supply effect of the labor-saving technology on agricultural production

| | **Cultivated area (A)** | **Cultivated area (B)** | **Cultivated area (C)** |
|---|---|---|---|
| cistern | 0.958 | 0.923 | 0.932 |
| | (1.16) | (1.24) | (1.19) |
| female head | -3.126*** | -3.021** | -2.884** |
| | (1.19) | (1.28) | (1.28) |
| children | -0.115 | -0.437 | -0.595 |
| | (0.48) | (0.59) | (0.58) |
| elder | -0.126 | -0.114 | -0.121 |
| | (0.63) | (0.66) | (0.66) |
| social assistance beneficiary | -0.133 | 0.018 | -0.271 |
| | (1.26) | (1.32) | (1.32) |
| durable walls | 1.947 | 2.222 | 2.215 |
| | (1.19) | (1.47) | (1.45) |
| durable roof | | -0.589 | -1.061 |
| | | (1.63) | (1.55) |
| toilet | | -0.745 | -1.012 |
| | | (1.48) | (1.48) |
| main water (piped) | | -2.142 | |
| | | (3.79) | |
| main water (underground) | | -0.218 | |
| | | (2.77) | |
| main water (surface) | | -1.915 | |
| | | (2.69) | |
| main water (other sources) | | -2.160 | |
| | | (3.72) | |
| household size | | 0.211 | |
| | | (0.41) | |
| household size: 1 to 3 members[1] | | | -2.103 |
| | | | (1.94) |
| household size: 4 or 5 members[1] | | | -1.458 |
| | | | (1.59) |
| N | 315 | 309 | 310 |
| N unconstrained | 280 | 277 | 277 |
| R2 | 0.004 | 0.008 | 0.008 |

Notes: * p<0.10, ** p<0.05, *** p<0.01. Estimated by tobit propensity score weighted regression. Selected variables shown. The control variables *female head, children* and *elder* were used as eligibility/priorization criteria for receiving the cistern. The dummies *social assistance beneficiary* and *durable walls* are covariates that were not well balanced at a few blocks in the pscore estimation. We also control for additional variables in models (B) and (C) such as the head's educational level and variables related to living conditions in the community – lack of schools, health care facilities, leisure options, transportation, employment opportunities, and the perceived safety in terms of violence, crime and vandalism. (1) The baseline category is household size of 6 or more members.

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