Chimborazo Rural Investment Project: Irrigation Component Impact Evaluation

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Chimborazo Rural Investment Project

Irrigation Component Impact Evaluation

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Abstract

This paper evaluates the impact of irrigation improvement works to benefit indigenous communities in the highlands of Ecuador, largely dependent on agriculture for their livelihoods. The findings suggest that the program increased access to irrigation, investment in productivity enhancing agricultural inputs, and cultivation of crops that required irrigation, and crop productivity. The impact on household income was estimated to be positive, although, due to lack of precision, we cannot reject the hypothesis of it being equal to zero. Finally, the program significantly increased food security by reducing the number and the frequency of "food insecurity" events. Robustness checks confirm the validity of the main results.

JEL classifications: O12, O13, Q12, Q15, Q54

Keywords: Irrigation, Rehabilitation Works, Indigenous Communities, Food Security, Ecuador

1 Introduction

Access to water and irrigation is considered a major determinant of land productivity (FAO, 2015) and is becoming more and more important in presence of climate risk and irregular rainfall. In fact, irrigation plays a key role in reducing risk of crop failure and allowing farmers to cultivate year-round without having to rely on rain patterns.

A large body of literature, summarized by Giordano et al. (2019), found that irrigation is clearly associated with increased agricultural output, both directly and by increasing productivity

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or agricultural inputs (improved seeds, fertilizers, etc.). Given that a large part of the world's poor rely on agriculture for their livelihoods, irrigation has been found to have a wide range of other important outcomes including poverty reduction and improvements in nutrition and health.

However, irrigation systems require a large investment to be constructed as well as continued maintenance and occasional rehabilitation and improvements to keep operating efficiently. While most of the literature evaluate the effect of irrigation per se (i.e. comparing a situation with irrigation with a situation without irrigation), little is known about the benefits from irrigation rehabilitation and works, which might require a substantial investment but potentially have a lower return.

This paper presents a rigorous impact evaluation of an irrigation rehabilitation and improvement project implemented by the provincial government of Chimborazo, Ecuador (GADPCH) between 2013 and 2018 with funding from the Inter-American Development Bank. To reduce the risks of potential false discoveries from hypothesis testing across many outcomes, we base the analysis on an impact evaluation plan that was laid out by the project team during the design phase. Indeed, we take this document as a "pre-analysis plan", to the extent possible, and carry out the analysis that was pre-specified. In particular, we evaluate the impact of the project on agricultural investment, crop diversification, agricultural productivity and sales, household income, and food security. As per the "plan", we use a Difference in Difference approach, with data collected through two agricultural household surveys: baseline and endline, carried out on a set of treated and carefully chosen control communities.

We find that the project increased access to irrigation by 10 percentage points and use of aspersion sprinkles, a more efficient irrigation technology, by 18 percentage points. Treated households were found more likely to hire agricultural labor and plant crops that require irrigation. Moreover, we find that program increased crop productivity. Although we cannot reject the hypothesis that the program had no effect on household income, the coefficient of interest is positive but imprecisely estimated. Finally, we find that the program significantly decreased food insecurity.

To support these results, we carry out a robustness test taking advantage of changes in the treatment assignment that occurred during the program's implementation. All the main results are robust to the placebo test based on excluding the communities that changed treatment assignment from the analysis.

The rest of this paper is structured as follows. Section 2 describes the context. Section 3 illustrates the main features of the program and its theory of change. Section 4 presents the evaluation design and data collection. Section 5 describes the econometric approach. Section 6 presents the results. Section 7 concludes.

2 Context

The province of Chimborazo, located in the Sierra region of central Ecuador, has a population of over 450,000 inhabitants, of which about 65% identify as indigenous and 48% live in rural areas. In 2010, 67% of the population was found to be poor, according to the NBI index (INEC, 2010).[1] Before the beginning of the project, the agricultural sector employed over 50% of the economically active population in the province, but its contribution to the province's GDP was only about 12.5%.

According to a diagnostic study conducted by the provincial government (GADPCH, 2012), poor infrastructure, in particular with respect to irrigation and rural roads were found to be among the main causes of low agricultural productivity. Moreover, 99% of Chimborazo farmers lacked formal training in production for high-value crop markets and 90% of them had between 1 and 5 hectares of land under production. Additionally, 32% of the producers within the province used irrigation for crop production, however, most of the systems were in need of construction, improvement or rehabilitation. Crop yield levels were in general lower than the average for the country, in part due to agricultural activities being conducted in steep slopes (58% of the provincial area has slopes above 50°) and poor soils.

Recognizing that the limited access to irrigation represented a major constraint for the livelihood of rural populations, the provincial government (GADPCH) has been committed to investing in the improvement and rehabilitation of such infrastructure. Indeed, between 2009 and 2013 the GADPCH implemented a World Bank financed rural investment project, the Chimborazo Development Investment Project (CDIP), which focused on the improvement of local irrigation systems and rural roads. According to its Implementation Completion and Results Report (ICRR) (WB, 2015), the irrigation component of this program supported investments in 55 irrigation systems, benefiting 7,957 families and increasing the total irrigated area by 562 hectares. Although no rigorous impact evaluation study was conducted, a before-after comparison re-

[1] The NBI is an index measuring unsatisfied basic needs, or *Necesidades Básicas Insatisfechas*.

ported in the ICRR indicates that the program generated a substantial increase in the value of agricultural production (+91%) and family income (+78%).

The Chimborazo Rural Investment Project, object of this study, can be considered a continuation of the CDIP. Indeed, it was designed to improve irrigation and rural road systems that had been left out from the previous project due to resource limitations(IDB, 2013).

3 Description of the program & theory of change

Implemented by the GADPCH between 2014 and 2018 with funding from Inter-American Development Bank, the Chimborazo Rural Investment Project aimed at improving the livelihoods of rural households in Chimborazo province, Ecuador, by increasing agricultural productivity and access to markets and services. To do so, the program financed the improvement of two types of infrastructure: irrigation systems and rural roads.

This study focuses on the impact of the irrigation component of this project. Given that investment in the two types of infrastructure took place in different areas (see figure 1), targeting different sets of communities, we can disregard the effects of the roads component since it had no direct impact on the communities included in the irrigation sample.

3.1 Irrigation component

The irrigation component consisted in improved irrigation infrastructure and technical support to the water users associations (WUAs) with the aim to increase access to water and farmers' ability to manage their irrigation systems, in order to ensure sustainability. In addition, once the irrigation works were completed, farmers received technical training on agricultural practices (operational assistance, maintenance, soil fertility, production, and input planning), aimed at improving the efficient use of the increased water resources.[2] Finally, activities aimed at protecting the micro-watersheds from which the irrigation systems sourced the water were also included in the project with the purpose of increasing climate change resilience and ensuring continued access to water (IDB, 2013).

The irrigation infrastructure improvements were aimed at rehabilitating existing systems and increasing their efficiency by reducing water losses. In many of the treated systems, irrigation

[2]These training took place in 2018 or 2019. Therefore, we do not expect their impact to be realized during the agricultural season captured in the endline survey (November 2017-October 2018).

in the form of aspersion sprinkles was also introduced, which represents an improvement over the previous gravity-based system. The program supplied the irrigation lines up to the producer plots and producer were expected to obtain their own irrigation equipment. Moreover, the WUAs participating in the project were required to co-finance 5% of the cost of the improvement works.

The program originally planned to improve 19 irrigation systems chosen for being located in rural communities with predominantly indigenous population and high levels of poverty. Other eligibility criteria included the existence of a formal WUA, considered necessary for the sustainability of the project, and that the existing irrigation system suffered from high level of estimated water losses (low efficiency).

During the implementation of the program, the list of systems to be improved partially changed. Four systems originally selected were excluded because either their WUA did not meet the eligibility requirements or because it rejected the project. The systems excluded where replaced by others that met eligibility criteria. By the end of the project 26 irrigation systems had been improved, benefiting 2,382 families and increasing total irrigated areas by 737 hectares.[3]

3.2 Expected results

A large body of literature has found irrigation infrastructure can affect rural household livelihoods through multiple channels (see Giordano et al. (2019) for a comprehensive summary). Without a clear initial plan, the researcher who conducts the impact evaluation might test a large number of hypotheses, look at the results, and then describe the theory of change of the project accordingly. To avoid incurring in this risk, we follow the impact evaluation plan that was outlined by the project team during the design phase, considering it as a “pre-analysis plan”.[4]

According to the impact evaluation plan, the primary effect expected from the program was an increase in the irrigated area and in the frequency of irrigation due to the increased water availability. Additionally, it was expected that a larger share of farmers would adopt aspersion sprinklers, a more efficient water use technology compared with the dominating gravity-based irrigation.

[3]Information obtained from the Project Completion Report produced by the Inter-American Development Bank, preliminary.

[4]During the design phase the theory of change of the project, its expected outcomes, and the evaluation strategy were outlined in detailed by the project team in two documents: (i) “Plan de seguimento y evaluación”, which provides information also on the M&E strategy; and (ii) “Evaluation Plan”, which is specific to the impact evaluation and provides more details.

Better irrigation should allow farmers to: (i) increase crop diversification by introducing crops that could not be produced under unreliable water condition, and (ii) increase the number of cropping seasons in the agricultural year by cultivating outside the main rainy season. Both mechanisms should allow farmers to increase their value of agricultural production and, assuming they have access to the market, also their sales, profits, and income. Farmers engaged in livestock rearing activities will also benefit from better access to irrigation as it would increase feed availability. As a consequence, we should observe increased livestock production and income.

Farmers were also expected to invest more in agricultural assets (plot improvements, machinery, etc.) and inputs (fertilizers, hired labor, etc.) as the profitability of complementary inputs should be increased by the improved water access. Moreover, the ability to produce more on the land, given the increased water access, should also lead to higher land values, as the value of land is the discounted future stream of profits.

The evaluation plan also mentioned increase in female empowerment as one of the expected outcomes of the project. However, this was supposed to be achieved through a nutrition training, which was not implemented. Instead, a gender component was included in the technical support activities provided to the WUAs.

Finally, increased food production, higher incomes, and female empowerment, should lead to improved food security.

4 Evaluation design & data

The impact evaluation is based on a Difference in Difference (DD) strategy. This strategy consists in comparing the *change* in the mean of the outcome variable(s) for the treatment households with that of a (carefully selected) control group. To implement this strategy, a baseline survey was conducted in 2015, prior to the beginning of the irrigation rehabilitation works, and a follow-up survey in 2019, after the program took place, with 636 households in treatment and control communities.

4.1 Selection of treatment & control groups

The irrigation systems to be improved were selected by the implementing entity, the GADPCH, before the beginning of the project following a set of eligibility criteria as well as political priorities. This process resulted in the identification of 19 irrigation systems to be improved, benefiting 30 communities.

The principal challenge in the identification of the causal impact of the program is to select a control group that could plausibly satisfy the DD identification assumption, that is, for which changes in outcome variables would likely be the same of those in the treatment group, absent the treatment (parallel trends). With this objective, the team who designed the impact evaluation, identified a set of irrigation systems that satisfied the eligibility criteria for treatment, but were unlikely to be treated during the intervention period.[5] In addition, control group communities (served by the identified irrigation systems) were selected to be as similar as possible to the treated communities, in terms of observable characteristics.

Specifically, the team identified 55 systems that had applied for the program in the period 2009-2014, but that were not going to be treated due to various reasons, such as not having an updated permit (Sentencia) granted from the Water Secretary (SENAGUA).[6] From this list, 25 systems were chosen based on the following criteria: (1) they applied for the project following a formal application process; (2) they met eligibility to be treated in the future;[7] (3) having similar observable characteristics as the treated systems.[8] These 25 systems corresponded to 25 communities.

[5] The design of this impact evaluation was done in collaboration between the IDB (Leonardo Corral, Heath Henderson, Mario Gonzalez Flores, and Paul Winters (SPD/SDV)) and the GADPCH (Irrigation team, led by Juan Carlos Brito).

[6] GADPCH noted that having an updated permit was exogenous to the irrigation system since SENAGUA had a long backlog of applications.

[7] Eligibility for future projects involved having submitted the following documents: (i) copy concession granted by SENAGUA; (ii) proof appointment of the directory of the Water Users Association; (iii) sketch of the irrigation system; (iv) census of water users; (v) proof of being a legally constituted community; (vi) pre-feasibility study.

[8] Similarity with the treatment communities were assessed based on following variables, measured by the GADPCH at the time of project design: (i) GPS coordinates; (ii) altitude; (iii) type of water conduction (pipe, open channel, coated open channel), (iv) main type of irrigation used (gravity, sprinkling, drip), (v) characteristics of the population (primarily indigenous or mestiza), (vi) primary economic activity (crop or livestock agriculture).

4.2 Data collection

The original plan was to survey 10 households in each of the 30 treated communities and 12 household in each of the 25 control communities, for a total of 600 households. For the treated communities, the households to be surveyed were selected randomly from a list of residents. In the case they were not found, a set of replacement households were also identified. For the control communities, given that lists of residents were not available, household selections was carried out through systematic sampling with a random starting point.

The baseline survey was implemented through in-person interviews conducted between April and May 2015. An extensive questionnaire, based on the World Bank's Living Standard Measurement Study - Integrated Survey on Agriculture (LSMS-ISA) survey was administered. The questionnaire included 12 modules with individual level questions about each household member's socio-economic characteristics (demographics, employment, income, etc.) and details parcel-crop level information about agricultural inputs and outputs. Additionally, the survey contained a food security' module, based on the FAO's Food Insecurity Experience Scale Survey Module, in which the person in charge for preparing meals for the household, usually a woman, was asked a set of 15 questions about whether, in three months prior to the survey, the household had faced any episode of " food insecurity" such as having to skip meals.

Additionally, both in the treatment and control communities and irrigation systems, a "community survey" was conducted with community leaders, and a "WUA survey" was conduced with the members of each WUA. The former contained questions about the services available to community members and the latter contained information about the workings of the irrigation system and the management of the WUA.

During the baseline data collection field activities, some adjustments had to be made as 2 communities originally included in the sample could not be surveyed (one on the treatment group and one in the control group). Moreover, 2 communities identified to be part of the control group were also included in the treatment group of the roads component of the project and hence had to be excluded from the irrigation sample. As a result, at baseline, the treated sample constituted of 18 irrigation systems, 29 communities, and 300 households; while the control sample constituted of 22 systems, 22 communities, and 336 household.

In February 2019, an endline survey was conducted with the same sample and same questionnaire. Overall, 91% of household that participated in the baseline could be found and accepted to participate.

4.3 Changes in treatment assignment

During the implementation of the project, 6 irrigation system originally selected to be treated, 5 of which were surveyed at baseline, were dropped from the project. These systems included 9 communities surveyed at baseline, for a total of 90 households.

The reasons for these changes ranged between the failure of the community to fulfill the program requirements, such as having an organized Water User Association (WSA), and the rejection of the project by the community with the subsequent decision not to comply with the payment of their share of the cost of the infrastructure.

Moreover, one irrigation system that was selected to be part of the control group, ended up being treated to replace one of those that were dropped. This included one community in which 24 households were surveyed.

Table 1 illustrates these changes in the sample composition. The main analysis will be based on the final treatment assignment, taking into account these changes. However, these changes in the treatment assignment will be used to assess the robustness of the results. Indeed, we will use the communities that were selected to be treated and then were dropped as a placebo test to ensure that the results we find are attributable to the provision of better irrigation infrastructure, not to unobservable characteristics of the the communities that determined their selection into the treatment group.

4.4 Balance & attrition checks

Table 3 reports summary statistics and balances checks for demographic characteristics of the households and variables related to access to irrigation. Although we can reject the hypothesis of overall balance (the F-test that all coefficients are jointly equal to zero has p-value=0.0001), we notice that for only 4 out of the 13 variables considered the difference between treatment and control group is statistically significant. Specifically, in treated communities household heads were on average 3 years older than in control communities and were 9 percentage point more likely to speak Kechwa as primary language. Treated households had 0.6 more plots than the control group, and that they were 9 percentage points more likely to have access to irrigation in at least one plot at baseline.

The endline survey was completed by 91% of the sample. Table 4 shows that completion rates were 2.7 percentage points higher in the treatment group than in control group. However, the difference is not statistically significant.

5 Empirical strategy

Within the DD strategy, the following equation is estimated in order to generate estimates of the average program impact:

$$y_{it} = \beta_0 + \beta_1 Treated_i + \beta_2 Post_t + \beta_3 Treated_i * Post_t + \epsilon_{it} \quad (1)$$

where y_{it} is an outcome variable of interest for household i in period t, such as income, $Treated_i$ is a dummy variable equal to one if the household belongs to a treated community, $Post_t$ is a period indicator taking the value one if the observation corresponds to the post-program period, and ϵ_{it} is an error term. The parameter β_1 measures the average pre-program difference in the outcome variable between treatment and control groups, while β_2 measures the time trend – or the average difference in the outcome variable in the post- versus pre-program periods for the control group. Finally, β_3 measures the average impact, or treatment effect, of the program. The identifying assumption for β_3 to be an unbiased estimator of the causal impact of the program is that there are no systematic differences across treatment and control groups in terms of unobservable variables that affect the change in the outcome variable. This is the assumption of “parallel trends”, which states that in the absence of the program the average change in the outcome variable of treatment households would have been the same as the average change of the control households.

5.1 Outcome variables

As explained in section 3, irrigation improvement projects are expected to affect a large number of outcomes, many of which can be measured (in different ways) given that the survey administered was quite extensive. In order to avoid incurring in the risk of conducting multiple tests, this analysis follows, to the extent to which it is possible, the original impact evaluation plan. This plan was described in two documents: (i) “Plan de seguimento y evaluación”, which provides information also on the M&E strategy; and (ii) “Evaluation Plan”, which is specific to the impact evaluation and provides more details. Table 2 reports the complete list of outcomes included in these documents and information on whether they can be measured based on the data collected.

This impact evaluation includes results for all the outcomes included in the original impact evaluation that can be measured, and additional outcomes deriving from the theory of change outlined in section 3.

First, we test whether the project increased use of irrigation and, in particular, adoption of aspersion sprinkles. Although these outcomes were not explicitly mentioned as part of the evaluation plan, it is important to remember that the project brought the water up to the farmers' plot, in order to be able to use it, farmers had to make some investment.

Second, we assess to what extent treated farmers increased their purchases of agricultural inputs: seeds, hired labor, fertilizer, and other chemicals. Given that the variables measuring amounts spent in each of these inputs are very noisy and likely to be measured with error, we choose to use as outcome variables dummies equal to one if the household purchased any quantity of the respective input.

Third, we test whether the program increased crop diversification by testing whether the number of crops cultivated increased and whether there was an increase in crops requiring irrigation. To do so, we define as "crop requiring irrigation" those crops that, at baseline, have higher probability to be cultivate in irrigated plots.[9]

Fourth, we estimate the effect of the program on agricultural productivity and sales. Specifically, we measure agricultural production as "total value of crops harvested" and agricultural productivity "total value of crop harvested per m^2 sown". We consider sales of crops, livestock, and livestock by-products (milk, eggs, etc.). Following the project's result matrix, we also estimate whether the program increased agricultural productivity measured in terms of quantity of potatoes harvested per hectare. Given that production and sales values are noisy, we exclude outliers from the analysis.

Fifth, we evaluate the impact of the program on net household income, calculated following the methodology proposed by the Rural Income Generating Activities (RIGA) study (Carletto et al., 2007). Specifically, for each of its main sources: agricultural wages, non agricultural

[9]Specifically, we use the baseline dataset to calculate the probability that each crop is cultivated in an irrigated plot, then we calculate the median probability for a crop to be cultivated in an irrigated plot and, finally, we tag as "crop requiring irrigation" all those crops with a probability to be cultivated in an irrigated plot above the median.

wages, crop production, livestock production, transfers, and income from self-employment, net income is calculate as the difference between (gross) income and expenditure. Total income is calculated as the sum of its components. Self-consumption of crop and livestock products is considered to be a part of the household income. Given that self-reported income data are very noisy, households with “total income” below the 1st percentile or above the 99th percentile either at baseline or at endline are dropped from this analysis. We report both the results in terms of household income and income per capita.

Sixth, we test whether the program had any effect on female employment, considered as an important “enabling factor” for female empowerment as it increases the woman’s access to and control over the household resources (Malhotra and Schuler, 2002).

Finally, we estimate the effect of the program on three measures of food insecurity. Specifically, households were asked 15 standard question aimed at assessing whether they had experienced episodes of food insecurity in the 3 months prior to the survey. For example “In the past 3 months, did any household member skip a meal?” If the answer was “yes”, then they would be ask to describe the frequency of such event choosing among three options: “almost never”, “some times”, and “almost always”. The first measure we created is simply a dummy, “Any event”, equal to 1 if the answer was “yes” for at least 1 of the questions. The second measure, “N events”, is a count variable equal to the number of events for which the household answered “yes”. The third variable, “Intentsity”, is the sum of the frequency reported for each event where “almost never” is counted as 1, “some times” is counted as 2, and “almost always” is counted as 3.

6 Results

Tables 5 to 11 report the main results of this impact evaluation. It is interesting to notice, that while the effects of the project (reported as the coefficient of the interaction term “Treated*Post”) are generally positive, the trend for the control group (reported as the coefficient for the variable “Post”) is negative and statistically significant for most outcomes. This is not surprising given the context of progressive degradation of rural infrastructure and environmental conditions (increase in soil erosion, climate risk, etc.), experienced by communities in the highlands of Ecuador (GADPCH, 2012).

Access to irrigation: table 5 shows the effect of the program on access to irrigation. Although not all the estimates are statistically significant, we find that the program increased the share of irrigated plots increase by 10 percentage points (column 2) and that treated farmers are 19 percentage points more likely to receive irrigation through aspersion sprinklers (the more efficient technology) in at least one of their plots (column 3). It is important to remember that farmers had to make some investments in order to have irrigation in their own plots, particularly so in the case of aspersion sprinkles, which were not provided by the program. This result highlights the fact that the program, being focused on rehabilitation and improvement, did not change access to irrigation (as in the majority of studies available in the literature, which focus on the impact of providing access through the construction of new irrigation systems) but rather increased the efficient use of irrigation in communities that already had some access to it.

Investment in agricultural inputs: table 6 shows that treated households are 10 percentage points more likely to hire farm labor (column 2). The results also show an increase in the probability of purchasing seeds and fertilizer and a decrease in the probability of purchasing other chemicals (pesticides, fungicides, etc.) but these coefficients are not statistically different than zero.

Crop diversification: we test whether increased availability of irrigation results in increased crop diversification. Table 7 reports the results. Although we do not find evidence that the program increased the number of crops cultivated (column 3), treated households were 13 percentage points more likely to cultivate at least one crop that is likely to require irrigation (column 1) and they cultivate, on average, 0.25 more of such crops (column 2), although this result is not statistically significant. Crops are classified as more likely to require irrigation when their probability to be cultivated in an irrigated plot at baseline is above the median.

Agricultural productivity & sales: table 8 shows the results of the program on crop production and productivity and on sales of crops, livestock, and livestock by-products (milk, eggs, etc.). We find that the program increased overall crop productivity by about 5 US$ per m^2 cultivated, a 33% increase (column 3). The other coefficients, although not statistically significant, show an increase in value harvested and sales of livestock and livestock products. The coefficients for crop sales is negative, suggesting and increase in self consumption.[10] The lack

[10] The results presented in 8 are sensitive to the way outliers are dealt with, the presented specification is obtained by dropping all households with values above the 99^{th} percentile either at baseline or at endline (excluding zeros) for the variables representing value of harvest and sales, and all households with values above the 95^{th} percentile or below the 5^{th} either at baseline or at endline for the variables measuring productivity.

of statistical significance for many of these results might be due to the fact that self-reported production and sales data are typically noisy and measured with error. Given that the sample is relatively small, this analysis might be under-powered. Additionally, the results might be underestimating the overall impact of the program as, at the time of data collection, the beneficiaries were still receiving training on good agricultural practice, which were expected to further increase their productivity. Moreover, some of the irrigation works were completed in the few months prior to data collection, and, therefore, some benefits might not have been captured in this analysis.

Income: table 9 reports the effects of the program on the main income sources: agricultural wages, non agricultural wages, crop agriculture, livestock agriculture, transfers, and self employment (columns 1-6). It also reports the effect on total household income, the sum of all the sources mentioned above (column 7), and on income per capita (column 8). Although none of the coefficients are statistically significant, there is suggestive evidence that the program had a positive impact on household income per capita and, in particular on the income generated from crop production, as expected.[11] As discussed above for the case of production and sales, self-reported income variables are very noisy and this analysis is likely to be under-powered. Moreover, the magnitude of these results might be underestimated since data collection took places shortly after the completion of the irrigation improvement works.

Female empowerment: to test whether the program had an impact on female empowerment, we look at the probability for women (age 18-65) to be employed and to be employed outside agriculture. For the purpose of this analysis "unpaid family workers" are considered "not employed". Table 10 reports the result for all (columns 1 and 2) and for women below 40 (columns 3 and 4). The treatment effect on these outcomes is negative but close to zero and not statistically significant, suggesting that the program did not have any impact on female employment outside the farm. This is not surprising since the program did not include any activities specifically aimed at promoting female empowerment.

Food security: table 11 shows that the program significantly reduced the number of food insecurity events faced by the household in the the 3 months prior to the survey (column 2) as well as the intensity of such events (column 3). Moreover, the program decreased proba-

[11] The results reported in table9 are sensitive to the way outliers are dealt with, the presented specification is obtained by dropping all households with "total income" above the 99th percentile or below the 1st percentile either at baseline or at endline.

bility of facing any food insecurity event by 1.9 percentage points. However, this results is not statistically significant (column 1).

6.1 Robustness checks

Tables 12 to 16 report a set placebo tests exploiting the original treatment assignment. In particular, we split the sample into four groups: the first, “Always T’’, represents the set of communities that were identified as “to be treated’’ during the design phase of the project and received the program; the second “Switched from T to C’’, represents the communities that were originally identified as “to be treated’’ but were dropped from the program during the implementation; the third “Switched from C to T’’, includes the community originally part of the control group that was included in the program; finally, “Always C’’, the omitted category,includes the communities who were originally included in the control group and did not receive the program.

The main purpose of this exercise is to test whether the communities that were originally included in the treatment group and dropped out during the implementation presented similar results to those that were treated (i.e. if the coefficient for “Always T*Post” and “Switched from T to C*Post” are equal). If this was the case, we could conclude that the results are not due to the program but to the fact that the communities selected to be treated were more likely to improve in the considered outcomes because of some unobservable factors. On the other hand, if the treatment assignment was as good as random and the reason from dropping out of the program was exogenous, we would find the coefficient for “Switched from T to C*Post” to be equal to zero.

Looking at the five set of results produced, we can conclude that, in general, the households in the “Switched from T to C” group are generally doing “worse” than those in the “Always C” control group. This suggests that, on the one hand, there is no reason to worry about the fact that the selection into treatment during the design phase was based on unobservable factors correlated with more positive outcomes at endline. On the other hand, we might worry that these communities dropped out of the program because of some unobservable characteristics that would lead them to do worse at endline, which suggests that they do not constitute a valid control group.

Fortunately, these placebo tests also show that the main results of this evaluation are robust to comparing the “Always T” set of communities with the “Always C” control group. Indeed, the coefficients for “Always T*Post” show that treated communities increased access to irrigation (table 12), purchase of inputs (table 13), probability of cultivating crops that require irrigation (table 14), and food security (table 16).

7 Conclusions

This paper used a rigorous quasi-experimental approach to evaluate the impact of the irrigation improvement works implemented as part the Chimborazo Rural Investment Project, in Chimborazo province, Ecuador. The findings suggest that the program increased access to irrigation, investment in productivity enhancing agricultural inputs, cultivation of crops that required irrigation, and agricultural productivity. The impact on household income was estimated to be positive, although, due to lack of precision, we cannot reject the hypothesis of it being equal to zero. Finally, the program significantly increased food security by reducing the number and the frequency of “food insecurity” events.

Robustness checks exploiting changes in the treatment assignment support the validity of the main results. However, further analysis will be needed to assess the validity of the comparison group, for example using matching techniques.

This impact evaluation followed the plan laid out by the project team during the design phase as a “pre-analysis plan” and hence limited itself to the techniques and the outcomes that were pre-specified in those documents. However, further analysis should be carried out to explore additional potential results. For example, it would be interesting to see if in addition to increasing food security, the project also had an impact on health and child nutrition.

Nonetheless, the results of this study might be underestimating the overall impact of the program as, at the time of data collection, the beneficiaries were still receiving training on good agricultural practice, which were expected to further increase their productivity. Similarly, some of the irrigation works were completed in the few months prior to data collection, and, therefore, some benefits might not have been captured in this analysis.

To conclude, it is important to point out that, for the results to be sustained in the future, it will be crucial to ensure that appropriate system maintenance is carried out. As part of the project, the beneficiary WUAs received management training and were encouraged to set up a payment system that will ensure enough resource are collected to cover their Operations and Maintenance costs. At project closure, 75% of the systems were collecting enough to cover their cost of operations and all of them were carrying out maintenance through a system of turns.

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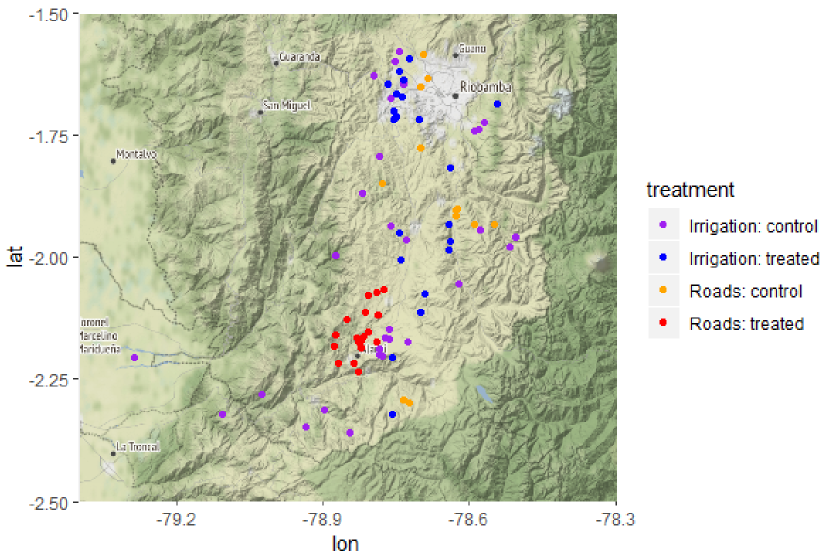
A Figures

Figure 1: Project map



B Tables

Table 1: Sample

	Planned			At baseline			Final assignment		
	Sys	Comm	HH	Sys	Comm	HH	Sys	Comm	HH
Irrigation T	19	30	300	18	29	300	15	21	234
Irrigation C	25	25	300	22	22	336	25	30	402
Total	44	55	600	40	51	636	40	51	636

Table 2: Outcome variables (original plan)

	Outcome	Indicator	Can it be measured?
1*	Inputs	Expenditure in inputs for agricultural production	Yes
2*	Investment	Farm investment	No, not specific
3*	Specialization	Area planted	Yes
4*	Diversification	Number of new products	No,not measured
		Number of products	Yes
5*	Lower volatility	Seasonal variation	No, not specific
6*	Proper input use	Appropriate quantity and type of chemical fertilizer used	No, the information available is not detailed enough.
7	Agricultural productivity	Value of production/cultivated area	Yes
		Quantity of potatoes harvested per hectare	Yes
8	Gross margin	Return to fixed factors of production (agricultural income/cultivated area)	Yes
9	Agricultural income	Income from crop and livestock farming	Yes
10*	Income	HH per capita income [from all sources]	Yes
11*	Personal income	Consumption	No, not measured
12	Asset value	Value of agricultural assets (land)	No, self reported data not reliable
		Value of non-agricultural assets	No, not measured
13	Female empowerment	Employment [except ag self-employed]	Yes
		Occupation [in service sector]	Yes
		Time use	No, not measured at baseline
		Control over income	No, not measured
		Participation in hh decision making	No, not measured
		Attitude towards gender roles	No, not measured
14	Food security	Household Dietary Diversity Index (HDDI)	HDDI cannot be calculated as there is no consumption data. But information on food security is available

Notes: The list of outcomes is obtained from the document“Plan de Seguimiento y Evaluación”, Table 4. The symbol (*) indicated the additional outcomes mentioned in the document “PIDD Impact Evaluation Plan”, Table 1.

Table 3: Summary Statistics & Balance - Baseline, Final Treatment Assignment

	Irrigation: treated	Irrigation: control	(1) vs. (2)
	(1)	(2)	(3)
HH head female	0.18	0.16	0.02
	(0.03)	(0.02)	(0.03)
HH head age	55.78	52.96	2.82**
	(0.97)	(0.81)	(1.30)
HH head indigenous	0.69	0.60	0.09**
	(0.03)	(0.02)	(0.04)
HH head education (years)	3.73	3.83	-0.10
	(0.16)	(0.12)	(0.20)
HH size	4.02	4.17	-0.15
	(0.15)	(0.11)	(0.19)
N adults	2.28	2.16	0.11
	(0.11)	(0.07)	(0.13)
N plots	4.14	3.52	0.62***
	(0.18)	(0.12)	(0.21)
Land size (m^2)	21581.50	33332.88	-11751.38
	(1873.80)	(6490.90)	(8629.57)
Irrigation	0.77	0.68	0.09**
	(0.03)	(0.02)	(0.04)
Share plots irrigated	0.46	0.46	0.01
	(0.02)	(0.02)	(0.03)
Aspersion	0.15	0.20	-0.05
	(0.02)	(0.02)	(0.03)
Irrigation available (hrs/week)	15.70	17.98	-2.29
	(2.62)	(2.15)	(3.45)
Irrigation use (hrs/week)	14.02	15.21	-1.19
	(2.38)	(1.89)	(3.08)
N	234	402	636
Joint F-Stat			3.17
P-value			0.000

Notes: * $p < .10$,** $p < .05$, *** $p < .01$.

Table 4: Attrition Checks

	Probability of Completing Endline
	(1)
Treated	0.027
	(0.023)
Mean Control	0.900
Observations	636

Notes: * $p < .10$, ** $p < .05$, *** $p < .01$.

Table 5: Access to Irrigation

	Any plot irrigated (1)	Share plots irrigated (2)	Any plot with aspersion (3)	Share plots with aspersion (4)
Treated	0.113	0.020	-0.039	-0.028
	(0.090)	(0.091)	(0.087)	(0.055)
Post	-0.064*	-0.069**	0.030	0.018
	(0.035)	(0.034)	(0.046)	(0.028)
Treated*Post	0.096	0.103**	0.186**	0.098
	(0.058)	(0.049)	(0.087)	(0.059)
Mean Control Baseline	0.680	0.455	0.191	0.107
Observations	1158	1158	1158	1158

Notes: Robust standard errors in parenthesis, clustered at the irrigation system level. * $p < .10$, ** $p < .05$, *** $p < .01$.

Table 6: Inputs

	Paid Seeds (1)	Hired Labor (2)	Paid Fertilizer (3)	Paid Chemicals (4)
Treated	0.03	-0.00	-0.02	-0.04
	(0.06)	(0.04)	(0.09)	(0.12)
Post	-0.11**	-0.23***	-0.10**	-0.10**
	(0.05)	(0.04)	(0.04)	(0.05)
Treated*Post	0.12	0.10*	0.06	-0.05
	(0.08)	(0.06)	(0.06)	(0.10)
Mean Control Baseline	0.40	0.63	0.46	0.55
Observations	1158	1158	1158	1158

Notes: Robust standard errors in parenthesis, clustered at the irrigation system level. * $p < .10$, ** $p < .05$, *** $p < .01$.

Table 7: Crop Diversification

	Any irr crop (1)	N irr crops (2)	N crops (3)
Treated	-0.02	0.11	0.50*
	(0.03)	(0.20)	(0.28)
Post	-0.14***	-0.42***	-0.78***
	(0.03)	(0.10)	(0.11)
Treated*Post	0.13***	0.25	0.01
	(0.04)	(0.15)	(0.30)
Mean Control Baseline	0.94	1.60	3.18
Observations	1158	1158	1158

Notes: Robust standard errors in parenthesis, clustered at the irrigation system level. * $p < .10$, ** $p < .05$, *** $p < .01$.

Table 8: Agricultural Productivity & Sales

	Potatoes t/ha (1)	Value Harvest (2)	Val Harv $/m^2$ (3)	Crop sales (4)	Lvst sales (5)	Lvst prod sales (6)
Treated	1.49	373.20***	-0.01	163.78	20.95	-7.48
	(1.57)	(129.80)	(0.02)	(163.27)	(64.03)	(145.08)
Post	-0.40	-28.09	-0.01	-1.11	-147.60***	64.40
	(1.18)	(96.32)	(0.02)	(82.40)	(39.14)	(74.66)
Treated*Post	0.44	114.32	0.05*	-107.74	25.49	159.62
	(2.15)	(199.43)	(0.03)	(161.00)	(71.43)	(125.64)
Mean Control Baseline	6.79	468.50	0.15	289.35	317.34	434.57
Observations	182	1136	552	1148	1150	1144

Notes: Robust standard errors in parenthesis, clustered at the irrigation system level. * $p < .10$, ** $p < .05$, *** $p < .01$. All values are expressed in USD except for column (1) that is expressed in t/ha. In columns (2), and (4)-(6) households with values above 99$^{\text{th}}$ percentile (excluding zeros) at either baseline or endline are dropped. In columns (1) and (3) the sample is restricted to households with positive both baseline and endline and households with values above 95$^{\text{th}}$ or below the 5$^{\text{th}}$ percentile at either baseline or endline are dropped.

Table 9: Household Income

	Wage ag (1)	Wage non ag (2)	Crop (3)	Livestock (4)	Transfers (5)	Self emp (6)	Tot (7)	Tot PC (8)
Treated	-105.97	251.77	53.41	224.09	-116.32	0.35	307.33	136.96
	(123.94)	(489.85)	(169.89)	(214.05)	(138.27)	(50.26)	(426.41)	(131.98)
Post	58.65	-74.95	-25.08	-16.99	-279.96***	-39.83	-378.17	-71.49
	(93.05)	(153.42)	(101.57)	(114.55)	(103.21)	(31.60)	(305.35)	(84.38)
Treated*Post	-52.94	-170.26	272.85	-95.35	26.80	29.88	10.99	80.23
	(120.98)	(280.28)	(182.66)	(221.06)	(122.98)	(86.23)	(454.11)	(166.35)
Mean Control Baseline	372.90	1546.11	285.60	421.16	601.40	99.24	3326.42	858.07
Observations	1098	1098	1098	1098	1098	1098	1098	1098

Notes: Robust standard errors in parenthesis, clustered at the irrigation system level. * $p < .10$, ** $p < .05$, *** $p < .01$. All values are expressed in USD. Households with “Tot income” above 99$^{\text{th}}$ percentile or below the 1$^{\text{th}}$ percentile at either baseline or endline are dropped. PC=per capita.

Table 10: Female Employment

	Employed	Employed non-ag	Employed	Employed non-ag
	All		age < 40	
	(1)	(2)	(3)	(4)
Treated	0.012	0.019	0.038	0.048
	(0.049)	(0.040)	(0.076)	(0.069)
Post	0.007	-0.006	-0.033	-0.023
	(0.024)	(0.016)	(0.044)	(0.032)
Treated*Post	-0.019	-0.002	-0.006	-0.016
	(0.031)	(0.022)	(0.059)	(0.042)
Mean Control Baseline	0.179	0.100	0.234	0.130
Observations	1404	1404	700	700

Notes: Robust standard errors in parenthesis, clustered at the irrigation system level. * $p < .10$, ** $p < .05$, *** $p < .01$.

Table 11: Food (In)security

	Any event	N events	Intensity
	(1)	(2)	(3)
Treated	-0.059	0.118	0.305
	(0.045)	(0.524)	(1.160)
Post	-0.152***	0.660*	1.326
	(0.045)	(0.371)	(0.885)
Treated*Post	-0.019	-1.370**	-3.073**
	(0.084)	(0.545)	(1.224)
Mean Control Baseline	0.870	3.218	6.953
Observations	1158	1158	1158

Notes: Robust standard errors in parenthesis, clustered at the irrigation system level. * $p < .10$, ** $p < .05$, *** $p < .01$.

C Robustness checks

Table 12: Access to Irrigation - Placebo Test

	Any plot irrigated (1)	Share plots irrigated (2)	Any plot with aspersion (3)	Share plots with aspersion (4)
Post	-0.058	-0.063	0.068	0.041
	(0.046)	(0.041)	(0.045)	(0.028)
Always T	0.193**	0.098	0.018	0.011
	(0.085)	(0.084)	(0.086)	(0.050)
Always T*Post	0.109	0.106*	0.147	0.073
	(0.066)	(0.057)	(0.094)	(0.064)
Switched from T to C	0.247*	0.227*	0.170	0.133*
	(0.132)	(0.133)	(0.113)	(0.077)
Switched from T to C*Post	-0.026	-0.025	-0.164**	-0.100**
	(0.047)	(0.056)	(0.068)	(0.038)
Switched from C to T	-0.031	-0.151**	-0.151***	-0.076***
	(0.069)	(0.057)	(0.035)	(0.020)
Switched from C to T*Post	-0.079*	0.019	0.159***	0.085***
	(0.046)	(0.041)	(0.045)	(0.028)
Mean Always C Baseline	0.622	0.402	0.151	0.076
Observations	1158	1158	1158	1158

Notes: Robust standard errors in parenthesis, clustered at the irrigation system level. * $p < .10$, ** $p < .05$, *** $p < .01$.

Table 13: Inputs - Placebo Test

	Paid Seeds (1)	Hired Labor (2)	Paid Fertilizer (3)	Paid Chemicals (4)
Post	-0.10*	-0.25***	-0.08*	-0.08
	(0.05)	(0.05)	(0.04)	(0.06)
Always T	0.05	-0.00	-0.00	0.00
	(0.07)	(0.05)	(0.10)	(0.11)
Always T*Post	0.11	0.14*	0.05	0.00
	(0.09)	(0.07)	(0.06)	(0.09)
Switched from T to C	0.04	0.04	0.13*	0.37***
	(0.05)	(0.05)	(0.07)	(0.07)
Switched from T to C*Post	-0.05	0.09	-0.08	-0.06
	(0.12)	(0.07)	(0.10)	(0.07)
Switched from C to T	-0.07*	0.10**	0.07	0.44***
	(0.04)	(0.04)	(0.05)	(0.05)
Switched from C to T*Post	0.05	0.02	-0.10**	-0.60***
	(0.05)	(0.05)	(0.04)	(0.06)
Mean Always C Baseline	0.39	0.62	0.43	0.47
Observations	1158	1158	1158	1158

Notes: Robust standard errors in parenthesis, clustered at the irrigation system level. * $p < .10$, ** $p < .05$, *** $p < .01$.

Table 14: Crop Diversification - Placebo Test

	Any irr crop (1)	N irr crops (2)	N crops (3)
Post	-0.129***	-0.331***	-0.806***
	(0.032)	(0.097)	(0.140)
Always T	-0.008	0.242	0.631***
	(0.036)	(0.212)	(0.219)
Always T*Post	0.109**	0.157	0.154
	(0.042)	(0.155)	(0.310)
Switched from T to C	0.067***	0.409***	1.072***
	(0.019)	(0.144)	(0.254)
Switched from T to C*Post	-0.049	-0.383**	0.115
	(0.063)	(0.163)	(0.228)
Switched from C to T	0.034*	-0.098	1.754***
	(0.019)	(0.122)	(0.112)
Switched from C to T*Post	0.175***	0.195*	-0.967***
	(0.032)	(0.097)	(0.140)
Mean Always C Baseline	0.921	1.507	2.928
Observations	1158	1158	1158

Notes: Robust standard errors in parenthesis, clustered at the irrigation system level. $^{*}\ p < .10$, $^{**}\ p < .05$, $^{***}\ p < .01$.

Table 15: Agricultural Productivity & Sales - Placebo Test

	Potatoes t/ha (1)	Value Harvest (2)	Val Harv $/m^2$ (3)	Crop sales (4)	Lvst sales (5)	Lvst prod sales (6)
Post	0.95	-16.09	0.00	-96.83***	-150.98***	84.60
	(1.03)	(111.70)	(0.02)	(31.83)	(49.70)	(95.81)
Always T	2.10	474.50***	-0.01	199.69	-28.62	-109.36
	(1.92)	(136.82)	(0.02)	(188.52)	(64.76)	(155.94)
Always T*Post	-0.57	157.46	0.05*	-2.23	65.04	135.42
	(2.29)	(211.08)	(0.03)	(156.44)	(75.46)	(147.67)
Switched from T to C	1.11	336.51***	0.01	94.60	-58.39	-321.25**
	(1.11)	(64.21)	(0.02)	(110.23)	(51.07)	(150.49)
Switched from T to C*Post	-4.00***	-51.34	-0.03	414.04**	14.48	-86.32
	(1.03)	(212.10)	(0.03)	(153.25)	(64.26)	(100.76)
Switched from C to T	0.29	255.40***	0.00	62.46	322.72***	149.26
	(1.11)	(61.42)	(0.01)	(91.87)	(44.27)	(117.32)
Switched from C to T*Post	-3.21***	-376.46***	-0.02	-97.79***	-288.52***	174.13*
	(1.03)	(111.70)	(0.02)	(31.83)	(49.70)	(95.81)
Mean Always C Baseline	6.42	389.83	0.15	267.48	330.96	509.74
Observations	182	1136	552	1148	1150	1144

Notes: Robust standard errors in parenthesis, clustered at the irrigation system level. $^{*}\ p < .10$, $^{**}\ p < .05$, $^{***}\ p < .01$. All values are expressed in USD except for column (1) that is expressed in t/ha. In columns (2), and (4)-(6) households with values above 99th percentile (excluding zeros) at either baseline or endline are dropped. In columns (1) and (3) the sample is restricted to households with positive both baseline and endline and households with values above 95th or below the 5th percentile at either baseline or endline are dropped.

Table 16: Food (In)security - Placebo Test

	Any event (1)	N events (2)	Intensity (3)
Post	-0.169***	0.353	0.612
	(0.055)	(0.322)	(0.663)
Always T	-0.071	0.207	0.529
	(0.047)	(0.600)	(1.327)
Always T*Post	0.025	-1.055*	-2.432**
	(0.089)	(0.549)	(1.155)
Switched from T to C	-0.001	0.398	1.038
	(0.031)	(0.332)	(0.752)
Switched from T to C*Post	0.074	1.326*	3.079
	(0.069)	(0.668)	(1.830)
Switched from C to T	0.039**	0.238	0.697
	(0.014)	(0.293)	(0.667)
Switched from C to T*Post	-0.240***	-1.125***	-1.702**
	(0.055)	(0.322)	(0.663)
Mean Always C Baseline	0.871	3.126	6.712
Observations	1158	1158	1158

Notes: Robust standard errors in parenthesis, clustered at the irrigation system level. * $p < .10$, ** $p < .05$, *** $p < .01$.