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# Are Irrigation Rehabilitation Projects Good for Poor Farmers in Peru?

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## Abstract

This paper analyzes changes in agricultural production and economic welfare of farmers in rural Peru resulting from a large irrigation infrastructure rehabilitation project. The analysis uses a ten-year district panel and a spatial regression discontinuity approach to measure the causal effect of the intervention. While general impacts are modest, the analysis shows that the project is progressive--poor farmers consistently benefit more than non-poor farmers. Farmers living in districts with a rehabilitated irrigation site experience positive labor dynamics, in terms of income and agricultural jobs. Poor farmers increase their total income by more than $220 per year compared with the control group, while rich farmers do not experience such an income gain. The results also show crop specialization patterns in the economic status of farm households; poorer farm households increase their production of staple crops, such as beans and potatoes, while non-poor beneficiary farmers cultivate more industrial crops. Findings from this evaluation have important implications for pro-poor policy design in the agricultural sector.

This paper—a product of the Corporate, Global and Methods Division, of the Independent Evaluation Group—is part of a larger effort in the department to assess impacts of World Bank projects in Agriculture. Policy Research Working Papers are also posted on the Web at http://econ.worldbank.org. The author may be contacted at xdelcarpio@worldbank.org.

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*A Spatial Regression Discontinuity Approach*

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## I. Introduction

In many developing countries, improving agricultural performance is seen as a critical component of sustained poverty reduction. This view is supported by the fact that most impoverished people still live in rural areas and derive their livelihoods from agricultural activities (World Bank 2008). This paper measures agricultural and economic impacts of the first phase of the Peruvian Irrigation Subsector Project (PSI) – a large irrigation infrastructure rehabilitation project implemented in the coastal regions of Peru – on farmers below the poverty line[1]. A key objective of the project was to raise agricultural production and productivity by enhancing the sustainability and efficiency of existing public irrigation systems (World Bank 1996), and thus reduce poverty.

An important policy question for which little evidence exists is whether public projects such as irrigation infrastructure can be specifically designed so that gains are redistributive among all farmers and progressive for the poor. Pro-poor interventions have either been defined as those that impact the poor to a more positive extent (or a less negative extent) than they impact the non-poor, or as interventions that reduce aggregate poverty. Thus, the first definition takes distributional effects into account, requiring that pro-poor interventions reduce inequality and differentially impact those above and below the poverty line, while the second takes positivity into account, requiring that pro-poor interventions lead to positive growth (Ravallion, 2004). This

[1] The project has two other components – plot level irrigation support (technology and capacity building) and training for Water Users' Associations – that are accounted for in the analysis.

paper examines whether the infrastructure rehabilitation component of the PSI project meets either definition of a pro-poor intervention.

Inequity of impacts may occur because wealthier farmers may be better positioned to take advantage of increased water access, either due to higher economic welfare which facilitates better on-plot technology, or through general characteristics such as more education. If wealthier farmers are able to reduce their costs, and thus their prices, this may negatively influence poor net-sellers who have to compete with them in the market while benefiting poor net-consumers who can access cheaper agricultural goods. On the other hand, it is possible that the program provided access to crucial irrigation access and services previously only available to those who could afford to pay for them, thus closing the gap between the poor and not poor. Quantitative and qualitative tools are employed to understand whether and how impact differs among these groups.

Previous studies show measurable economic impacts due to infrastructure improvements in rural areas (Jacoby 2002; Van de Walle and Cratty 2002; Lipton 2005; Khandker and others 2006); more specifically, recent evaluation work of irrigation infrastructure enhancements find increases in farm household production (Hussain and Hanjra 2004; Smith 2004; Van Den Berg and Ruben 2006) and marketing improvements of agricultural products (Dorward et al. 2004). While much evidence demonstrates a relationship between rural infrastructure development and improvements in agricultural performance, the relationship between small-scale irrigation interventions of this sort and whether they improve outcomes for those below the poverty line remains a topic of debate among development practitioners.

There are at least three relevant impact channels identified in the broad literature through which irrigation infrastructure can positively affect agricultural performance; the paper measures various dimensions in order to test each one of these channels. First, irrigation can lead to stabilization of cropping patterns and yields. Thus, it can serve as insurance against poor rainfall. In this respect, irrigation can have both income maximizing and risk minimizing effects. Decreases in downtime for land use can increase returns to farmers' endowments of land and labor resources.

Second, irrigation can affect cropping intensity. Farmers in many parts of South Asia farm three times per year due to irrigation, unlike their solely rain-fed counterparts who can hardly farm once per year. High cropping intensity implies that farmers can grow several crops per year from the same plot of land under irrigated conditions. Third, reliable irrigation can enable crop-switching, as consistent water allows for farmers to cultivate high-yield and more profitable crops rather than low-yield and low-profit crops. Generally, this entails switching from subsistence production to market-oriented production. Irrigation thus can lead to crop diversification and enable farmers to spread risk more evenly over the year.

The rest of the paper is organized as follows. Section II provides information about the background and context of the program. Section III discusses the mixed-methods approach and distinct sources of data used. Section IV describes the empirical approach, focusing on the identification strategy used for the evaluation. Section V provides the empirical findings as well as the mixed-methods discussion. The last part of the paper, section VI, provides concluding remarks.

## II. About the project

Context and project description

The agricultural sector on the coast of Peru has received much attention, largely because of its role in the country's economic growth experience over the past decade. The government has repeatedly said that improving the performance of the agricultural sector is fundamental for the eradication of poverty in the country; particularly for rural poverty (Ministry of Agriculture, 2007). About one-third of Peruvians live in rural areas and the majority of their income is derived from agriculture. Recent estimates by the Ministry of Agriculture show that 28 percent of the population is economically active in agricultural activities and the sector contributes up to 8 percent of gross national product. The coastal region is covered with small landholders who own on average less than three hectares. The proliferation of several inefficient irrigation schemes exacerbates the challenges many rural farmers face, particularly those below the poverty line (Escobal, 2005).

The project aims to improve some inefficiencies stemming from disinvestment in agriculture infrastructure. It rehabilitated and improved various irrigation infrastructure sites in several districts, for example, resurfaced canals, improved intakes, and invested in some collective irrigation infrastructure. Figure 1 shows the distribution of the treatment along the Peruvian coast. Project documents indicate that 313 kilometers of canals were rehabilitated, rebuilt, or improved, which includes 165 main intakes, 1,257 structures and 49 wells affecting 125,200 families and 443,000 hectares of land in 40 water users' associations (WUAs). This paper looks at seven of these water users' associations, for which various rounds of data exist and outcomes for both control and treatment localities can be properly measured. The project also addressed weak water management through institutional capacity building for water users' associations, and provided on-farm support for some plots through capacity building and a subsidy for drip irrigation technology. This evaluation controls for the other components of the project, but focuses on measuring impacts of the irrigation rehabilitation part of the intervention.

[INSERT FIGURE 1]

PSI was designed in the late 1990s and implemented in two formal phases over the past nine years. The first phase was meant to be implemented between 1997 and 2004. However, the project only started in 1998, and stopped soon after due to heavy rains and extreme weather conditions during the El Niño natural disaster, which led to heavy losses and new priorities. In 2000, the first phase began again with its original mandate of increasing agricultural production and productivity along the Pacific coast of Peru by improving public irrigation systems and making them more sustainable and efficient through institutional strengthening. The second phase was planned for 2005 and began its implementation in 2006. The focus of this paper is projects completed during the informal part of the first phase. The geographical area of influence is characterized by a desert-like environment with fertile soil that can produce more than two harvests per year when supplied with adequate water (World Bank 2008).

## III. Data used for the analysis

Mixed-methods approach

The multi-component design of this project—coupled with the diversity in methods of implementation, beneficiary types, timing, and geography—provides for a complex evaluation context; this is compounded by limited program data collected and the non-random assignment of the intervention. The mixed-methods approach seeks to lessen the limitations from one data source alone; qualitative information can shed light on how the work was implemented and help contextualize the information into the social and cultural systems of the coastal region, and elucidate the realities of program participants (Ravallion 2003, Rao and Woolcock 2004) that may have influenced the impact (or lack thereof) of the infrastructure rehabilitation component.

Data

The survey data available are very rich in terms of coverage and themes covered, but they was not designed specifically to evaluate PSI, thereby restricting the analysis to measure impacts on treated localities rather than treated households. In other words, while some households may have been in areas that benefited from rehabilitated infrastructure, they may not have used water from this infrastructure. This issue is reduced by limiting the analysis to only farm households. Other limitations from the data can be attenuated by using qualitative information collected specifically to evaluate PSI, particularly to assess non-quantifiable aspects of the program that may have influenced the impacts.

The primary dataset used for the analysis is the Peruvian household survey Encuesta Nacional de Hogares (ENAHO) collected by the National Institute of Statistics and Informatics. This annual household survey has been conducted for more than a decade, and the data used in this evaluation span ten years, 1998 to 2007. The survey is multi-topic, aiming to measure poverty-related variables, and it contains modules on household characteristics, economic welfare (including economic activity), social welfare, and agricultural activity. A feature of this survey is the availability of geographic coordinates for populated centers (referred to as "communities" in this paper). Project coordinates for the rehabilitation sites were documented by the implementation team making it possible for the location of the rehabilitation work to be identified and matched to the data.

ENAHO uses a three-stage stratified rotating sample of 22,000 households (8,800 in the rural area in the country from which 2,300 are in the rural coast) representative at the urban, rural and regional levels. The first stage uses the census to derive randomly selected primary sampling units or conglomerates with probability proportional to size. Once the conglomerates are selected, samples of 7 to 10 household are randomly picked. Households are surveyed over the course of a year, and in the next year, 7 to 10 households from the same sampling unit are randomly chosen to be surveyed. While households (and communities) within the sample regularly rotate, preventing the creation of household or community-level panels, districts stay in the sampling units over years which enable us to build district panels.

Qualitative information

Communities selected for the qualitative work were all part of the ENAHO sample; they were selected after a systematic stratification of the water users' associations in the three coastal regions (north, center, and south) to ensure coverage of a variety of contexts. The thematic areas of potential impact of the project on agricultural performance are presented in Table 1. The qualitative strategy relied on individual interviews and focus group exercises; the instruments were semi-structured and modularized around the themes in the ENAHO survey. The instruments aimed to capture associations between the project intervention and changes in agricultural performance from various angles, particularly where the quantitative data were weakest; for example, it includes information on the quality of natural endowments (such as the soil and types of cultivation), other activities affecting agricultural production active in the region, farmer attitudes and labor activities with relation to the project (Gutierrez and Velez-Vega 2009).

[INSERT TABLE 1]

## IV. Empirical strategy

Estimating treatment effects using non-experimental data is a common challenge faced by evaluators (Lokshin and Yemtsov, 2005). Generally, one seeks to estimate the difference between households located in treatment and control localities along several outcomes of interest. The assumption is that at baseline the treated were on average similar to the control along most relevant dimensions. However, given that the project did not have an experimental design and beneficiaries were not randomly assigned to control or treatment groups before the program started, obtaining a legitimate counterfactual to the treatment group is a challenge. Nonrandom program placement may indicate that infrastructure projects were only implemented in WUAs where water management capacity was better or worse than others. Thus, WUAs that received infrastructure projects may likely differ from WUAs that did not receive the project. This bias can result in overestimates or underestimates of the impact because the two groups, those with and those without the project, may not be statistically equivalent before the program started.

In order to overcome such selection bias, we design an identification strategy that exploits the fact that water flows in one direction of the canal, and that canal rehabilitation will therefore only directly improve water access for households in areas that are within a reasonable distance past the location of refurbishment. A sharp discontinuity between households directly affected by the improvements due to the rehabilitation and those that are not affected at all allows us to address the challenges by using a spatial regression discontinuity design to identify a valid control group. With this approach, households along the canal differ only in the treatment and are similar in relevant aspects such as: WUA administration, major water body or river, soil quality, tenure legal systems, and proximity to major markets.

Therefore, the identification strategy relies heavily on geography to find an appropriate counterfactual. Geographical technology was used to pinpoint accurate treatment locations and to find comparable areas to serve as control localities in the analysis. As the analysis was limited to projects that refurbished canals, the communities that are considered to be treated are only those in proximate downstream areas. Households located directly upstream, or downstream but far away from the work site are in the same water catchment area and therefore have the same major water source, agro-climatic conditions, and similar social and economic conditions of the treated locality, but would not be directly affected by the rehabilitation.

To supplement this strategy, we use extensive qualitative information to ensure comparability between the control and treatment groups; it provides evidence to inform the empirical strategy, particularly related to program targeting, the context and the implementation. Qualitative information shows that soil quality does not vary much within communities, but can vary greatly across WUAs and coastal regions. Thus, households located in downstream communities within a designated boundary of influence that are both within the catchment area and within the appropriate water users' associations are in the treatment group. Households located in upstream communities within the same WUA, or in downstream households in the same WUAs but very far from the rehabilitation site, are in the control group. As the specific project location along the canal provides for a somewhat arbitrary cut-off point between the treatment area and the control area, the project is the main factor that differentiates them. Figure 2 demonstrates the methodology of determining the treatment and control area. The specifics of how the GIS data were used are described below.

[INSERT FIGURE 2]

We first used the longitude and latitude coordinates of the beginning and end of each canal refurbishment project, which were obtained from the project team in Lima to identify the geographic location of each work site. We used geographic information system (GIS) software and Hydro-SHEDS data for water accumulation levels and flow direction to delineate the catchment area for each infrastructure project. This was done by first moving the irrigation coordinate location to the highest accumulation grid value, and then determining the catchment area using a flow direction grid.

Second, we drew the appropriate radius of project influence, determined using the number of hectares that the infrastructure was estimated to affect[2], along with Glob Cover Version 2.2 (Figure 2b) that was used to identify agricultural land. Thirdly, the team identified communities that were upstream from the infrastructure location within the water users' association (demonstrated by the large area marked "WUA" in Figure 2a) and downstream from the infrastructure location within a radius slightly larger than the radius of influence, also within the WUA.

As the infrastructure improvement would only influence those communities downstream (because water flow would not be affected upstream) and within the radius of influence, the upstream communities and communities beyond the determined radius serve as appropriate controls. This strategy eliminates the issue of nonrandom project placement, as the control group is restricted to households in communities within the same water users' association. Additionally, as the institutional strengthening component of PSI was implemented at the level of the WUA, and for each rehabilitation project, the treatment and control group for this analysis are by definition within the same WUA, this component of PSI is held constant and does not

[2] PSI officers and Ministry of Agriculture officials estimated this amount based on the size of the water source, the size of the project, and the number and location of households likely to benefit.

serve as a bias. Therefore, all communities included in the analysis have been "selected" for the project, and the upstream/downstream discontinuity is exploited to identify an appropriate counterfactual.

[INSERT FIGURE 3]

To minimize biases from differences in the upstream and downstream communities, the analysis uses difference-in-difference estimators to compare the average changes between treatment and control groups before and after treatment. The estimator controls for time-invariant fixed effects by differencing them out of the estimation and it assumes that treatment and control groups are on statistically similar trends. The qualitative information gives little reason to doubt the validity of this assumption.

Moreover, we conduct a trend analysis and run a few falsification tests; the trend analysis tests differences for the treatment and control in the pre-program period (Table 2, annex). The estimation, which allows the control and treatment to differ in their intercept and slope, demonstrates that the rate at which outcome variables changed was not significantly different for the treatment and control groups, as the coefficient on "*time*treat*" was only significant for the number of times industrial crops were cultivated, with a coefficient of 0.01 and p-value of 0.097. Figure 3 visually demonstrates the similar trends of the treatment and the control group in relation to the time of intervention for two key outcome variables: expenditures per capita and non-wage income per capita.

Furthermore, when baseline tests are conducted, both treatment and control groups are on average statistically similar before the treatment occurs; there were only some exceptions (number of staple crop cultivations, number of agricultural workers hired). Table 3 in the annex contains these results. Fortunately, given that neither of these variables differs in their trends prior to the intervention, the difference-in-difference model will adequately account for this baseline difference. The analysis is also restricted to WUAs for which adequate data in the treatment group (both before and after the intervention) and the control group (also both before and after the intervention) exist. This limits the sample to seven WUAs, and 23 rehabilitation projects. The limitations are based solely on the availability of data, which was collected through a random selection of communities by the national statistical institute and following a pre-set sampling framework; thus, the community selection for data collection is entirely orthogonal to the project. Consequently, the analysis does not evaluate all of the projects, but a random sample of them for which adequate data happens to exist.

Additional biases may exist from spillover effects on labor activity; the rehabilitation projects may have increased income-generating opportunities for neighboring control communities as well as treatment ones, thereby contaminating the control group. If these spillover effects are positive, there would be an underestimation of labor impacts. It is also possible that negative spillover effects may occur due to disruption or water-borne diseases (as found in Amacher, 2004; Duflo and Pande, 2005), which would render an overestimation of impact. However, qualitative work did not find any indication of these sorts of negative effects, and thus, the identification strategy likely provides a lower bound impact.

Outcome and control variables

The analysis looks at 15 outcome variables (Table 2), each selected because it reflects one of the impact channels posited earlier and/or is aligned with the objective of the project--to reduce poverty through increased agricultural productivity.

[INSERT TABLE 2]

Control variables include household head characteristics such as gender, age (and a squared term for age), and education level; the estimation also controls for the number of household members and whether the household hold a legal title to the property or not. Additionally, there are natural factors related to the specific water source that may confound the outcomes; for example, average water flows from the relevant river in a given year. Water along the coast is scarce and coastal river flows are influenced by rains in the highlands as well as glaciers in the Andean high summits that give origin to the rivers of the Pacific basin. Therefore, the analysis takes into account river flows rather than precipitation levels. When limited water flowed through the rivers, outcomes may have been less positive. The opposite is also true; too much water can lead to flooding and waste. However, this is not a concern in the years of the program, as flooding did not occur. Another potentially relevant factor is farm household distance to the project because it can potentially confound the treatment effect.

The analysis includes a dummy variable to control for whether the district had been treated for other components of the program, namely the subsidy for drip irrigation technology and the extension services and demonstration plots. It is not possible to identify which specific households were treated, and thus the control is a district-level dummy. All estimations include fixed effects (FE) for water users' association (WUA) to ensure each treatment group is compared to a control group within the same WUA. Additionally, all estimations use appropriate weights to account for the sampling strategy; standard errors are clustered at the WUA since these are likely to be correlated.

Specification tests are first run on four key outcome variables—total value of production per capita, probability of hiring an agricultural worker, total expenditures per capita, and total income per capita—to determine the most appropriate estimation specification. The coefficient for *post_treat* shows the impact of the project; this is an interaction variable identifying a household that received the irrigation infrastructure rehabilitation treatment and the time of the treatment. The variable *post* is a dummy variable for whether the rehabilitation had taken place yet (regardless of whether the household was in a treatment or control community), and *treat* is a dummy variable for whether the household is in a downstream community, within the appropriate radius and WUA (regardless of whether the rehabilitation had taken place or not). The first specification includes only these variables and the error term. All of these estimations are restricted to farm households and include fixed effects for water user associations.

$$Y_h = \alpha + \beta_1(post) + \beta_2(treat) + \beta_3(post\_treat) + WUA\ FE + \varepsilon_h \qquad (1)$$

The next specification includes some control variables; these are status of ownership over the property (title), distance to the rehabilitation site, the amount of river flows in the year, and year fixed effects to account for unobservable variables that change over time.

$$Y_h = \alpha + \beta_1(post) + \beta_2(treat) + \beta_3(post\_treat) + Title + River\ Flow + Distance + WUA\ FE + YearFE + \varepsilon_h \quad (2)$$

The third specification includes household characteristics that are expectedly orthogonal to the treatment effect.

$$Y_h = \alpha + \beta_1(post) + \beta_2(treat) + \beta_3(post\_treat) + Title + River\ Flow + Dist + WUA\ FE + YearFE + X_h + \varepsilon_h \quad (3)$$

The fourth specification controls for whether a district also received the plot-level irrigation treatment and/or extension services by including a dummy variable that takes a value of 1 if the district has been treated by this component (*PPtreat* in the estimation). The treatments were implemented independently, and the on-farm component does not confound the impact of the infrastructure rehabilitation project under evaluation; it is not surprising as the staff, the processes, and the implementation period for the various components were all different.

$$Y_h = \alpha + \beta_1(post) + \beta_2(treat) + \beta_3(post\_treat) + \gamma_1(PPtr) + Title + Riv\ Fl + Dist + WUA\ FE + YearFE + X_h + \varepsilon_h \quad (4)$$

## V. Results and discussion

The analysis is restricted to farm households in WUAs that have adequate data. In order to see how impacts vary across the poor and non-poor (those below and above the poverty line), the analysis is repeated for both economic segments of the population. As the data is not a household level panel, the analysis does not track those who may have moved across economic class. However, as it is more likely that households moved from below the poverty line to above the poverty line over time, this bias would result in an underestimation of impact and thus provide a lower bound estimate.

The average treatment effect on the treated for the entire population shows that the rehabilitation projects have positive effects on labor demand in the treatment areas, but there are no statistically significant impacts on various agricultural outcomes. Beneficiaries hired 30 percent more agricultural workers than the control group; reflecting this, wage income increased by 285 soles (roughly $95) per capita relative to controls (Table 3). Non-wage and total income were not affected. Thus, it appears that on aggregate, the project has a positive, although moderate, impact on poverty. Therefore, by one definition of pro-poor interventions – those that reduce poverty (in this case, as measured by wage labor) – the project is pro-poor.

[INSERT TABLE 3]

The differential analysis between the poor and the non-poor sheds light on whether the poor are benefitted more positively by the intervention than the non-poor this conforms to the second definition of pro-poor proposed in the literature and outlined earlier.. The differential analysis demonstrates that the poor and non-poor respond to the intervention in different ways. Tables 4a and 4b display the outcomes separately for each economic group; poor farmers increase their production of staple crops relative to the control (e.g. potatoes, beans, and grains) while non-poor farmers increase production of industrial crops (e.g. sugarcane, cotton, and cocoa) relative to the control. On the other hand, the non-poor decrease their staple crop production relative to the control, and the poor slightly decrease their industrial crop production relative to the control, suggesting that the non-poor are switching to higher value crops. The number of cultivations for any crop type did not change, though the non-poor increased their cultivations of industrial and export crops relative to the control, while the poor decreased cultivations of these crops.

While few agricultural indicators show a statistically significant change for either poor or non-poor households, total value of output per capita and total agricultural profit per capita show that the poor have positive point estimates, while the non-poor have large and negative point estimates.

[INSERT TABLE 4a]

In terms of broader economic welfare, poor farmers benefited by the rehabilitation work are driving the increase in labor demand in the aggregate results; their probability of hiring agricultural workers increases 41 percent more than the control group. Additionally, the poor engage in 35 percent less manual labor relative to the control, while at the same time the poor increase their total income per capita by $221 per year, which amounts to 64 percent of the average. Given that the sample is restricted to farm households, this income is likely derived from agricultural activities. Therefore, this finding is consistent with positive impacts for poor farm households on total income, expenditure and agricultural profit; however, agricultural profits were not statistically significant from zero, indicating that most of the change is through the labor side.

[INSERT TABLE 4b]

Thus, the infrastructure rehabilitation work had more positive impacts on the poor than the non-poor. However, the poor appear to have focused on producing staple crops, while the non-poor specialized in higher value crop production. Crop switching of the non-poor likely led to non statistically measurable economic impacts, likely because farmers need to adapt to different markets and farming techniques. It is also possible that limited agricultural impacts are due to the length of time required to grow most cash and export crops; the mean time span between the completion of the project and the data used is less than three years. This is enough time to produce crops such as beans, but not enough time to produce most permanent crops; oranges for example, take more than five years.

Moreover, impacts on productivity from greater access to water can be expected for existing production but not for new crop production, particularly in the case of industrial crops. Coffee (produced in the northern region), sugarcane and cotton require longer periods of farming; however, while coffee can take three to four years from the time it is planted to produce its first harvest and several more years to produce prime production, sugarcane and cotton only take a few months to produce its harvest.

Qualitative work found other non-quantifiable impacts. For example, there is evidence that the rehabilitation projects improved efficiency of labor; many respondents felt that infrastructure improvements significantly reduced the labor they had to devote to maintenance and operation of the irrigation system. A farmer pointed out that "before we used to go to the river almost daily to put fences, branches, rocks and the water overflow came and took it all away, and we had to go back again. Now we don't do that and it saves us time."

Another main qualitative finding related to agricultural productivity was that water availability had greater impacts in those WUAs with water supply deficiencies, for example, those located at the end of the water system or with major irrigation infrastructure bottlenecks. The easing of these bottlenecks led to increases in extensive and intensive land use in areas previously not receiving water. Thus, it is possible that the impact varied greatly across localities, resulting in limited average gains.

However, while the irrigation investments increased system-wide water distribution efficiency, and resulted in more even distribution of water to the soil, qualitative work indicates that the absolute impact was small because the rehabilitation projects were not large enough to affect many hectares. Thus, the general perception was that the first and second channels of impact, access and distribution of water, did not have a large impact beyond the specific irrigation commission in which the infrastructure project was placed.

## VI. Concluding remarks

This project took place in a complex socioeconomic and political context. Peru had been implementing general pro-market reforms during the period in which this project was implemented, and largely due to various macroeconomic conditions that benefited exporters, the agricultural sector experienced a surge. The primary catalysts for the surge in the economy and the agriculture sector specifically cited by informants were: the arrival of new capital investments, favorable price fluctuations and changes in the agricultural legal framework, and increased availability of credit and new technology.

Due to the generally positive economic trend experienced in the project region, the analysis sought to clearly isolate the causal link between the rehabilitation projects and improvements in production, productivity and economic well-being. The evaluation overcomes the lack of suitable project data by using rigorous quantitative techniques, complemented by rich qualitative information, to evaluate the specific effects of the project. Generally, the quantitative and qualitative results demonstrate that the project had positive – although limited – impacts, which were largely focused on those below the poverty line. More specifically, the infrastructure projects mainly improved labor demand in beneficiary communities, as more agricultural laborers were hired, and more wage income was earned.

The poor benefited more than the non-poor, particularly by increasing their incomes more than the poor control group. However, the non-poor are switching to higher yield and higher income crops, whereas the poor are increasing production of staple crops. Thus, although the project appears to be progressive as it positively impacts the poor to a greater extent than the non-poor, results may reverse in the longer term when income-generating crops reach their prime cultivation state.

TABLES AND FIGURES TO INSERT

Figure 1. Infrastructure Rehabilitation Sites


Table 1: Areas of Potential Project Impacts

| *Area of impact* | *Description* |
|---|---|
| Impacts on rural institutions | Whether (and how)the program changed the manner in which WUA operate |
| Impact on individual farmers and households | How the project might affect farming practices, use of resources (such as fertilizers, labor), household income and productivity. |
| Impact on markets and community | Effects on community relations (conflict, interactions), commercialization of products, and market creation. |
| Impacts by other factors | Nonproject factors that took place parallel to the project intervention and believed to have had an impact on productivity in the intervention areas. |

*Source:* Gutierrez and Velez-Vega (2009).

Figure 2a: Identifying Treatment and Control Areas Using Geographic Data

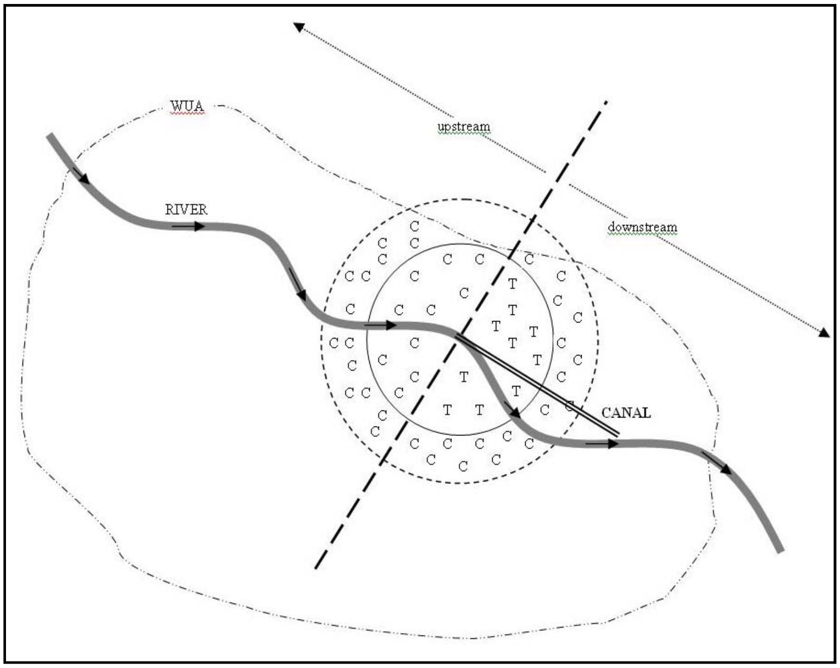
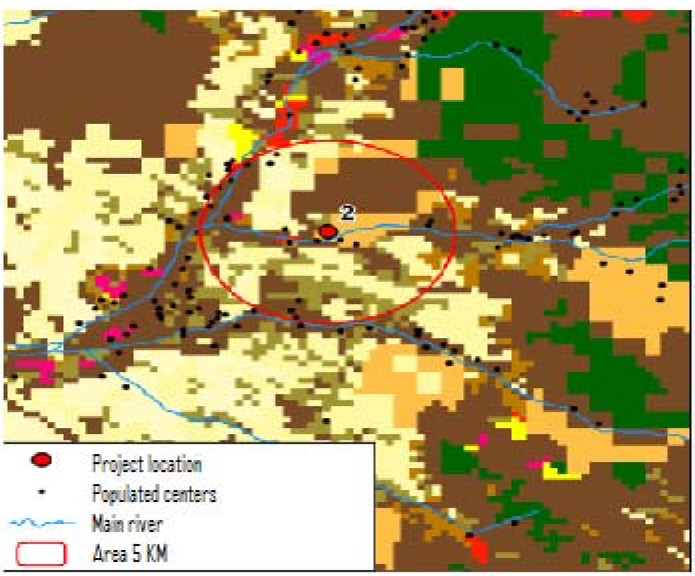
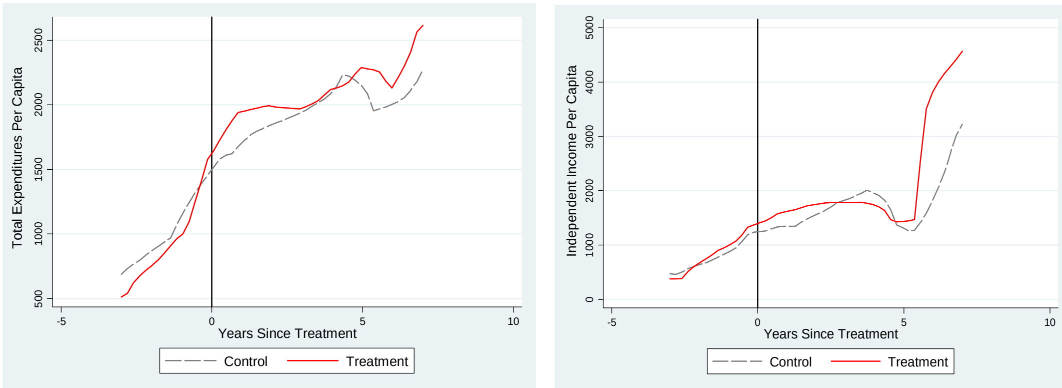



Figure 2b: Land Use Information Help Determine Treatment Area



## Figures 3: Treatment and Control Trends




## Table 2. Outcome Variables for Component A

| *Variable* | *Description* |
|---|---|
| Total Value of Output per Capita | Value of total production per capita in soles |
| Total Agro Profit per Capita | Total agricultural profit per capita |
| Export Crop Production | Value of fruit and vegetable production |
| Industrial Crop Production | Value of industrial crop (e.g. coffee, cotton, sugar cane) production |
| Staple Production | Value of grain, beans, and root vegetable production |
| Number Export Crop Cultivations | Number of times households has cultivated export crops |
| Number Industrial Crop Cultivations | Number of times households has cultivated industrial crops |
| Number Staple Crop Cultivations | Number of times households has cultivated staple crops |
| Hire Worker | 1 if the household has hired a worker to work, 0 if not |
| Work as Manual | 1 if the HH head is working as a manual laborer, 0 if not |
| Total Expenditures per Capita | Total expenditures per capita |
| Total Income per Capita | Total income per capita |
| Dependent (Wage) Income (ln) | Natural log of total wage income |
| Independent (Non-wage) Income (ln) | Natural log of total non-wage income |

## Table 3a: Difference-in-difference: Agricultural outcomes

| | (1) Total Value of Output Per Capita | (2) Total Agro Profit Per Capita | (3) Export Crop Production | (4) Industrial Crop Production | (5) Staple Crop Production | (6) Number Export Crop Cult. | (7) Number Ind. Crop Cult | (8) Number Staple Crop Cult. |
|---|---|---|---|---|---|---|---|---|
| Post_Treat | -2382.87 | -1084.57 | -11949.89 | 2428.00 | 1994.13 | 0.37 | 0.14 | -0.44 |
| | (1804.92) | (1138.34) | (9779.53) | (1987.73) | (3207.16) | (0.52) | (0.15) | (0.70) |
| Treat | -308.24 | -642.93 | -2150.52 | -3818.75 | 190.88 | -0.17 | -0.32** | 0.88*** |
| | (450.71) | (405.01) | (3446.58) | (2242.12) | (2732.93) | (1.24) | (0.10) | (0.23) |
| Post | 3045.79 | 2224.84 | 12158.45 | -3232.65 | 4878.83 | 0.31 | 0.20 | -0.28 |
| | (1664.14) | (1362.03) | (11213.29) | (2296.39) | (2895.70) | (0.51) | (0.12) | (0.57) |
| Component C: | -493.57 | -655.83 | 1055.59 | -222.04 | -1830.13 | -0.65 | 0.12 | 0.38 |
| PIRT/PERAT | (994.34) | (683.08) | (5782.03) | (762.25) | (3413.53) | (0.70) | (0.12) | (0.53) |
| Land Title | 558.16 | 516.64** | -1765.33 | 620.76 | 2649.91 | 0.13 | 0.01 | 0.11 |
| | (323.49) | (162.77) | (1831.71) | (605.76) | (1493.70) | (0.33) | (0.10) | (0.19) |
| River Flow | -37.29 | -26.18 | -124.70 | 58.47 | -86.49*** | -0.01 | -0.00 | 0.00 |
| | (32.95) | (23.87) | (164.07) | (44.93) | (17.15) | (0.01) | (0.00) | (0.01) |
| Distance to work site | -108.90 | -101.15 | -917.39 | -124.63 | 302.06 | -0.09 | -0.01*** | -0.01 |
| | (110.27) | (91.41) | (957.62) | (99.66) | (242.12) | (0.09) | (0.00) | (0.04) |
| HH Head Gender | 505.86 | 325.93 | 6030.37 | 275.63 | -68.64 | -1.27 | 0.03 | -0.01 |
| | (342.88) | (276.19) | (3604.59) | (948.48) | (1268.28) | (1.09) | (0.07) | (0.33) |
| HH Head Age | 201.88 | 99.36 | 498.56 | 72.47 | 453.64 | 0.09 | -0.08 | -0.03 |
| | (171.89) | (116.84) | (512.57) | (88.66) | (381.10) | (0.06) | (0.05) | (0.07) |
| HH Head Age2 | -1.38 | -0.63 | -3.22 | -0.36 | -3.30 | -0.00 | 0.00 | 0.00 |
| | (1.34) | (0.90) | (3.75) | (0.82) | (2.90) | (0.00) | (0.00) | (0.00) |
| HH Head Education | 3.86 | -35.52 | -454.94 | -38.67 | 473.21 | 0.09** | -0.02 | -0.03 |
| | (71.87) | (36.42) | (395.96) | (119.50) | (354.22) | (0.03) | (0.02) | (0.03) |
| HH # Members | -214.50 | -101.33 | 542.81 | 418.82^ | 310.78 | 0.06 | 0.02 | -0.01 |
| | (122.84) | (78.62) | (410.25) | (221.90) | (203.43) | (0.10) | (0.03) | (0.06) |
| WUA Fixed Effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year Fixed Effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Constant | -6229.80 | -1560.15 | -21548.50 | -1072.38 | -21560.99 | -1.20 | 2.25 | 1.73 |
| | (6255.00) | (3880.33) | (19309.70) | (2228.02) | (17438.96) | (1.93) | (1.74) | (1.77) |
| Observations | 489 | 441 | 496 | 496 | 496 | 419 | 432 | 423 |
| R-squared | 0.365 | 0.387 | 0.325 | 0.382 | 0.237 | 0.280 | 0.264 | 0.339 |

Notes: ^ p<.11 * p<0.10 ** p<0.05 *** p<0.01

Table 3b: Difference-in-difference: Welfare outcomes

| | (9) | (10) | (11) | (12) | (13) | (14) |
|---|---|---|---|---|---|---|
| | Hire Worker | Work as Manual | Total Expend Per Capita | Total Income Per Capita | Wage Income Per Capita | Non-Wage Income Per Capita |
| Post_Treat | 0.30** | -0.13 | -147.05 | -285.98 | 285.03* | -341.02 |
| | (0.10) | (0.18) | (137.55) | (386.94) | (126.39) | (481.02) |
| Treat | 0.03 | 0.12 | -32.04 | -242.03 | -194.23* | -208.33 |
| | (0.08) | (0.09) | (87.56) | (240.20) | (92.92) | (163.57) |
| Post | -0.12 | 0.12 | 259.44 | 776.71 | -3.92 | 983.58** |
| | (0.17) | (0.08) | (146.88) | (421.68) | (77.16) | (374.32) |
| Component C: | -0.12 | 0.11 | -85.25 | -793.10 | 74.38 | -321.83 |
| PIRT/PERAT | (0.08) | (0.10) | (184.59) | (616.60) | (123.91) | (464.01) |
| Land Title | 0.01 | -0.03 | 126.36* | 202.12 | -50.58 | 270.42* |
| | (0.05) | (0.05) | (64.38) | (150.79) | (37.16) | (110.71) |
| River Flow | -0.00 | -0.00 | -3.58 | -11.50 | 4.25*** | -7.78 |
| | (0.00) | (0.00) | (4.36) | (12.21) | (1.13) | (10.51) |
| Distance to work site | 0.01 | -0.01^ | -16.21 | -50.52 | -4.94 | -27.03 |
| | (0.01) | (0.01) | (15.95) | (30.70) | (6.77) | (23.82) |
| HH Head Gender | -0.12 | 0.2 | -197.56 | -228.50 | -34.12 | 228.06 |
| | (0.08) | (0.11) | (140.28) | (364.17) | (106.90) | (221.90) |
| HH Head Age | -0.01 | 0.02 | 17.16 | 59.44 | 21.27 | 55.84^ |
| | (0.01) | (0.01) | (18.08) | (40.80) | (16.87) | (28.79) |
| HH Head Age2 | 0.00 | -0.00 | -0.08 | -0.19 | -0.21 | -0.38 |
| | (0.00) | (0.00) | (0.17) | (0.39) | (0.16) | (0.21) |
| HH Head Education | -0.00 | -0.01 | 43.28** | 61.05 | 12.23 | -1.65 |
| | (0.01) | (0.01) | (12.73) | (53.14) | (6.63) | (15.36) |
| HH # Members | 0.02 | 0.01 | -61.86* | -158.17** | 38.02*** | -117.20* |
| | (0.01) | (0.01) | (28.64) | (62.39) | (7.05) | (59.59) |
| WUA Fixed Effects | Yes | Yes | Yes | Yes | Yes | Yes |
| Year Fixed Effects | Yes | Yes | Yes | Yes | Yes | Yes |
| Constant | 0.85* | 0.58 | 1053.77* | -814.65 | -389.98 | -1161.77 |
| | (0.43) | (0.44) | (479.76) | (935.12) | (480.08) | (1024.32) |
| Observations | 496 | 496 | 478 | 486 | 484 | 488 |
| R-squared | 0.253 | 0.184 | 0.624 | 0.475 | 0.256 | 0.338 |

## Table 4a: Rich and Poor Segmentation: Agricultural outcomes

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total Value of Output Per Capita | | Total Agro Profit Per Capita | | Export Crop Production | | Industrial Crop Production | | Staple Crop Production | | Number Export Crop Cultivations | | Number Industrial Crop Cultivations | | Number Staple Crop Cultivations | |
| | Poor | Not Poor | Poor | Not Poor | Poor | Not Poor | Poor | Not Poor | Poor | Not Poor | Poor | Not Poor | Poor | Not Poor | Poor | Not Poor |
| Post_Treat | 469.27 | -3308.31 | 730.34 | -1726.69 | -3441.53 | -14408.02 | -38.60 | 4089.65^ | 7705.42* | -2534.24 | 0.63 | 1.39^ | -0.09 | 0.34* | -1.13 | 0.11 |
| | (669.18) | (2543.01) | (669.48) | (1951.25) | (2924.20) | (13578.41) | (1554.68) | (2555.92) | (3231.54) | (3119.58) | (0.90) | (0.87) | (0.16) | (0.18) | (0.90) | (0.48) |
| Treat | -297.23 | -1415.74 | -787.69 | -1441.77 | 822.21 | -6931.38 | -16.83 | -6745.06* | -6293.19 | 4773.21 | -0.50 | -0.36 | -0.05 | -0.60*** | 0.56 | 1.02** |
| | (786.73) | (1568.97) | (646.25) | (1274.13) | (1279.04) | (9539.96) | (1335.66) | (3004.90) | (4912.20) | (3894.06) | (1.36) | (1.14) | (0.07) | (0.10) | (0.58) | (0.31) |
| Post | 66.28 | 5644.00* | -267.18 | 4289.99* | 1392.10 | 19968.73 | -318.87 | -4231.69 | -3116.79 | 11226.82** | -0.07 | -0.34 | 0.54*** | -0.14 | 0.31 | -0.67 |
| | (569.57) | (2785.52) | (444.29) | (1997.95) | (3001.76) | (16181.87) | (1371.15) | (2716.92) | (2247.74) | (4233.69) | (0.92) | (0.67) | (0.14) | (0.25) | (1.04) | (0.38) |
| Component C: | -284.09 | -211.98 | -353.81 | -803.64 | -1500.97 | 2877.40 | -56.08 | 793.89 | -1046.49 | -3388.69 | -0.20 | -0.63 | 0.16 | 0.17 | 0.89 | 0.11 |
| PIRT/PERAT | (507.92) | (1108.46) | (455.24) | (798.64) | (1243.18) | (8663.54) | (866.09) | (676.13) | (1801.26) | (6223.15) | (0.36) | (0.71) | (0.15) | (0.18) | (0.55) | (0.56) |
| Land Title | 316.06 | 119.81 | 440.86* | 137.66 | -299.59 | -6308.23 | -358.12 | 423.19 | 1880.12* | 3286.88 | -0.35 | 0.46 | 0.04 | -0.01 | 0.17 | 0.06 |
| | (239.34) | (833.46) | (202.84) | (667.52) | (589.87) | (4999.88) | (1017.10) | (779.42) | (773.18) | (1923.84) | (0.44) | (0.37) | (0.05) | (0.08) | (0.60) | (0.22) |
| River Flow | -43.46 | -43.27 | -28.91* | -28.38 | -32.38 | -252.23 | -101.83 | 84.94*** | -217.28** | -59.12 | 0.01 | -0.01* | 0.00 | -0.00 | 0.02 | 0.00 |
| | (24.57) | (44.46) | (13.89) | (31.72) | (22.60) | (239.92) | (115.23) | (11.43) | (85.06) | (45.68) | (0.02) | (0.01) | (0.01) | (0.00) | (0.04) | (0.01) |
| Distance to work | 17.07 | -231.28 | 6.02 | -226.22 | 53.16 | -1867.82 | -37.91 | -246.23 | -53.54 | 460.10 | -0.04 | -0.09 | -0.01 | -0.02* | -0.05 | 0.05 |
| site | (38.27) | (211.79) | (40.77) | (165.63) | (32.84) | (1587.40) | (118.19) | (168.19) | (231.87) | (423.33) | (0.09) | (0.06) | (0.01) | (0.01) | (0.04) | (0.04) |
| HH Head Gender | -308.82 | 1277.04 | -684.52 | 1400.95 | 1949.93* | 5310.53 | 2459.95 | -567.41 | -3041.51 | 3348.51 | -2.95 | -0.31 | 0.22 | 0.02 | -0.18 | 0.01 |
| | (745.04) | (1194.44) | (646.56) | (999.82) | (849.99) | (2921.16) | (1667.05) | (1309.90) | (2280.37) | (2566.82) | (2.27) | (0.61) | (0.18) | (0.13) | (0.21) | (0.45) |
| HH Head Age | -2.03 | 258.02 | -3.17 | 71.08 | 134.96** | 209.40 | -16.33 | 59.01 | -7.85 | 592.59 | 0.08 | 0.15*** | -0.00 | -0.14^ | -0.07 | 0.06* |
| | (78.25) | (181.82) | (69.17) | (69.05) | (53.05) | (456.65) | (46.68) | (54.72) | (355.65) | (512.19) | (0.07) | (0.03) | (0.01) | (0.07) | (0.08) | (0.03) |
| HH Head Age2 | -0.00 | -1.72 | -0.02 | -0.34 | -1.31** | -0.16 | 0.49 | -0.17 | 0.07 | -4.17 | -0.00 | -0.00*** | 0.00 | 0.00* | 0.00 | -0.00 |
| | (0.70) | (1.33) | (0.60) | (0.56) | (0.53) | (3.31) | (0.35) | (0.70) | (3.18) | (3.83) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) |
| HH Head Educati | 21.94 | -90.73 | 0.63 | -103.69 | -82.09 | -782.91 | 50.42 | -108.05 | 181.68 | 530.04 | -0.01 | 0.10*** | -0.02 | -0.04 | -0.07 | 0.01 |
| | (26.97) | (90.20) | (12.06) | (89.46) | (75.12) | (586.70) | (103.98) | (156.96) | (116.42) | (571.90) | (0.04) | (0.02) | (0.01) | (0.03) | (0.04) | (0.05) |
| HH # Members | -48.89 | -235.96 | -41.84 | -71.81 | 63.02 | 2013.50 | 456.04* | 445.85 | 305.39 | 478.69 | 0.18 | 0.01 | 0.04 | 0.01 | 0.03 | -0.06 |
| | (51.22) | (274.74) | (36.66) | (225.08) | (77.89) | (1200.38) | (234.65) | (259.87) | (262.15) | (496.86) | (0.15) | (0.11) | (0.02) | (0.02) | (0.05) | (0.12) |
| WUA Fixed Effect | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year Fixed Effect | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Constant | 1145.85 | -9477.71 | 1965.04 | -5385.78 | -3629.80 | -13050.29 | -2875.80 | 2997.50 | 11884.38 | -37251.69 | 0.79 | -3.15* | -0.74 | 4.77* | 4.37** | -0.25 |
| | (1097.11) | (6781.43) | (1471.88) | (4174.16) | (2570.10) | (14330.17) | (3106.75) | (2426.93) | (10489.18) | (23495.55) | (3.08) | (1.53) | (0.53) | (2.16) | (1.50) | (1.07) |
| Observations | 245 | 244 | 234 | 207 | 249 | 247 | 249 | 247 | 249 | 247 | 221 | 198 | 229 | 203 | 221 | 202 |
| R-squared | 0.285 | 0.454 | 0.282 | 0.525 | 0.241 | 0.477 | 0.267 | 0.568 | 0.416 | 0.315 | 0.295 | 0.427 | 0.245 | 0.523 | 0.380 | 0.393 |

Notes: ^ p<.11  * p<0.10  ** p<0.05  *** p<0.01

Table 4b: Rich and Poor Segmentation: Welfare Outcomes

| | (17) | (18) | (19) | (20) | (21) | (22) | (23) | (24) | (25) | (26) | (27) | (28) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Hire Worker | | Work as Manual | | Total Expend Per Capita | | Total Income Per Capita | | Wage Income Per Capita | | Non-wage Income Per Capita | |
| | Poor | Not Poor | Poor | Not Poor | Poor | Not Poor | Poor | Not Poor | Poor | Not Poor | Poor | Not Poor |
| Post_Treat | 0.41*** | 0.26* | -0.35*** | -0.02 | 43.37 | -123.92 | 663.49** | -381.15 | 406.81^ | 126.76 | 106.14 | -191.59 |
| | (0.07) | (0.15) | (0.08) | (0.17) | (110.01) | (246.55) | (254.17) | (697.08) | (269.65) | (141.12) | (284.90) | (627.41) |
| Treat | 0.04 | 0.01 | 0.28 | 0.17** | 3.34 | -242.62 | -259.01 | -948.49 | -192.45 | -116.61* | -52.15 | -877.26 |
| | (0.18) | (0.15) | (0.19) | (0.06) | (80.80) | (251.75) | (189.19) | (648.11) | (146.58) | (59.34) | (211.94) | (580.89) |
| Post | 0.06 | -0.28 | 0.21 | 0.09 | 4.99 | 326.74* | -198.77 | 1507.59** | -159.49 | 89.34 | 328.33 | 1483.15*** |
| | (0.06) | (0.20) | (0.12) | (0.10) | (130.83) | (138.51) | (319.91) | (416.21) | (182.49) | (135.67) | (305.55) | (334.95) |
| PIRT/PERAT | -0.25* | -0.06 | 0.13 | 0.08 | -123.22 | 125.54 | 22.70 | -645.92 | -243.81 | 207.70** | -105.70 | -75.90 |
| | (0.13) | (0.10) | (0.12) | (0.12) | (91.57) | (291.86) | (541.49) | (579.74) | (209.02) | (77.65) | (536.15) | (446.29) |
| Land Title | -0.05 | 0.04 | -0.05 | 0.08 | -43.95 | 96.05 | 31.76 | -0.75 | -76.79 | -53.82 | 123.75 | 206.87 |
| | (0.05) | (0.07) | (0.05) | (0.07) | (76.43) | (183.58) | (49.49) | (444.88) | (55.45) | (77.86) | (72.34) | (326.81) |
| River Flow | 0.00 | 0.00 | 0.01^ | -0.00 | -4.25* | -3.02 | -21.57 | -8.21 | -3.00 | 3.18 | -10.70 | -4.46 |
| | (0.01) | (0.00) | (0.00) | (0.00) | (2.00) | (4.87) | (12.63) | (14.55) | (2.90) | (1.72) | (8.17) | (12.34) |
| Distance to Infra | 0.01 | 0.01 | -0.00 | -0.01 | -9.47** | -14.84 | -9.77 | -69.20 | -22.78* | 7.69 | 12.18 | -50.91 |
| | (0.01) | (0.01) | (0.01) | (0.01) | (3.79) | (25.45) | (14.94) | (50.72) | (11.50) | (5.74) | (18.28) | (43.94) |
| HH Head Gender | -0.29 | 0.11 | 0.30*** | 0.16 | 80.73 | -195.05 | -835.39* | 353.60 | 95.90 | -110.09 | -144.98 | 684.49 |
| | (0.16) | (0.09) | (0.07) | (0.13) | (94.31) | (267.55) | (408.25) | (928.28) | (133.55) | (194.33) | (362.60) | (540.95) |
| HH Head Age | -0.02 | -0.01 | 0.03 | 0.01 | 13.57 | 13.57 | 64.73** | 79.97 | 35.05* | 1.60 | 2.56 | 98.80* |
| | (0.02) | (0.01) | (0.02) | (0.03) | (7.37) | (30.44) | (19.66) | (80.93) | (15.79) | (13.09) | (17.27) | (46.81) |
| HH Head Age2 | 0.00 | 0.00 | -0.00 | -0.00 | -0.12 | -0.04 | -0.46* | -0.29 | -0.33* | -0.03 | 0.01 | -0.78 |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.07) | (0.34) | (0.19) | (0.82) | (0.16) | (0.13) | (0.15) | (0.42) |
| HH Head Educ | -0.00 | -0.01 | -0.01 | -0.00 | -1.04 | 40.06** | 73.68* | 14.56 | -6.00 | 21.18 | 6.33 | -44.85 |
| | (0.01) | (0.01) | (0.01) | (0.01) | (9.56) | (13.39) | (32.99) | (91.87) | (14.54) | (11.76) | (8.22) | (41.51) |
| HH Members | 0.03 | 0.01 | 0.00 | 0.01 | -8.55 | -53.09 | -29.32 | -245.22 | 20.32* | 76.92** | -13.86 | -213.00 |
| | (0.01) | (0.01) | (0.01) | (0.02) | (10.96) | (61.85) | (17.98) | (131.94) | (10.45) | (24.08) | (14.13) | (114.26) |
| WUA Fixed Effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year Fixed Effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Constant | 0.86 | 0.95** | -0.10 | 0.81 | 1404.63** | 79.20 | 1351.21 | -2191.68 | -200.95 | 138.81 | 630.94 | -2441.15 |
| | (1.20) | (0.30) | (0.39) | (0.85) | (209.63) | (785.12) | (887.13) | (1246.17) | (430.15) | (473.09) | (670.50) | (1559.89) |
| Observations | 249 | 247 | 249 | 247 | 238 | 240 | 245 | 241 | 246 | 238 | 247 | 241 |
| R-squared | 0.308 | 0.394 | 0.247 | 0.217 | 0.792 | 0.679 | 0.617 | 0.521 | 0.332 | 0.312 | 0.316 | 0.414 |

Notes: ^ p<.11 * p<0.10 ** p<0.05 *** p<0.01

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## Annex

### Table 1a: Summary Statistics - Baseline

| *Variable* | *Obs* | *Mean* | *Std. Dev.* | *Min* | *Max* |
|---|---|---|---|---|---|
| *Outcome Variables* | | | | | |
| Total Value of Production Per Capita | 294 | 2346.21 | 4533.03 | 2.86 | 25515.67 |
| Total Agro Profit Per Capita | 310 | 1268.77 | 3016.99 | -1297.00 | 18648.67 |
| Export Crop Production | 312 | 3864.20 | 19612.71 | 0.00 | 144094.00 |
| Industrial Crop Production | 312 | 1339.73 | 5200.77 | 0.00 | 45000.00 |
| Staple Crop Production | 312 | 4269.49 | 8293.53 | 0.00 | 41520.00 |
| Number of Export Crop Cultivations | 294 | 1.64 | 3.03 | 0 | 12 |
| Number of Industrial Crop Cultivations | 312 | 0.18 | 0.57 | 0 | 6 |
| Number of Staple Crop Cultivations | 301 | 2.14 | 2.56 | 0 | 12 |
| Hire Worker | 312 | 0.58 | 0.49 | 0 | 1 |
| Work as Manual | 312 | 0.72 | 0.45 | 0 | 1 |
| Total Expenditures Per Capita | 299 | 658.53 | 538.40 | 115.75 | 4219.00 |
| Total Income Per Capita | 308 | 1044.76 | 1325.71 | 76.44 | 12095.50 |
| Wage Income Per Capita | 312 | 134.72 | 285.13 | 0.00 | 2895.00 |
| Independent Income Per Capita | 308 | 610.11 | 1035.74 | 4.71 | 9677.00 |
| *Treatment Variables* | | | | | |
| Treat (within radius of influence) | 312 | 0.83 | 0.38 | 0 | 1 |
| Post (after work completed) | 312 | 0 | 0 | 0 | 0 |
| post_treat | 312 | 0 | 0 | 0 | 0 |
| *Control Variables* | | | | | |
| Title | 235 | 0.68 | 0.47 | 0 | 1 |
| Distance to Infrastructure | 312 | 6.49 | 4.44 | 0.16 | 22.72 |
| River Flow | 275 | 24.23 | 21.40 | -25.95 | 110.50 |
| Male Household Head | 312 | 0.95 | 0.22 | 0 | 1 |
| Household Head Age | 312 | 51.97 | 14.30 | 20 | 92 |
| HH Head Years Education | 310 | 5.90 | 4.09 | 0 | 16 |
| Number of HH Members | 312 | 5.26 | 2.65 | 1 | 16 |
| PIRT/PERAT | 312 | 0.00 | 0.05 | 0 | 1 |

Table 1b: Summary Statistics – Follow-up

| *Variable* | *Obs* | *Mean* | *Std. Dev.* | *Min* | *Max* |
|---|---|---|---|---|---|
| *Outcome Variables* | | | | | |
| Total Value of Production Per Capita | 368 | 2490.46 | 3933.85 | 0 | 25670 |
| Total Agro Profit Per Capita | 312 | 1693.49 | 3125.82 | -1050 | 18472 |
| Export Crop Production | 368 | 1738.18 | 5757.54 | 0 | 63720 |
| Industrial Crop Production | 368 | 1784.58 | 4604.65 | 0 | 29900 |
| Staple Crop Production | 368 | 5533.82 | 13862.98 | 0 | 154210 |
| Number of Export Crop Cultivations | 301 | 0.26 | 1.43 | 0 | 12 |
| Number of Industrial Crop Cultivations | 304 | 0.07 | 0.28 | 0 | 3 |
| Number of Staple Crop Cultivations | 303 | 0.31 | 1.27 | 0 | 12 |
| Hire Worker | 368 | 0.63 | 0.48 | 0 | 1 |
| Work as Manual | 368 | 0.75 | 0.43 | 0 | 1 |
| Total Expenditures Per Capita | 362 | 1948.44 | 1185.95 | 182.83 | 5702.67 |
| Total Income Per Capita | 360 | 3479.75 | 2959.23 | 222.67 | 15531 |
| Wage Income Per Capita | 356 | 571.27 | 725.91 | 0 | 3687 |
| Independent Income Per Capita | 361 | 1683.56 | 1942.10 | 17.14 | 11136.50 |
| *Treatment Variables* | | | | | |
| Treat (within radius of influence) | 368 | 0.70 | 0.46 | 0 | 1 |
| Post (after work completed) | 368 | 1 | 0 | 1 | 1 |
| post_treat | 368 | 1 | 0 | 0 | 1 |
| *Control Variables* | | | | | |
| Title | 262 | 0.61 | 0.49 | 0 | 1 |
| Distance to Infrastructure | 368 | 8.37 | 5.27 | 0.16 | 20.16 |
| River Flow | 368 | 26.28 | 8.08 | 8.18 | 48.47 |
| Male Household Head | 368 | 0.90 | 0.30 | 0 | 1 |
| Household Head Age | 368 | 53.98 | 14.30 | 22 | 88 |
| HH Head Years Education | 368 | 5.00 | 4.05 | 0 | 17 |
| Number of HH Members | 368 | 5.12 | 2.56 | 1 | 16 |
| PIRT/PERAT | 368 | 0.26 | 0.44 | 0 | 1 |

Table 2: Time Trend Tests

| | (1) Total Value of Output Per Capita | (2) Total Agro Profit Per Capita | (3) Export Crop Production | (4) Industrial Crop Production | (5) Staple Crop Production | (6) Number Export Crop Cult. | (7) Number Industrial Crop Cult. | (8) Number Staple Crop Cult. | (9) Hire Worker | (10) Work as Manual | (11) Total Expend Per Capita | (12) Total Income Per Capita | (13) Wage Income Per Capita | (14) Non-Wage Income Per Capita |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time*Treat | -120.22 | -107.94 | -1127.37 | 44.44 | 233.82 | -0.07 | 0.01* | -0.03 | -0.00 | -0.00 | -14.99 | -6.78 | 2.91 | -23.61 |
| | (125.47) | (109.74) | (896.01) | (85.96) | (169.23) | (0.06) | (0.01) | (0.05) | (0.01) | (0.01) | (13.02) | (31.30) | (4.07) | (27.28) |
| Time | 53.33 | 33.62 | 458.54 | -85.81 | -102.55 | 0.07 | -0.02** | 0.01 | 0.00 | 0.01 | 34.27*** | 48.96*** | 4.29 | 32.73** |
| | (59.81) | (48.81) | (266.63) | (68.46) | (156.81) | (0.04) | (0.01) | (0.04) | (0.01) | (0.01) | (7.59) | (11.36) | (2.90) | (11.05) |
| Treat | 2478.79 | 1444.48 | 18403.56 | -2933.43 | -4981.42 | 0.83 | -0.53* | 1.07 | 0.27* | 0.10 | 494.99* | 156.63 | -193.20 | 451.36 |
| | (2503.76) | (1944.34) | (15003.90) | (2904.96) | (4205.59) | (2.03) | (0.26) | (0.85) | (0.12) | (0.36) | (226.63) | (583.33) | (187.51) | (460.56) |
| Land Title | -127.56 | 109.68 | -2751.42 | -297.07 | 2330.95 | 0.09 | -0.08 | 0.19 | -0.03 | 0.01 | 91.69 | 87.01 | 12.05 | 92.40 |
| | (699.16) | (393.69) | (3097.12) | (903.58) | (1727.42) | (0.29) | (0.08) | (0.14) | (0.08) | (0.09) | (67.93) | (111.97) | (39.70) | (128.50) |
| Distance to Infra | -138.94 | -149.87 | -1709.20 | -39.65 | 423.42 | -0.18 | -0.01 | -0.05 | 0.02** | -0.01 | 1.54 | -23.13 | 6.95 | -30.72 |
| | (175.76) | (150.06) | (1400.57) | (104.92) | (239.78) | (0.11) | (0.01) | (0.09) | (0.01) | (0.01) | (7.92) | (39.19) | (6.01) | (31.11) |
| River Flow | -36.86 | -24.53 | -217.88 | 32.28 | -20.84 | -0.03*** | -0.00 | -0.01 | 0.00 | -0.00 | -7.34** | -16.29 | 2.01** | -11.36 |
| | (33.30) | (24.42) | (205.19) | (21.38) | (27.58) | (0.01) | (0.00) | (0.01) | (0.00) | (0.00) | (2.01) | (9.29) | (0.70) | (7.38) |
| HH Head Gender | 1569.13 | 810.31 | 12471.58 | 1764.21 | -1428.24 | -3.69* | 0.16 | -0.01 | -0.30 | 0.14^ | -183.12 | 146.85 | -1.93 | 367.55 |
| | (1010.38) | (565.68) | (7922.86) | (2572.03) | (2481.74) | (1.81) | (0.13) | (0.83) | (0.20) | (0.07) | (144.88) | (457.82) | (82.76) | (321.18) |
| HH Head Age | 186.71 | 115.38 | 978.83 | 50.37 | 122.57 | 0.10 | -0.10 | -0.02 | -0.03* | 0.02 | 5.65 | 29.74 | 8.84 | 44.30 |
| | (265.06) | (189.30) | (1277.90) | (148.02) | (295.41) | (0.09) | (0.08) | (0.05) | (0.01) | (0.03) | (31.19) | (97.82) | (11.36) | (61.73) |
| HH Head Age2 | -1.57 | -0.93 | -8.01 | 0.00 | -1.20 | -0.00 | 0.00 | 0.00 | 0.00* | -0.00 | 0.00 | -0.12 | -0.06 | -0.33 |
| | (2.38) | (1.63) | (10.73) | (1.38) | (2.54) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.28) | (0.86) | (0.11) | (0.53) |
| HH Head Educ | -122.97 | -129.70 | -1106.10 | 117.85 | 86.96 | 0.11*** | -0.02 | -0.05 | 0.00 | -0.02 | 37.01 | 39.79 | 17.81** | -18.11 |
| | (196.28) | (122.91) | (866.62) | (180.50) | (103.92) | (0.03) | (0.02) | (0.05) | (0.01) | (0.01) | (23.28) | (64.41) | (7.00) | (40.32) |
| HH Members | -73.75 | -24.53 | 488.89 | 636.43 | 245.13 | 0.09 | 0.03 | 0.01 | 0.01 | 0.01 | -33.15** | -36.99 | 20.23 | -27.39 |
| | (91.72) | (44.21) | (380.39) | (343.31) | (322.04) | (0.09) | (0.04) | (0.10) | (0.01) | (0.02) | (9.68) | (28.66) | (11.99) | (22.61) |
| WUA Fixed Effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Constant | -4106.11 | -1324.41 | -25455.59 | -4712.37 | 418.97 | 0.32 | 3.64 | 2.78 | 1.37** | 0.11 | -503.02 | -1399.36 | -421.01 | -1462.16 |
| | (6138.34) | (4528.14) | (34764.92) | (5814.16) | (5748.13) | (3.08) | (2.56) | (2.30) | (0.46) | (0.83) | (761.98) | (2579.98) | (238.45) | (1620.00) |
| Observations | 227 | 233 | 234 | 234 | 234 | 224 | 234 | 226 | 234 | 234 | 222 | 231 | 234 | 232 |
| R-squared | 0.522 | 0.483 | 0.522 | 0.467 | 0.383 | 0.387 | 0.282 | 0.257 | 0.304 | 0.210 | 0.448 | 0.384 | 0.235 | 0.387 |

Notes: ^ p<.11 * p<0.10 ** p<0.05 *** p<0.01

Table 3: Baseline Tests

| | (1) Total Value of Output Per Capita | (2) Total Agro Profit Per Capita | (3) Export Crop Production | (4) Industrial Crop Production | (5) Staple Crop Production | (6) Number Export Crop Cult. | (7) Number Industrial Crop Cult. | (8) Number Staple Crop Cult. | (9) Hire Worker | (10) Work as Manual | (11) Total Expend Per Capita | (12) Total Income Per Capita | (13) Wage Income Per Capita | (14) Non-Wage Income Per Capita |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Treat | -210.09 | -1047.15 | -7353.89 | -2140.66 | 336.25 | -0.68 | -0.27 | 0.44* | 0.21** | 0.05 | 244.32 | 154.51 | -108.64 | -12.53 |
| | (707.94) | (821.64) | (7641.72) | (1967.35) | (2165.53) | (1.07) | (0.15) | (0.22) | (0.05) | (0.13) | (198.96) | (371.19) | (126.55) | (264.10) |
| Land Title | -3.32 | 237.21 | -1619.83 | -312.77 | 2099.44 | 0.16 | -0.08 | 0.20 | -0.02 | 0.01 | 95.04 | 62.45 | 6.79 | 106.78 |
| | (580.73) | (332.04) | (1328.27) | (953.90) | (1708.60) | (0.38) | (0.09) | (0.11) | (0.08) | (0.08) | (135.93) | (219.40) | (31.36) | (162.53) |
| Distance to Infra | -126.25 | -152.27 | -1635.41 | -99.01 | 401.91 | -0.15 | -0.03*** | -0.05 | 0.03* | -0.01 | 25.88* | 15.18 | 11.33* | -9.91 |
| | (206.65) | (183.36) | (1641.59) | (90.63) | (216.74) | (0.10) | (0.01) | (0.09) | (0.01) | (0.01) | (10.86) | (36.03) | (5.49) | (35.07) |
| River Flow | -40.13 | -30.32 | -258.13 | 21.06 | -13.90 | -0.03** | -0.00 | -0.01 | 0.00 | -0.00 | -2.61 | -7.84 | 3.15* | -7.78 |
| | (39.80) | (29.52) | (259.19) | (30.09) | (26.53) | (0.01) | (0.00) | (0.01) | (0.00) | (0.00) | (7.91) | (17.92) | (1.54) | (11.61) |
| HH Head Gender | 1748.79 | 984.15 | 13939.55 | 1901.50 | -1711.24 | -3.72* | 0.20 | 0.03 | -0.31 | 0.13 | -248.74 | 31.85 | -21.51 | 332.77 |
| | (1256.35) | (643.05) | (9032.15) | (2497.15) | (2837.32) | (1.89) | (0.15) | (0.87) | (0.21) | (0.07) | (175.64) | (518.08) | (85.31) | (386.04) |
| HH Head Age | 163.70 | 97.69 | 802.59 | 55.15 | 158.89 | 0.09 | -0.10 | -0.03 | -0.03* | 0.02 | 3.42 | 30.50 | 9.47 | 41.63 |
| | (235.13) | (173.58) | (1085.75) | (164.14) | (288.33) | (0.10) | (0.08) | (0.06) | (0.01) | (0.03) | (25.57) | (88.69) | (11.21) | (53.96) |
| HH Head Age2 | -1.31 | -0.71 | -5.90 | -0.06 | -1.64 | -0.00 | 0.00 | 0.00 | 0.00* | -0.00 | 0.03 | -0.13 | -0.07 | -0.30 |
| | (2.08) | (1.46) | (8.87) | (1.47) | (2.55) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.23) | (0.77) | (0.11) | (0.46) |
| HH Head Educ | -103.17 | -111.03 | -893.11 | 104.91 | 42.29 | 0.13*** | -0.02 | -0.04 | 0.00 | -0.02 | 42.34** | 44.06 | 17.63^ | -12.37 |
| | (194.67) | (121.67) | (860.29) | (166.45) | (67.18) | (0.03) | (0.03) | (0.05) | (0.01) | (0.02) | (16.35) | (54.11) | (9.15) | (35.88) |
| HH Members | -30.33 | 22.57 | 900.82 | 656.26^ | 163.66 | 0.10 | 0.03 | 0.02 | 0.01 | 0.01 | -42.34** | -59.23** | 16.25 | -31.26 |
| | (73.64) | (66.54) | (851.74) | (346.30) | (321.75) | (0.11) | (0.04) | (0.11) | (0.02) | (0.01) | (12.94) | (19.67) | (10.89) | (20.13) |
| WUA Fixed Effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Constant | -3189.04 | -833.85 | -18248.95 | -6254.34 | -1214.03 | 1.53 | 3.21 | 2.91 | 1.46** | 0.21 | 130.98 | -496.33 | -337.88 | -884.91 |
| | (4999.65) | (3509.72) | (23452.05) | (6122.36) | (7250.03) | (3.10) | (2.63) | (2.08) | (0.57) | (0.77) | (729.19) | (2608.57) | (225.73) | (1400.70) |
| Observations | 227 | 233 | 234 | 234 | 234 | 224 | 234 | 226 | 234 | 234 | 222 | 231 | 234 | 232 |
| R-squared | 0.504 | 0.445 | 0.459 | 0.460 | 0.356 | 0.364 | 0.242 | 0.253 | 0.301 | 0.204 | 0.311 | 0.309 | 0.203 | 0.361 |

Notes: ^ p<.11 * p<0.10 ** p<0.05 *** p<0.01

## Table 4: Specification Tests

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total Value of Output Per Capita | | | | Hire Worker | | | | Total Expend Per Capita | | | | Total Income Per Capita | | | |
| Treat | 900.49 | 262.69 | 425.16 | 319.34 | 0.00 | -0.06 | -0.08 | -0.08 | 61.19 | -173.91 | -29.54 | -38.47 | 9.86 | -413.32 | -231.01 | -304.91 |
| | (877.40) | (1503.78) | (1296.64) | (1240.89) | (0.09) | (0.07) | (0.08) | (0.08) | (53.85) | (136.44) | (116.90) | (107.37) | (134.48) | (331.31) | (315.97) | (319.30) |
| Post | 1120.54* | 1362.15 | 1498.25 | 1834.60 | -0.09 | -0.05 | -0.08 | -0.09 | 1292.22*** | 97.53 | 172.63 | 200.92^ | 2483.71*** | 23.81 | 104.79 | 341.64 |
| | (503.02) | (1308.04) | (1165.24) | (1116.53) | (0.12) | (0.19) | (0.20) | (0.19) | (258.71) | (116.61) | (112.02) | (110.95) | (471.98) | (424.72) | (372.62) | (371.34) |
| Post_Treat | -1232.46** | -1167.65 | -1265.64 | -1108.12 | 0.19 | 0.31** | 0.33** | 0.33** | 7.86 | 29.53 | -78.53 | -65.12 | -68.15 | 70.82 | -46.37 | 62.65 |
| | (485.63) | (1465.69) | (1177.22) | (1150.96) | (0.15) | (0.12) | (0.12) | (0.12) | (194.51) | (140.62) | (113.18) | (126.30) | (388.08) | (378.86) | (319.38) | (320.63) |
| PIRT/PERAT | | | | -1049.64 | | | | 0.02 | | | | -88.58 | | | | -734.06 |
| | | | | (1112.37) | | | | (0.06) | | | | (219.62) | | | | (529.34) |
| Land Title | | 1846.13* | 1368.43** | 1331.31** | | 0.02 | 0.03 | 0.03 | | 222.88*** | 197.11** | 193.88** | | 638.01** | 414.72* | 390.84* |
| | | (880.26) | (543.78) | (518.16) | | (0.04) | (0.04) | (0.04) | | (53.87) | (66.06) | (68.81) | | (231.79) | (175.37) | (172.38) |
| Distance to Infra | | -119.19^ | -86.62 | -108.62 | | 0.01 | 0.01 | 0.01 | | -30.66 | -20.18 | -22.04 | | -62.71* | -39.30 | -54.27 |
| | | (63.32) | (70.63) | (83.34) | | (0.01) | (0.01) | (0.01) | | (17.23) | (17.85) | (15.84) | | (27.98) | (30.54) | (31.76) |
| River Flow | | -26.62 | -31.04 | -31.25 | | 0.00 | -0.00 | -0.00 | | 0.74 | 0.57 | 0.55 | | 4.37 | 2.06 | 1.97 |
| | | (37.69) | (46.65) | (46.55) | | (0.00) | (0.00) | (0.00) | | (1.55) | (3.17) | (3.16) | | (6.82) | (11.96) | (11.76) |
| HH Head Gender | | | 91.92 | -4.81 | | | -0.14 | -0.14 | | | -271.15 | -279.14^ | | | -350.46 | -395.57 |
| | | | (441.27) | (464.77) | | | (0.08) | (0.08) | | | (154.84) | (155.66) | | | (380.03) | (404.00) |
| HH Head Age | | | 246.05 | 240.93 | | | -0.01 | -0.01 | | | 21.46 | 21.05 | | | 66.20 | 62.27 |
| | | | (185.68) | (184.29) | | | (0.01) | (0.01) | | | (19.10) | (19.39) | | | (44.38) | (45.16) |
| HH Head Age2 | | | -1.78 | -1.71 | | | 0.00 | 0.00 | | | -0.12 | -0.11 | | | -0.27 | -0.22 |
| | | | (1.43) | (1.41) | | | (0.00) | (0.00) | | | (0.18) | (0.18) | | | (0.42) | (0.43) |
| HH Head Educ | | | 69.38 | 77.91 | | | -0.00 | -0.00 | | | 56.23*** | 57.00*** | | | 81.57 | 86.83 |
| | | | (94.04) | (93.31) | | | (0.01) | (0.01) | | | (13.60) | (13.30) | | | (52.76) | (53.56) |
| HH Members | | | -268.02* | -258.08* | | | 0.02 | 0.02 | | | -71.18** | -70.34** | | | -186.45** | -179.53** |
| | | | (128.72) | (122.66) | | | (0.01) | (0.01) | | | (28.03) | (27.49) | | | (70.50) | (66.29) |
| Year Fixed Effects | | Yes | Yes | Yes | | Yes | Yes | Yes | | Yes | Yes | Yes | | Yes | Yes | Yes |
| Constant | 1601.62*** | 1741.67 | -5300.08 | -5135.38 | 0.58*** | 0.75*** | 0.86 | 0.85 | 607.88*** | 1762.25*** | 1109.25* | 1121.93* | 1036.59*** | 3559.92*** | -851.67 | -619.91 |
| | (426.24) | (2293.48) | (5745.80) | (5711.35) | (0.09) | (0.14) | (0.51) | (0.51) | (54.61) | (383.57) | (497.38) | (506.57) | (153.29) | (683.30) | (923.69) | (884.62) |
| Observations | 662 | 490 | 489 | 489 | 680 | 497 | 496 | 496 | 661 | 479 | 478 | 478 | 668 | 487 | 486 | 486 |
| R-squared | 0.005 | 0.069 | 0.117 | 0.121 | 0.014 | 0.153 | 0.169 | 0.169 | 0.357 | 0.515 | 0.585 | 0.585 | 0.242 | 0.352 | 0.427 | 0.432 |

Notes: ^ p<.11 * p<0.10 ** p<0.05 *** p<0.01