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Yuri Barreto
Bocconi University

Diogo G. C. Britto
Bocconi University and IZA

Bladimir Carrillo
Sao Paulo School of Economics-FGV

Daniel Da Mata
Sao Paulo School of Economics-FGV

Lucas Emanuel
Federal University of Bahia

Breno Sampaio
Federal University of Pernambuco and IZA

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IZA – Institute of Labor Economics

Schaumburg-Lippe-Straße 5–9
53113 Bonn, Germany

Phone: +49-228-3894-0
Email: publications@iza.org

www.iza.org

ABSTRACT

Cisterns for Life: Climate Adaptation Policies for Water Provision and Rural Lives*

Worsening climatic conditions and water scarcity pose major threats to rural livelihoods and to the economic development of arid regions. This paper evaluates a large-scale, low-cost climate adaptation program that built one million rain-fed water storage cisterns in Brazil's poorest and most drought-prone areas. Using novel individual-level administrative data and a difference-in-differences design, we show that the program substantially improved both economic and health outcomes, benefiting adults and children alike. Within ten years, household dependency on cash transfers fell by up to 34%, while formal labor income increased by 20%. Hospitalizations due to waterborne diseases declined by 16% among adults and 37% among children, and compliance with cash transfer conditionalities on child health and education improved. Additional evidence suggests that these gains were driven by a relaxation of time constraints: cisterns markedly reduced the time burden of water collection, enabling beneficiaries to allocate more time to productive activities. A cost-benefit analysis indicates a high marginal value of public funds relative to a broad range of public policies.

JEL Classification: Q54, Q25, Q58, J01

Keywords: climate adaptation, labor market, cisterns, water, health

Corresponding author:
Diogo G. C. Britto
Bocconi University
Via Roentgen 1
20136 Milan
Italy

E-mail: diogo.britto@unibocconi.it

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1 Introduction

Worsening climate conditions and water scarcity threaten rural life, with some predicting a massive exodus from drought-prone regions (Brown, 2012; Hennessy, Lawrence and Mackey, 2022; Morton, 2007). Families affected by water scarcity often travel long distances daily to collect water that is frequently unsafe for human consumption. This daily requirement can reduce the time available for productive activities and income. Limited and unsafe water consumption can also undermine health and, in turn, reduce individual productivity. As a consequence, beyond its health risks, water scarcity may pose a major barrier to the economic prosperity of affected families and, more broadly, to the economic development of dry areas.

Despite progress along several dimensions such as hunger and schooling, many developing countries still fail to deliver stable access to safe water to over two billion people (WHO, 2021). Stable water provision demands enormous investments and the ability to undertake complex infrastructure projects, which may not be feasible in several parts of the world, even more so in dry rural areas. This paper studies the effectiveness of a simple, low-cost, and scalable adaptation technology for water provision in a large and poor Brazilian rural area -– namely, the use of cisterns to capture rainwater next to rural households. Such technology has the technical potential to reduce water insecurity in most parts of the world, including dry areas (Musayev, Burgess and Mellor, 2018; Piemontese et al., 2020), and is increasingly being adopted in large-scale worldwide.[1] However, it remains an open question whether these decentralized systems, which do not match the stability and abundance of networked water provision, can deliver significant improvements in health, productivity, and household welfare.

We study the First Water Cistern (FWC) program, which has built one million cisterns in Brazil's semiarid region. This poor rural area has historically been affected by recurring droughts and is considered one of the six biomes most vulnerable to climate change worldwide (Seddon et al., 2016).[2] Each household receives a cistern built next to their

[1] These include the One Million Cisterns for the Sahel initiative in Africa, the "Beyond Cotton" program in Benin, Tanzania and Mozambique, the "Ebwiranyi Project" in Kenya, the "Sistemas de captación de agua" in Nicaragua, the "PROCAPTAR" in Mexico, and the "My Dam at My Door" in Ethiopia.

[2] The semiarid region is one of the poorest in Brazil, where the main economic activities are subsistence

house that captures rainwater and can also be filled by water trucks. These cisterns store enough water to meet the drinking and cooking needs of a family of five throughout the entire dry season, which can last several months. Families also received basic training to keep the water clean and the program costs are fully covered by the government. The share of families spending less than 15 minutes a day to fetch water rises from 7% to 93% after cistern delivery, indicating substantial time savings.

Our main analyses focus on economic and health outcomes, leveraging multiple individual-level administrative datasets that offer comprehensive information on beneficiary families spanning 15 years (2003-2017). They track income, employment, welfare program usage, and health outcomes of adults and children, including detailed demographic data and family composition information. This is a unique data ecosystem that is rarely available in low-income contexts such as ours.

To identify the causal effects of the FWC policy, we leverage variation in the timing of cistern delivery using a difference-in-differences design and the estimator by Callaway and Sant'Anna (2021). Our control group is composed of not-yet-treated households and we focus on yearly outcomes, estimating effects for up to ten years after treatment. We provide evidence of parallel pre-trends for up to ten years before treatment and show that our estimates are robust to the use of alternative estimators, control groups, and to the inclusion of municipality by year fixed effects.[3]

Our first core analysis focuses on economic outcomes. A key challenge is that a large share of income in our context comes from informal sources, which are typically not tracked in administrative datasets. We address this issue using two indicators directly related to total family income, including informal sources. First, we analyze the receipt of Bolsa Família (BF) means-tested cash transfers. At baseline, as many as 56% of families in our sample relied on these transfers. Program eligibility depends solely on per capita family income, which must not exceed a poverty cutoff. Income is monitored through a welfare registry (CadÚnico), maintained for the administration of federal social programs, and

agriculture and livestock farming (Da Mata and Resende, 2020). In 2020, the Gross Domestic Product per capita (PPP) in the semiarid was about $7,000, similar to that of African countries such as Angola and Nigeria.

[3]This last specification explores within municipality variation in the timing of cistern delivery generated by the program rollout.

includes both formal and informal sources. Second, we analyze CadÚnico enrollment. The registry targets families earning up to an income threshold – roughly 3 times higher than the poverty line defining BF eligibility –, so that enrollment in this registry also works as a low-income indicator.

We show that the cistern program led to a remarkable reduction in BF receipt – on average, it decreases by 10 percentage points (p.p.) in ten years, which is equivalent to a 18% drop relative to the baseline. The effect gradually kicks in, increasing up to the tenth year after treatment, when it reaches a sizable 19 p.p. reduction (equivalent to a 34% reduction). Second, we show that the FWC program also reduces the probability that families remain enrolled in CadÚnico welfare registry – up to 9 p.p. in three years after treatment. The reductions in BF and CadÚnico enrollment indicate that the cisterns significantly improve family income.[4] To the extent that income tracked through CadÚnico is self-reported, these results are likely a lower bound of FWC effects since families have underreporting incentives to continue receiving cash transfers.

To better understand the economic impact of the cisterns, we next analyze impacts on formal jobs. Differently from informal or subsistence work, they provide access to numerous social security benefits and protection from labor legislation. Only 13% of individuals in our sample held a formal job in the year before treatment. Ten years after the cistern delivery, adult beneficiaries are 2 p.p. more likely to hold formal jobs, a 15% increase relative to the baseline. Notably, total formal earnings increased by 20% on average in the ten years after treatment, which we show to be driven by both an increase in days worked and wages. A striking pattern of the effects on all economic outcomes is that they gradually accumulate over time and do not appear to fade, even a decade after treatment.

Our second core analysis focuses on health outcomes. We use individual-level data on hospitalizations covered by Brazil's public health system (SUS), which is provided free of charge to all citizens and extends coverage to the country's most remote areas (Bhalotra et al., 2019). Starting with adult health, we find a reduction in hospital admissions related to infectious and parasitic diseases, as well as diseases of the genitourinary system, conditions

[4]The only other reason for exclusion from BF is failure to comply with program conditionalities on child health and education. However, we show that the cistern policy actually *increase* compliance with BF conditionalities.

associated with poor water quality (Li and Wu, 2019; Wolf et al., 2022) and inadequate water consumption (Armstrong, Muñoz and Armstrong, 2020). On average, their incidence declines by 0.1 p.p., representing a sizable 16% reduction relative to the baseline. We find no effects on admissions for causes unrelated to water quality, reinforcing the interpretation that these effects are driven by the cisterns' impacts on water consumption. We interpret the reduction in hospitalizations, a relatively extreme manifestation of broader water-related health risks, as indicative that the cisterns improved overall adult health conditions.

Next we analyze impacts on child health. We find a 0.2 p.p. reduction in the yearly incidence of hospitalizations associated with waterborne diseases for children in ages 0-14. This effect is equivalent to a 37% drop relative to the baseline, suggesting meaningful improvements in child health. We complement this analysis by studying effects on family compliance with BF conditionalities on child health and education. We show that beneficiary families are 23% less likely to have their BF payments suspended for non-compliance with conditionalities. In addition, using unique data on school attendance by children in BF, we provide evidence that the cistern program reduced school absenteeism, an effect that is mainly driven by absences related to health issues. Although the latter estimates are somewhat imprecise, the overall evidence suggests that the cistern program improved child health and education.

The last part of our analysis investigates the mechanisms explaining the economic gains by the cistern policy. First, we show that health effects are entirely driven by women, who are typically more exposed to waterborne diseases (e.g., see Oluwasanya et al., 2024; United Nations Children's Fund and World Health Organization, 2024; De Guzman et al., 2023; Pal et al., 2018; Prüss-Ustün et al., 2019). If the positive effects on economic outcomes were primarily driven by better health leading to higher worker productivity, employment gains should be concentrated among women, who enjoy the cisterns' health benefits. Contrary to this hypothesis, we find that the increase in formal employment is strongly concentrated among men, indicating that a health-productivity mechanism is unlikely to be a main driver of the economic effects.

Finally, we provide evidence that a time-saving mechanism can better explain the economic gains driven by the cisterns. Our hypothesis is that cisterns release family

time from water collection which can then be allocated to productive activities – the share of families reporting to spend over an hour daily to fetch water drops from 46% to virtually zero after treatment. Three sets of results support this hypothesis. First, the positive effects on formal employment are entirely driven by beneficiaries taking up jobs in municipalities away from home, requiring longer commutes. This is consistent with the idea that cisterns offer additional time to families, which can now reach better employment opportunities away from home, mainly in larger urban areas.[5] In addition, the cisterns increase predictability in access to water and reduce emergency needs, which may be a related factor preventing individuals from taking far away jobs. Second, the effects on formal employment and the probability of receiving BF transfers are stronger in families with small children, who likely face tighter time constraints and water collection costs (Kremer et al., 2011). Lastly, the improvements in child health that we document may also reinforce a time-saving mechanism: healthier children require less caregiving and have fewer school absences, freeing up parents' time that can be allocated to productive work.

Overall, our results show that the FWC policy significantly improved family health and economic outcomes, with significant gains also observed among children. These effects are remarkably persistent and do not seem to fade away even ten years after treatment. These results show that simple decentralized technologies can substantially improve rural livelihoods, even if they do not provide the abundant and stable water supply of networked systems. They also indicate that lack of water in a rural context plagued by recurrent droughts imposes significant constraints on families, hindering their economic development. The FWC policy alleviates such constraints by reducing the daily burden of fetching water and by improving health conditions, allowing families to reach better economic opportunities.

Based on these results, we provide a simple cost-benefit analysis considering the FWC effects on economic outcomes. It shows that the private value for beneficiary households exceeds by at least 90% the cistern costs (4,140 BRL, about 740 USD). In turn, positive externalities in the government budget, thanks to reduced cash transfers and taxes on

[5]The employment effects mainly driven by men taking far away jobs are also consistent with evidence that women have strong preferences for shorter commute jobs (Le Barbanchon, Rathelot and Roulet, 2020). We also show that the increase in employment away from home is not driven by increased migration.

formal earnings, compensate for at least 35% of the direct cistern costs. Finally, we compute the marginal value of public funds (MVPF). These vary from 2.9 in a conservative scenario where FWC effects last for exactly ten years (our period of analysis), and go up to 6.8 if we assume that the effects persist for an additional five years. This places the FWC policy at the upper range of MVPF estimates for a wide range of public policies analyzed by Hendren and Sprung-Keyser (2020) and by Hahn et al. (2024) who specifically focus on policies related to climate change. Our simple calculation is likely a lower bound since it disregards several potential benefits, e.g., the valuation of improved health, future income gains by children, and improved birth outcomes documented in Da Mata et al. (2023). A natural question is why more individuals do not privately adopt the cisterns. This likely relates to their large costs relative to family income – about 7 months of earnings –, and the strong credit constraints faced by poor households in developing countries.[6]

A primary contribution of this paper is assessing the effectiveness of a simple adaptation technology that has the potential to reduce water insecurity globally and that is currently being adopted in several parts of the world. A large stream of research shows that climate shocks, such as droughts and extreme weather events, can have strong adverse effects on several individual outcomes (e.g., see Blakeslee, Fishman and Srinivasan, 2020; Carrillo, 2020; Dell, Jones and Olken, 2014; Dinkelman, 2017; Justino et al., 2025; Rocha and Soares, 2015). Our results show that cisterns may be highly effective in improving rural lives and resilience to water scarcity, yielding significant economic and health gains, benefits for children, and a high MVPF. They may be a viable adaptation technology to governments that have failed to deliver stable networked water infrastructure to billions of individuals, which is particularly challenging in dry rural areas.

Most previous work has focused on different climate adaptation technologies, tackling related but different issues — several papers have studied agricultural practices and their productivity effects, e.g., seeds, crop diversification, and soil conservation techniques (Dar et al., 2013; Emerick et al., 2016; Glennester and Suri, 2023; Auffhammer and Carleton, 2018), while other papers have analyzed the impacts of air-conditioning (Davis and Gertler,

[6]The latter has been widely documented in previous literature – e.g., see Banerjee, Karlan and Zinman (2015); Buera, Kaboski and Shin (2015); Ghosh et al. (2000), and Jack et al. (2023) which shows how asset collateralization can improve credit take-up for the adoption of rainwater harvesting tanks in Kenya.

2015; Pavanello et al., 2021; Randazzo, Pavanello and De Cian, 2023). Closest to our work, Da Mata et al. (2023) has analyzed the same policy focusing on *in utero* exposure and birth outcomes.[7] In turn, a randomized control trial by Jack et al. (2023) with milk farmers shows that asset collateralization increases the adoption of rainwater harvesting tanks in rural Kenya. They also report positive short-term effects on milk production, "but standard errors are too large to rule out either a high financial rate of return or zero impact on milk production".

Other stream of work has analyzed several adaptation behavior strategies such as migration, labor reallocation, or credit use – (for a review, see Kala, Balboni and Bhogale, 2023). They show that these strategies do not fully compensate for the costs of the climate shocks, including water scarcity, highlighting the need for policy interventions and the use adaptation technologies.

Second, this paper contributes to the literature studying water infrastructure, which shows positive effects of better water access and quality, mainly on birth outcomes and child health (Galiani, Gertler and Schargrodsky, 2005; Gazze and Heissel, 2021; Kremer et al., 2011; Zhang, 2012; Bhalotra et al., 2021; Marcus, 2022; Da Mata et al., 2023). In addition, previous work has also shown positive effects on education and adult health (Zhang, 2012; Zhang and Xu, 2016). To our knowledge, only two papers, using survey data and village-level variation, study the effects of water infrastructure programs on economic outcomes. Meeks (2017) studies the impact of shared tap water infrastructure in rural Kyrgyzstan, and shows an increase in home production explained by the reallocation of time towards work in household farming. In turn, Li, Xi and Zhou (2024) show that drinking water facilities led to higher off-farm employment and income in rural China.

We contribute to this literature by shifting the focus to economic outcomes, which have not been extensively studied, and by focusing on a simple adaptation technology that demands much lower investments relative to networked water infrastructure and whose implementation has shown to be feasible across large and dry rural areas. To the best of our knowledge, we are the first to use fine-grained individual-level data and variation

[7] In addition, a small-scale randomized control trial by Bobonis et al. (2022) has shown that the FWC policy reduced citizens' clientelistic exchange with local politicians and vulnerability as measured by self-reported health, depression, and child food security.

to measure the impact of low-cost climate adaptation policies on wide array of economic and health outcomes, comprising also effects on children. Our data allow us to track rich individual outcomes for over a decade and control for individual fixed effects. This rich empirical setting is a rare one within this literature, which has been largely based on survey data and area-level variation, or small-scale interventions. This allows us to document effects on different outcomes and study in detail their persistence for over a decade, and to provide rich additional analyses offering insights into mechanisms.

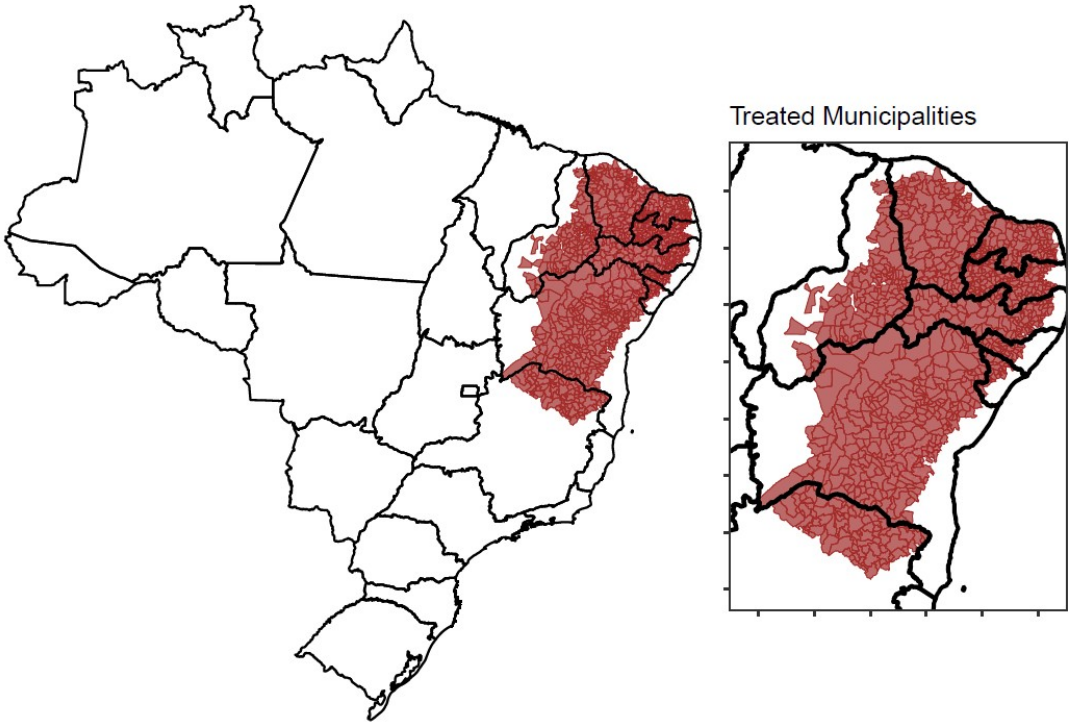
The paper proceeds as follows. Section 2 provides details on the FWC program and the Brazilian semiarid context, while Section 3 and 4 describe the data and the empirical strategy, respectively. Section 5 presents the main results on the effects of the FWC program and associated mechanisms, followed by Section 6 providing a cost-benefit analysis and Section 7 presenting our conclusions.

2 Background

The First Water Cistern (FWC) program focuses on the Brazilian semiarid, one of the poorest Brazilian regions with a per capita income 73% below national average – see Figure 1. The region hosts approximately 28 million people and comprises 1,135 municipalities covering 12% of the country's territory – an area roughly twice as large as Spain or France. The semiarid climate imposes a long history of severe droughts, irregular rainfall, and low soil water retention. This is a predominantly rural region where a large share of families rely on Bolsa Família cash transfers, the main program fighting poverty in the country. In turn, only 13% of the adult population holds formal jobs, which generally offer better salaries, job security, and access to social security coverage (Ulyssea, 2020). Hence, the semiarid population is strongly dependent on welfare support and has limited access to good jobs.

The FWC program aims to provide stable access to clean water for families in the Brazilian semiarid. Beneficiary households receive a cistern that stores rainwater redirected by a gutter system installed on the roof of each house. The cisterns are built with precast concrete slabs and cost around 4,100 BRL per unit – see Figure 2. The tank can store up to

Figure 1: The Brazilian Semiarid Region and the Spatial Distribution of Municipalities Treated by the FWC Program



The figure highlights all municipalities in the Brazilian semiarid region that received at least one cistern between 2002 and 2017.

16,000 liters of water, which should fulfill the needs of a five-people family for drinking and cooking during the dry season, lasting up to eight months. Building a cistern typically takes from two to three days and the program relies on low-skilled workers, usually hired in the local area. Overall, these cisterns are a simple and scalable climate adaptation technology, suitable for dry conditions. Similar rainwater harvesting technologies have been adopted in various regions of the world (Zhu, 2015).[8] Since its introduction in 2003, the FWC program built over one million cisterns. Although they are not perfect substitute for piped water infrastructure, they are a feasible alternative demanding much lower investments and less complex implementation. In fact, many government attempts to deliver stable piped water access have failed in the Brazilian semiarid.

When the cisterns are delivered, the beneficiary families also receive a brief maintenance

[8] Mintz et al. (2001) argue that "decentralized approaches to making drinking water safer, including chemical and solar disinfection at the point of use, safe storage and behavior changes deserve high priority for rapid implementation".

Figure 2: Cistern in the Brazilian Semiarid

Notes. The picture displays a typical cistern distributed through the Cistern First Water Program. Photo provided by the Brazilian Ministry of Social Development and Assistance, Family and Fight against Hunger.

training to keep the water clean and safe for domestic use. They receive instructions on water disinfection and how to clean the pond annually using the first rain of the season added with bleach (Palmeira, 2006). The training received by the families is pointed out by Da Mata et al. (2023) as directly related to the quality of the water in the tanks, reinforcing the importance of this stage of the program.

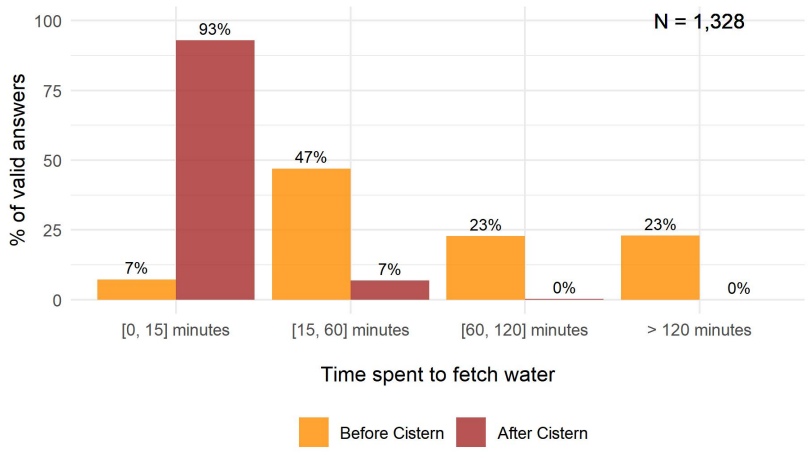
Non-profit organizations selected through public calls and the state governments in partnership with the Federal Government are responsible for the execution of the program. These partners are responsible for identifying and selecting families based on criteria established by the Federal Government (Ministério do Desenvolvimento Social, 2018).[9] To be eligible for the program, families living in rural areas without regular access to water must register in a welfare registry maintained by the Federal Government (CadÚnico) for the administration of social programs. Among eligible families, priority is given for those: (i) with low per capita income; (ii) headed by women; (iii) with a large number of children under age six or school-age children; (iv) with people with special needs and (v) with elderly people.

Silva (2009) conducted a representative survey with 1,328 beneficiaries of the FWC

[9]The process of locating eligible families is carried out in local meetings involving different entities, such as local public authorities, civil society organizations, and social assistance councils, among others.

program. He collected information on the perceived impacts of the cisterns, showing self-reported improvements along different dimensions. Figure 3 shows that most of the survey respondents declared that the cistern significantly reduced the daily time spent fetching water. Before receiving the cisterns, only 7% of the individuals reported spending less than 15 minutes a day fetching water, while 46% and 23% spent more than one and two hours, respectively. Remarkably, after cisterns are built, as much as 93% of individuals report spending less than 15 minutes daily. The same survey shows that 78% of beneficiary families have no tap water infrastructure in their houses. Before receiving the cisterns, they usually relied on alternative sources to obtain water, such as small lakes and reservoirs, which are often far away from their residences and vulnerable to contamination by pathogens. Moreover, 94% of beneficiaries report that the cisterns improved their lives, most of them indicating perceived gains in income and health. Appendix Figures A.1–A.2 provide additional descriptive statistics on beneficiary households.

Figure 3: Daily Time Spent to Fetch Water Before and After the Cistern



Notes. The figure shows the time spent by FWC beneficiaries to fetch water daily before and after the program, based on survey data collected by Silva (2009). The analysis excludes 12% who did not reply to the question.

The fact that individuals in the Brazilian semiarid spend a considerable amount of time to fetch water is consistent with evidence for other regions where clean water availability is difficult. United Nations (2010) estimates that 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. Similarly, Meeks (2017) estimates that households lacking water infrastructure spend

an average of 26 minutes per water collection trip in rural Kyrgyzstan. Hence, households in areas lacking access to safe water usually face a significant time burden, in addition to the associated health risks. In what follows, we investigate how drastically reducing such burden affects key economic and health outcomes.

3 Data

Main data sources. Our main analysis of the FWC program's impacts relies on four key datasets. First, we use primary data from the FWC program on cisterns built since the beginning of the program in 2003 until 2017. This dataset includes the construction date of the universe of cisterns distributed.[10] Additionally, this dataset provides individual-level information on the head of each household, including their date of birth and a unique individual identifier (CPF, "Cadastro de Pessoas Físicas", a nine-digit individual taxpayer identification number), which we use to link these data with other sources.

Second, we incorporate individual-level data from CadÚnico welfare registry. This registry targets low-income Brazilian families with monthly earnings of up to the value of three monthly minimum wages or with a per capita income below half the value of one monthly minimum wage. The Federal Government uses CadÚnico to administer social programs such as Bolsa Família. Importantly, it includes data on all FWC beneficiaries, offering detailed individual-level information such as date of birth, gender, education, household composition, and a unique CPF identifier. The registry allows us to directly link beneficiaries with the other members of their households. Our analysis draws on annual snapshots of this registry from 2012 to 2020, covering nearly two-thirds of the Brazilian population.

Third, we use data on Bolsa Família cash transfers which is the main program offering means-tested cash transfers to families living below the poverty line in Brazil. The program covers nearly one-fourth of the Brazilian population (Gerard, Naritomi and Silva, 2021) and over 56% of households in our analysis. In 2010, the average monthly transfer was 97 BRL (17% of the value of the monthly minimum wage at the time) and the program

[10]The cistern construction process is notably short, typically lasting between two to three days.

targeted families with per capita income below 140 BRL. This dataset covers the universe of Bolsa Família payments for 2004-2017, indicating the head of beneficiary households by their CPF identifier.

Fourth, we use linked employer-employee data from RAIS (*Relação Anual de Informações Sociais*) covering the population of formal workers in Brazil for the 2002-2019 period. RAIS provides comprehensive details on formal labor contracts, including unique identifiers for workers (CPF), contract types, start and end dates, occupational and sector codes.

Finally, we use SIH-SUS data from 2000-2018 (*Sistema de Internações Hospitalares*) on all hospital admissions covered by the Brazilian public health system (SUS). The latter offers free and universal coverage for all Brazilian residents, covering 75% of all hospital admissions in the country (Albuquerque and Machado, 2021). The SIH-SUS dataset includes detailed information on each admission, such as ICD-10 codes, admission date, length of stay, the total cost, and patient information such as birthdate, gender, municipality and postal code of residence.

4 Empirical Strategy

To estimate the effects of the FWC program on individual outcomes, we use a difference-in-differences (DID) design leveraging variation in the *timing* when cisterns are delivered across households. We employ the estimator proposed by Callaway and Sant'Anna (2021) which is well suited for designs with staggered treatment adoption and irreversible treatment such as ours. The estimator follows a two-step procedure. The first step consists in separately estimating the average treatment effect on the treated ($ATT(g,t)$) for each cohort group receiving treatment in year g in each time period t. Namely, we estimate the ATT for cohorts of individuals who first received the cisterns in 2003 in all calendar years of our panel. Then, we repeated the procedure for the cohorts who received treatment in 2004, 2005, and so on. We estimate $ATT(g,t)$ by comparing the average change in an outcome for cohort g between periods $t-1$ and t relative to a control group composed of all not-yet treated cohorts. This procedure effectively absorbs individual and time fixed effects.[11] The

[11] For a comprehensive discussion, one may refer to Callaway and Sant'Anna (2021) and Roth et al. (2022).

key identifying assumption is that outcomes would have evolved in parallel for all groups had treatment not occurred (generalized parallel trends). Using not-yet-treated units rather than a never-treated units as the control group enhances the comparability across the treatment and control groups, making this assumption more plausible. In addition, it is assumed that there are no anticipation effects.

This procedure will result in as many parameters as the possible cohort-time combinations in our data. Therefore, the second step is aggregating these parameters. We use a dynamic event-study specification averaging the $ATT(g,t)$s in a single parameter for each year relative to the treatment year (l). This average is weighted by group size. The coefficients $ATT_{l\geq 0}$ define the estimates of the dynamic treatment effects. To test for the paralell trends assumption, we repeat the same procedure for estimating placebo effects between periods $l-1$ and l for all period $l \geq 0$. For inference, we follow Callaway and Sant'Anna (2021) bootstrapping procedure clustered at the household level for estimating confidence intervals.

Since our control group is composed of not yet treated cohorts and the last treated cohort receives their cisterns in 2017, we can estimate effects up to year 2016 – the end date of our panel.[12] In our main analyses, we will estimate placebo effects up to ten years before the delivery of the cistern and treatment effects up to ten years after the event.[13]

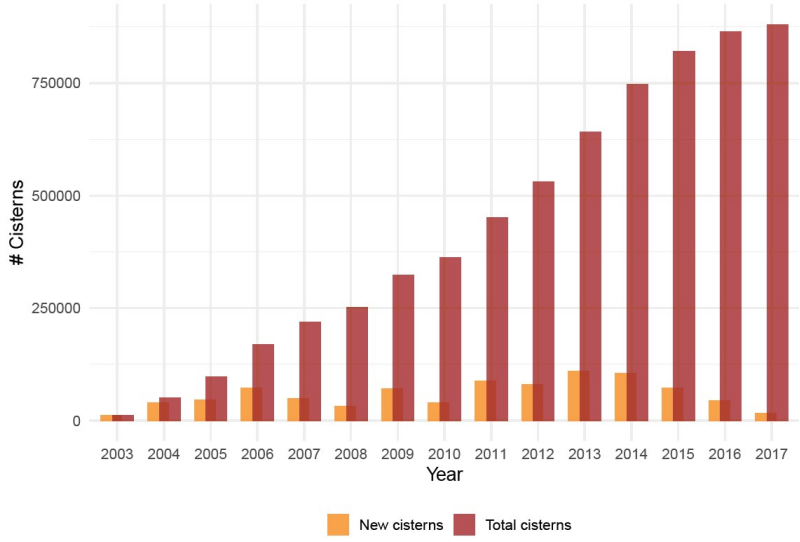
Program rollout. Figure 4 reports the number of cisterns built over time. The implementation gave priority to vulnerable families as described in Section 2, generating variation in coverage within municipalities. Nearly 70% and 90% of municipalities received at least one cistern one and four years after the implementation of the program, respectively – see Appendix Figure A.3. Thanks to the within municipality variation, we will show that our results are robust to the inclusion of fine municipality by year fixed effects, emphasizing that our DID design relies on fine within municipality comparisons. At the same time, control units in our setting might also benefit from the treatment if water is shared between

[12] All estimates were obtained using the open-source did R package by Callaway and Sant'Anna (2020). Our implementation sets the cohort treated in 2017 as a never-treated group, following Callaway and Sant'Anna (2021)

[13] Although our panel allows us to estimate effects up to 14 years after treatment, these estimates would be based on significantly smaller samples, making estimates more imprecise as few cohorts are observed after so many years.

neighbors. In that case, our results will likely estimate a lower bound of the cistern effects. However, survey data by (Silva, 2009) indicates that only 8.1% of households report frequently sharing water with neighbors.[14]

Figure 4: First Water Cistern Program Expansion Over Time



Notes. This figure plots the number new cisterns built in each year along with the total number of cisterns.

4.1 Analysis Sample

The process of building up our baseline sample is straightforward. First, we identify all individuals in treated households that received a cistern during the 2003-2017 period. To do so, we start by identifying the head of each treated family in the FWC program data. Next, we identify their households in CadÚnico data for 2012-2020, which allow us to identify all household members. This process allows us to retrieve all individuals in treated households along with the timing that cisterns are delivered.

Second, we create a yearly panel tracking health, economic, and employment outcomes for treated individuals in the 2002-2016 period.[15] For the analysis on formal employment,

[14] Another 21.9% report sharing water very rarely. The fact that most municipalities are treated since the onset of the program makes it challenging to find "pure" control units who live far away from treated units and to get rid of potential spillovers attenuating our estimates. In addition, we are not aware of any anecdotal evidence indicating the cisterns as a source of conflict between neighbors.

[15] All individual linkages across data sources are based on individuals' unique CPF identifiers. The only exception is the health dataset on hospitalizations, for which we explain the linkage in Section 5.2.

we exclude from the sample individuals below the legal age (18) who face severe employment restrictions due to labor legislation, and older individuals close to the retirement period. Specifically, we restrict attention to individuals above age 18 in 2002 and up to age 55 in 2016. Our final panel tracks employment outcomes throughout the 2002-2016 period for 672,614 individuals who received the cistern between 2003 and 2017. Our panel ends at 2016 since our difference-in-differences design, described in Section 4, uses a control group composed of eventually treated individuals. As such, it is not possible to estimate effects after 2016 when all groups have been treated.

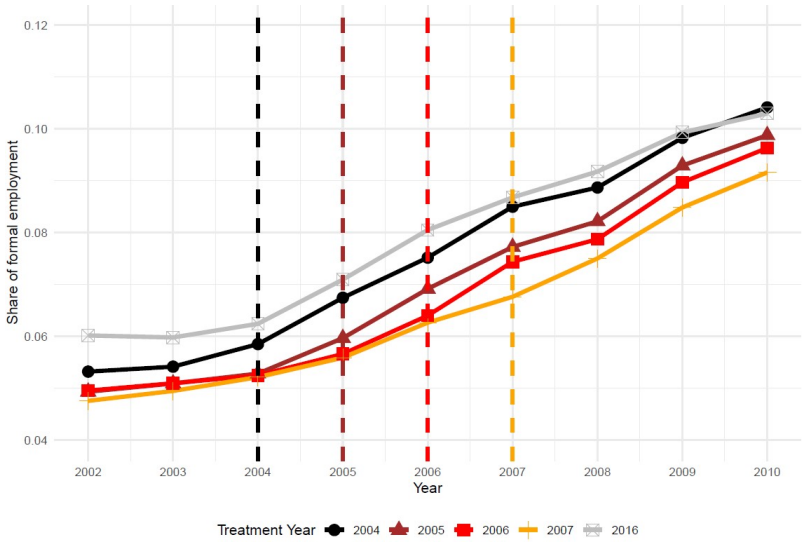
Raw Data Patterns. Figure 5 provides an initial view of the raw data that summarizes the underlying intuition of our empirical design. It focuses on the probability that individuals treated in different years hold a formal job over time. First, the figure suggests that formal employment evolves in parallel across cohorts before treatment takes place. In addition, cohorts treated in similar years have similar formal employment levels before treatment, which offers support to the parallel trends assumption. Second, the figure indicates that formal employment disproportionally increases once each cohort is treated (relative to other cohorts treated in the future). Hence, this descriptive evidence suggests that the FWC program increased the employment of beneficiaries. In the following section, we will formally estimate the effects of the FWC on this and other outcomes.

5 The Effects of the FWC Program

5.1 Economic Outcomes

We first analyze impacts of the cistern policy on economic outcomes, using the DID design outlined in Section 4. We consider different indicators of beneficiary families' economic conditions. These indicators tackle the challenge that much of the income in the Brazilian semiarid is informal, and thus is usually not directly reported in administrative datasets such as ours.

Figure 5: Trends in Formal Employment by Treatment Cohort



Notes. This figure displays the yearly share of individuals formally employed for cohorts of individuals receiving the cisterns in different years in our main sample.

5.1.A Bolsa Família Dependency

We start by studying effects on the probability that individuals receive Bolsa Família means-tested cash transfers, which we explore as a key indicator of household economic conditions. This is the main transfer program supporting poor families in Brazil, covering 56% of our sample at baseline. The program targets families living below the poverty line, defined by a monthly per capita income below 140 BRL for most of our sample period.[16] Income is monitored through CadÚnico welfare registry, and beneficiary families are mandated to update their information every two years. Income in this registry is self-reported and comprehensive of any formal and informal sources.

Hence, Bolsa Família receipt serves as a natural indicator of economic conditions, comprising informal income, which is extremely relevant in our context and rarely observed in administrative datasets. To the extent that participation depends on self-reported income, any reductions in participation due to the cistern policy will be attenuated if beneficiary families omit improvements in family income.

[16]Income per capita is the sole criterion for Bolsa Família eligibility. Despite having no formal time limit, nearly 23% of families exit the program within three years, and the average receipt duration is five years, which indicates substantial turnover in the program (Morgandi, Fietz and Superti, 2023). There is no direct interaction between Bolsa Família eligibility and participating in the cistern program.

We track the yearly probability that households receive any transfer from Bolsa Família. Since these transfers are defined at the household level, we consider a household to be a beneficiary if at least one individual in the household is registered as a beneficiary in the Bolsa Família data.[17] Figure 6 presents the results. It shows a progressive and remarkable reduction in Bolsa Família receipt. The average effect in ten years is a 10 p.p. reduction in Bolsa Família receipt, representing a sizable 18% drop relative to the baseline mean, going up to a 19 p.p. reduction in the tenth year (equivalent to a 34% reduction). Placebo effects up to ten years before treatment are small and generally statistically insignificant, supporting the parallel trends assumption. These results indicate a significant improvement in individuals' economic conditions driven by the cistern program. In addition, the effects on participation define a positive externality on the government budget that is relevant from a welfare perspective – in Section 6, we will provide a cost-benefit analysis of the FWC policy.

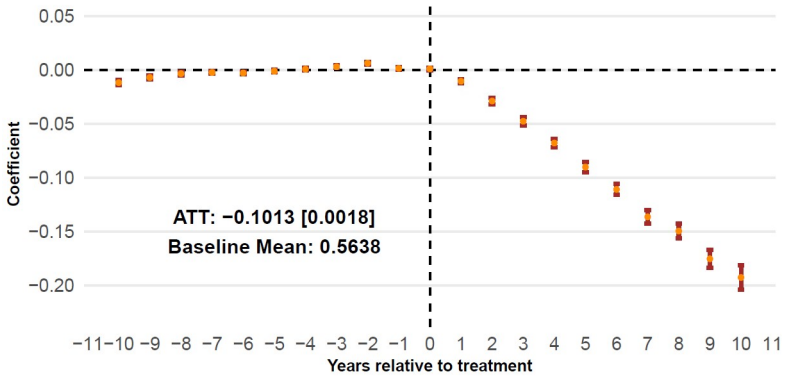
The reduction in Bolsa Família dependency might be even stronger if one considers that eligibility depends on self-reported income. Hence, the impacts on take-up might be a lower bound effect if some income gains steaming from the cisterns are underreported. Moreover, in Section 5.3, we will provide evidence that the FWC program increases compliance with the program's conditionalities, related to child health screenings and school attendance. Positive effects on compliance are another factor that might attenuate the impact on program exit due to improved economic conditions.

5.1.B Enrollment in CadÚnico Welfare Registry

Next, we analyze yet another marker of economic welfare that takes into account the high prevalence of labor informality in the semiarid region. Specifically, we study the probability that families are enrolled in CadÚnico welfare registry over time. Presence in the registry serves as a useful proxy for income, as individuals are eligible for registration and for staying in the registry if their monthly per capita household income is up to the value of half monthly minimum wage, or if their total monthly household income is below the value

[17] Payment data identifies the head of the households receiving Bolsa Família. Using CadÚnico data, we identify household and thus all individuals benefiting from the program. Our sample tracks 721,010 familes.

Figure 6: The Effect of Cisterns on the Probability of Receiving BF Cash Transfers

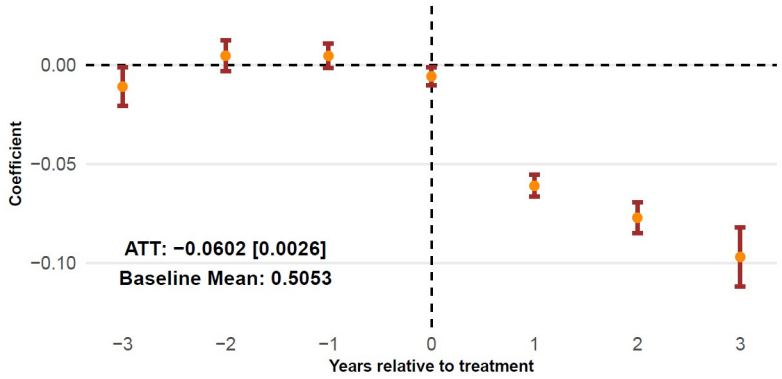


Notes. This figure presents estimates of the effect of cisterns on the probability of being a beneficiary of Bolsa Família using Callaway and Sant'Anna (2021) estimator. Families f are considered beneficiaries in year t if they received cash from the program in that year. Results are based on panel data from 2004 to 2016, using a balanced panel at the household-year level.

of three monthly minimum wages. Relative to the initial indicator based on Bolsa Família, enrollment in CadÚnico is based on a significantly higher income cutoff (0.5 minimum wage in per capita income vs. roughly 0.17 for Bolsa Família).

Hence, we study impacts on the probability that individuals are registered in CadÚnico as another proxy for economic welfare, using our main specification. Since CadÚnico data is available for the 2012-2020 period, we run this analysis using an alternative sample: a panel for the period 2012-2016 comprising cohorts treated between 2013 and 2017. In this analysis, a family f is considered registered in year t if at least one of its members appears in the CadÚnico data for that year. The results in Figure 7 show that the cisterns significantly reduce the probability that individuals remain in CadÚnico welfare registry. On average, individuals are 6 p.p. less likely to be enrolled in CadÚnico in the three years after cistern delivery, and the effect goes up to a 9 p.p. reduction in the third year. This confirms the improvement in families' economic conditions using a significantly higher income cutoff, relative to the previous analysis based on Bolsa Família benefits (Figure 6).

Figure 7: The Effect of Cisterns on the Probability of Being Registered in CadÚnico



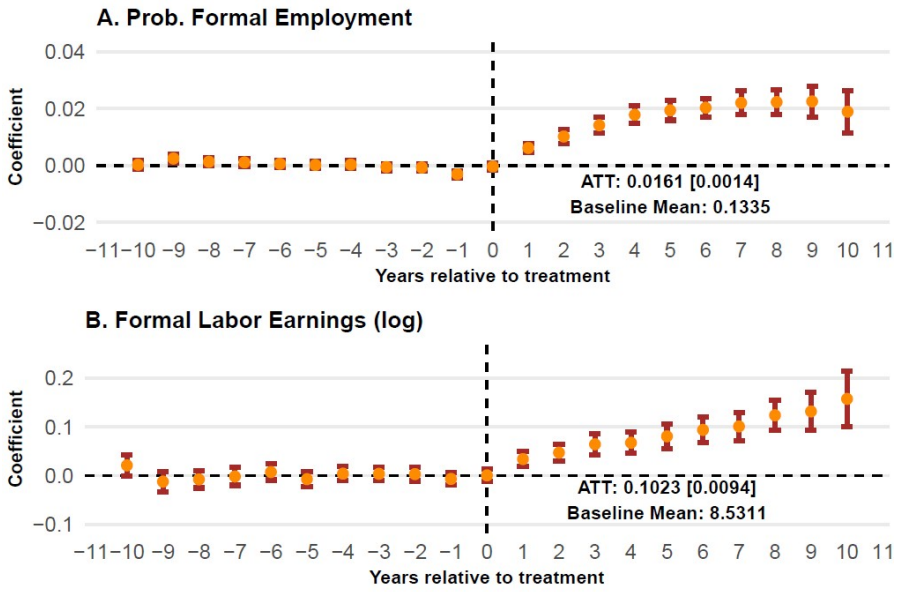
Notes. This figure presents estimates of the effect of cisterns on the probability of being registered in CadÚnico, using the Callaway and Sant'Anna (2021) estimator. A family f is considered registered in year t if at least one of its members appears in the CadÚnico data for that year. Results are based on panel data from 2012 to 2016, using an unbalanced panel at the household-year level.

Overall, the results in Figures 6 and 7 indicate that the cistern program significantly increased the income of beneficiary families. The consistent results across the two indicators suggest broader improvements in family economic conditions, rather than minor improvements across poverty cutoffs.

5.1.C Formal Employment Outcomes

We next analyze impacts on formal employment outcomes which can be accurately measured in the administrative employment data (RAIS) described in Section 3. Relative to informal work, formal jobs offer several additional benefits to workers. They provide access to social security benefits, such as disability and unemployment insurance, and pension contributions. In addition, there is a binding minimum wage that has substantially increased in real terms since the 2000's (Engbom and Moser, 2022) and workers are entitled to receive a government mandated severance payment upon dismissal. Overall, these are arguably high value jobs in our context which are also scarce; only 13% of individuals in our sample held a formal job in the year before receiving the cistern.

Figure 8: The Effect of Cisterns on Formal Employment Outcomes



Notes.This figure presents the event-study estimates using the Callaway and Sant'Anna (2021) estimator with individual-level panel data spanning from 2002 to 2016. The control group consists of individuals who have not yet been treated, as well as those who received the cistern in 2017. In Panel A, the dependent variable is a binary variable indicating whether the individual has a formal job in a given year. In Panel B, the dependent variable is the natural logarithm of earnings, and the sample is limited to employed individuals.

Figure 8 presents our main empirical results on the effect of receiving a cistern on formal labor market outcomes. Panel A shows effects on the yearly probability of formal employment while Panel B shows the effects on earnings, as measured by the log of the total yearly earnings among employed individuals each year. The results reveal improvements in formal labor market outcomes, which progressively fade in from the first treatment year. In ten years, the probability of formal employment increases by 2 percentage points (p.p.) and, among the employed, earnings increase by as much as 15%.[18]

The average effects in the ten-year post-treatment period are reported in Table 1. Employment increases on average by 1.6 p.p. (column 1), a 12% increase relative to the baseline. In addition, the table shows that total annual earnings – including individuals with no

[18] As described in Section 4.1, we restrict our main sample to individuals who were at least 18 years old at the beginning of the panel in 2002 and up to 55 in 2017. Since this criterion is somewhat restrictive, we rerun our main analysis with a much less stringent sample restriction. We use an unbalanced panel that tracks employment in all years when individuals are in the age range 18-55 (thus comprising individuals who turn 18 after 2002 and who turn 55 before 2017). The results in Figure A.4 shows that the employment results are robust to this less restrictive sample, and somewhat stronger for the extensive margin employment, supporting our main results.

formal job and zero earnings – increases by 20% relative to the baseline (column 4). The increase in yearly labor income is driven both by more months worked and higher monthly earnings conditional on employment, which increase by 14% and 7% relative to the baseline (columns 2 and 3). Hence, formal labor earnings increase both due to the extensive margin of labor supply and higher wages. Overall, these results indicate that the FWC policy leads to a meaningful and long-lasting improvement in formal employment outcomes.

Table 1: The Effect of Cisterns on Formal Employment Outcomes

			Formal Labor Earnings (brl)	
	(1)	(2)	(3)	(4)
	Emp.	Months worked	Monthly Earnings	Total Earnings
DD	0.016	0.156	48,772	131,029
	(0.001)	(0.012)	(5,191)	(10,390)
N. Obs	10,089,210	10,089,210	1,335,514	10,088,695
N. Individuals	672,614	672,614	219,028	672,614
Mean dep. variable	0.133	1.12	620.585	650.776

Notes. This table shows the baseline results from the difference-in-differences estimator proposed by Callaway and Sant'Anna (2021). The control group consists of individuals who had not yet been treated, as well as those who received a cistern in 2017. The dependent variable in column (1) is an indicator equal to one if the individual had at least one formal job during the year. In column (2), the dependent variable is the number of months worked in the year. Column (3) reports the monthly earnings in the formal labor market, including only employed individuals. The dependent variable in column (4) is the annual earnings from the formal labor market. Coefficients represent the simple average of $ATT_{l\geq 0}$ from the baseline event-study model. The panel data covers the years 2002 to 2016.

5.2 Cisterns and Health Outcomes

The provision of a cistern may represent an improvement in both the quantity and quality of the water available for consumption, which, in turn, may lead to better health outcomes.[19] First, this analysis may capture an important dimension of the benefits provided by the policy to beneficiary families. Second, it may help explain potential effects on economic outcomes, as better health can increase individual productivity and income. Hence, this analysis bears its own interest and may also shed light on the link between water scarcity and economic outcomes.

We use data on hospitalizations covered by the Brazilian public health system, as described in Section 3. The public health system provides universal coverage free of charge,

[19]Previous studies have shown that improvements in water quality and quantity (Armstrong, Muñoz and Armstrong, 2020; Galiani, Gertler and Schargrodsky, 2005; Kremer et al., 2011; Wolf et al., 2022; Da Mata et al., 2023) lead to better child health outcomes.

being the main provider of health services for low-income Brazilians. One shortcoming of this data is that individual CPF identifiers are not available and, hence, it cannot be directly linked to our other main data sources. To link these data to our baseline sample at the individual level, we leverage the fact that 76% of Brazilian residents can be uniquely identified by their date of birth, gender, and postal code of residence (Amorim et al., 2023). We proceed by associating hospital admissions to an individual in our baseline sample when there is a perfect match between the individual and the patients' date of birth, gender, and postal code of residence – which we observe in both datasets. Amorim et al. (2023) first used this procedure and provides evidence that it generates classical measurement error in hospitalization outcomes. This will reduce the precision of our estimates but should not bias them.

5.2.A Adult Health

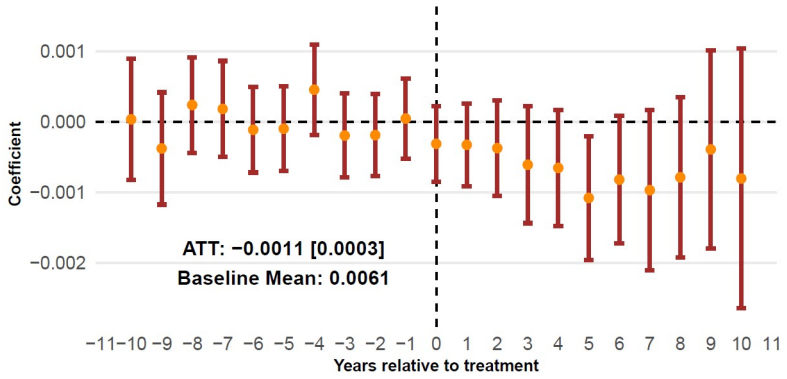
We start by investigating the effects of cisterns on working-age adult health, following the same sample restrictions used for studying formal employment outcomes; namely with a panel of individuals above age 18 in 2002 and below age 55 in 2016. The results follow our main specification, as described in Section 4, and are displayed in Figure 9. The dependent variable is an indicator for yearly hospitalization with ICD-10 codes linked either to the consumption of low-quality water (infectious and parasitic diseases, see Wolf et al., 2022) or to insufficient water intake (genitourinary system diseases, see Armstrong, Muñoz and Armstrong, 2020). The results indicate a decrease in the probability of hospitalization due to water-related diseases, with the effect gradually phasing in over time. On average, the probability of hospitalization decreases by 0.1 p.p. in the ten years after treatment, equivalent to a 16% reduction relative to the baseline. Since hospitalizations are an extreme manifestation of waterborne health risks, we mainly focus on effects relative to the baseline, which we interpret as an indicator of broader health improvements.[20]

In Appendix Figure A.5, we show that effects on hospitalization for other causes, unrelated to water quantity and quality, are close to zero and statistically insignificant.[21] This

[20] Unfortunately, similar data for broader health indicators (e.g., outpatient visits) are not available.

[21] We analyze the primary ICD-10 (International Statistical Classification of Diseases and Related Health Problems) codes associated with each admission in the SIH-SUS data.

Figure 9: The Effect of Cisterns on Hospitalization for Water-Related Issues



Notes. This figure presents the event-study estimates using the Callaway and Sant'Anna (2021) estimator for different samples with individual-level panel data spanning from 2002 to 2016. The control group consists of individuals who have not yet been treated, as well as those who received the cistern in 2017. The dependent variable is a binary variable indicating whether the individual was hospitalized by infectious and parasitic diseases or genitourinary system diseases.

suggests that the improvement in health outcomes are driven by better access to water, reducing the scope for potential alternative explanations. This also addresses the potential threat that the reduction in public hospitalizations might be driven by families getting higher income and turning to private health services after receiving the cisterns. If this was the driver of the reduction in public hospitalizations, one would expect similar effects to emerge for other causes, unrelated to water consumption.[22]

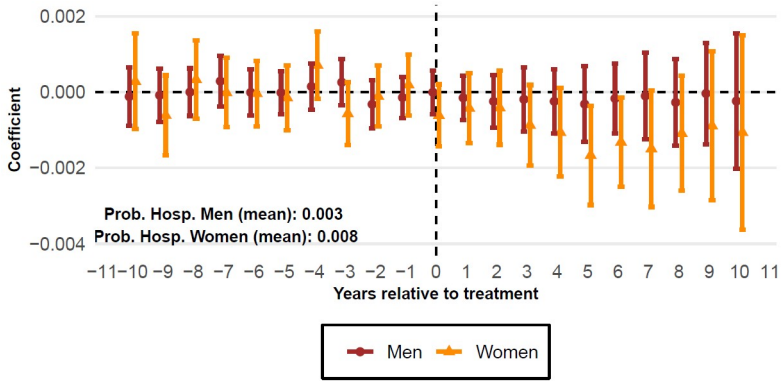
Next, we show that the effects on health mask strong heterogeneity across gender. Figure 10 estimates these effects separately for men and women in the household. It reveals that health improvements are entirely driven by women. These results are in line with the fact, relative to men, women are more exposed to waterborne diseases (Oluwasanya et al., 2024; United Nations Children's Fund and World Health Organization, 2024) and more likely to die due to diarrheal diseases (De Guzman et al., 2023; Pal et al., 2018; Prüss-Ustün et al., 2019). They are also in line with the baseline hospitalization rates for water-related issues in our sample which are nearly three times higher for women than men (0.008 vs. 0.003, respectively).[23] These heterogeneous effects will help us assess the role of health

[22]This is also unlikely because private health coverage is strongly on concentrated on high-income individuals, covering only 15% of Brazilians (Amorim et al., 2023), while our study focuses on a very low-income population.

[23]In previous literature, higher exposure has been linked to the fact that women have worse access to sanitation facilities and are often responsible to toilet cleaning activities, increasing their exposure. Differential exposure may also be related to the fact that a larger proportion of men work outside the home, which may provide them with better access to water and sanitation facilities, regardless of the cistern provision.

improvements in explaining the economic gains generated by the cistern policy.

Figure 10: The Effect of Cisterns on Hospitalization for Water-Related Issues, by gender



Notes. This figure presents the event-study estimates, by gender, using the Callaway and Sant'Anna (2021) estimator with individual-level panel data spanning from 2002 to 2016. The control group consists of individuals who have not yet been treated, as well as those who received the cistern in 2017. The dependent variable is a binary variable indicating whether the individual was hospitalized by infectious and parasitic diseases or genitourinary system diseases.

5.2.B Child Health

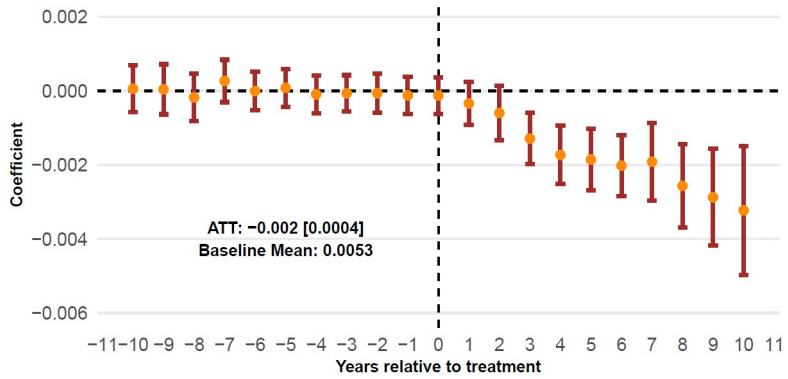
We now turn our attention to the effects of cisterns on children, who, similarly to women, are at high risk of waterborne diseases (UNICEF et al., 2023). We focus on panel years when children are aged 0-14 and on children born prior to cistern delivery – so that our estimates are clean from potential effects on *in-utero* health, as documented by Da Mata et al. (2023).[24] We then estimate our baseline specification using the probability of being hospitalized for a water-related disease as the dependent variable. We display the results in Figure 11.

Estimates in Figure 11 show that cisterns reduced the probability of child hospitalization by 0.2 percentage points, which amounts to a 37% drop relative to the baseline mean. This is a substantial reduction, suggesting that better access to water significantly improve children's health. Importantly, we find no evidence of pre-treatment effects, lending credibility to our causal interpretation. Also, Figure A.6 in the Appendix breaks down the effects by cause (mapped through ICD-10 codes) and shows a pattern similar to that in Figure A.5 for adults – effects are mainly driven by causes associated with water-related risk diseases.[25]

[24]Thus we rely on an unbalanced panel, since we stop tracking individuals once they are older than 14.

[25]Differently from the effects on adult health, the reduction in hospitalizations for children is similar across gender – see Appendix Figure A.7.

Figure 11: The Effect of Cisterns on Hospitalization for Water-Related Issues, Children



Notes. This figure presents the event-study estimates, by gender, using the Callaway and Sant'Anna (2021) estimator with individual-level panel data spanning from 2002 to 2016. The control group consists of individuals who have not yet been treated, as well as those who received the cistern in 2017. The dependent variable is a binary variable indicating whether the individual was hospitalized by infectious and parasitic diseases or genitourinary system diseases. The sample is an unbalanced panel including individuals aged 0 to 14 who were already born when the cistern was constructed.

5.3 Compliance with Bolsa Família Conditionalities on Child Health and Education

We next analyze the impacts on different indicators related to Bolsa Família conditionalities. Program participation is conditional on school-aged children being enrolled in school and attending 85% of school days, and on adherence to the vaccination and medical check-up schedules for young children, pregnant women, and lactating mothers (Brollo, Kaufmann and La Ferrara, 2020). This analysis will offer further insights into the impacts of the FWC program on investments in child human capital and welfare.

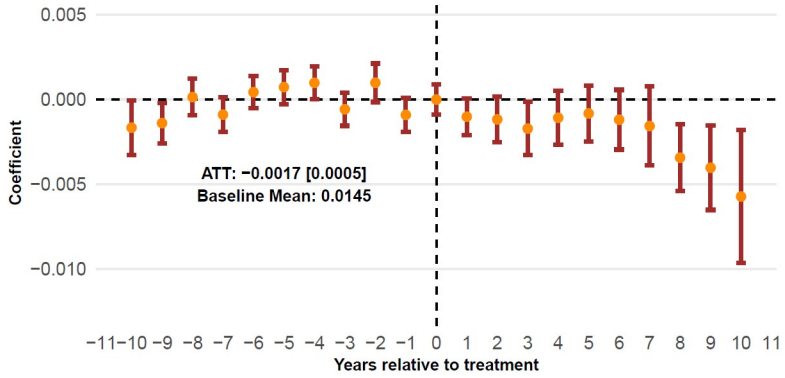
5.3.A Bolsa Família Suspensions

Noncompliance with the Bolsa Família conditionalities on children may lead to temporary or even permanent suspension of benefit payments. The program administration tracks conditionalities through mandatory reports on daily attendance sent by schools and health data sent by SUS. Failure to comply first results in warnings sent to families, which are followed by temporary and then permanent program suspensions in case families remain noncompliant. Since data on warnings are not available, we use Bolsa Família monthly payment data to create an indicator of conditionality compliance. Specifically, we track gaps in Bolsa Família monthly payments which indicate that the family has been temporarily suspended from the program. We track only gaps between the first and last Bolsa Familia

payments in our data to avoid confounding temporary suspensions with program exits, e.g., due to increased income. By construction, the panel data for this analysis is unbalanced, being restricted to panel years when household were Bolsa Família beneficiaries.

The results in Figure 12 show that the FWC program reduced the probability of interruptions in Bolsa Família payments among beneficiaries. In ten years, this probability declines on average by 0.017 p.p., reaching 0.5 p.p. in the tenth year after treatment. Although suspensions are relatively infrequent, the average effect in ten years represents a sizable 23% reduction relative to the 1.45% baseline mean.[26] These results indicate that the FWC program increased family compliance with program conditionalities on child health and education. They also indicate that the reduction in Bolsa Familia take-up, documented in Section 5.1.A, cannot be explained by any potential adverse effects on program compliance.

Figure 12: The Effect of Cisterns on the Probability of Interruptions in Bolsa Família Payments



Notes. This figure presents our estimates of interruptions in Bolsa Família payments. The panel covers the period from 2004 to 2016 and includes only beneficiaries. The dependent variable is a dummy equal to one if the family experienced any suspension between the first and last month in which they received benefits.

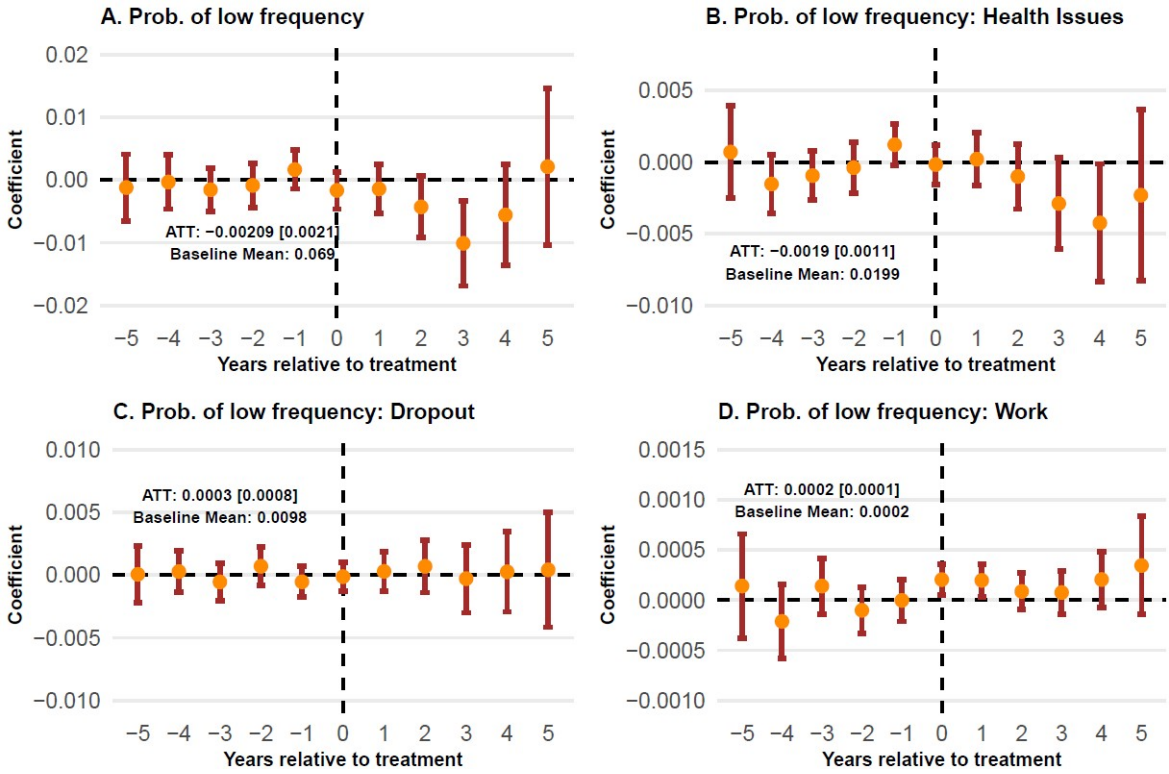
5.3.B Cisterns and Children School Attendance

Next, we leverage unique data on school attendance and reasons for school absenteeism used by the program administration to monitor the compliance of Bolsa Família beneficiaries – these records are available for 2009-2016, and children can be identified through an unique person identifier. We built an yearly indicator that the child has not reached the minimum 85% attendance required by the program. We also build a low-attendance indicator for

[26] In Appendix Figure A.8, we show that this result holds when focusing on one-month interruptions, showing that the reduction in this measure is not driven by families exiting and then returning to the program.

different underlying reasons such as those motivated by health issues and the need to work. This analysis excludes families that received cisterns before 2010 so that we can observe at least one pre-period, and focuses on children aged 6 to 17, the range in which the attendance rule applies, yielding an unbalanced panel.

Figure 13: The Effect of Cisterns on School Attendance, Children



Notes. This figure presents the event-study estimates using the Callaway and Sant'Anna (2021) estimator with child-level panel data from the Bolsa Família program spanning 2009 to 2016. The control group consists of children who have not yet been treated, as well as those whose families received a cistern after 2016. In each panel, the dependent variable is a dummy that equals one if the child recorded school attendance below the required threshold in at least one of the months they were tracked in that year. Panel A considers any cause of low attendance, while Panel B restricts to health-related absences (e.g., illness of the child or a parent), Panel C to school dropout, and Panel D to child labor. The sample excludes families that received cisterns before 2010 and is restricted to children aged 6–17, for whom the attendance requirement applies, yielding an unbalanced panel.

We estimate the effect of the FWC cistern program on the probability of low-attendance for different reasons – see Figure 13. Panel A shows a reduction in the overall probability of low-attendance. The results show a 1 p.p. reduction in the low-frequency indicator in year 3 after treatment. The effect is stastically significant and sizable relative to the 6.9% baseline, although it is somewhat short-lived, vanishing entirely in five years after treatment. In turn, Panel B shows a reduction in the incidence of low-attendance due to health issues, dropping by 0.19 p.p. in a five-year period after treatment (significant at the 10% level).

Finally, Panels C and D show that there are no statistically significant effects on absenteeism due to school dropouts or the need to work. Overall, these results offer some indication of increased attendance due to the cistern program, mainly related to improved child health. Nevertheless, we interpret them with some caution as the effects seem to vanish by the end of our panel and because estimates are not particularly precise. In any event, they line up well with our prior results showing improvement in child health outcomes and higher overall compliance with program conditionalities.

5.4 Additional Robustness

Our baseline specification uses the DID estimator by Callaway and Sant'Anna (2021) which is well suited for staggered settings such as ours. To reinforce the robustness of our findings, we test an alternative estimation procedure. Specifically, we use the Two-Stage Difference-in-Differences estimator by Gardner et al. (2024). The estimator uses never treated units as controls, differently from our baseline estimation relying on not-yet treated units.[27] The results in Appendix Table A.1 show that the alternative estimator leads to similar average treatment effects to our baseline specification for our main outcomes. Next, we show that our results are robust to the inclusion of fine municipality by year fixed effects, emphasizing that our design leverages within municipality variation in the rollout of the FWC program. To do so, we take advantage of the fact that the DID estimator by Gardner et al. (2024) is well suited to the inclusion of controls. The results in Appendix Table A.1 show that estimates for our main outcomes survive using only within municipality variation and, thus, they cannot be explained by alternative policies or factors varying at the municipal level.

5.5 Mechanisms and additional results

We have shown that better access to clean water through the delivery of cisterns significantly improved economic outcomes. On average, the cistern policy reduces dependency on Bolsa Família cash transfers by 10 p.p. in ten years and enrollment in CadÚnico welfare registry

[27] Specifically, it uses the cohort treated in 2017 which is never treated in the time spam of our panel(2003-2016). We run this estimator based on the implementation package provided by Butts and Gardner (2022).

targeting low-income families by 6 p.p. in three years. Adult beneficiaries are also more likely to secure scarce formal jobs, achieving on average 20% higher formal earnings in ten years. These effects are meaningful in size and sustainable for long periods of at least ten years. Moreover, we have documented positive impacts on adult and child health, and have provided evidence that families are more likely to comply with Bolsa Família conditionalities on child health and education after cistern delivery.

We now investigate the mechanisms that explain the positive effects on family economic conditions. The first potential mechanism relates to the impact of the FWC program on health outcomes, which could enhance productivity and, in turn, explain the observed improvements in income. The second mechanism relates to the time constraints imposed by scarce and unstable access to water. Forty-six percent of cistern beneficiaries report spending more than an hour a day fetching water before receiving the cistern, and this number drops to virtually zero after the program (Figure 3, Section 2). This suggests that the program significantly alleviates family time constraints, potentially enabling individuals to work more. This mechanism, in which infrastructure frees up time and increases labor market participation, was found to be particularly meaningful in the context of rural electrification by Dinkelman (2011). Relatedly, by providing more predictable access to clean water, the cisterns may reduce emergency needs, allowing individuals to better commit to the time demands associated with stable formal jobs.

The evidence presented so far supports both mechanism. First, the positive impacts on adult health is consistent with the health-productivity mechanism leading to higher income. Second, the improvements in child health and the suggestive evidence showing improvements in school attendance could reinforce the time-saving mechanism. In particular, better child health may free up parents' time, allowing them to dedicate more time to productive activities. We next provide additional analyses to shed light on the role of each mechanism.

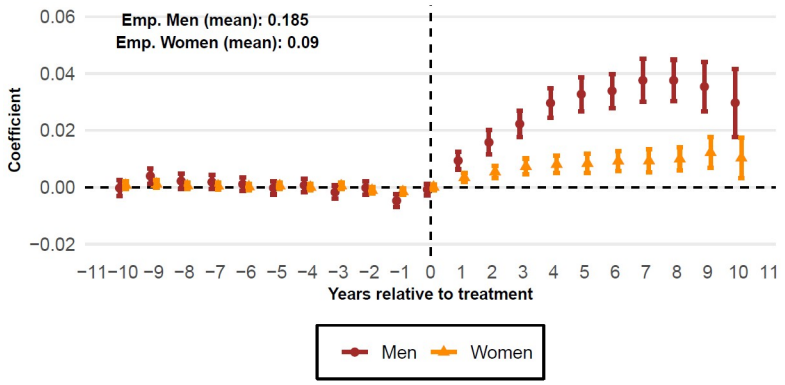
5.5.A Heterogenous Employment Effects

In Section 5.2, we have shown that the cistern policy improves adult health, but these effects are entirely driven by women who are at higher risk of waterborne diseases (Figure 10).

Thus, if cisterns improve economic outcomes due to the health-productivity mechanism, formal employment effects documented in Figure 8 should be mainly driven by women, who enjoy the health benefits. We test for this hypothesis by studying heterogeneous employment effects by gender. The results in Figure 14 show that formal employment effects are strongly concentrated in men, being three times as large relative to women in the ten years after cistern delivery (on average, 2.4 p.p. vs. 0.9 p.p.).[28]

The stronger employment effects for men are in stark contrast to the improvements in health outcomes, which are entirely concentrated on women. Hence, direct health effects driving higher productivity cannot explain the improvements in formal labor market outcomes, and thus are unlikely to explain the improvements in overall economic conditions.

Figure 14: The Effect of Cisterns on Formal Employment by Gender



Notes. This figure presents the event-study estimates by gender using the Callaway and Sant'Anna (2021) estimator with individual-level panel data spanning from 2002 to 2016. The control group consists of individuals who have not yet been treated, as well as those who received the cistern in 2017. In the yellow plot, the sample only include women. In the red plot, the sample include only men. The dependent variable is a binary variable indicating whether the individual has a formal job in a given year.

Hence, by exclusion, these results indicate that a time-constraint mechanism is a better candidate to explain the improvement in economic conditions by the cisterns. Since the time burden associated with water collection tends to disproportionally fall on women (and children), the employment gains driven by men suggest that families reallocate the time released by the cisterns towards male employment.[29] Women may take on activities

[28] We cannot provide the same heterogeneity analysis for BF receipt and CadÚnico enrollment because they are defined at the household level.

[29] United Nations Children's Fund and World Health Organization (2024) indicate that women are the main responsible for water collection in 70% of households worldwide – see also Dinkelman and Ngai (2021).

initially covered by men – e.g., work on subsistence agricultural production –, which may allow the latter to work more outside home. This likely maximizes household income since men tend to enjoy better employment opportunities in the labor market. This process is likely magnified by the fact that gender disparities are particularly strong in low-income rural areas, such as the Brazilian semiarid.[30]

5.5.B Job Characteristics

We next analyze the characteristics of formal jobs to gain more direct insight on the role of a time-constraint mechanism. As discussed in Section 2, cistern beneficiaries reside in low-income rural areas, where formal job opportunities are scarce and often require long commutes to larger urban centers – indeed, over half of formally employed beneficiaries work outside their municipality of residence before treatment. Thus, the time constraints imposed by limited and unstable access to water may prevent individuals from accessing such opportunities. If alleviating time constraints is a key driver of the cisterns' impact on employment, we would expect stronger effects on jobs located further away from home, which require longer commuting times. Far away jobs also make it more difficult for people to address unpredictable emergency water needs, which are likely mitigated by the cisterns.

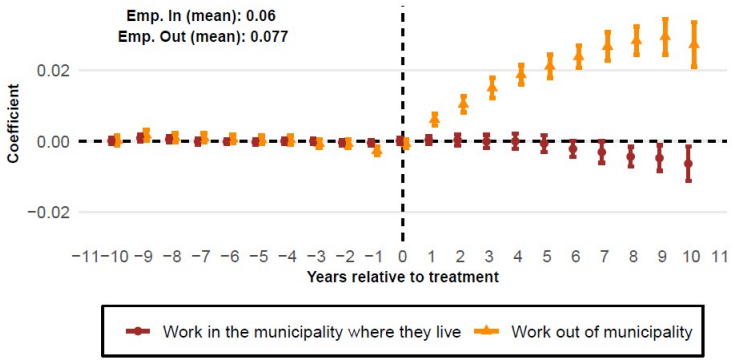
To test for this hypothesis, we estimate the effect of cisterns on the probability of formal employment both in the municipality of residence, where the cistern is installed, and in different municipalities, following our main specification described in Section 4. The results displayed in Figure 15 are striking. In line with the time constraints hypothesis, the cistern effect on employment is entirely driven by the take-up of formal jobs away from home. This evidence suggests that the cisterns enable individuals to access more distant employment opportunities that were previously out of reach due to the time constraints imposed by water scarcity. Moreover, the employment effects mainly driven by men taking far away jobs are also consistent with evidence that women have strong preferences for shorter

Similarly statistics are not available for the Brazilian semiarid, although qualitative studies and anecdotal evidence indicate that the burden of water collection mainly falls on women (Lindoso et al., 2018; Pontes, 2013).

[30] In Appendix Table A.2, we complete our heterogeneity analysis by showing that employment effects are 2.4 times stronger for more educated individuals – also indicating the formal employment gains are accrued by individuals with higher earnings potential. In turn, the same table shows that the effects do not vary strongly over age.

commute jobs (Le Barbanchon, Rathelot and Roulet, 2020).

Figure 15: The Effect of Cisterns on Formal Employment Location



Notes. This figure presents the event-study estimates using the Callaway and Sant'Anna (2021) estimator with individual-level panel data spanning from 2002 to 2016. The control group consists of individuals who have not yet been treated, as well as those who received the cistern in 2017. In the yellow plot, the dependent variable is a binary variable indicating whether the individual has a formal job located in a municipality different from their place of residence in a given year. In the red plot, the dependent variable is a binary variable indicating whether the individual has a formal job located in the same municipality of residence in a given year.

An alternative explanation for the effects on jobs away from home is that they are driven by migration to other municipalities rather than commuting. However, cisterns do not provide incentives for individuals to migrate, rather, they should increase resilience to weather shocks which may more plausibly reduce migration. We use CadÚnico data for 2012-2016 tracking residential location over time to test cistern effects on migration, while focusing on cohorts treated between 2013 and 2017.[31] In Appendix Figure A.9, we show that migration probabilities decrease by .23 p.p. The effect is statistically significant but small in magnitude relative to the employment effect.[32] Hence, the increase in formal employment away from the place where the cistern is installed cannot be explained migration – if anything, the reduction in migration would mitigate the increase in formal employment in a different municipality.

In Appendix Figure A.10, we show that formal employment effects are essentially driven by non-agriculture jobs. In particular, they are mainly driven by higher employment in the manufacturing and construction sector. Since non-agriculture jobs typically pay higher wages, these patterns help explain the increase in average wages documented in Section

[31] We consider that a person has migration if she shows up in a different municipality in CadÚnico. In case a person leaves CadÚnico in any given year, we assume her to have remained in the same municipality.

[32] These results are in line with Britto et al. (2025) who study the impacts of the FWC on migration, focusing on families receiving the cisterns in 2013, immediately before a severe drought season.

5.1.C.

5.5.C Heterogeneous Effects by Family Structure

We further investigate the time-constraint hypothesis by examining heterogeneous treatment effects across families with and without very young children. We expect the former group to face stricter time constraints and to be more sensitive to water shortages, as this issue is arguably more pressing when young children are present in the household (Kremer et al., 2011). Using CadÚnico data on family composition, we divide our main sample into two groups: families with at least one child aged 0–2, and those without.[33] Children in this age range are unlikely to already be in school and typically spend more time at home, imposing a higher time burden on caregivers. We study effects on the probability of receiving Bolsa Família cash transfers and the probability of formal employment.

Consistent with the time-constraint hypothesis, the results in Table 2 shows that the positive effects on economic conditions are stronger for families with young children. In the ten years after treatment, the probability of receiving cash transfers decreases by 16.9 p.p. in families with young children, while it decreases only by 10 p.p. for families without them (columns 1-2). The same pattern is observed for formal employment which is 25% larger in families with young children (2 p.p. vs. 1.6 p.p., columns 3-4). We interpret these results as indirect, suggestive evidence consistent with a time-constraint mechanism.

5.5.D Discussion on Mechanisms

We have considered two main mechanisms as potential drivers of the positive cistern effects on economic outcomes. Namely, a health-productivity mechanism whereby better health leads to higher worker productivity, and a time-constraint mechanism whereby cisterns free up time that can be allocated to productive activities. Overall, our several pieces of evidence provide stronger support for the latter. The health mechanism seems unable to explain family economic gains through higher productivity as health benefits are entirely concentrated on women (Figure 10) while employment gains are concentrated on men

[33] We use information on the date of birth of household members present in CadÚnico registry to identify the age of children at the time of cistern arrival.

Table 2: The Effect of Cisterns on Economic Welfare by Having Children Status

	Bolsa Família Ind.		Formal Emp.	
	Children (0–2)	No children	Children (0–2)	No children
	(1)	(2)	(3)	(4)
DD	-0.1689	-0.1001	0.0207	0.0161
	(0.0049)	(0.0015)	(0.0042)	(0.0010)
N. Obs	927,810	8,445,320	1,298,805	8,790,405
Mean dep. variable	0.683	0.550	0.108	0.137

Notes. Table shows results from Callaway and Sant'Anna (2021) difference-in-differences estimator for the alternative sample. The dependent variable for columns (1) and (2) is an indicator variable that equals one if the individual received Bolsa Família cash transfers in that year. The dependent variable for columns (3) and (4) is an indicator variable that equals one if the individual was formally employed in a that year. Table presents results of estimates splitting the sample into families with children under 2 years old living in the household one year before receiving the cistern (columns (1) and (3)) and families without children (columns (2) and (4)). Coefficients represent the simple average of $ATT_{l\geq 0}$ from the baseline event-study model. Panel data covers 2002 to 2016.

(Figure 14).

In turn, different pieces of evidence are in line with a time-constraint mechanism. First, formal employment effects are strongly concentrated on jobs further away home, demanding longer commuting time. Second, employment effects are stronger for families who are more likely to be time-constrained and sensitive water shortages, specifically, families with very young children. Finally, the positive impacts on child health documented in Section 5.2.B may further free up parental time, reinforcing the time-constraint mechanism.

Hence, our evidence mainly supports the idea that cisterns release time which can them be allocated to productive activities. The additional time arguably steam from the daily reduction water collection time, but can also be reinforced by the improvements in child health. While the direct time burden from water collection mainly falls on women and children, formal employment gains are mainly accrued by men. This indicates that families reallocate the time savings by the cisterns toward male employment, in line with the fact that men have higher earnings potential in the labor market and are more willing to do longer commutes. Thus, our results suggest that time constraints imposed by the lack of water in rural areas may pose a significant barrier to economic development. Such barrier seems more relevant than the direct health costs associated with exposure to low-quality water and scarce access to water.

6 Cost-Benefit Analysis

Next we provide a back-of-the-envelope cost-benefit analysis of the FWC program. We estimate the marginal value of public funds (MVPF), following the approach by Hendren and Sprung-Keyser (2020). Our analysis considers the net present value of FWC impacts on total family income, BF transfer receipt, and formal labor income along with the associated taxes. Since we cannot directly measure total family income, comprising formal and informal sources, we assume that family income increases in proportion to the relative reduction in BF receipt – i.e., families are 18% less likely to be enrolled in the program on average in ten years (Figure 6), so we assume that total income increases by the same figure.[34] Using these estimates, we calculate the private value of the cistern to each family as the impact on their total income minus the losses due to reduced cash transfers and increased taxes on formal earnings. In turn, the net government cost considers the cisterns' unit cost of 4,140 BRL (Da Mata et al., 2023), and the fiscal externalities due to reduced BF receipt and increased taxes levied on formal earnings.[35]

Table 3 presents the results. First, it considers a conservative scenario where FWC impacts last only ten years, which can be directly estimated in our data (Panel A). Second, it analyzes a scenario where FWC last 15 years, remaining constant from year 10, the last time period in our main estimates (Panel B). This follows from the fact that cistern effects on key outcomes do not seem to fade away by the end of our event study – e.g. see Section 5.1.A for BF receipt.

The cisterns' private value for households are nearly twice as large as the initial costs borne by the government in the more conservative scenario, where effects last for ten years (Panel C, column 1). In turn, externalities on the government budget reduce the initial cistern cost for the government by 35%, leading to a marginal value of public funds of 2.94. In turn, if cistern effects last additional five years, the private value is nearly three times

[34] To estimate the baseline total family income, we consider the average income for rural household in the semiarid region based on the 2010 Brazilian Population Census.

[35] The cistern cost for the government are comprehensive of the costs to fill cisterns with water trucks during severe droughts. In addition, our calculations use a 5% discount rate to compute net present values and consider that workers bear one third of taxes and contributions on formal labor income (the remaining share is levied on employers). We also rescale individual-level effects on formal labor income and associated taxes considering that there are 2.02 adults per household in our sample.

as large as the initial government costs and budget externalities reduce the initial cistern costs by 53%, leading to a 6.83 MVPF. The latter estimate places the FWC policy in the upper range of MVPF estimates for wide range of public policies analyzed by Hendren and Sprung-Keyser (2020) and by Hahn et al. (2024) who specifically focus on policies affecting climate change.

Table 3: FWC Cost-Benefit Analysis

	(1)	(2)	(3)	(4)
	Total income	Cash Transfers	Formal Labor Income	Taxes Labor Income
Baseline year	6465.42	546.63	1315	427
A. Period: years 1-10				
Relative effect	18.0%	-18.0%	20.1%	6.5%
Absolute effect	1162	-98	265	86
Net present value	8970	-758	2044	664
B. Period: years 11-20				
Relative effect	33.7%	-33.7%	26.0%	8.5%
Absolute effect	2178.84	-184	342	111
Net present value	5791	-490	910	296
C. Marginal value of public funds (MVPF)				
	Years 1-10	Years 1-15		
Cistern cost	4140			
Private value (1+2-3)	7990	13193		
Net government costs (cistern cost-2+4)	2717	1932		
MVPF	2.94	6.83		

Notes. This table reports the results of a cost-benefit analysis considering the effects of the FWC program on income, taxes, and welfare dependency measured in BRL. The baseline total income is the average income in rural households in the Brazilian semiarid based on the 2010 Population Census. Baseline values for cash transfers and formal labor income are directly observed in our data in the year before treatment. Taxes on labor income are based on a 32.2% tax wedge for 2010 (Dominique, 2021). Net present value calculations consider a 5% discount rate. The cisterns private value is the sum of the effect on total income and cash transfers, and also takes into account that one third of labor taxes are born by workers. The cisterns public value considers their direct costs and impacts on the government budget through cash transfers and taxes.

Overall, our results suggest a high MVPF for the FWC policy. Our MVPF estimates are likely a lower bound since they disregard some benefits, such as improved health outcomes, potential long-term impacts on child income, and improved birth outcomes documented in Da Mata et al. (2023).[36] Although fiscal externalities do not fully cover the initial costs of the cisterns, they significantly mitigate them, especially when considering that impacts last for 15 years. This happens despite the fact that high labor informality reduces the impacts on tax revenues. These fiscal externalities provide a rationale for the provision of subsidies for the cisterns costs by the government (although not for the full costs, as done by the FWC

[36]We disregard hospitalization costs externalities on the government budget because effects on hospitalization costs are extremely low, below .12 BRL per year per household. This is because hospitalization events are a rare outcome, implying that baseline yearly expenditures are low.

policy). In turn, the significant and long-lasting impacts on family income drive a high private value of the cisterns for families. A natural question is why a large share of families do not privately invest in the cisterns, prior to the program. This likely relates to the fact that cistern costs represent a large investment for households in our low-income context – their unit cost is equivalent to seven months of family earnings – and to the presence of credit constraints, which tend to be particularly binding in developing countries (Banerjee, Karlan and Zinman, 2015; Dupas and Robinson, 2013; Dupas et al., 2018).[37]

7 Conclusion

In this paper, we evaluate the effectiveness of a simple climate adaptation technology for water provision -— rain-harvesting water cisterns. They have the potential to reduce water insecurity even in dry areas of the world, despite climate change, and large programs are spreading their use in different regions. Using detailed administrative data and exploiting the varying timing of access to the First Water Cistern Program, we show that cisterns can significantly improve rural lives in dry areas. The FWC program substantially improves economic and health outcomes, with significant gains also for children. In particular, it strongly reduces family dependency on conditional cash transfers by up to 34% in ten years, increases formal earnings by up to 20%, and reduces female and child hospitalizations associated with waterborne diseases by 20% and 37%, respectively. Moreover, families are more likely to comply with cash transfer conditionalities on child health and education, which suggests the program might also generate long-run gains for children. Finally, a remarkable pattern in the effects we estimate is that they are sustainable for several years and do not seem to fade away even ten years after the program.

Overall, our results suggest that water scarcity is an important barrier to the economic prosperity of dry rural areas, and possibly to the general development of these areas. They highlight the relevant role that simple and low-cost policies can play in alleviating these constraints. In terms of mechanisms, our results suggest that the time constraints associated with daily water collection play an important role in worsening economic outcomes.

[37] See Jack et al. (2023) for direct evidence that credit collateralization may increase family investments in rain harvesting water tanks in rural Kenya.

From a public policy perspective, cisterns may be a valuable technology for tackling water insecurity experienced by over two billion people globally (WHO, 2021). Several governments in low- and middle-income countries have repeatedly failed to provide stable access to water, especially in dry rural areas, which demands major investments and state capacity to manage complex projects. Cisterns may offer a viable alternative to reduce water insecurity, requiring lower investments and the undertaking of less complex projects. In this regard, a cost-benefit analysis of the FWC in Brazil indicates a high MVPF relative to a wide array of public policies. It also indicates a high private valuation of the cisterns, which suggests that programs providing access to credit may increase their adoption, possibly requiring lower public investments —- in line with the evidence by Jack et al. (2023), which shows that asset collateralization sharply increases the adoption of cisterns in rural Kenya.

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Supplemental appendix for online publication

Yuri Barreto Diogo G. C. Britto Bladimir Carrillo
Daniel Da Mata Lucas Emanuel Breno Sampaio

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Bocconi University, CLEAN Unit for the Economic Analysis of Crime, Baffi, GAPPE, e-mail: yuri.barreto@unibocconi.it

Bocconi University, CLEAN Unit for the Economic Analysis of Crime, CEPR, IZA, BAFFI, IGIER, GREEN, GAPPE, e-mail: diogo.britto@unibocconi.it

Sao Paulo School of Economics-FGV, e-mail: bladimir.carrillo@fgv.br

Sao Paulo School of Economics-FGV, e-mail: daniel.damata@fgv.br

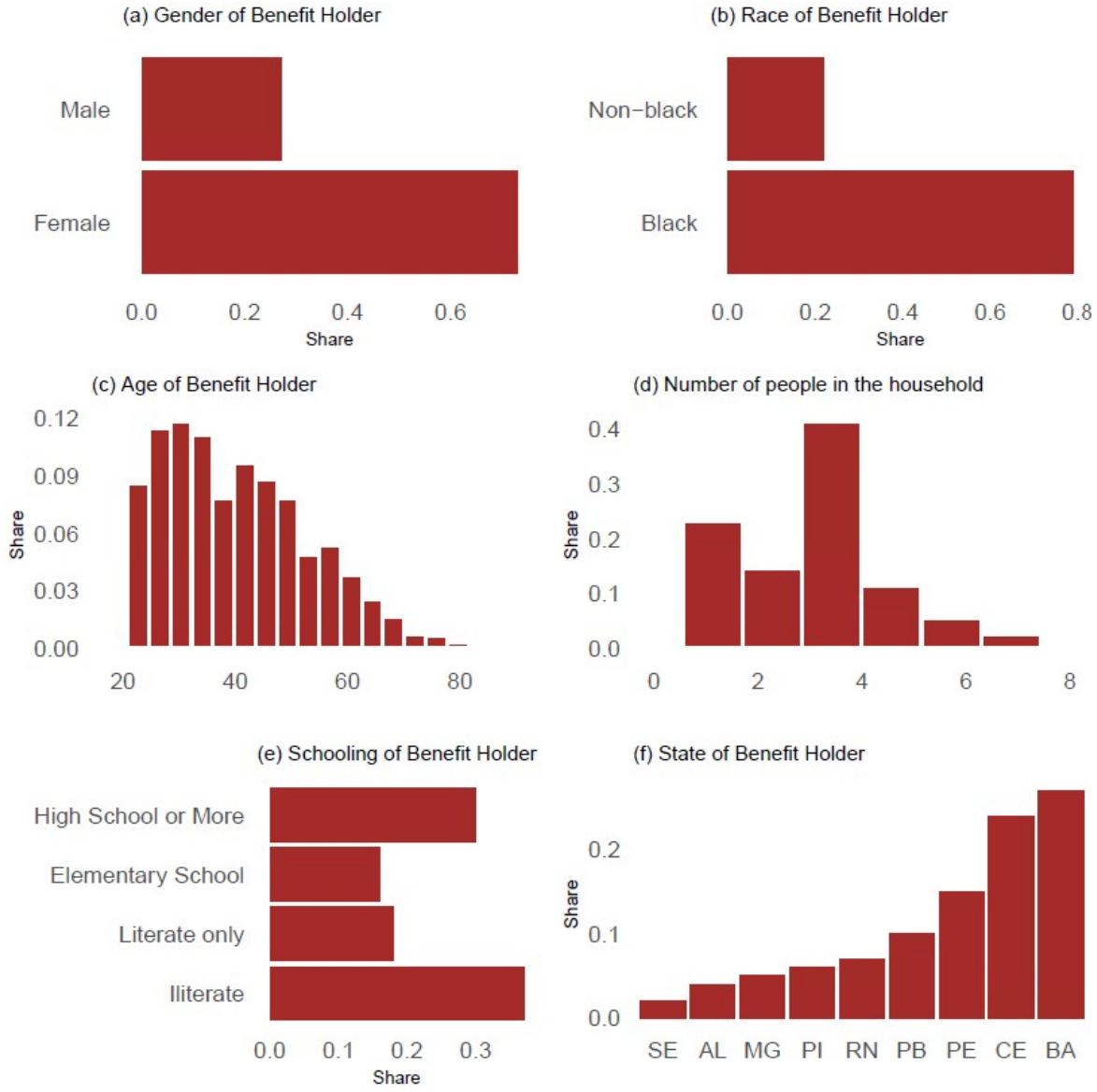
Federal University of Bahia, e-mail: lucasemanuel@ufba.br

Federal University of Pernambuco, IZA, BAFFI, CLEAN Unit for the Economic Analysis of Crime, GAPPE, e-mail: breno.sampaio@ufpe.br

A Appendix

A.1 Summary Statistics on Beneficiaries

Figure A.1: Summary Statistics on Benefit Holders



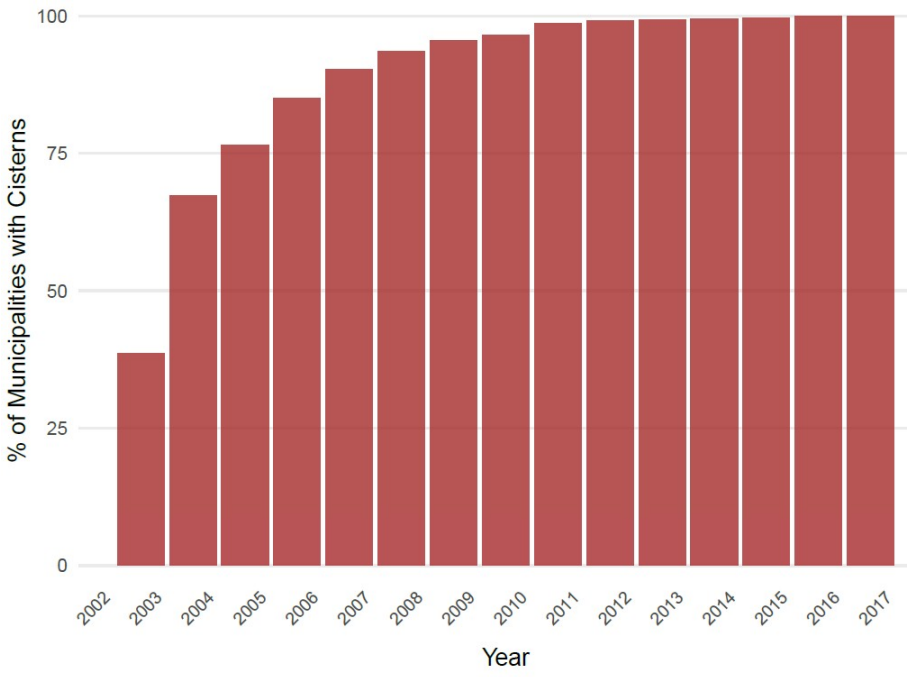
Notes. This figure presents descriptive statistics for the households in our sample. Individual demographics refer to the official benefit holder identified in the administrative data.

Figure A.2: Summary Statistics on Beneficiaries: Additional Characteristics

Notes. This figure presents descriptive statistics for the households in our sample. Individual demographics refer to the official benefit holder identified in the administrative data.

A.2 Program's Municipality Coverage Over Time

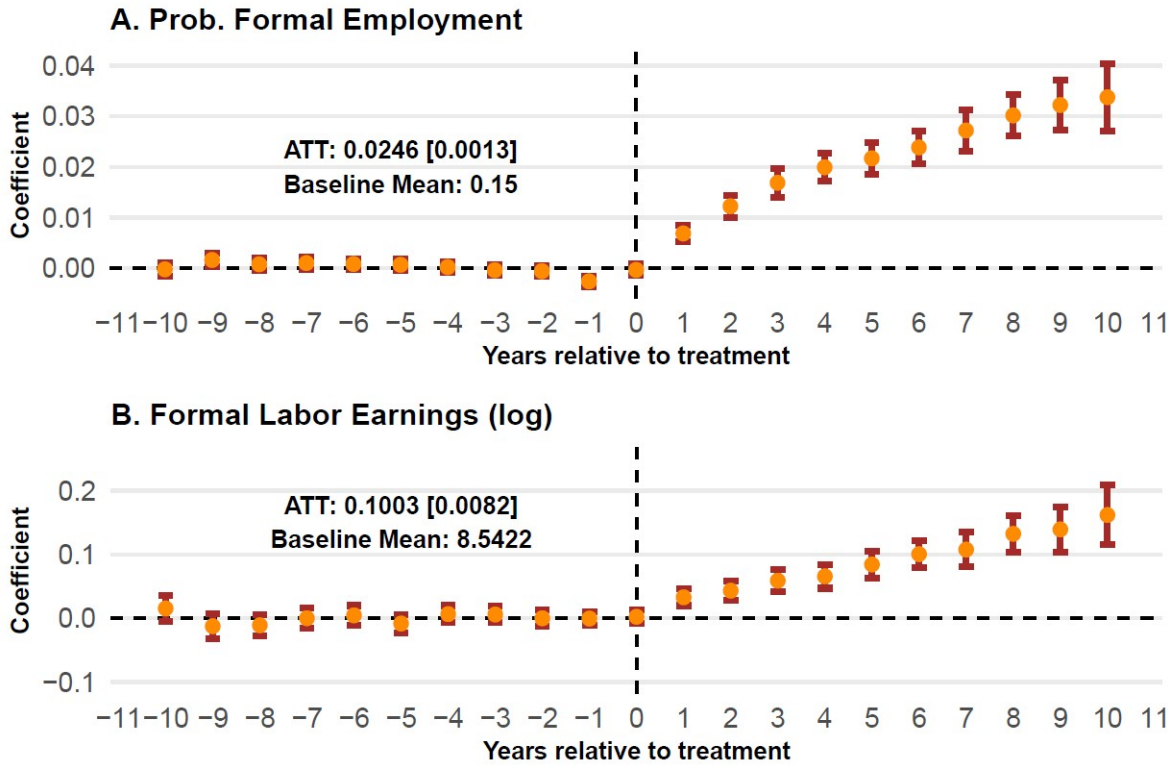
Figure A.3: FWC Program Coverage Over Time



Notes. This figure plots the share of treated municipalities that had at least one cistern in each year.

A.3 The Effect of Cisterns: Robustness to Age Restrictions

Figure A.4: The Effect of Cisterns on Formal Labor Market Outcomes, Unbalanced Panel



Notes. This figure presents event-study estimates from the Callaway and Sant'Anna (2021) estimator using individual-level panel data from 2002 to 2016. The control group includes individuals who have not yet been treated and those who received a cistern in 2017. The panel is unbalanced, with individuals observed only when aged 18 to 55. In Panel A, the outcome is an indicator for having a formal job in a given year. In Panel B, the outcome is the natural logarithm of annual labor earnings, with the sample restricted to employed individuals.

A.4 Robustness to Alternative Estimators and Controlling for Municipality-by-Year Fixed Effects

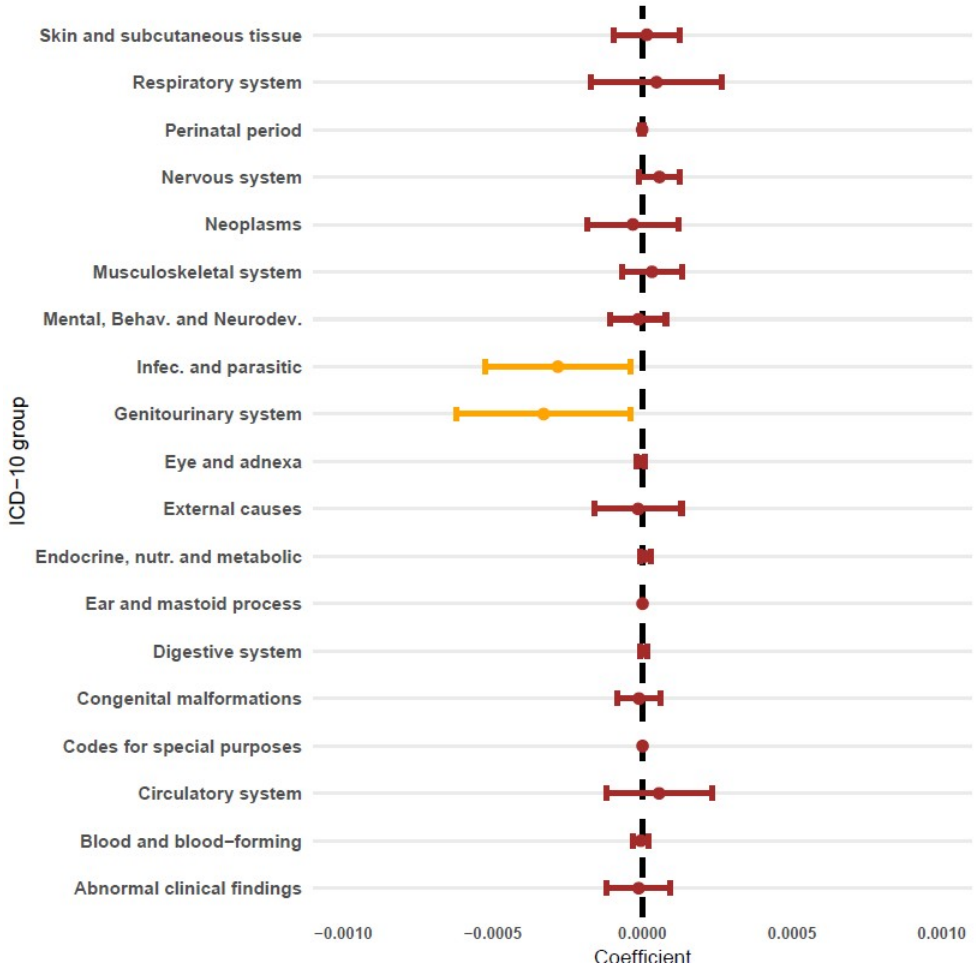
Table A.1: Controlling for Municipality-by-Year Fixed Effects

	Prob. Bolsa Família		**Prob. BF Suspension**		**Prob. Emp.**		**Prob. Hosp. Adults**		**Prob. Hosp. Children**	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Post	-0.0485***	-0.0456***	-0.0007***	-0.0005***	0.0271***	0.0273***	-0.0008***	-0.0008***	-0.0017***	-0.0020***
	(0.0005)	(0.0005)	(0.000065)	(0.000065)	(0.0003)	(0.0003)	(0.000076)	(0.000076)	(0.000094)	(0.000094)
Observations	9,448,127	9,448,127	9,448,127	9,448,127	10,089,210	10,089,210	10,089,210	10,089,210	8,686,633	8,686,633
Individual FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Municipality-by-Year FE	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes

Notes: This table presents results from estimating the effect of receiving a cistern on different outcomes using the two-stage difference-in-differences estimator proposed by Gardner et al. (2024). Odd-numbered columns control only for individual and year fixed effects, as in our baseline specification. Even-numbered columns additionally control for the interaction of municipality fixed effects with year dummies, allowing for flexible control of municipality characteristics.

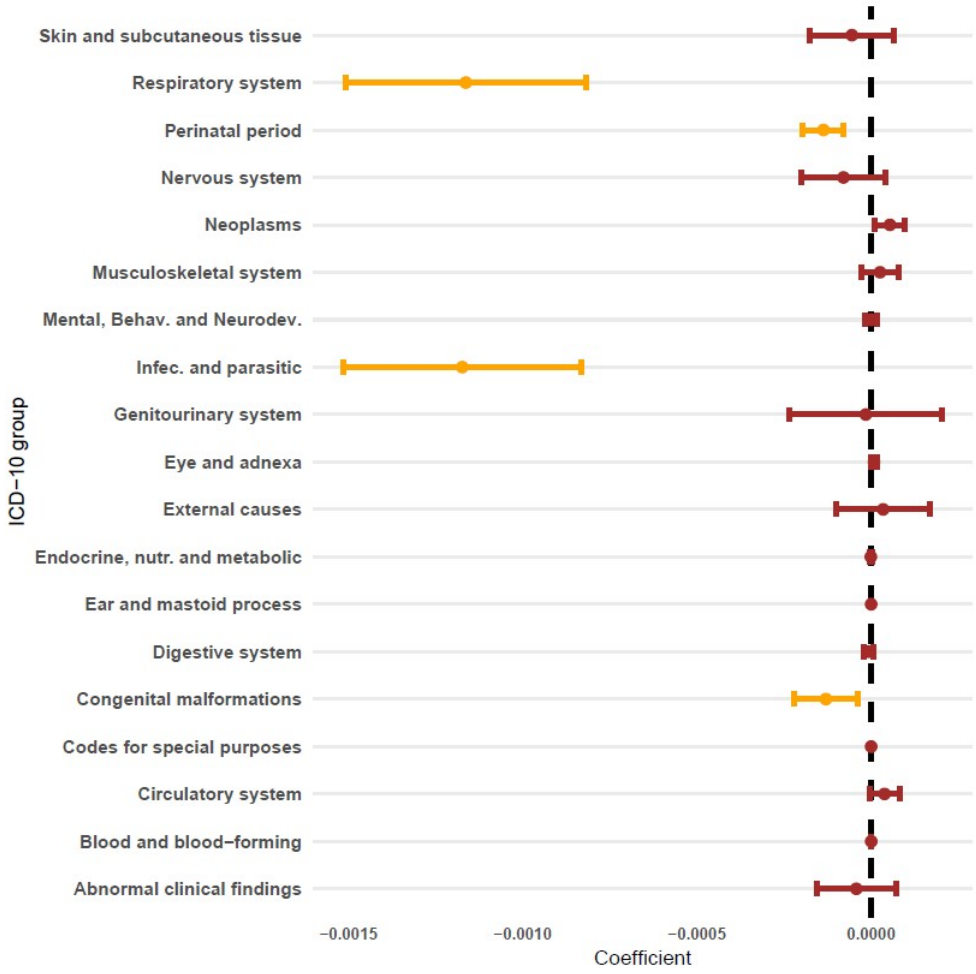
A.5 The Effect of Cisterns on Health, Additional Results

Figure A.5: The Effect of Cisterns on the Probability of Hospitalization by Cause



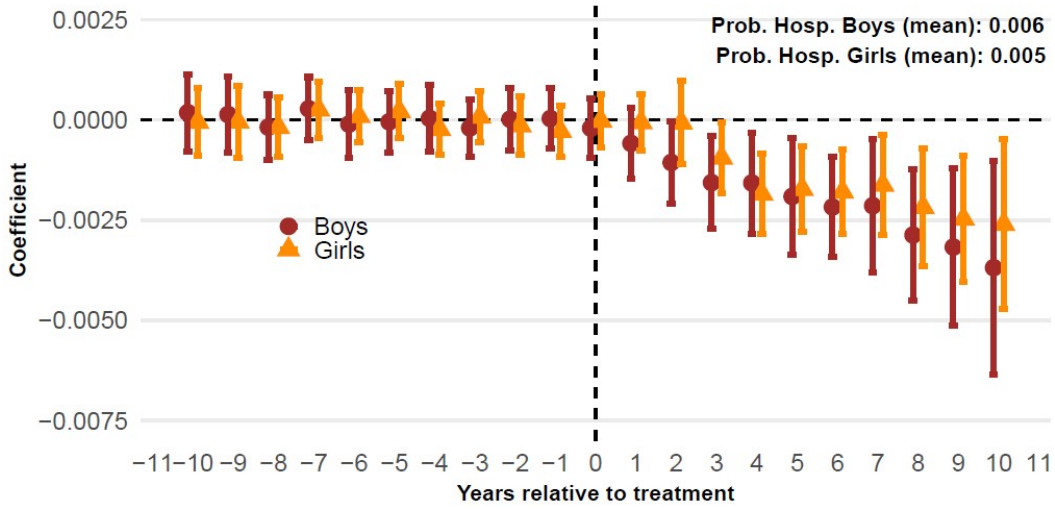
Notes. This figure presents the grouped post coefficients using the Callaway and Sant'Anna (2021) estimator for different causes of hospitalizations. The control group consists of individuals who have not yet been treated, as well as those who received the cistern in 2017. The dependent variable is a binary variable indicating whether the individual was hospitalized in that year by ICD-10 groups.

Figure A.6: The Effect of Cisterns on the Probability of Children Hospitalization by Cause



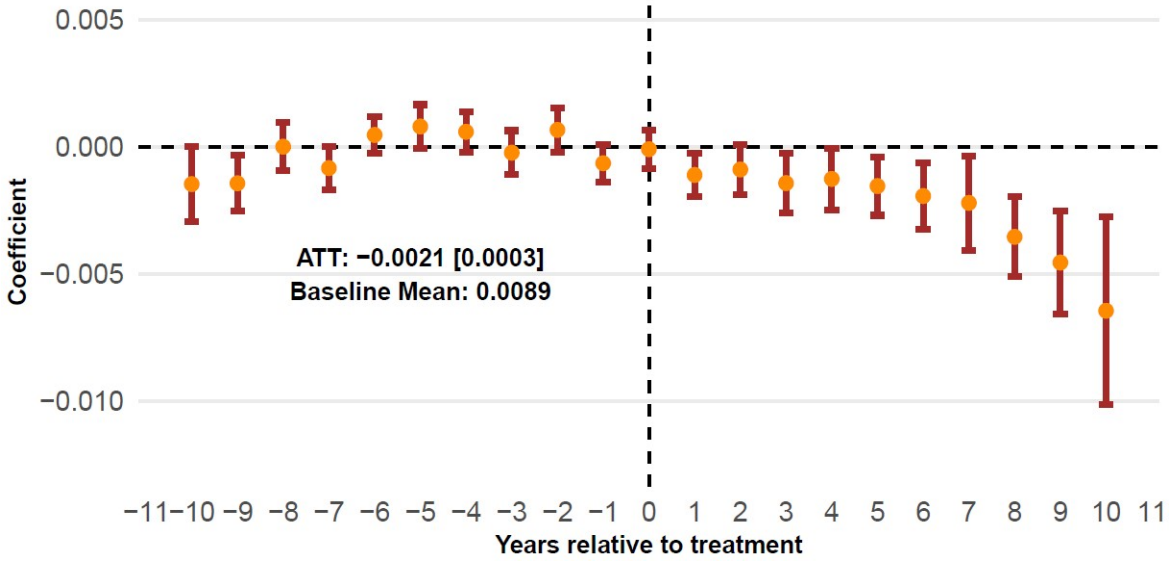
Notes. This figure presents the grouped post coefficients using the Callaway and Sant'Anna (2021) estimator for different causes of hospitalizations. The control group consists of individuals who have not yet been treated, as well as those who received the cistern in 2017. The dependent variable is a binary variable indicating whether the individual was hospitalized in that year by ICD-10 groups.

Figure A.7: The Effect of Cisterns on Hospitalization for Water-Related Issues, Children by Gender



Notes. This figure presents the event-study estimates, by gender, using the Callaway and Sant'Anna (2021) estimator with individual-level panel data spanning from 2002 to 2016. The control group consists of individuals who have not yet been treated, as well as those who received the cistern in 2017. The dependent variable is a binary variable indicating whether the individual was hospitalized by infectious and parasitic diseases or genitourinary system diseases. The sample is an unbalanced panel including individuals aged 0 to 14 who were already born when the cistern was constructed.

Figure A.8: The Effect of Cisterns on the Probability of One-Month Interruptions in Bolsa Família Payments



Notes. This figure presents our estimates of the effect of interruptions in Bolsa Família payments. The panel covers the period from 2004 to 2016 and includes only beneficiaries. The dependent variable is a dummy equal to one if the family experienced a one-month interruption in payments between any two months with payment.

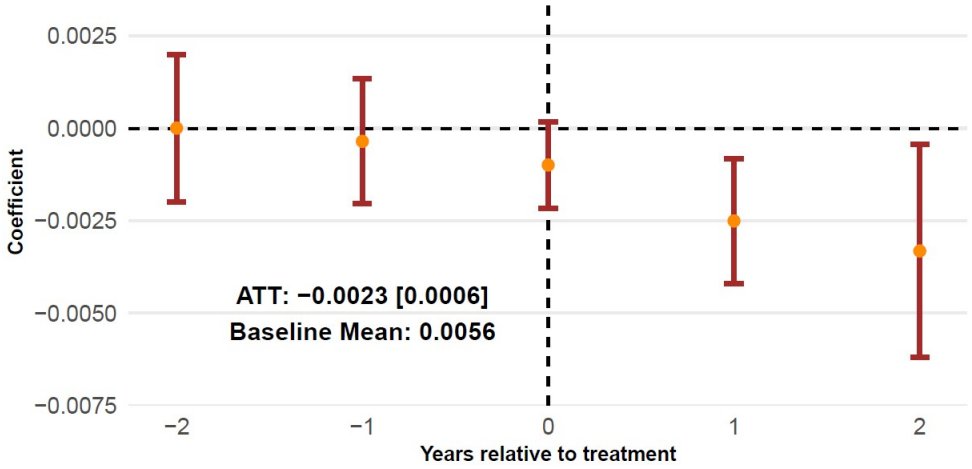
Table A.2: Heterogeneous Treatment Effects on Formal Employment by Demographics

	Age		Schooling	
	18–25	>25	No High School	Completed High School
	(1)	(2)	(3)	(4)
DD	0.022	0.020	0.013	0.031
	(0.002)	(0.002)	(0.001)	(0.003)
N. Obs	3,901,785	6,187,425	6,460,530	3,628,680
N. Individuals	260,119	412,495	430,702	241,912
Mean dep. variable	0.158	0.118	0.094	0.203
Effect/Mean	0.137	0.169	0.143	0.151

Notes. This table reports baseline difference-in-differences estimates by demographic subgroups. Columns (1) and (2) split the sample between individuals aged 18 to 25 and those older than 25, respectively. Columns (3) and (4) show estimates for individuals without a high school degree and those who have completed high school. Coefficients represent the simple average of $ATT_{l\geq 0}$ from the baseline event-study model.

A.6 The Effect of Cisterns on Migration

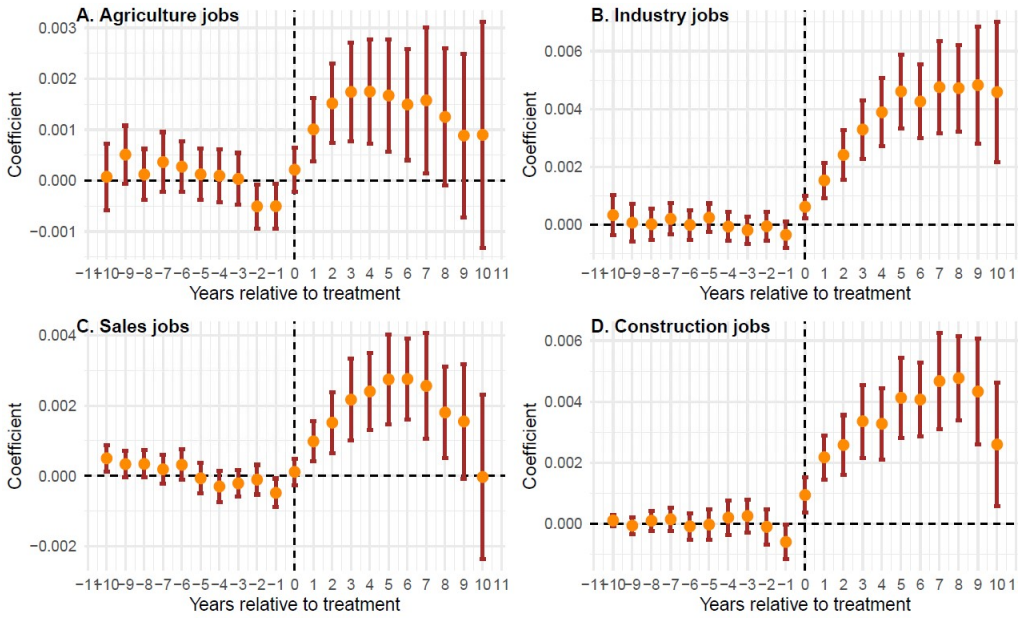
Figure A.9: The Effect of Cisterns on the Probability of Moving to Another Municipality



Notes. This figure presents the event-study estimates using the Callaway and Sant'Anna (2021) estimator with individual-level panel data spanning from 2012 to 2016. The control group consists of individuals who have not yet been treated, as well as those who received the cistern in 2017. The dependent variable is a binary variable indicating whether the individual have moved to a different municipality, relative to the municipality in the previous period in the panel.

A.7 The Effect of Cisterns on Formal Employment: Agriculture vs. Non-Agriculture Jobs

Figure A.10: The effect of receiving a Cistern on formal employment by sector



Notes. This figure presents the event-study estimates using the Callaway and Sant'Anna (2021) estimator with individual-level panel data spanning from 2002 to 2016. The control group consists of individuals who have not yet been treated, as well as those who received the cistern in 2017. In each panel the dependent variable is a dummy that equals one if the individual is employed in the formal sector in a given sector.