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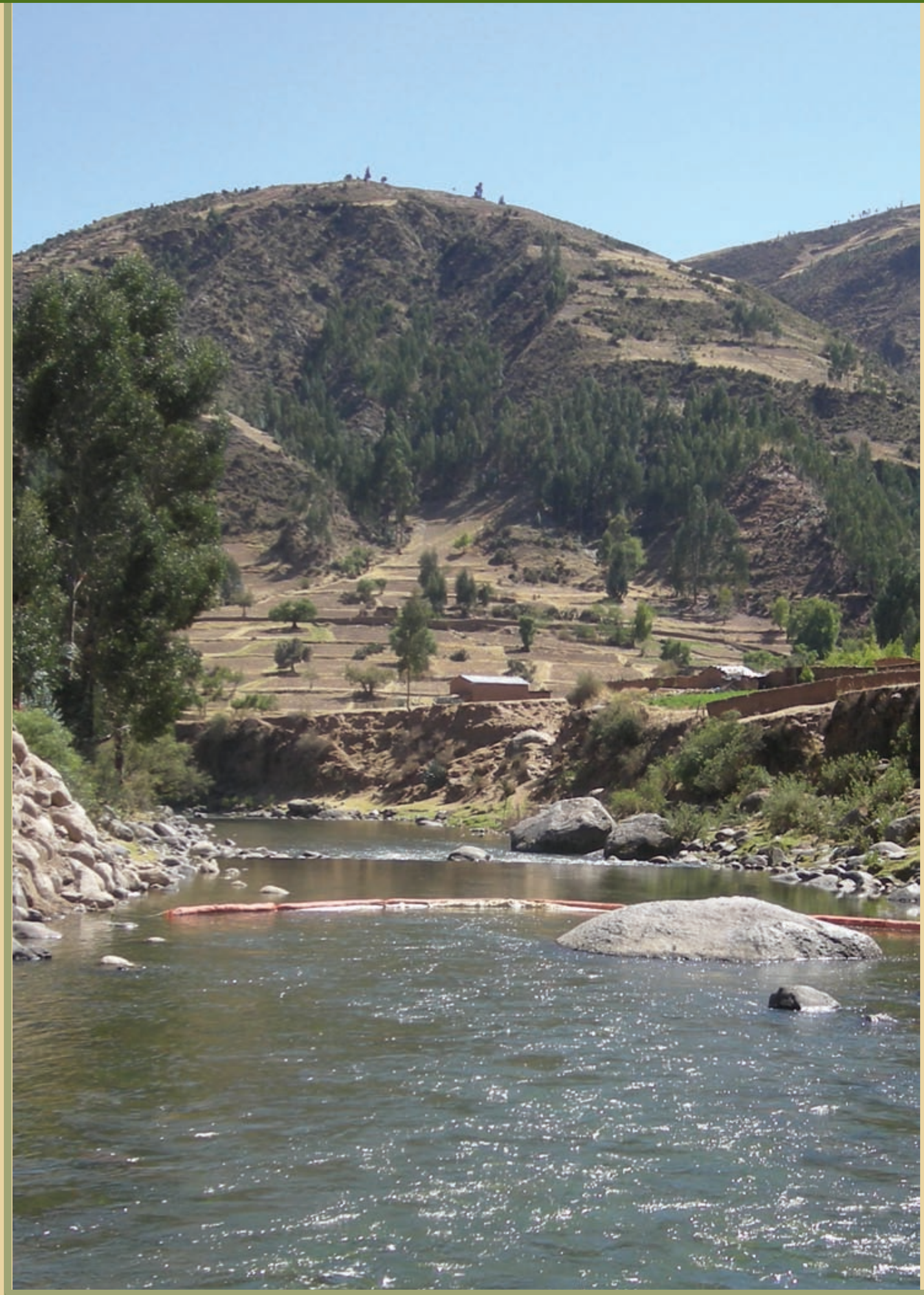
EVALUATING THE IMPACT ON FARM HOUSEHOLDS

A Multicomponent Irrigation Program in Peru



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A Multicomponent Irrigation Program in Peru: Evaluating the Impact on Farm Households

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Contents

Abbreviations 5

Acknowledgments 6

Executive Summary 7

1. Introduction 16
- Motives and Objectives 16
- The Link between Irrigation and Agricultural Production 18
- Country Context 19
- The Program 22

2. Impact Evaluation Approach 26
- Using Mixed Methods to Identify Impacts 26
- Data Used in the Evaluation 26

3. Technical Analysis to Identify Impacts 31
- Evaluation Focus Areas 31
- Estimation Approach 32

4. Impacts of the Program 43
- Question 1: Did the Program Improve the Agricultural Performance and Economic Well-Being of Farmers? 43
- Question 2: Was the Multicomponent Design Effective in Improving Agricultural Performance and Economic Welfare? 53
- Question 3: Did the On-Farm Investments in Irrigation Technology and Extension Have Spillover Benefits? 55

5. Concluding Remarks 58

Appendixes

A: Tables and Figures 60
B: Secondary Analysis—Centro Peruano de Estudios Sociales 66
C: Estimations 76

Bibliography 89

Endnotes 91

Boxes

1.1 General Concepts 17
1.2 Other Irrigation Interventions around the World 19
3.1 Design and Methodological Concepts 34

4.1 Perceived Productivity Improvements Varied across Components 44
4.2 Perceived Impacts of the Infrastructure Rehabilitation and Institutional Strengthening Components 45
4.3 Perceived Impacts from Institutional Strengthening 48
4.4 Perceived Impacts from the Irrigation Technology Subsidy 49
4.5 Perceived Impacts from On-Farm Training 51
4.6 Spillover Benefits of Private Investments 56

Figures

ES.1 The Programa Subsectorial de Irrigaciones and Its Components 8
ES.2 Delineation of Control and Treatment Areas 9
ES.3 Perceptions of Water Access 10
ES.4 Perceived Effects from On-Farm Modern Irrigation Technology 11
ES.5 Participation in On-Farm Extension 12
ES.6 Activities that Prompted the Hiring of Laborers 14
1.1 Infrastructure Rehabilitation Sites 22
1.2 The Programa Subsectorial de Irrigaciones and Its Components 23
2.1 Trends of Key Variables over Time—ENAHO 29
3.1 Identifying Treatment and Control Areas Using Geographic Data 37
3.2 Project Sites and Agriculture Density 38
3.3 Treatment and Control Trends 39

Tables

2.1 Areas of Potential Program Impacts 27
2.2 Study Informants by Category 28
2.3 List of Variables by Survey Type 30
3.1 Outcome Variables for Component A 40

Abbreviations

CEPES	Centro Peruano de Estudios Sociales (Peruvian Center of Social Studies)
ENAHO	Encuesta Nacional de Hogares (National household survey)
ENAPROVE	Encuesta Nacional Agropecuaria sobre Producción y Ventas (National Production and Sales Survey)
GIS	Geographic information system
IEG	Independent Evaluation Group
INEI	Instituto Nacional de Estadística e Informática (National Institute of Statistics and Information)
MINAG	Ministry of Agriculture
O&M	Operations and maintenance
PIRT	Irrigation technology program
PERAT	Programa de Entrenamiento en Riego y Asistencia Técnica en Práticas Culturas (Irrigation Extension and Technical Assistance Program)
PSI	Programa Subsectorial de Irrigaciones (Irrigation Subsector Program)
WUA	Water users' association

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Executive Summary

This impact evaluation of a World Bank-supported irrigation program in Peru finds that the program led to agricultural improvements and economic welfare gains for farmers in the rural coastal area of that country. Two of the three components of the program, relating to irrigation infrastructure rehabilitation and the management of water user associations, led to a 27 percent increase in farm labor demand and a 47 percent increase in wage income, equal to a 10 percent increase in total farmer income.

The analysis also reveals complementarities in the multicomponent design between support for on-farm modern irrigation technology and the infrastructure rehabilitation projects. Localities where farmers received on-farm modern irrigation technology alone showed no impacts on total production value, whereas farmers in localities benefiting from both the on-farm modern irrigation component and the infrastructure rehabilitation component increased their total production value by 7 percent.

Introduction

This report examines the impact of a Bank-supported irrigation program, which included several distinct interventions, on the economic welfare and agricultural productivity of farming households in rural Peru. The program's objectives were to increase agricultural production and productivity by enhancing the sustainability and efficiency of existing public irrigation systems and reducing the role of the public sector in irrigation.

This impact evaluation aims to shed light on three questions: whether the program improved the agricultural performance of beneficiaries and their economic welfare; whether the multicomponent design of the program contributed to improvements in agricultural productivity and economic well-being; and whether there were spillover effects of on-farm investments to households in surrounding areas that did not receive direct program support.

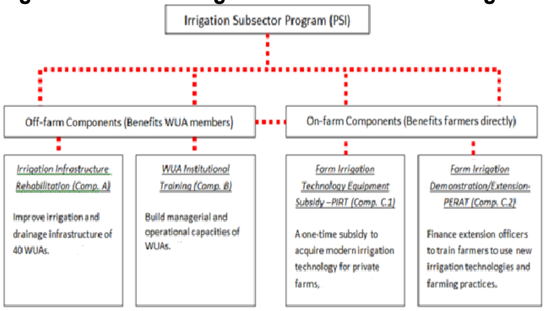
The Program

Irrigation is important because it increases reliable access to water, which reduces farm risks and allows greater crop intensity. The Programa Subsectorial de Irrigaciones (PSI) is a multicomponent program designed to improve opportunities for agricultural development in the rural coastal area of Peru.

The program has three main components: two off-farm components directed at all water user association (WUA) members and one on-farm component directed at individual farmers. The two off-farm components involve the rehabilitation of small-scale public irrigation facilities (component A) and institutional training of WUA members (component B). The on-farm component (component C) has two subcomponents: the first (C.1, also referred to by its Spanish acronym PIRT) provides subsidies for modern irrigation equipment, and the second (C.2, also called PERAT) on-farm demonstration and extension services.

The program was implemented by Peru's Ministry of Agriculture with financial and implementation assistance from the World Bank. Figure ES.1 elaborates on the activities and beneficiaries of each component.

Figure ES.1. The Programa Subsectorial de Irrigaciones and Its Components



Source: World Bank project documents.

Evidence of what has worked in the past to improve agricultural output and productivity is generally thin. This program was selected for an impact evaluation by the Independent Evaluation Group (IEG) for three reasons: first, it was a recent World Bank-supported project whose design and available data were amenable to impact evaluation; second, it was expected to contribute to filling existing gaps of evidence in the agriculture literature; third, the evaluation complemented other IEG evaluation work on the agriculture sector.

Methodological Approach

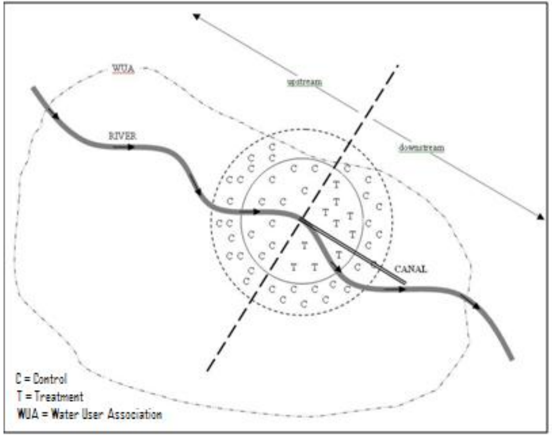
The methodology used in this evaluation aims to ensure that the impacts measured are due to the intervention and not to other factors in the environment. The program was launched in a complex context in which nationwide pro-market reforms undertaken during the same period benefited exporters, and the agricultural sector experienced a surge. Impact evaluation allows clear identification of the causal link between the program (and its individual components) and changes in agricultural productivity, independent of these trends affecting the region.

The evaluation used a mix of qualitative information and quantitative data (a mixed-methods approach) to compensate for the limitations of either method, to help understand why the observed impacts occurred, and to situate the information gathered in the broader context of the sociocultural systems of Peru and the realities of program participants that may have influenced the impact (or lack thereof) of the program.

The complexity of the program's design posed challenges but also offered opportunities. The main challenge was that the program was not planned with impact evaluation in mind. As a result, limited data were collected and the program benefits were not allocated randomly. Nevertheless, it was possible to undertake this evaluation by drawing on existing data sources in Peru, exploiting the phased design of the program and its unique geographic distribution, and constructing control and treatment groups ex post that allowed for a quasi-experimental evaluation design.

In addition to the use of well-known impact evaluation techniques, an innovation in this evaluation was the use of location coordinates, land-use data, and information related to water sources to delineate the catchment area for each infrastructure project.

Figure ES.2. Delineation of Control and Treatment Areas



Source: IEG.

Figure ES.2 illustrates how benefited localities (treated communities, labeled T in the figure) and nonbenefited localities (control communities, C) were delineated. The center of the concentric circles indicates where a rehabilitation work was undertaken. Treated communities were defined as those downstream from the work and within the inner circle (the "area of influence"), and control communities as all those upstream from the work and within the outer circle, plus those downstream and in the region between the two circles. The analysis was then restricted to a comparison of households in communities within the area of influence with households outside it but nearby, thus eliminating concern stemming from nonrandom project placement.

Another feature of the analysis is that it distinguishes between poor and nonpoor households and thus assesses distributional impacts.

Question 1: Did the Program Improve the Economic Well-Being and Agricultural Performance of Beneficiaries?

Impacts of the irrigation rehabilitation and institutional training components

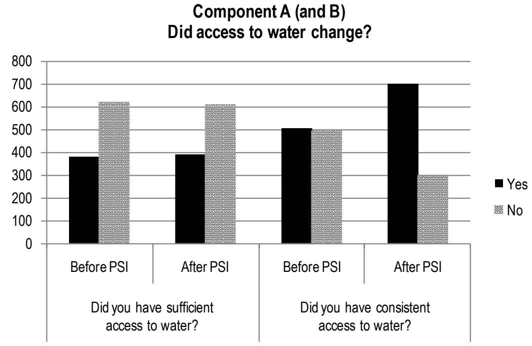
The two off-farm components increased labor demand and wage income and promoted changes in the types of crops farmed for all farmers. Unfortunately, data limitations for the analysis of both off-farm components do not permit a distinction between production increases caused by an increase in cultivated area and those caused by more intensive cropping patterns; thus, this part of the analysis cannot identify whether the off-farm infrastructure rehabilitation and WUA training increased productivity or not.

Beneficiaries hired 27 percent more agricultural workers than the control group. Wage incomes (which on average amount to 20 percent of total income per capita) reflect this increase in labor demand: wage income for farm households in treated localities increased by 47 percent per capita relative to farm households in control localities.

The analysis shows that production of two main food staples (potatoes and beans) and of general industrial crops (such as cotton, coffee, and cocoa) increased for the treated group in comparison to the control group; for example, the value of bean production more than doubled, and root crop production increased by almost 50 percent compared with the control localities.

The shift in crops did not lead to immediate changes in agricultural profits or agricultural production; however, it is expected to yield higher agricultural income in the future. Insights from the qualitative analysis reveal that crop switching likely resulted from the increased regularity of water distribution, allowing farmers to plan for future harvests with new crop investments, even if the total quantity of water did not change. Figure ES.3 illustrates the perceptions of a group of 1,000 farmers about changes in water availability.

Figure ES.3. Perceptions of Water Access



Source: IEG survey.
Note: Component A is rehabilitation of small-scale public irrigation facilities; component B is institutional training of WUAs.

The mean time between project completion and data collection is less than three years—sufficient time to produce a crop of beans but not enough time for most newly planted permanent crops to reach their first harvest (for example, oranges and coffee require a minimum of four to five years). Hence, production data do not reflect expected output or income from these investments.

Findings related to the *institutional strengthening* component (component B) are mostly derived from the qualitative analysis. About 40 percent of those interviewed perceived this component as the most successful in the program. The training is credited with creating a culture of respect for and compliance with the irrigation distribution schedule, helping to ensure that fees were used for operations and maintenance of water infrastructure and raising awareness among water users of the importance of their economic contributions to further developing and maintaining water facilities.

Impacts on poor farmers. The analysis separates poor farmers (households below the national poverty line) from the full sample to measure how the program affected them specifically. Results show that poorer farmers tend to specialize in main staple crops (potatoes and beans), and nonpoor farmers in industrial crops. Output per capita, income per capita, and agricultural profit per capita all increased for poor farmers, relative to the poor in comparable localities where the program was not offered.

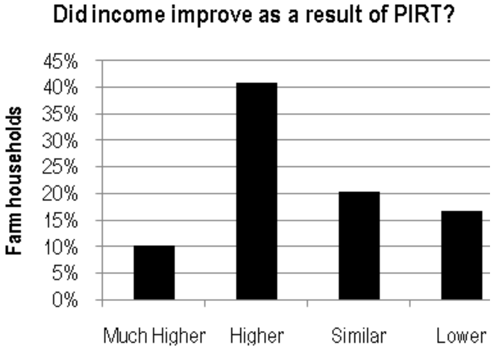
In addition, poor farmers in beneficiary localities worked significantly less as manual laborers on other farms and earned more nonwage income per capita—likely derived from agricultural activity on their own farm—than poor farmers in control localities. This finding is consistent with positive impacts on production, agricultural income, and agricultural profit.

Impacts of the on-farm irrigation technology and extension components

On-farm modern irrigation technology (the PIRT subcomponent of the program) affected farmers receiving the technology in at least three ways. First, it increased the proportion of their agricultural output sold in the market (rather than consumed) by 12 percent compared with control farmers. Second, it increased the probability of a household growing permanent crops by 15 percent. Third, it improved production and productivity when off-farm irrigation infrastructure was also improved.

Results of the qualitative analysis were consistent with the finding that on-farm modern irrigation technology improved agricultural outcomes. Beneficiaries reported significant improvements in the variety of crops they could farm on their plots, in their knowledge about modern farming practices, and in their overall use of labor resources for more effective production.

Figure ES.4. Perceived Effects from On-Farm Modern Irrigation Technology



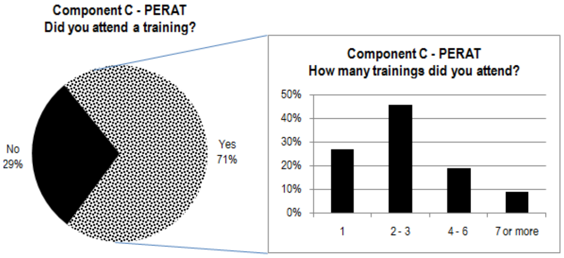
Source: IEG.
Note: PIRT is the on-farm modern irrigation technology subcomponent of component C.

Figure ES.4 shows the perceptions of farm households regarding income changes due to the new on-farm irrigation technology; 50 percent reported income improvements.

The results for farmer extension and training (the PERAT subcomponent) were also positive in at least three dimensions. First, the demonstrations and lessons on irrigation techniques and farming imparted by the program increased productivity in treated localities by more than 20 percent. Second, the extension component increased the proportion of agricultural production sold in the market by 12 percent compared with farmers in control localities. Third, farmer training increased production of export crops such as rice, cotton, maize, onions, and grapes. Some of these are nontraditional crops that experienced a boom in the agricultural sales market in Peru and abroad.

The qualitative analysis revealed that although most informants were satisfied with the training component, some felt that too much time was spent on marketing and not enough on irrigation technology. Of those who attended training sessions in the four WUAs surveyed, more than half (53 percent) said they were using the new techniques in their everyday farming activities. Figure ES.5 shows that of a subset of beneficiaries interviewed, 71 percent attended at least one training session, and of those, more than 70 percent attended more than one.

Figure ES.5. Participation in On-Farm Extension



Source: IEG.
Note: PERAT is the irrigation extension and technical assistance subcomponent of component C.

Because of data limitations, all impacts were measured in terms of the average effect of the treatment on the entire locality. Therefore, impacts on those farmers actually receiving the treatment are likely underestimated, especially for the on-farm irrigation technology subcomponent, because outcomes of actual beneficiaries were not necessarily observed in the analysis.

Impacts on poor farmers. The on-farm irrigation technology subcomponent had some differing effects on poor and nonpoor farmers. Both groups increased their proportion of cultivated land and their farming of permanent crops by approximately 14 percent relative to poor farmers in control localities. However, nonpoor farmers reduced their total crop production, thereby experiencing an overall decline in productivity in the short term; the likely reason is that the new permanent crops take a few years to produce marketable goods.

There were also some differential impacts of the farmer extension services and demonstration plots. The increase in permanent crop cultivation due to the training was mostly driven by increases for poor farmers. Also, training led to increases in market sales for both groups, with a 10 percent increase for poor farmers.

According to the qualitative analysis, some respondents perceived that the on-farm extension and the demonstration plots led to increases in knowledge. Some of the direct impacts mentioned were changes in crop selection, improved crop management, and more efficient irrigation techniques.

Question 2: Was the Multicomponent Design Effective in Improving Outcomes?

A general pattern in the qualitative analysis was that people perceived that increased water supply alone was unable to guarantee agricultural improvements, because the quality of production also depends on factors such as quality of land, availability of other inputs (such as seeds, fertilizers, and pesticides), access to agricultural services, and suitability of farming practices. Nearly a third of interview participants did not specify a particular component as most important in meeting program objectives; rather, they said that it was their combination that effected change through synergies, complementarities, and diversity of focus areas.

The quantitative analysis found positive complementarities between the on-farm modern irrigation technology component and the infrastructure rehabilitation component when both were implemented in the same locality. Farmers who benefited from both components saw an increase in their total agricultural production by value of 7 percent; farmers who received the modern irrigation component alone experienced no significant impacts. There is also evidence that farmers who benefited from both components cultivated more of their existing land and increased their productivity (defined as gross value of production per unit area of total land holdings) compared with the control group farmers.

These results are important because they partially agree with the insight from the qualitative analysis that modern irrigation technology, when implemented alone, is unable to achieve such positive results. Unfortunately, the impacts of on-farm extension and infrastructure rehabilitation do not seem to be complementary.

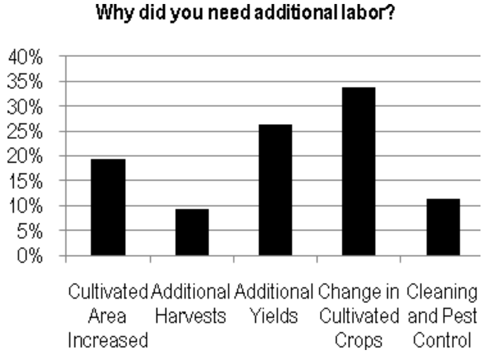
Question 3: Do On-Farm Investments in Irrigation Technology and Extension Have Spillover Benefits?

Survey respondents believed that improvements of water-use efficiency at the plot level had positive spillover effects. They attributed the widespread adoption of modern irrigation technology throughout the Peruvian rural coastal area to the program. Several respondents—including both beneficiaries and nonbeneficiaries—disagreed with this assessment, however, stating that impacts were seen only on the private plots of direct beneficiaries. The quantitative analysis shows positive direct effects of both on-farm activities and general locality improvements in production and productivity.

Program participants felt that on-farm extension and plot demonstration lessons had positive community-level effects. Extension activities and demonstration work were important in encouraging better technology use among farmers, in part because the demonstrations allowed them to assess and verify the effectiveness of new technologies without incurring personal costs or facing risks.

The quantitative analysis showed a clear spillover effect of on-farm irrigation technology on farming outcomes. In particular, the analysis found a shift toward export and industrial crops and increases in the proportion of the harvest sold in the market. Given data limitations, it is not possible to measure the actual effects of the on-farm components on beneficiaries themselves; therefore, all quantitative analysis and overall impacts reported reflect effects on beneficiary farmers and neighboring farmers (spillover effects) combined.

Figure ES.6. Activities that Prompted the Hiring of Laborers



Source: IEG.

There is qualitative evidence that beneficiaries were more likely to hire manual laborers to work on their plots, which suggests that some of the spillover effects took the form of increased labor demand and the promotion of new work opportunities in the local market. In four WUAs visited, only 22 percent of beneficiary farmers hired new laborers; and workers were required to apply new farming practices and/or new crop selection. Figure ES.6 shows a breakdown of the main activities performed by farm workers. Increases in cultivated area, change in crops, and increases in yields were the main reasons for additional hiring.

Conclusions

The goal of the irrigation program was to improve agricultural production and increase productivity. The program sought to reach this goal by enhancing the sustainability and efficiency of existing public irrigation systems and reducing the role of the public sector in irrigation. Specific program objectives were to improve WUA management capacity, fund irrigation rehabilitation schemes, and actively involve WUAs in the process of rehabilitation. This impact evaluation investigated whether the program's objectives were met and the various channels by which farmers were affected.

The evaluation found that all three of the above objectives were largely accomplished: most WUAs were successfully trained, 42 irrigation systems were rehabilitated, and WUAs were active partners with the Ministry of Agriculture in the rehabilitation schemes. However, the impact on farmers is more difficult to quantify. The evaluation sought to overcome the difficulties, including the lack of suitable program data, by using a quasi-experimental quantitative approach, complemented by rich qualitative information.

The analysis demonstrates that the program had positive impacts from both its off-farm and its on-farm components. Off-farm components showed positive impacts on labor demand and income, with more agricultural laborers being hired and more wage income being earned. Unfortunately, for the off-farm components, only production changes could be measured, not productivity. One of the on-farm subcomponents, the introduction of modern irrigation technology, successfully increased market sales on its own and increased agricultural production when it was complemented by infrastructure work. The data used to evaluate the on-farm work allowed productivity to be measured. The results show that where the off-farm infrastructure rehabilitation work was also undertaken, productivity improved.

The other on-farm subcomponent, which provided extension services and training for farmers, also showed positive results on productivity and on the amount of farm output that is sold rather than consumed by farm households. However, some negative externalities were found from having both infrastructure rehabilitation works and on-farm extension services in the same locality; these are seen in lower production value and lower productivity in localities were both components were implemented.

Finally, impacts of the program differed depending on the initial wealth of the farm household. Poor farmers were more likely to plant staple crops when off-farm components were implemented; nonpoor farmers were more likely to increase their production of industrial crops such as cotton, coffee, and sugar. The on-farm irrigation technology investments led poor farmers to increase their production of permanent crops; however, poor farmers saw no changes in productivity. The extension services led farmers to switch crops, planting more export crops and increasing permanent crop cultivation, particularly among poor farmers.

Chapter 1
Introduction

Motives and Objectives

Improving agricultural productivity is seen as a critical component of sustained poverty reduction. Most of the world's poor still live in rural areas and derive their livelihood from agricultural activities (World Bank 2008b). Hence, the relationship between government-sponsored rural infrastructure development and agricultural productivity is a topic of much debate among development practitioners. The consensus in the academic literature is stronger: much of the macro literature agrees that government investments are an important determinant of economic growth (Lipton and Ravallion 1995). Rural infrastructure is one such government investment, from which the micro literature finds measurable economic improvements in rural areas (Jacoby 2002; van de Walle and Cratty 2002; Lipton 2005; Khandker and others 2006). Previous work also finds that infrastructure improvements can increase farm household production (Hussain and Hanjra 2004; Smith 2004; Van Den Berg and Ruben 2006) and improve the marketing of agricultural goods (Dorward and others 2004).

The literature remains unclear, however, about whether rural infrastructure investments alone can ensure positive change, or if they need to be complemented by other services to ensure proper use and management of the investment and sustain its success. The effectiveness of infrastructure rural improvements may or may not depend on their being accompanied by services such as resource management training at the institutional level or farmer support at the plot level. Furthermore, even if infrastructure investments are effective alone, potential interactions (synergies) between infrastructure and plot-level interventions may produce impacts greater than the sum of their parts. It would be important to take advantage of such synergies in project design to improve cost-effectiveness. The microeconomic impacts of improvements in agricultural infrastructure stem from changing the setting in which farmers produce, through three key aspects that affect farmer behavior: capital-intensive investments such as dams or canals, capital-extensive investments such as extension services, and institutional infrastructure such as formal or informal institutions (Wharton 1967, cited in Escobal 2005).

Investments vary in their reach. Some are public in nature whereas others are limited to small groups. When the latter are publicly financed, they become subject to the criticism that government is providing subsidies for the private gain of a few. The critics say that such investments create efficiency losses due to distortions and underprovision of the public goods necessary to increase the productivity of other public and private investments (Lopez and Galinato 2007). The argument is that subsidies for private gains have low or even negative economic returns and that they crowd out private investors; in addition, such subsidies carry a high risk of being regressive, benefiting only those farmers who can afford the subsidized good. Others, however, argue that subsidies for private inputs (such as fertilizer or technical equipment) can increase the general welfare by promoting the adoption of new technologies and thus increasing agricultural productivity (Ellis 1992). This side of the argument finds that subsidies reduce the disincentives to adoption arising from factors such as risk aversion, liquidity constraints, and uncertainty about productivity.

This report presents findings of an impact evaluation of a rural irrigation investment program with multiple components in coastal Peru. It addresses three questions: whether the program was effective, whether the program's multicomponent design contributed to its effectiveness, and whether the program had spillover effects. The impact evaluation adopted an evaluation strategy that included both qualitative and quantitative analysis, the latter consisting of the application of econometric techniques to measure the impacts of the intervention and reduce any biases that could otherwise lead to mismeasurement (see box 1.1 for definitions). The program under evaluation, the Programa Subsectorial de Irrigaciones (PSI), includes the following three components: the first addresses the rehabilitation of public irrigation facilities, the second provides institutional training to local WUAs, and the third is devoted to on-farm capacity building. Two subcomponents of the third component provide subsidies for irrigation equipment and extension and demonstration services. Given this complex design, the evaluation investigated the benefits of these multicomponent interventions and whether the program, or some part of it, had any spillover effects that affected general agricultural performance or economic well-being. More formally, the evaluation sought to accomplish three things:

- To shed light on whether the program as a whole and, where possible to determine, each component improved the economic well-being of the target population
- To investigate whether the multicomponent design was effective in improving agricultural productivity
- To measure whether the on-farm investments had spillover effects, positive or negative, on nonbeneficiaries.

Box 1.1: General Concepts

Impact evaluation: An assessment of changes in indicators of program goals that can be attributed to a particular intervention. Impact evaluations use many different methods to examine and establish the causal link between an intervention and the desired outcomes. Such an evaluation faces two interrelated challenges: establishing a viable counterfactual and attributing the impact to an intervention. Generating counterfactual data requires establishing a control group to compare with the group receiving the benefits. The credibility of the counterfactual is related to the attribution concern. Credibility entails comparability between control and treatment groups, in all relevant dimensions, before the program to ensure that any changes in outcomes for the treatment group are due solely to program participation.

Mixed-methods approach: The use of both qualitative and quantitative methods to obtain a holistic picture of the impact of a program. Qualitative information provides a nuanced understanding of the context and implementation of the program and allows the researchers to understand why the impact occurred.

Impact transmission channel: The specific means through which the outputs of a program may make an impact. In irrigation infrastructure, for example, a rehabilitated canal in and of itself does not transmit an impact; rather, the channel by which the impact occurs consists of increased access to water, which then improves the quality of farmers' plots and allows them to improve their productivity (the goal of the program).

The primary audiences for this report are development practitioners engaged in designing similar projects, evaluators interested in using similar methodology, and the general evaluation community. The rest of this report is organized as follows. This chapter first briefly explains how irrigation projects transmit their impacts, identifies potential areas of concern for this type of project, and illustrates these with experiences in water-related projects around the world. Another section in this chapter provides some necessary background on the agricultural sector in Peru, past and present, and a brief description of the irrigation program and each of its components. Chapter 2 discusses the mixed-methods approach used in the impact evaluation, focusing on data description. Chapter 3 elaborates on the technical strategy used to identify impacts. Chapter 4 presents and discusses the findings. Chapter 5 presents concluding remarks.

The Link between Irrigation and Agricultural Production

Land and water are essential natural resources for agricultural development; irrigation schemes can lead to productivity gains through various impact transmission channels. Irrigation affects agricultural performance through several channels, three of which are identified in the literature (Hussain and Hanjra 2004):

- By serving as insurance against poor rainfall, irrigation can lead to more stable cropping patterns, crop yields, and agricultural outputs. In this respect, irrigation can have both income-maximizing and risk-minimizing effects. Decreases in downtime for land use can increase the returns to farmers' endowments of land and labor resources. Yield improvements can lead to higher productivity through higher land-use intensity and cropping intensity.
- Irrigation positively affects cropping intensity: with irrigation, farmers may be able to grow several crops per year from the same plot of land. For example, farmers in many parts of South Asia raise three irrigated rice crops per year, unlike their rain-fed counterparts who can barely grow one crop.
- Reliable irrigation can enable crop switching, substituting low-yield and low-profit crops with new, high-yield and more profitable crops. The increase in yields and in crop value allows farmers to switch from subsistence production to market-oriented production. Irrigation thus can lead to crop diversification and enable farmers to spread their risk more evenly over the year.

Previous evaluations of water-related projects for agriculture, and of irrigation schemes specifically, show positive results on agricultural outcomes but mixed results on other outcomes related to well-being. A review of a group of impact evaluations undertaken in the past decade of irrigation-related projects around the world provides insight into some of the challenges associated with irrigation and evidence of its impacts. Although these evaluations do not cover the full breadth of issues confronted in assessing the productivity impacts of irrigation, and their geographic coverage is limited, a good number of examples show that despite delivering general good results, irrigation projects can also have negative consequences for some segments of the population. For example, irrigation has a tendency to generate gains for the command area (the area downstream from the reservoir) but not for the catchment areas (the area upstream and the area submerged by the reservoir). The only gains enjoyed by the catchment population are from the construction activity itself and from increased economic activity around the reservoir (Duflo and Pande 2005). Dam construction can cause significant loss of agricultural and forest land and can increase the salinity and waterlogging of the land around the reservoir. Upstream populations are also likely to be more exposed to diseases caused by the large-scale impounding of water (Singh 2002, cited in Duflo and Pande 2005). One large-scale irrigation scheme yielded low returns and attracted negative publicity because of its potentially adverse environmental and social impacts. Box 1.2 provides examples of interventions that have had positive and negative impacts.

Box 1.2: Other Irrigation Interventions around the World

An irrigation management transfer program launched under the World Bank's second irrigation operations support project in the Philippines involved changing management structures to give farmers greater leverage, for example, through water users' associations. The evaluation asked whether the timeliness and distribution of water delivery and the improved maintenance structure had impacts at the farm level. The evaluation compared predicted yields of the treated areas with those of nontreated areas. The authors found that maintenance of irrigation facilities improved with such a shift in management and had a positive indirect impact on rice production. These impacts were measurable for both rich and poor households.

A large irrigation construction project implemented in Andhra Pradesh, India, with World Bank funding sought to improve the economic and social impacts of farmers in that state. The evaluation compared a group of farmers receiving water from the new irrigation infrastructure with a group of nonrecipient farmers across localities and time. It found that cropping intensity increased as a result of water availability in additional seasons. It also reduced year-to-year income fluctuations caused by variations in rainfall. The new construction raised net farm income by about 60 percent. Indirect benefits may also have occurred from additional wage employment. The intervention had several negative aspects, however, resulting from cost overruns, construction delays, and discrepancies between realized income increases and those expected at project appraisal.

Country Context

The agricultural sector in Peru is a major contributor to the country's economic dynamism, employing nearly one-third of the population and contributing close to one-tenth of national product. The agricultural sector on the coast of Peru has received much attention, largely because of its role in the country's economic growth over the past decade. The Peruvian government has repeatedly said that increased productivity in agriculture is fundamental for the eradication of poverty in the country, especially rural poverty. About one-third of Peru's population live in rural areas, and the majority of their income comes from agriculture. Recent estimates by the Ministry of Agriculture show that 28 percent of the population are economically active in agricultural activities. Moreover, agriculture contributes up to 8 percent of national product, and traditional and nontraditional agricultural products account for 7 percent of total exports. The government's vision for the sector, according to the ministry, is threefold: first, to correct market failures that prevent farmers from accessing information, markets, and services; second, to reduce poverty by contributing to rural development through projects that improve rural opportunities; and third, to contribute to the conservation and strategic use of natural resources and the environment through improvements in water management and the establishment of protective policies (MINAG 2008).

Economic policy in Peru is characterized by strong central government control; the agricultural sector has been undergoing change that affects rural investment, in land and infrastructure, for at least five decades. At the end of the 1960s, the military government in Peru began an agrarian reform process whereby land was expropriated from large landowners and given to small farmers under a collectivized agriculture arrangement. The failure of this reform to boost agricultural efficiency led to the dismantling of the cooperatives in the 1970s, and the land was reassigned to individual households. This policy was formally pursued throughout the 1980s. As a result, the coastal region (and part of the highlands) was covered by small landholdings of less than 3 hectares each, whose owners often had little or no operation and maintenance ability. The policy was accompanied by a proliferation of various inefficient irrigation schemes. In general, the country's agricultural sector during this period is often characterized as one of deteriorating infrastructure, weak institutions, and lack of technical advancement.

Various reforms over the last two decades led to the devolution of water rights and increased public and private investments in rural areas, especially in the agriculture sector. At the end of the 1980s the government embarked on a program of broad-based reforms. Among them was the devolution of responsibility for operating and maintaining large irrigation systems to citizens through WUAs. During the next two decades, waves of pro-market reforms included efforts to strengthen property and water user rights. The strengthening of land and resource rights led to increased private capital in agricultural production and increased activity in global markets through agro-exports. As expected, these reforms and rapid economic change led to heated debates among stakeholders about the quality of investments in agriculture. This debate resulted in a transformation of the government's agricultural project portfolio (with some obvious exceptions) from one consisting mainly of large-scale infrastructure projects (such as highways and large irrigation system construction) to one of mostly smaller-scale projects with locally relevant, specifically targeted investments (such as rural roads, rehabilitation of existing infrastructure, capacity building, and subsidies).

Under current arrangements, WUAs encompass full irrigation districts, and local water commissions encompass irrigation sectors within a WUA jurisdiction. WUAs in Peru are nonprofit entities that manage irrigation and drainage systems and are responsible for the management of water resources within an irrigation district; irrigation commissions manage subsections of the irrigation district comprising a single village or a few villages.[1] Although WUAs and irrigation commissions are established independently, they are interconnected: the WUAs partially supervise the commissions' work and finances. WUAs are formed and financed by water users, who commit to paying water fees and participate in the governance of the WUA. The WUAs' main sources of revenue are water fees, loans, donations, interest on capital they lend, and fines imposed on users for not participating in elections or General Assembly sessions. There are 112 WUAs in Peru, including 64 along the coast; these encompass a total of about 1,500 irrigation commissions and represent half a million water users.

The Program

The Programa Subsectorial de Irrigaciones (PSI) was designed to improve agricultural production and productivity by enhancing the sustainability and efficiency of existing public irrigation systems and reducing the role of the public sector in irrigation. This multicomponent program fits well within the vision of the ministry, outlined in its strategic plan for the sector. The main objective of the program is to raise agricultural production and productivity by enhancing the sustainability and efficiency of existing public irrigation systems (World Bank 1996). The program has three main components, each of which has its own specific goals relating to the main objective. According to program documents, the total cost was nearly $124.6 million.[2] The government of Peru financed this program with resources from the World Bank and its own national funds. The program was designed in the late 1990s and implemented in two main phases over nine years.[3] Its geographical area of influence is the entire Peruvian coast (figure 1.1), which is characterized by desert-like climatic conditions but fertile soil that can produce more than two harvests per year when supplied with adequate water.[4]

Figure 1.1: Infrastructure Rehabilitation Sites

Source: World Bank Group data.

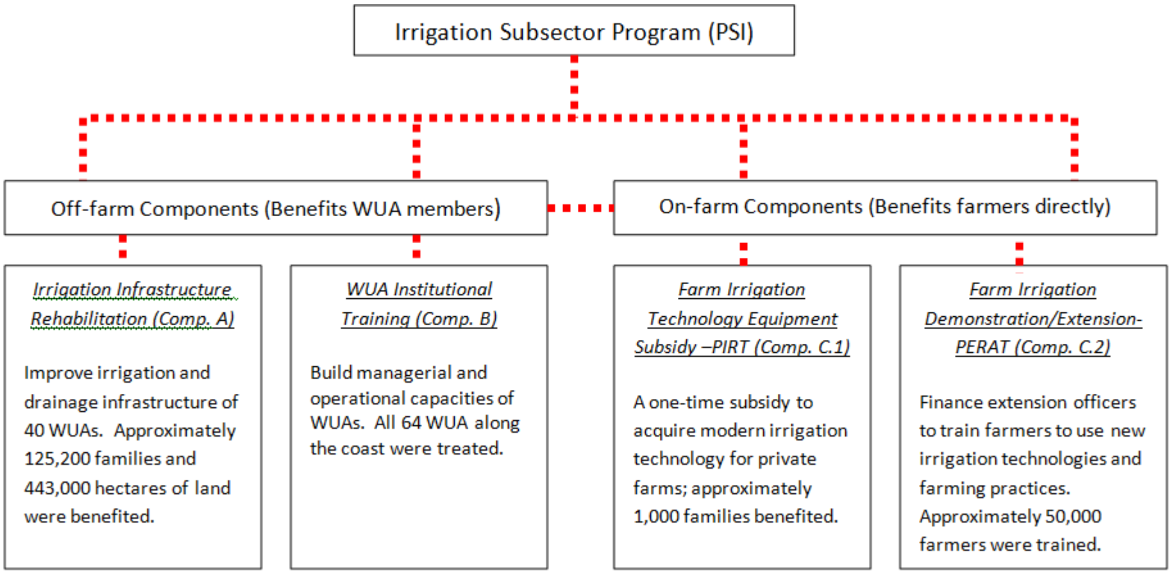
This evaluation focuses on one of the implementation phases, the delayed first phase during which most of the work was undertaken, to improve the probability of measuring impacts more accurately in terms of time elapsed and data available. The PSI was implemented in two formal phases and one informal phase (as part of the first). The first phase was meant to be implemented between 1997 and 2004. However, the program started only in 1998 and stopped soon thereafter because of heavy rains and extreme weather conditions during the El Niño natural disaster, which led to heavy losses and a resetting of priorities. In 2000 the first phase began again under its original mandate of increasing agricultural production and productivity by improving public irrigation systems and making them more sustainable and efficient through institutional strengthening. The second phase was planned for 2005, and implementation began in 2006. The focus of this impact evaluation is on the informal, delayed part of the first phase, because most of the work was done in that phase, and implementation is complete and closer to the intended design than the part before El Niño, and because the available data cover this period and geographic location very well.

Program components

The program had three components, one of them divided into two distinct subcomponents. The components of the program are illustrated in figure 1.2 and can be described as follows:

- The first component (component A) was oriented to rehabilitating and improving specific small-scale irrigation infrastructure works in various districts, for example, resurfacing canals, improving intakes, and investing in collective irrigation infrastructure.
- The second component (component B) aimed to strengthen the WUAs and train the administrative water management teams in fee collection, operations, and management. Component B was implemented in every WUA along the coast.
- The third component (component C) worked directly with farmers through two (on-farm) subcomponents: first, the provision of subsidies for drip irrigation technologies to individual farmers at the plot level (PIRT, or the on-plot irrigation technology subcomponent), and second, the provision of limited farm goods (such as inputs, instruments such as hoses, and small pieces of equipment), training, and technical assistance through demonstration work at selected plots (PERAT, or the extension and technical assistance subcomponent).

Figure 1.2: The Programa Subsectorial de Irrigaciones and Its Components



Improve irrigation and drainage infrastructure of 40 WUAs. Approximately 125,200 families and 443,000 hectares of land were benefited.

Build managerial and operational capacities of WUAs. All 64 WUA along the coast were treated.

A one-time subsidy to acquire modern irrigation technology for private farms; approximately 1,000 families benefited.

Finance extension officers to train farmers to use new irrigation technologies and farming practices. Approximately 50,000 farmers were trained.

Source: World Bank project documents.

Components A and B: Infrastructure rehabilitation and WUA strengthening

Component A, the infrastructure rehabilitation part of the program, sought to improve irrigation and drainage infrastructure in several public irrigation schemes along the coast. Figure 1.1 shows the distribution of the treatment along the Peruvian coast. This component was originally designed to work on a 100 percent cost recovery basis by having WUAs borrow money from commercial banks and repay it with water fee collection resources, but this design proved unrealistic. According to program documentation, the design was adjusted and WUAs were asked to cover only 15–30 percent of the investment costs. According to program documents, this component rehabilitated, rebuilt, or improved 165 main intakes, 1,257 structures, 49 wells, and 313 kilometers of canals; it affected 125,200 families and 443,000 hectares of land in 40 WUA jurisdictions. Table A.1 in appendix A lists all the infrastructure projects. Approximately 63 projects in eight regions were considered in the analysis; however, because of data constraints, impacts of all worksites were not measured.

Component B, the institutional strengthening component, was designed to build the managerial and operational capacities of WUAs to attain full recovery of operational and maintenance costs and to promote the long-term sustainability of the program. Activities under this component included the training of WUAs' leaders and technical and administrative personnel in the financing, administration, and operation and maintenance (O&M) of irrigation systems. All 64 WUAs on the coast were targeted for training and capacity building, although the 40 that received component A were likely targeted more heavily. Component B helped build the institutional capacity necessary for WUAs to become eligible for support from component A, the infrastructure rehabilitation component. WUA personnel were trained on such topics as users' rights, the duties of farmers and irrigation commissions, O&M, tariff collection, cost recovery policies, water charge rate structures, and construction and contract management.

Component C: On-farm irrigation technology and on-farm irrigation extension

Component C.1 (PIRT) was designed as an economic incentive subcomponent that consisted of one-time subsidies (or grants) from the government to farmers investing in modernizing farm-level irrigation systems. Modern irrigation systems range from irrigation by aspersion to microjet irrigation (also known as micro aspersion) to drip irrigation. Both individual farmers and groups of more than two farmers applied for the grants. Beneficiaries were expected to contribute 20–50 percent of the total investment. The program provided an 80 percent subsidy for farmers with fewer than 15 hectares and a subsidy of 50 percent or less for farmers owning more than 15 hectares. This component experienced delays because intended beneficiaries faced difficulties in obtaining financing. It was finally implemented between 2001 and 2003. According to project documents, 252 projects were financed, directly benefiting approximately 1,000 families.

Component C.2 (PERAT) was designed as an extension subcomponent intended to train and finance extension officers to promote new irrigation technologies and farming practices among farmers. These new practices were taught on demonstration parcels where farmers would have first-hand experience with the technology and be able to assess the feasibility and value of adopting them on their own land. The PSI hired trainers to provide extension services. According to the program documentation, 50,000 farmers were trained under this component.

Chapter 2
Impact Evaluation Approach

Using Mixed Methods to Identify Impacts

The mixed-methods approach used in this evaluation sought to address the limitations of quantitative techniques in understanding how a project affects poverty trends. Mainly, it did this by placing the information gained from the quantitative analysis into the broader context of the social and cultural systems of the country and the realities of program participants that may have influenced the impact (or lack thereof) of the program. Given the richness of quantitative data available in Peru, much of the analysis to measure this impact could be done using quantitative methods; however, understanding the transmission channels through which the impacts came about, as well as the unquantifiable aspects of the program, would have been difficult with survey data alone. Moreover, the main survey data sources used in this evaluation were not designed for the purpose of evaluating the PSI. Therefore, supplementing the quantitative information with qualitative information enhanced the evaluators' understanding of the program's impacts and the determinants of success or failure by attenuating the disjuncture that exists among stakeholders involved in program design and evaluation. Thus, the mixed-methods approach yielded insights for operational policy recommendations that neither method could have produced alone (Rao and Woolcock 2004).

Data Used in the Evaluation

Qualitative data

The convergence between the two methods used for this analysis is very strong; statistical principles were used in the design and sampling stages of the qualitative work and in the analysis itself. Sampling for the qualitative analysis was based on the existing household surveys that were expected to be used in the impact measurement exercises. The team conducting the qualitative analysis purposely selected localities that had been previously surveyed by the national household survey used in the quantitative analysis. A sample of villages was selected after a systematic stratification of the WUAs in the three coastal regions: northern, central, and southern. The last criterion for selection was that the locality had been targeted for more than one of the program components; this ensured a wider spectrum of beneficiaries and exposure to the program.

The qualitative approach was planned specifically for this evaluation to validate (or nullify) the quantitative findings and explore alternative impact channels. The purpose of the extensive qualitative work commissioned for this evaluation was twofold: first, to obtain information that would either confirm or fail to confirm whether a set of predetermined factors could explain relationships between the intervention and observed productivity improvements; and second, to learn about other meaningful explanations or relationships not hypothesized. The areas of potential impact of the PSI on productivity are presented in table 2.1. The qualitative design used a cause-effect approach to assess the relevance of the predetermined factors hypothesized to influence productivity as compared with other factors outside the program's scope. This was done by focusing on changes experienced by beneficiaries (the treatment group) and nonbeneficiaries (the control group) in the same intervention areas during a specific period. A comparative analysis was done of both groups to provide a more balanced view of the role that program interventions played in improving farmers' productivity and welfare.

Table 2.1: Areas of Potential Program Impacts

Area of impact	*Description*
Impact on rural institutions	How the program can affect rural institutions, including, but not limited to, water users' associations in intervention areas
Impact on individual farmers and households	How the program 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 program's intervention and believed to have had an impact on productivity in the intervention areas.

Source: Gutierrez and Velez-Vega 2009.

The qualitative part of the evaluation used three research methods: review of existing program documents, individual in-depth interviews, and focus group discussions. The structured review of existing program documents aimed to identify issues to be addressed in the interviews and focus group discussions. The informants were a wide range of stakeholders including, but not limited to, program staff, beneficiary and nonbeneficiary WUA leaders, and farmers. Table 2.2 describes the informants and reports the number interviewed of each type. The interviews and focus group instruments were semi-structured and modularized. Their design aimed to capture associations between the program intervention and changes in productivity from various angles, particularly where the quantitative data were weakest (for example, on relations and attitudes). The information collection procedures were set ex ante to obtain the most informative results, and facilitators went through intensive training to learn the process and apply it homogeneously throughout the localities. The use of structured instruments and a structured application methodology allowed the evaluation to identify patterns across respondents on the same questions and topics. This evaluation report elaborates on only the most relevant findings; for a comprehensive picture, see the background report prepared for this evaluation (Gutierrez and Velez-Vega 2009).

Table 2.2: Study Informants by Category

Informant category	*Participating informants*
Senior World Bank staff, government officials	5 senior and operational Bank staff 3 representatives from private associations 6 representatives from regional government agencies
Program staff directly related to the implementation	5 senior program staff 13 technical program staff 4 former program staff
Beneficiaries	9 leaders of beneficiary water users' associations 19 farmers of component A beneficiary commissions 9 beneficiary farmers of component C
Nonbeneficiaries	18 farmers of component A nonbeneficiary commissions 7 nonbeneficiary farmers of component C

Source: Gutierrez and Velez-Vega 2009.

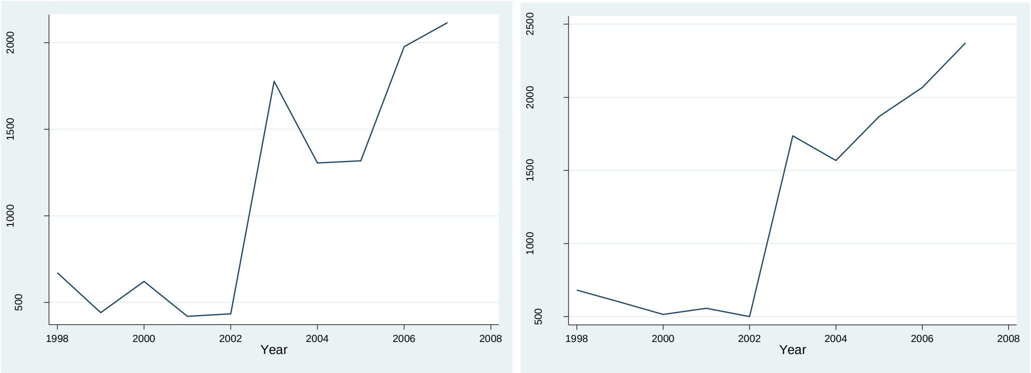
Quantitative data

The multicomponent design of the program, the lack of household data collected specifically for the evaluation, and the country's dynamic economic context made for a complex evaluation. The diversity in methods of implementation, beneficiary types, and timing length, together with the expansive geography, limited program data, and nonrandom distribution of the program, made this evaluation a challenge. Econometric techniques had to be used to control for factors that might bias impact measurement. However, the complexity of the design also allowed for the separation of component A from component C in the analysis, as they were implemented independently. Because component B was implemented in WUAs along the coast, it is difficult to find a proper counterfactual; therefore, the findings for the off-farm component can be interpreted either as the impact of a combination of components A and B for treated localities or as the incremental impact of having received the infrastructure work. As already noted, component C had two targets and objectives, each of which can be evaluated separately.

The national household survey is one of two quantitative data sources used for the analysis; it contains an agricultural module, spans more than ten years, and provides good geographical coverage. The first data source used in the analysis is the Peruvian household survey, the Encuesta Nacional de Hogares (ENAHO), conducted by the National Institute of Statistics and Informatics (Instituto Nacional de Estadística e Informática, INEI). This annual survey has been conducted for more than a decade; the data used in this evaluation span nine years, 1998 to 2007. ENAHO is a multitopic survey that seeks to measure poverty-related variables; it contains modules on main household characteristics, economic welfare (for example, economic activity), social welfare, social program participation, and agricultural activity. The variables used for this analysis are listed in table 2.3.[5] A feature of this survey is the availability of geographic coordinates for populated centers (referred to as "communities" in this evaluation). PSI staff provided coordinates for the infrastructure rehabilitation sites as well, allowing those communities close to the sites to be identified. These data were used to evaluate the effects of various infrastructure rehabilitation projects on agricultural performance and economic welfare.

The general economic trends for the coastal region over the time period covered by the evaluation were positive. The simple trends for communities within proximity of infrastructure projects for two key variables of interest – independent income per capita (under which most self-employed farming income would be classified), and expenditure per capita – are displayed in figure 2.1. It is evident from the figure that the general trend over time was positive for both variables; therefore, it is crucial to identify a control group against which the treated households can be compared, to avoid attributing to the program impacts that were in reality due to the general economic environment.

Figure 2.1: Trends of Key Variables over Time—ENAHO



Source: World Bank Group data.

The second data source used in the analysis is the national agriculture survey, known as the Encuesta Nacional de Producción y Ventas (ENAPROVE); it focuses on agricultural performance, spans five years, and covers the rural coast only. The availability of data from this survey allows for a deeper analysis of both subcomponents of component C. ENAPROVE was launched in 2002 (with all questions referring to the agricultural cycle in the previous year) in response to problems found in the statistical system of the Ministry of Agriculture, which was based on the use of "qualified informants" to assess representative monthly production data at the district level. The main goals of ENAPROVE were to estimate quantities, values of production, sales, production destiny, and commercial channels for main crops.

ENAPROVE's units of observation are farm plots within water commissions, contained in most WUAs along the coast of Peru. The sampling framework used a previous setup using the national cadastre (land register). Unlike ENAHO, this survey collects data on agricultural variables at the plot level within water commissions, not household data in populated centers. The survey focuses on land use and related agricultural variables.[6] The sum of production from all subplots within a given plot is considered the total production of that plot, which is valued at nominal producer prices for each period. Sales are distinguished from total gross value of production. The variables used for this analysis are listed in table 2.3. Descriptive summary statistics for each dataset are provided in tables A.2–A.4 of appendix A. A third dataset was available for this evaluation; unfortunately, it suffers from potential biases that are hard to fully overcome, and therefore it can be used only for secondary analysis. A full description of the data, empirical strategy, and results can be found in appendix B.

Table 2.3: List of Variables by Survey Type

Dataset 1—ENAHO *Infrastructure*	*Dataset 2—ENAPROVE* *Infrastructure, PIRT, PERAT*
Agricultural outcomes	**Agricultural outcomes**
Total value of output per capita	Total value of production (soles, annual)
Total agricultural income per capita	Productivity (soles of production per hectare)
Total agricultural costs per capita	Proportion of production sold
Total agricultural profits per capita	Probability of planting export crops
Value of fruit production	Probability of planting permanent crop (1 if permanent crop is grown, 0 otherwise)
Value of industrial crop production	Proportion of cultivable land
Value of beans production	Total value of specific crops (soles, annual)
Value of root vegetable production	
Number of crops	
Economic welfare outcomes	
Hire agricultural worker	
Work as manual laborer	
Total expenditure per capita	
Total income per capita	
Dependent income per capita	
Independent income per capita	

Source: IEG.

Chapter 3
Technical Analysis to Identify Impacts

Evaluation Focus Areas

The main focus of the evaluation was to understand the differential and joint effects of each program component; the mixed-methods analysis focused on localities that were treated by multiple components. This impact evaluation examined the role of each of the components, as well as their joint effects, in enhancing agricultural performance and general economic well-being. The evaluation also measured whether spillover effects on nonbeneficiaries could be identified, and whether the impact varied between the poor and the nonpoor. In the quantitative analysis, to the extent possible given data limitations, each component was controlled for in each specification. Additionally, the quantitative work enabled analysis of the components that were theoretically believed and qualitatively found to be synergetic.

A second focus of the evaluation was whether relatively richer farmers benefited more from irrigation projects than relatively poorer ones, or vice versa. Impacts may be inequitable if wealthier farmers are better positioned to take advantage of increased water access because they have better economic access, better irrigation systems that can manage the increased water supply, or more favorable general characteristics such as more education. If improved irrigation allowed wealthier farmers to reduce their costs, and thus their prices, this may have negatively influenced poor households who are net sellers in the same market, but positively influenced poor households who are net consumers. On the other hand, it is possible that the program provided access to crucial services previously available only to those who could afford to pay for them, so that the program narrowed the gap between the poor and the nonpoor. Quantitative and qualitative tools were employed to understand whether and how the impact differed between these groups.

A third focus was the extent of spillover effects from the on-farm components that directly benefited individual farmers to their communities as a whole. There are several reasons why the spillover effects of PIRT, the on-farm subsidies for modern irrigation technology, may have been positive. First, there is qualitative evidence that PIRT beneficiaries shared water with their neighbors: modern irrigation systems include a large reservoir of water, so that usually there is more water than the beneficiaries need for themselves. Second, there is a likely contagion effect. Neighboring farmers may get inspired by the effectiveness of the new technology, and previously risk-averse farmers may decide to make the investment. Finally, community members may benefit from the increased economic activity generated by PIRT beneficiaries, suppliers, and trainers, leading to general improvements in consumption per capita and nonagricultural income. The other on-farm subcomponent, PERAT, was designed to promote public knowledge: farmers were meant to learn from the demonstration plots and then imitate and share what they learned with others. This was a key question in the qualitative research, and the secondary quantitative analysis (see appendix B) allowed for the private and the spillover effects to be estimated separately.

Estimation Approach

Addressing biases through econometric methods

Because specific program data were not collected for the PSI, it was necessary to find innovative ways, using existing household datasets and econometric techniques, to isolate the effect of the program from that of other events that may have affected targeted beneficiaries. Estimating treatment effects using nonexperimental data, especially in complex program environments, is a common challenge for program evaluators (Lokshin and Yemtsov 2005). Because the PSI did not have an experimental design whereby beneficiaries were randomly assigned to control or treatment groups before the program started, more sophisticated econometric techniques and evaluation strategies are employed to address possible biases in estimating the impact (see box 3.1 for methodological definitions).

Addressing potential biases is crucial to obtaining accurate estimates and avoiding over- or underestimation of impacts. Unlike randomized experiments, where the likelihood of being selected is the same for the treatment group and the control group, and their distributions of observable and unobservable characteristics are equivalent in a statistical sense, nonrandomized selections are likely to suffer from biases. Of the several possible sources of bias, two are relevant to this evaluation: nonrandom program placement and nonobligatory program participation.

- *Nonrandom program placement* refers to the fact that infrastructure projects were implemented only in WUAs where water management capacity was sufficient. Thus, WUAs that received infrastructure projects are likely to differ from WUAs that did not.
- *Nonobligatory program participation* refers specifically to the on-farm subcomponents, in which only some farmers decided to participate. Those who chose to participate may differ from those who did not.

These biases can result in overestimates or underestimates of the impact because the two groups in each case may not have been statistically equivalent before the program started.

Biases in measuring the impact of the infrastructure rehabilitation component were overcome by using geographic boundaries, by comparing households within the same WUA, and by using difference-in-differences techniques to estimate impacts over time and across statistically comparable groups. For the infrastructure impact measurement strategy, the evaluation addressed potential biases by comparing households within the same WUA. These households were similar in most respects before the program began, so that the only major difference between the treatment and the control groups is the fact that only the former received the treatment. Groups comparable to these treatment groups were found by using geographic information system (GIS) data to pinpoint locations affected or not affected by the program. Households within the same geographic context that received or did not receive the treatment were then compared using econometric techniques common throughout impact evaluation work (Heckman, Ichimura, and Todd 1997; Jalan and Ravallion 2003; Smith and Todd 2005). Specifically, the evaluation exploited the fact that water in an irrigation canal flows in only one direction; therefore, canal rehabilitation will directly improve water access only for those households in areas downstream from the rehabilitation. Furthermore, a difference-in-differences estimation was used, which differences out time-invariant factors that may differ between the control and treatment groups.

Box 3.1: Design and Methodological Concepts

Random designs: Random designs (also known as experimental designs) allocate an intervention randomly (through a lottery, for example) among eligible beneficiaries. The assignment process itself creates comparable treatment and control groups that are statistically equivalent. This is considered a powerful approach because, in theory, a control group generated through random assignment serves as a perfect counterfactual, free from the selection biases that often plague evaluations. A well-conducted experimental evaluation using such a design can definitively establish that a program has caused an observed change in outcomes.

Quasi-random designs: Like random designs, these evaluation designs compare outcomes of a control and a treatment group; however, they might compare outcomes for individuals receiving program activities with outcomes for a similar group of individuals not receiving program activities who are identified through matching or regression discontinuity techniques. This type of evaluation also might compare outcomes for the same group of individuals before and after the group's involvement in a program (such designs are known as "pre/post" or "reflexive" designs).

Propensity score matching: This is an econometric technique often used in quasi-random evaluation designs to identify a group of observations that is similar to those for the treated group before the intervention took place. When the observational unit is an individual or a household, matching helps reduce selection bias (see below) by finding a group of individuals or households that would likely have taken up the treatment had it been offered to them.

Selection bias: In nonrandom designs, individuals can decide whether or not to take up a program. It is possible that those who decide to take up the program differ from those who do. For example, they may be less risk-averse, better educated, or more motivated, or they may differ on demographic characteristics such as sex, age, race, or religion. Simply comparing the changes in outcome of those who took up the program with those who chose not to may then be misleading; those who took up the program may have ended up better off than those who did not, even without the intervention. In other words, characteristics other than the intervention may have been the driving factor in the outcomes being different.

Difference-in-differences estimation: This technique takes into account the *change* in outcomes rather than simply the levels of outcomes after the intervention. An outcome is measured both before and after an intervention, and the difference between the two outcomes (the change in outcomes) is calculated; this is done for both the treatment and the control group. The estimation technique then determines whether there is a significant difference between the control group's change and treatment group's change. Such a technique allows for the impact estimation to control for the situation at baseline while still comparing the treatment group with a control group.

Sources: Various sources were consulted.

The estimation approach used to calculate the effects of both on-farm subcomponents is likely to underestimate the effects of the program on actual beneficiaries; therefore, the impacts reported represent a lower-bound estimate of the effect rather than the actual effect of these subcomponents. For the on-farm components, the evaluation addressed noncompulsory participation by using propensity score matching estimators to improve comparability between the groups compared. Also, because it is likely that some people in the targeted locality chose not to participate in the program, all estimates were done for all households in the locality (the area covered by the local irrigation commission in this case) rather than at the level of direct beneficiaries. This is likely to lead to underestimation of impacts but reduces selection bias. The approach also compared the change in each outcome over time for both control and treatment localities through a difference-in-differences estimation, reducing the bias from time-invariant characteristics that are then differenced out of the estimation.

Extensive qualitative work confirms that the empirical approach used was able to effectively reduce potential biases and render informative estimations of impacts (even if these are underestimates). There are limitations to these econometric methods, and they are unlikely to fully eliminate the role of unobservable factors that can influence outcomes. However, the evaluation's extensive qualitative work provided additional evidence that informed the empirical strategy (particularly with respect to program targeting), substantiated the quantitative findings, gave insight into questions whose answers were not clear from the data, and provided explanations for conflicting findings.

Component A: Irrigation rehabilitation

The infrastructure rehabilitation component (component A) and the institutional capacity-building component (component B) were implemented together in order to ensure that newly rehabilitated sites could be kept up by the WUAs and their users. WUA administrators were trained to better manage and operate existing infrastructure and to effectively collect fees to finance the maintenance of the rehabilitated works. According to the qualitative report, WUAs were made eligible to benefit from the infrastructure rehabilitation only when they met certain specific criteria;[7] once eligibility was established, the specific infrastructure investments to be funded were selected. Informants agreed that the selection process was appropriate, fair, and transparent. To reduce the likelihood that stronger WUAs were favored because of their higher implementation capacity, the PSI team in the central office chose 40 WUAs to benefit from component A. On the other hand, all 64 WUAs received institutional capacity training under component B.

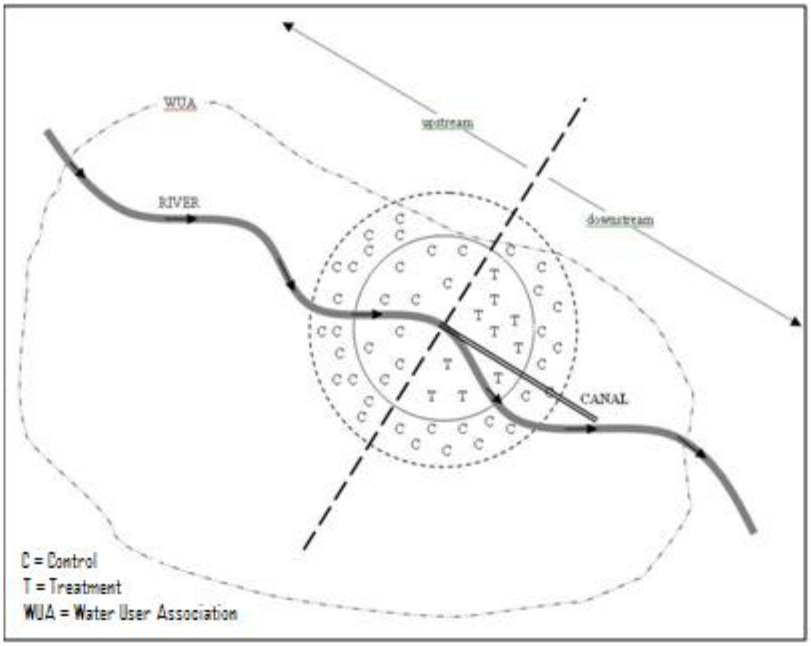
The selection of worksites to be rehabilitated was based on coverage, equity, and priority considerations. Informants gave various descriptions of the manner in which project locations were selected; however, most informants described the decision-making process as one of developing a consensus based on agreed priorities (for example, to benefit as many people as possible) and sector planning.

The strategy to isolate the impact of the program from that of other factors (the identification strategy) relied mostly on geography to find an appropriate counterfactual. GIS technology was used to pinpoint treatment locations and find comparable areas not receiving the treatment that could serve as control localities. As the analysis was limited to projects that refurbished canals, the communities considered treated are only those in proximate downstream areas. Households living directly upstream from the worksite, or downstream but far away from the worksite, are in the same water catchment area and therefore have the same major water source, the same agro-climatic conditions, and similar social and economic conditions as the treated locality but would not have been directly affected by the rehabilitation, and thus are appropriate controls.

Qualitative information confirmed that soil quality does not vary sufficiently within a WUA jurisdiction to change the composition of crops or how they are farmed. The qualitative data also reveal that soil and farming conditions can vary across WUAs and coastal regions, thereby confirming that accurate comparability requires that the groups to be compared be drawn from the same WUA. Thus, households located in downstream communities within a designated boundary of influence that are both within the catchment area and within the appropriate WUA jurisdiction are in the treatment group, and those households located in upstream communities within the same WUA, or in downstream communities in the same WUA but far from the rehabilitation site, are in the control group. As the specific project location along the canal provides for a somewhat arbitrary cutoff point between the treatment area and the control area, the project is the main factor that differentiates them. Figure 3.1 demonstrates the methodology used to determine the treatment and control areas. The specifics of how the GIS data were used are as follows:

- First, longitude and latitude coordinates of the irrigation projects were obtained from the program team in Lima.
- Second, the evaluation team used GIS software and Hydro-SHEDS data on water accumulation levels and flow direction to delineate the catchment area for each 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 (figure 3.2, left panel).

Figure 3.1: Identifying Treatment and Control Areas Using Geographic Data

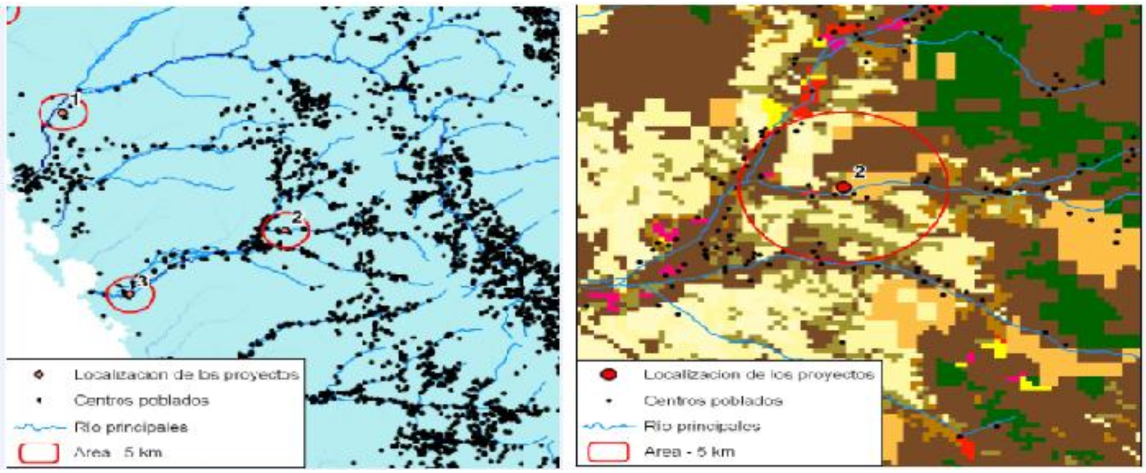


Source: World Bank project documents.

- Third, an appropriate radius of project influence was determined using the number of hectares that the infrastructure was estimated to affect,[8] along with GlobCover version 2.2 (a high-resolution mapping product), which was used to identify agricultural land (figure 3.2, right panel). This radius of influence is shown as the solid circle in figure 3.1.
- Fourth, the team identified communities that were upstream from the infrastructure location but within the appropriate WUA (indicated by the large area marked "WUA" in figure 3.1) and those downstream from the infrastructure location within a radius slightly *larger* than the radius of influence (the dashed circle in figure 3.1), but also within the WUA. As the infrastructure improvement would have affected only those communities downstream from it and within the radius of influence, all the upstream communities and those downstream communities beyond the radius of influence can serve as appropriate controls.

The four-step strategy also took care of nonrandom project placement, as the control group was restricted to households in communities within the same locality. Additionally, because component B was implemented at the level of the WUA, and because, for each works project, the treatment and control groups for this analysis were by definition within the same WUA, component B was held constant and did not create a bias. In other words, all communities included in the analysis were "selected" for the project, and the difference in exposure to project impacts between upstream and downstream communities was exploited to identify an appropriate counterfactual.

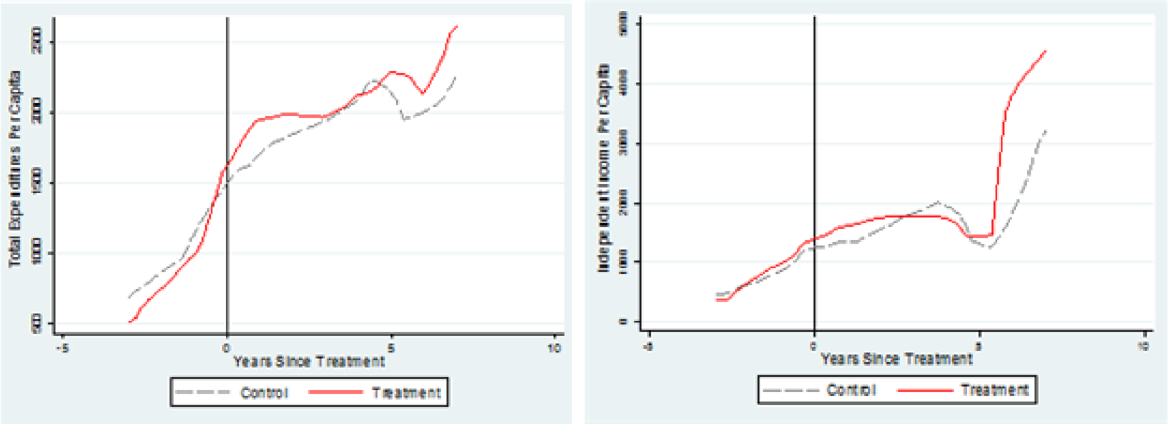
Figure 3.2: Project Sites and Agriculture Density



Source: World Bank project documents.

To further minimize biases from differences between the upstream and downstream communities, the analysis used an estimation approach that compares the average changes between treatment and control groups before and after treatment. This difference-in-differences estimation approach controls for time-invariant fixed effects by differencing them out of the estimation; this procedure assumes that the treatment and control groups are on statistically similar trends (Smith and Todd 2005). The qualitative information gave little reason to doubt the validity of this assumption, and table C.1 in appendix C shows that, in fact, the trends for the treatment and control groups in the preprogram period were statistically the same for every outcome variable. The estimation, which allows the fitted regression lines for the control and treatment groups to differ in their intercept and their slope, demonstrated that the rate at which outcome variables changed was not significantly different for the treatment and the control groups (the coefficient on the "Time*Treat" variable was never significant). Figure 3.3 demonstrates graphically the similarity of the trends between the treatment and the control groups for two key outcome variables: expenditure per capita and independent income per capita.

Figure 3.3: Treatment and Control Trends



Source: World Bank Group data.

The analysis was restricted to projects where household data for WUAs were available before and after the project; this ensured an appropriate data "balance," necessary for more accurate statistical comparability. Baseline means are compared in table C.2 of appendix C; the treatment and control groups were statistically similar before treatment occurred, except that households in treated communities were slightly more likely to grow root vegetables than households in control communities. The analysis was also restricted to WUAs for which adequate data existed in both the treated and the control communities, both before and after the intervention. This limited the sample to seven WUAs and 23 rehabilitation projects. The limitations were based solely on the availability of ENAHO data, which are collected in a random selection of communities; thus, the analysis did not evaluate all of the projects, but only a random sample of them.

Impacts of the rehabilitation work on labor variables in the beneficiary localities may be underestimated because of the potential for spillover labor effects in the control localities; although there is no qualitative indication of this effect, the results on labor may still represent a lower bound. Additional biases may exist from spillover effects on labor activity: the effect of the rehabilitation work on labor may have spilled over to neighboring localities, thereby contaminating the control group. If these spillover effects are positive, the labor impacts of treatment will be underestimated. Negative spillover effects may also be due to disruption, or to water-borne diseases, which would lead to an overestimation of the impact. However, the qualitative work found no indication of these sorts of negative effects.

Outcome variables. ***Each of the main outcomes of interest relates to a program goal or a theoretical prediction.*** Each outcome variable was chosen either because it related to the general goal of the program—to reduce poverty through increased agricultural productivity—or because it could serve to validate or clarify the qualitative findings. The analysis looked at 15 outcome variables, described in table 3.1. Results were calculated for farm households only, to restrict the sample to those who would have directly benefited in terms of agricultural outcomes.

Table 3.1: Outcome Variables for Component A

Variable	*Description*
Total value of output per capita	Value of total production per capita in soles
Total agro income per capita	Total agricultural income per capita
Total agro costs per capita	Total agricultural costs per capita
Total agro profit per capita	Total agricultural profit per capita
Fruit production	Value of fruit production
Industrial crop production	Value of industrial crop production
Bean production	Value of bean production
Root vegetable production	Value of root vegetable production
Number of Crops	Total number of crops cultivated
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 expenditure per capita	Total expenditure per capita
Total income per capita	Total income per capita
Dependent income (ln)	Natural logarithm of total dependent income
Independent income (ln)	Natural logarithm of total independent income

Source: IEG.

Control variables. ***The choice of control variables was prompted by the qualitative findings and the wider literature***. These variables included characteristics of the household head (gender, age, education) and the number of household members, to control for likely correlations with outcome variables. It is likely that individuals who are more educated are better suited to take advantage of infrastructure improvements by changing their farming practices.

Other natural factors, such as water flows and geographic distance from the project, are expected to affect project performance; these were included in the estimations for accuracy. Differences in certain natural characteristics of water sources, for example, average water flows in a given year, may confound outcomes. It is clear from the qualitative work that water along the coast of Peru is scarce. Coastal river flows are influenced by rains in the highlands, as well as by glaciers in the Andean high summits where the rivers rise. Therefore, the analysis takes into account river flows rather than precipitation levels. In places where river flows were low, outcomes may have been less positive. The opposite is also true in principle: too much water can lead to flooding and waste. However, this was not a concern for the present study, because flooding did not occur during the years covered by the study. Distance from the project may confound the treatment effect as well and was therefore included as a control. Finally, the analysis included a dummy variable to control for whether a district had received treatment under component C. This variable is a district-level dummy because it was not possible to identify which specific households were treated.[9]

Components C.1 and C.2: Plot-level irrigation and farmer capacity building

Whereas the quantitative approach described above focused on the off-farm components using household data from populated centers, a different quantitative approach focused on the two on-farm subcomponents, using agricultural information obtained from plot-level data in treated water commission jurisdictions. The preceding analysis was unable to measure the impact of interventions on agricultural productivity because of limited information about land (its extent and quality). The analysis described here used land area and crop inventory data to measure land-use productivity and crop diversification. Data from the national agricultural survey (ENAPROVE) were used to assess the impact of component C on productivity—defined as output, valued in local currency (soles), per hectare— for plots in a given water commission, whereas the previous analysis assessed other welfare indicators (labor, income, consumption) and a limited set of agricultural outcomes (such as total farm production and individual crop production).

Project documentation helped pinpoint treated localities (defined by water commissions) and in some cases actual treated plots; however, the estimation was done at the water commission level, resulting in estimates of average treatment effects across all farmers targeted, whether they took up the program or not. Given data restrictions, the specific individuals who received treatment under component C could not be identified. However, the program team provided a list of the water commissions[10] in which beneficiaries were located. Therefore, treatment was considered as applied at the commission level, so that any household that was in a treated district or commission was regarded as treated. In reality, only a few households in each of these areas benefited directly—some households that were targeted to receive the treatment may have, for various reasons, opted out—and so the estimates measure the effects on all farmers who were intended to be treated, rather than the effects on those actually treated. Because the estimates thus apply to a broader group than those who actually received treatment, they likely represent a lower bound of impacts. The implications of this approach, apart from the likely underestimation of impacts, are that the actual impacts and the spillover effects on productivity and economic well-being within a locality cannot be distinguished. A finding of a significant impact may be due to a relatively small number of direct beneficiaries driving the average outcome significantly higher, or due to spillover effects, or both.

The estimation approach ensured that the presence of an infrastructure project in a given commission was accounted for, and only localities treated within the dates for which data were available were evaluated. Both on-farm subcomponents were mostly implemented in 2002 and 2003, but specific dates of implementation are known only approximately, and commissions may have been treated more than once. Therefore, this analysis looked only at the change in agricultural outcomes from 2001 to 2004, to obtain clean pre-treatment and post-treatment groups. The estimation always took into account whether an infrastructure project was also undertaken within a commission's jurisdiction; not controlling for this could overestimate the effect of the on-farm subcomponents.

Control groups were identified separately for each on-farm subcomponent using matching techniques; the variables used to find these comparable groups were indicators of land quality and farming capacity. The analysis used propensity score matching to identify commissions that were similar at baseline on several key observable dimensions. Matching was done separately for commissions receiving the on-farm modern irrigation subcomponent and those receiving the farmer extension service, as the program beneficiaries for each component could be different.[11] All matching was conducted at baseline, to ensure that the plots that received the plot irrigation treatment were compared with plots that were similar in terms of the matched variables. The matching variables used were indicators of the quality and type of land as well as indicators of the ability and capacity of the people who worked the plots. There is little evidence, from either the qualitative or the quantitative work, to indicate that there was enough change in property ownership between 2001 and 2004 to bias the results.

Several "balancing" tests were conducted to ensure that the matching exercise led to statistically similar control and treatment groups at baseline. In other words, the analysis made sure that the commissions receiving treatment under both on-farm subcomponents were not significantly different from their matched control commissions before the program began. To control for any remaining differences at the plot level at baseline, all calculations were done using a difference-in-differences approach, where the differences between the control and treatment groups were estimated before and after the program.

Outcome variables. Limited data availability made it difficult to measure other important economic dimensions. The dataset allows for analysis of several agricultural variables (mainly production and productivity), as well as specific crop production variables. Production was measured in soles per year, and productivity in soles per hectare. Other outcomes related to general economic well-being, such as total household income or consumption, could not be determined from data available in the dataset, thereby limiting the analysis to agricultural outcomes. Tables A.3 and A.4 report summary statistics for the matched samples.

Control variables. The estimations took into account factors other than the program that could have affected the outcomes, such as plot area: control variables included the number of hectares in each plot, as well as the number of hectares squared. Fixed effects for location in one of the main areas of the coast (northern, central, or southern) were also included. Lack of data prevented the inclusion of other control variables that might have strengthened the estimations.

Chapter 4
Impacts of the Program

Measurable impacts on productivity are more likely to take place after a period of time when water practices change toward greater efficiency and conservation. Improvement in agricultural productivity was a goal of the PSI. The qualitative work found that stakeholders believed it to be an implicit higher goal of the program, although the explicit objective was seen as promoting change in water management by teaching better practices that could be applied and shared among neighbors. The results from the analysis show measurable impacts on both agricultural and economic outcomes.

All of the questions addressed by the evaluation relate to farm production, productivity, and household economic changes. Specifically, the evaluation investigated three questions: whether the program had general agricultural and economic impacts, whether the multicomponent design was effective, and whether the program had any spillover effects. The quantitative analysis of the off-farm components was restricted to farm households in WUAs that had adequate data; this restriction did not apply to the on-farm subcomponents. Findings are presented here for each evaluation question and presented for the off-farm components and the on-farm components separately. To show how impacts varied across the poor and nonpoor, the analysis is repeated for both groups.

Question 1: Did the Program Improve the Agricultural Performance and Economic Well-Being of Farmers?

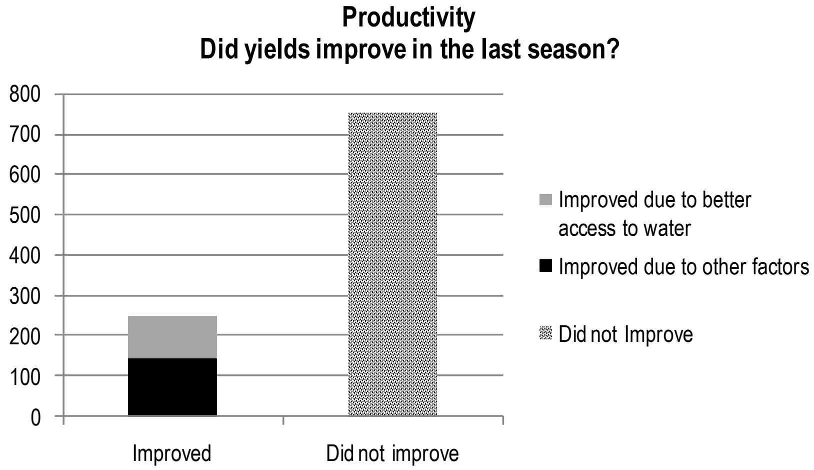
The qualitative work identified at least three channels by which the program could have had an impact on agricultural performance and farm income. Figure A.1 in appendix A presents a schematic view of the probable impact transmission channels. If any of these worked as intended, an effect on agricultural outcomes should be observed in the quantitative analysis. The diagram integrates the perceptions of interview respondents and focus group participants and organizes the most common beliefs about how the program could have influenced agricultural productivity (Gutierrez and Velez-Vega 2009). The three channels are as follows:

- Through improvements in water capture and increases in water availability and reliability (due to component A)
- Through improvements in water distribution (due to components A and B)
- Through improvements in water-use efficiency at the farm level (due to component C).

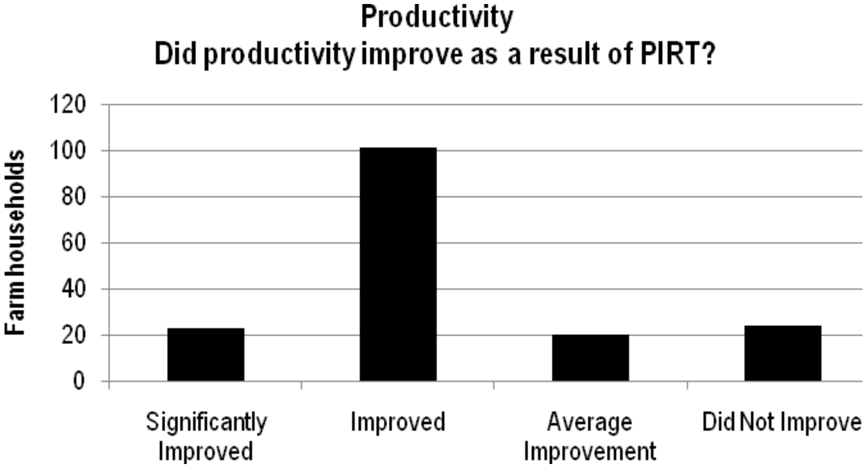
The second and third channels operate through both physical changes, mainly in infrastructure and new technology, and attitude changes (renewed interest in collaborating, new appreciation for innovative practices).

Box 4.1: Perceived Productivity Improvements Varied across Components

The general perception of public officials, program staff, and beneficiaries is that the improvement of irrigation management and the subsequent increase in availability and reliability of water supply played a role in increasing agricultural productivity in the areas of intervention, although productivity changes were considered marginal and difficult to definitively attribute to the program. The graph below shows that a minority of farmers in Viru, Tacna, La Joya, and Huaura (1,000 farm households) felt that productivity had improved in the last season, and 10 percent felt that productivity had improved and that the improvement was due to improved access to water.



Changes in productivity due to drip irrigation technology, however, were perceived to be large, even though PIRT had a direct impact on far fewer people than the infrastructure projects.



Sources: Gutierrez and Velez-Vega 2009; authors' calculations using CEPES data.

General effect of the infrastructure rehabilitation and institutional capacity components

The impacts of components A and B on agricultural outcomes for all farmers were mostly due to increased labor demand and increases in income (table C.4 of appendix C). Beneficiaries hired 27 percent more agricultural workers than the controls; reflecting this increase in labor demand, average annual wage income increased by $57 per capita in the treatment group relative to the control group.

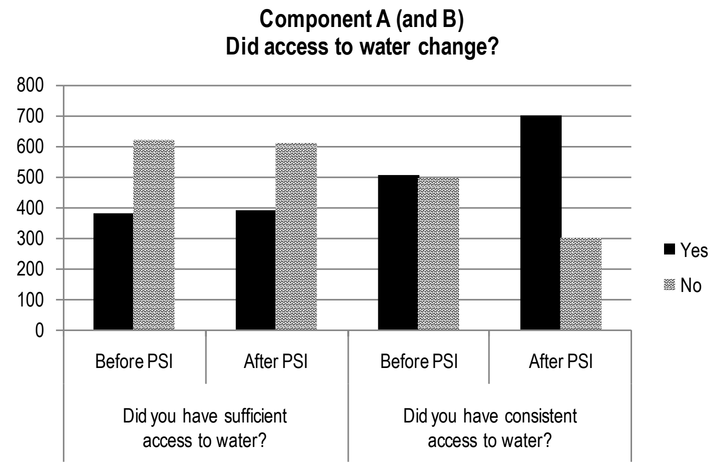
The program also induced clear changes in the types of crops farmed, particularly with respect to staple and industrial crops. The analysis shows that production of two main staples (potatoes and beans) and of general industrial crops (such as cotton, coffee, and cocoa) increased in the treatment group relative to the control group; for example, the value of the annual harvest of beans increased significantly, by approximately $125 per farmer, or more than 50 percent. Further analysis shows that poorer farmers who benefited from the program specialized in planting main staple crops such as potatoes and beans, whereas nonpoor farmers increased their production of industrial crops.

Box 4.2: Perceived Impacts of the Infrastructure Rehabilitation and Institutional Strengthening Components

Most informants reported improvements in water collection, distribution, and general water availability and reliability after having participated in the infrastructure rehabilitation component. However, some informants contended that although the infrastructure component had increased water availability, water was still not sufficient for their needs. The main reason was that new irrigation schemes had not been built, and the rehabilitation affected a relatively small number of people. The lack of water access continued to affect farming decisions greatly.

> *When it's rainy season, we plant almost the whole plot, but during hard times, we know that water won't be enough, so we do not plant the whole plot.*—A farmer in Huaura

The graph below, which is based on survey data from 1,000 farm households in the WUAs in Viru, La Joya, Tacna, and Huaura, shows that compared with five years before the survey, there was little improvement with respect to having sufficient access to water (component A). However, 40 percent more people said that they had consistent access to water (components A and B). Some program staff also estimated that component A reduced water loss by 40 percent.



Sources: Gutierrez and Velez-Vega 2009; authors' calculations using CEPES data.

There is some indication that, for poorer farmers, irrigation rehabilitation helped increase the value of agricultural output and the income derived from agricultural activity; the opposite is true for nonpoor farmers. Although few differences in impact were found between poor and nonpoor farm households, the analysis shows that, for the former, irrigation infrastructure improvements positively affected the value of agricultural output and the income derived from agricultural activity (table C.5). On the other hand, similar positive impacts were not found for the nonpoor on these dimensions. These results fall just short of statistical significance (p = 0.11), but the direction of the finding is clear.

The increases in labor demand likely came from poor farmers hiring other farmers. The analysis shows that beneficiaries decreased their labor activity outside their own farm but hired more laborers to work on their farm. This is verified by the fact that poor farmers increased their income from their own farming activity, meaning that the change in water patterns—be it greater availability, greater reliability, or both—promoted farming among the poor and turned some into employers rather than employees (table C.6). There are at least two reasons why labor demand may have increased: first, from the need to maintain the rehabilitated canals, pumps, wells, and other infrastructure, and second, from the increase in output. The maintenance work would be particularly attractive for land-poor or landless people in these rural areas, and the increased demand for farm labor was likely attractive to the same group because it opened up new labor opportunities in the area. The increase in labor demand identified in the analysis is also consistent with the positive impacts on farm production, agricultural income, and agricultural profit identified previously.

There is also evidence that the rehabilitation projects improved the efficiency of labor. A number of respondents said that the irrigation improvements significantly reduced the labor they had to devote to the maintenance and operation of irreparable irrigation systems. One farmer stated 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."

It is possible that the finding of limited impacts on agricultural income is due to the length of time required to grow most cash and export crops. The mean time span between the completion of a project and the collection of data used for the analysis was less than three years. This is enough time to produce some crops, such as beans and other legumes, but not enough to produce first harvests from most permanent crops; orange trees, for example, take more than five years to produce fruit. Moreover, impacts on productivity from greater access to water can be expected for existing production but not for new crop production (or productivity), particularly in the case of industrial crops. Sugarcane, coffee (grown in the northern coastal regions of Piura, Lambayeque, and La Libertad, and more prominently in other regions of Peru), and cotton are industrial crops; however, their growth cycles differ. For example, coffee can take three to four years from the time the tree is planted to produce its first harvest, and several more years to reach prime production, whereas cotton takes only a few months to produce its first harvest.

Qualitative evidence on agricultural productivity shows that improved water availability had greater impacts in those WUAs with water supply deficiencies. In water-scarce regions like much of the Peruvian coast, households located at the end of the water system suffer most, especially when major irrigation infrastructure bottlenecks exist. This was the case in some of the WUAs under review. The easing of these bottlenecks led to increases in extensive and intensive land use in areas previously receiving too little water. Thus, it is possible that the impacts of the project varied greatly across localities, resulting in limited average gains.

A clear pattern in the qualitative work is that the work done under component B was necessary for the WUA to function properly, in the short and the long term, and for the overall success of the program. This evaluation relies on the qualitative work for insight into the impact of the program's institutional strengthening component (component B); although the quantitatively measured impacts of the infrastructure component (component A) also reflect the work done under component B, data constraints made it impossible to disentangle the effects of the two components. The work done under component B to strengthen WUAs was perceived by almost half of those interviewed to have been the most important aspect of the program, whereas roughly 25 percent said that irrigation rehabilitation was the most important. Nearly a third of informants said all three components were important, and only a few thought the two on-farm subcomponents were the most important.

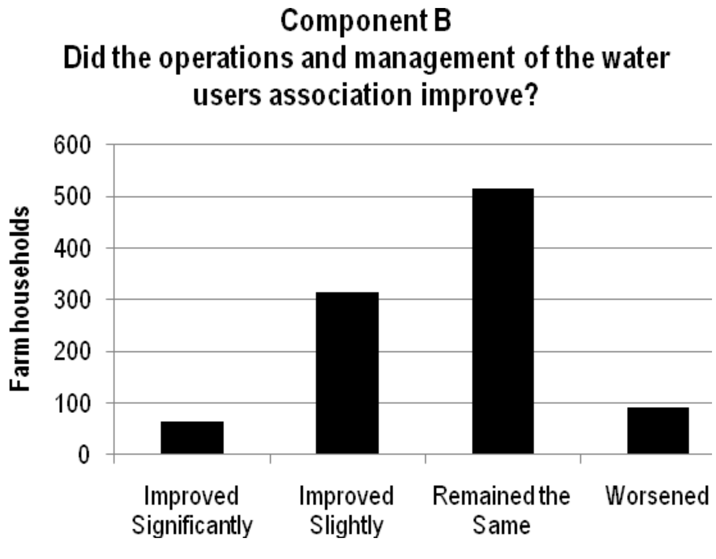
Although the institutional strengthening component was implemented at the WUA level, a crucial factor in its success was the extent of collaboration between WUA leadership and users. This collaboration between WUA leadership and farmers allowed for effective changes in administrative practices and in the views of water users. Informants believed that the work done by the ministry to strengthen water management systems improved the effective use of water, leading to productivity improvements in the WUA command area. Each WUA received training to ensure that fees were used for O&M of water infrastructure, and this raised awareness of the importance of economic contributions by water users toward further investments in and maintenance of water facilities. The training also focused on organizing water distribution so that farmers knew how much water to expect and when to expect it. In sum, the main reasons for these improvements were more effective fee collection and management and better distribution of water.

Box 4.3: Perceived Impacts from Institutional Strengthening

> *Land is now irrigated starting with the first user and ending with the last user… and each person knows when his turn is… and takes full advantage of it… and the plant grows better.*—A WUA leader

The general belief among informants was that WUA leaders had become more accountable, more committed to their organizations, and more knowledgeable about water management systems, and that this led to water distribution becoming more organized, efficient, and equitable. The figure below summarizes the views of informants in Viru, Tacna, La Joya, and Huaura who reported that WUAs' operations and management had improved over the past five years. The positive impression that water users had regarding their WUAs translated into improvements in the rule of law. People felt that the training had created a culture of respect and compliance with irrigation turns.

> *Our WUA has benefited from a permanent flow of water. Before [PSI] water used to go wasted, but after water distribution was organized, this has greatly improved a flow of water that cannot be measured [and therefore] cannot be managed… but [this was solved] with the installation of lock gates, so we can measure what is being irrigated*—A beneficiary in Viru



Sources: Gutierrez and Velez-Vega 2009; authors' calculations using CEPES data.

The irrigation rehabilitation projects were perceived as too small to affect many hectares; the seeming lack of funding for new on-farm irrigation systems was also seen as a limiting factor for the whole program. Although these components increased systemwide water distribution efficiency and resulted in more even distribution of water to the soil, the qualitative work indicated that the absolute impact was small because other components were limited in their reach. Despite some seemingly negative perceptions of the overall effectiveness of the irrigation rehabilitation and institutional strengthening components, quantitative evidence shows that positive agricultural and economic impacts were still possible, especially for poor farmers.

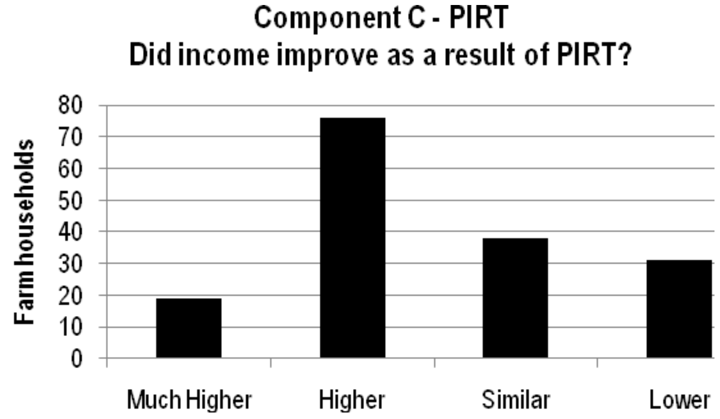
<B> General effect of the on-farm technology and demonstration components

The on-farm irrigation subcomponent increased the proportion of agricultural products sold in the market by 12 percent. The first subcomponent, the introduction of pressurized irrigation technology, increased the amount of agricultural output sold in the market (table C.7); the proportion of total output sold by farmers in treated localities increased by 12 percent compared with farmers in control localities. The on-farm irrigation equipment also influenced the type of crop farmed, increasing the probability of an individual farm growing permanent crops by 15 percent. Farmers who benefited from this component produced more cotton, asparagus, sugarcane, grapes, and oranges than farmers in the control group, but produced less rice, maize, mangoes, onions, mandarins, potatoes, and tomatoes. The first set of crops is heavily biased toward export and industrial crops, whereas the second contains a mix of these and staple crops.

Box 4.4: Perceived Impacts from the Irrigation Technology Subsidy

> *I have completely stopped planting grass for feeding animals, and now 100 percent of my production is in export crops such as paprika, bell peppers, and yellow and red onions … My yields per hectare have dramatically increased… my production is now top quality… now my sweet onion is competitive worldwide.* —A PIRT beneficiary in Arequipa

Irrigation technology improvements significantly increased crop yields and allowed farmers to plant higher-value export crops. Although this component was restricted to a limited number of farmers able to cover the collateral investment required (through means shown below), PIRT beneficiaries reported productivity increases ranging from 25 percent to 200 percent. Improvements translated into higher income for over 50 percent of farmers that adopted drip irrigation. Among almost 200 farm households interviewed, 41 percent felt that their income had improved as a result of the new irrigation technology.



Sources: Gutierrez and Velez-Vega 2009; authors' calculations using CEPES data.

Clear differences in effects between poor and nonpoor farmers emerge from the analysis, particularly in the amount of land cultivated, the types of crop farmed, total output, and productivity. Some interesting patterns emerge from a comparison of poor farmers—defined in this part of the analysis as farm households who produced for their own subsistence at baseline—and their nonpoor counterparts. Nonpoor farmers in the treatment group significantly reduced their total production and productivity compared with controls, perhaps because they increased the proportion of their land under cultivation (table C.9) and because many switched to producing crops that take a few years to produce marketable goods. (Nonpoor farmers increased their permanent crop production by 14 percent.) Poor farmers in the treatment group also increased their proportion of cultivated land and their probability of growing a permanent crop, relative to the control group. Therefore, the significant increase in the proportion of production sold was driven by the nonpoor farmers, who were already selling their output at baseline.

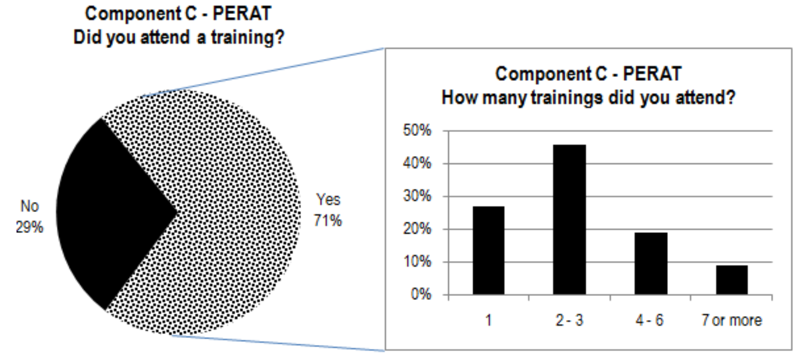
Qualitative work demonstrates that the on-farm irrigation technology component was very effective in improving agricultural outcomes through an immediate increase in the volume and reliability of water. Beneficiaries reported large improvements in crop selection, use of inputs, farming practices, and use of resources. The main reason for such clear impacts is the overhaul in farming activities, with direct consequences for production, productivity, and household income through increased water volume and reliability. One beneficiary farmer stated that, "with modern irrigation technology, [production] is higher. Before you got 1,500 kilos per hectare, now white asparagus is 7,000 kilos and green is 5,000 kilos."

The econometric approach used to evaluate the on-farm components likely underestimated their impact, because the treatment effect was observed for all plots at the water commission level, rather than for actually treated plots at the household level. In other words, it is possible that the private effect was large but did not raise the average for the locality by enough to make it statistically different from the control locality. This indicates that the spillover effect from this subcomponent was not large enough to be observed in the data. Along these lines, many informants believed that the impact of the irrigation systems was not far reaching (see the next section for further analysis) but rather was limited to a relatively small number of beneficiaries. In fact, major critiques of this part of the program were the limited number of beneficiaries and the fact that many farmers were required to contribute on average $600 to $1,000, an amount that restricted general access to the on-farm irrigation technology.

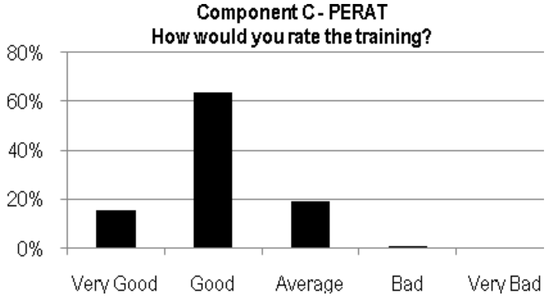
Box 4.5: Perceived Impacts from On-Farm Training

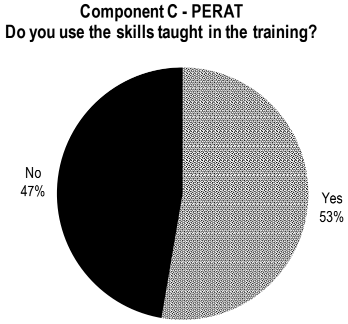
> *Everything starts [with] capacity building; it makes the program work. You can get them to change crops if you change their minds. I mean changing attitudes comes first.* —A PERAT beneficiary

This subcomponent of the program had significant popularity among attendees: farmers mentioned that the impacts were widely felt and that people were using more efficient irrigation techniques on their plots. Among a subset of potential PERAT beneficiaries surveyed, 71 percent answered yes when asked if they had attended at least one training session. Of these, 73 percent attended more than one session.



Out of those that had attended the sessions, about 80 percent considered the training good or very good, and 53 percent of the attendees reported using the skills learned at the training sessions.





Sources: Gutierrez and Velez-Vega 2009; authors' calculations using CEPES data.

The plot demonstration subcomponent rendered clear and positive results with respect to quantity of production, productivity, and types of crop farmed (table C.8 in appendix C). This on-farm subcomponent resulted in significant increases in productivity and raised the proportion of agricultural production sold in the market (the change for the treatment group was 8 percent greater than that for the control group), which was likely to be of better quality than production for household consumption. Farmers received lessons related to on-farm water-use improvements in arid and semiarid regions, such as the application of various irrigation methods, irrigation efficiency, utilization of water, and intensification and diversification of production. Farmers also learned about the differences between piped and open canal surface irrigation methods at the farm level, and specifically about water flow regimes, route direction of flows, system classifications, and fertilizer application through irrigation (fertigation), among other lessons. More broadly, farmers learned about other necessary concepts related to fertilizer application, soil quality, dealing with soil salinity, and general crop water requirements.

Localities (water commissions) that received extension services and demonstration plots significantly increased the number of plots dedicated to growing export crops. Increases were seen in rice, cotton, maize, grapes, onions, and potatoes. The application of modern irrigation methods allowed farmers to achieve higher irrigation efficiency, by improving the utilization of water and the intensification and diversification of products. Although the measured impacts are indicative of the average effect on the entire locality rather than the actual effect on households treated, and are thus likely underestimated, the knowledge effects can be widely felt because beneficiary farmers share information with others and bring new inputs (improved seeds and fertilizers, for example) to the locality. Thus, the finding of positive average effects may demonstrate a strong impact on the specific plots that received the intervention, which then had spillover effects on others. Therefore, the finding of stronger positive impacts of farmer extension than of on-farm irrigation equipment may be due to the fact that the demonstration work had stronger spillover effects, as it was intended to by design.

Poor and nonpoor farmers in the treatment localities had better results in terms of production and productivity than poor and nonpoor farmers in control localities. When the analysis for the extension component is restricted to the poor and nonpoor at baseline, the difference in impacts is very small. Both types of farmers increased their agricultural output similarly (table C.10). This is evident in crop production and general productivity; all farmers in the treatment group increased their output levels and yields, likely because they now experienced greater water reliability, which means lower crop losses, and they were producing more because they were now farming in areas where rain-fed production was marginal. Also, both poor and nonpoor farmers were equally more likely to grow permanent crops than their counterparts in the control group; this may reflect a move from seasonal crops to crops that are more sensitive to water deficit at various growth stages. Some plants, depending on how deep rooted they are, have lower tolerance to the depletion of water and are more dependent on moisture. Common permanent crops on the coast are citrus fruits, alfalfa, grapes, and other fruits. These usually require larger investment upfront and are usually difficult to farm when water is unpredictable; staple crops, such as beans and root vegetables, are usually seasonal.

There is a clear pattern of agreement among program staff and implementers that the on-farm demonstration subcomponent led to increases in knowledge. Illustrating this, an informant stated that his conception of this subcomponent was “not to do all the works for [farmers] all the time but just [as] demonstration.” Some of the impacts mentioned were changes in crop selection, improved crop management, and more efficient irrigation techniques. Some respondents criticized the extension services, however, for spending too much time imparting lessons on how to market, organize, and participate in production chains rather than on explaining the irrigation technology.

Question 2: Was the Multicomponent Design Effective in Improving Agricultural Performance and Economic Welfare?

Both beneficiaries and program staff believed that the inclusion in the program design of investments that go beyond infrastructure, such as technical assistance, financial support, and capacity building, was essential to program success and impact sustainability. A finding of the qualitative analysis was that many program staff attributed the success of the program to its multicomponent approach. They felt that only by addressing all three components was the program able to have a real impact. Informants perceived that increased water supply alone was unable to guarantee higher productivity, because the quality of production depends on several other factors such as quality of land, availability of other inputs (such as seeds, fertilizers, and pesticides), access to agricultural services, and suitability of farming practices. Nonprogram factors such as the educational level of the farmer, access to markets, and membership in a farmer organization can also influence outcomes. Half of the respondents said that the program as a whole may have had an impact on welfare through its effect on productivity and agricultural income.

From the qualitative analysis, it does not seem that the program took full advantage of the potential for synergies in design: only 72 out of 622 irrigation commissions were treated by all components, and respondents from commissions that had been treated with many interventions offered very positive feedback. An important reason for undertaking multicomponent strategies is the potential for *synergies* among the various components. In other words, programs should be designed so that each intervention strategy complements others, so that the program as a whole has a greater impact than the sum of its parts. Nearly a third of interview respondents did not specify a particular component as most important in meeting the program’s objectives, saying instead that it was the combination that produced the impact, through synergies, complementarities, and the diversity of focus areas. Informants also emphasized that the rehabilitated infrastructure increased both *access to* and the *distribution of* water, and that the demonstration techniques and the deployment of on-farm irrigation technology improved the *effectiveness* of water use, which led to synergies. As the on-farm technology deployed included a large reservoir on each farm that provided regular water access, its effectiveness was dependent on the availability of water to fill the reservoir.

The quantitative results show some synergies between farmer extension and infrastructure projects in the same locality;[12] however, synergies were more apparent where on-farm irrigation technology and infrastructure were offered in the same locality. Localities that were treated with either plot irrigation or infrastructure rehabilitation, but not both, showed no significant change or a smaller change in productivity and production, whereas localities treated with both interventions increased their annual productivity substantially (by $859 per hectare) and their annual total production value by $4,591, on average, compared with the control group.

Relative to the controls, those who received both on-farm irrigation technology and infrastructure rehabilitation increased their probability of farming and producing permanent crops. This change was possible because the treatments allowed farmers to schedule the watering of their crops, which is more economically viable with permanent crops because farmers can control crop water requirements and soil water status, which in turn increases water savings and crop yields. Similarly, the two components together positively influenced the amount of land cultivated, leading to measurable increases in land use. The farmer extension subcomponent and the infrastructure component did not appear to generate impacts greater than the sum of their parts except in terms of the proportion of production sold, which increased by 15 percent more among the treatment group than among the control group when these components were available in the same locality.

The combination of extension services and infrastructure rehabilitation was not without its negative impacts on production and productivity. In general, irrigation improvements are expected to increase mean crop yields by increasing the quantity and the reliability of water supply, thereby potentially lowering the variance of farm output and employment and allowing farmers to shift away from less-reliable water sources. However, negative impacts can take place for various reasons. Perhaps the most relevant in this case is that the increased reliability of water from the infrastructure rehabilitation may have prompted farmers to adopt new crops or shift toward permanent crops. This change implies either using more land or substituting the new crops for existing crops on already cultivated land, thereby either increasing the area cultivated or reducing the output (measured in the data as value of production) of the existing land in the short term. The results of the analysis in fact show a reduction in production, accompanied by an increase in sales and a reduction (the opposite of what was expected) in land dedicated to cultivation. Also, there is no evidence of an increase in permanent crops when both infrastructure and extension were present at the same locality, making this explanation implausible.

Other possible reasons for this seemingly counterintuitive finding emerged from the qualitative work. The improved efficiency made possible by more reliable water supply may have significantly reduced the return flows utilized by other users, particularly downstream, thereby limiting the extent to which farmers could apply the new techniques learned through extension lessons. Similarly, the intensification of water use, motivated by the extension lessons and demonstration work, may have led to groundwater pollution from the increased use of fertilizer and pesticides. Unless something is also done to improve water quality, be it surface or groundwater, the excess of poor-quality water could lead to the degradation of irrigated land and increase the incidence of water-related disease among users.

Similarly, farmers benefiting from extension and infrastructure improvements decreased the proportion of land they cultivated. Qualitative information reveals that the adoption of new farming techniques may have led to an intensification of water use that exceeded the existing water capacity. Also, where inputs and new farming practices were costly, some farmers who received the extension lessons may have had to work for someone else or sell their labor to the rehabilitation and construction site, thereby missing a full farming cycle, in order to acquire the necessary capital to implement the new techniques on their own farms in the future.

The modern irrigation subcomponent, when complemented by the infrastructure component, showed significant increases in the probability of growing industrial crops and export crops. In general, the combination of modern irrigation technology with infrastructure rehabilitation showed overwhelmingly positive synergies, although the effect was somewhat limited when combined with the extension and demonstration subcomponent. The intensification of cultivation of industrial crops, such as cotton or sugarcane, and of export crops such as asparagus and grapes, likely occurred because irrigation generally increases yields by reducing crop loss due to erratic rainwater supply and an overall lowering of losses and risks. It is likely that the effects are more obvious with on-farm irrigation because it includes a water tank or reservoir that provides access to water on an ongoing basis.

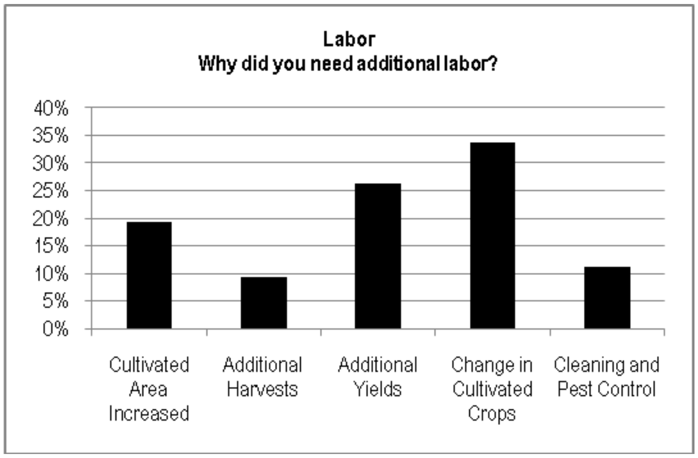
Question 3: Did the On-Farm Investments in Irrigation Technology and Extension Have Spillover Benefits?

The qualitative analysis found that some informants attributed the widespread adoption of modern irrigation technology throughout the region to the on-farm modern irrigation subcomponent of the program; others disagreed, arguing that too few directly benefited. Many respondents believed that the multiplier effects of improving water-use efficiency at the plot level through on-farm investments were strong, despite the small number of actual beneficiaries. Others mentioned that by showcasing new technologies to neighbors and other farmers in the Piura region, that region increased its area under pressurized irrigation technologies from 2,000 hectares to 22,000 hectares; this catalyzed the modernization of agriculture in the region. Some disagreed with this assessment, stating that the impact of the on-farm irrigation equipment was limited to the private plots of direct beneficiaries. Others said that although multiplier effects did exist, and nonbeneficiaries also increased their productivity, they never reached the level of productivity experienced by beneficiaries; in other words, everyone in the target locality saw improvement, but the direct beneficiaries saw significantly more.

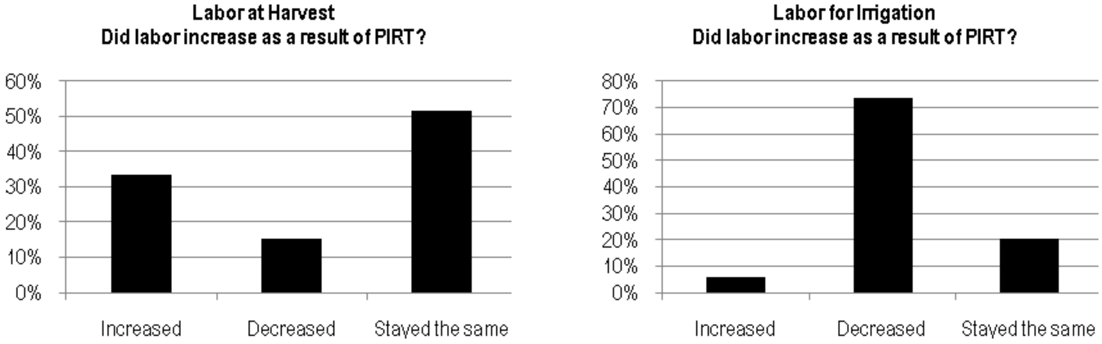
Box 4.6: The Spillover Benefits of Private Investments

> *Laborers are used very little for irrigation, but more for harvesting.*—A PIRT beneficiary

Informants generally reported that their need for labor had remained the same over the past five years, except for some whose demand for labor had changed slightly because of changes in farming practices or crop selection. Twenty-two percent of informants in Viru, Tacna, La Joya, and Huaura reported that their need to hire labor had increased, largely as a result of changes in crop selection (34 percent of informants who had hired more labor gave this answer), increases in yield (26 percent), and increases in cultivated area (19 percent).



PIRT beneficiaries, on the other hand, experienced significant reductions in their need for labor related to irrigation needs, and increases in their demand for harvest-related labor. One stated that drip irrigation had increased his demand for labor by 90 percent.



Sources: Gutierrez and Velez-Vega 2009; authors' calculations using CEPES data.

Most informants felt that the extension subcomponent had had a wide impact; both direct beneficiaries and their neighbors experienced a positive change. Respondents said that the farmer extension services and the demonstration work had had positive community-level effects; together they played a key role in encouraging more farmers to replicate these practices and technologies, in part because the demonstrations allowed them to assess and verify the effectiveness of the new technologies without incurring personal costs or facing risks.

The analysis shows positive spillover effects of both on-farm irrigation and farmer extension. The irrigation technology led to increases in the percentage of income derived from agriculture production, whereas the extension services led to increases in expenditure per capita. As expected, the private effect was both more significant and larger in magnitude (see the analysis outlined in appendix B). Also, direct beneficiaries were more likely to hire a farm worker and less likely to work themselves as manual laborers, suggesting that the spillover effect occurred through increased demand for labor and the promotion of new work opportunities in the local market. This analysis also shows that the beneficiaries of farmer extension increased their percentage of agricultural income and their expenditure per capita and were more likely to hire a farm worker and less likely to work as manual laborers on other farms. The interpretation is similar to that for plot irrigation technology: nonbeneficiaries were likely employed to work on beneficiary farms, and their employment in turn positively affected their own consumption per capita. Also, the increase in per capita expenditure likely occurred because irrigation led to increases in food output locally, which may have resulted in lower prices. Net purchasers of food in these rural areas, many of them likely to be poor or landless households, are likely to have gained from cheaper food and more plentiful stock in the local markets.

Chapter 5
Concluding Remarks

This program took place in a complex socioeconomic and political context, so that isolating the effect of the program from other conditions was a necessary challenge for the evaluation. Peru was implementing general pro-market reforms during the period covered by this program, and, largely because of various macroeconomic conditions that benefited exporters, the agricultural sector experienced a surge. According to informants, the primary catalysts for the surge in the economy and in the agriculture sector were the arrival of new capital investments, favorable price fluctuations, changes in the agricultural legal framework, and increased availability of credit and new technology. Given the generally positive economic trend, the analysis sought to clearly isolate the causal link between the program (and its individual components) and improvements in production, productivity, and economic well-being. The evaluation overcame the lack of suitable program data by using rigorous quantitative techniques, complemented by rich qualitative information, to evaluate the specific effects of the program.

Improvements in production and productivity were specific goals of the program; however, improving economic well-being was not explicitly delineated as an objective, making its measurement a challenge. Agricultural production and yield improvements were meant to be affected by enhancing the sustainability and efficiency of existing public irrigation systems and reducing the role of the public sector in irrigation. Impacts on economic welfare were not explicitly outlined in the program documentation, making it difficult to expect statistically measurable changes, although economic welfare is one of several farm household indicators that can be observed and measured.

The results from both the quantitative and the qualitative analysis demonstrate that the program succeeded in making improvements along several important agricultural and economic dimensions. As expected, the impacts were not uniform across all components and all wealth groups. Both off-farm components of the program—the irrigation infrastructure rehabilitation component and the institutional capacity-building component—led to increases in labor demand, as more agricultural laborers were hired to work on farms in benefited localities, which also led to increases in wage income. The subcomponent devoted to acquisition of on-farm modern irrigation equipment led to increases in agricultural sales. When infrastructure improvements and on-farm irrigation were combined in the same locality, both production and productivity improved.

The evaluation found clear positive synergies between the rehabilitation of irrigation infrastructure and the acquisition of on-farm irrigation technology; synergies were less clear between irrigation infrastructure and farmer extension and demonstration work. The results for on-farm extension and training for farmers show positive results with respect to productivity and the amount of farm output that is sold rather than consumed by farm households. There were, however, some negative externalities from undertaking both infrastructure rehabilitation and on-farm extension services in the same locality, as evidenced by the negative effects on the value of production and on productivity when both components were implemented. This finding is counterintuitive and presents a puzzle for future evaluations of a similar nature.

There is clear evidence of an intensification of production in areas where the off-farm components of the program were implemented, and of crop switching where the on-farm components were implemented; poor farmers produced more staple crops and nonpoor farmers produced more export crops. Impacts of the program differed across farm households depending on their initial wealth. Poor farmers were more likely to specialize in planting staple crops where off-farm components of the program were implemented, whereas nonpoor farmers were more likely to increase their production of industrial crops. On-farm irrigation technology investments led poor farmers to increase their production of permanent crops; however, they experienced no changes in productivity. Farmers who received extension services, particularly poor farmers, switched toward more export crops and increased their permanent crop cultivation.

Appendix A: Tables and Figures

Figure A.1. Channels of the Impact on Productivity

PSI – Phase I

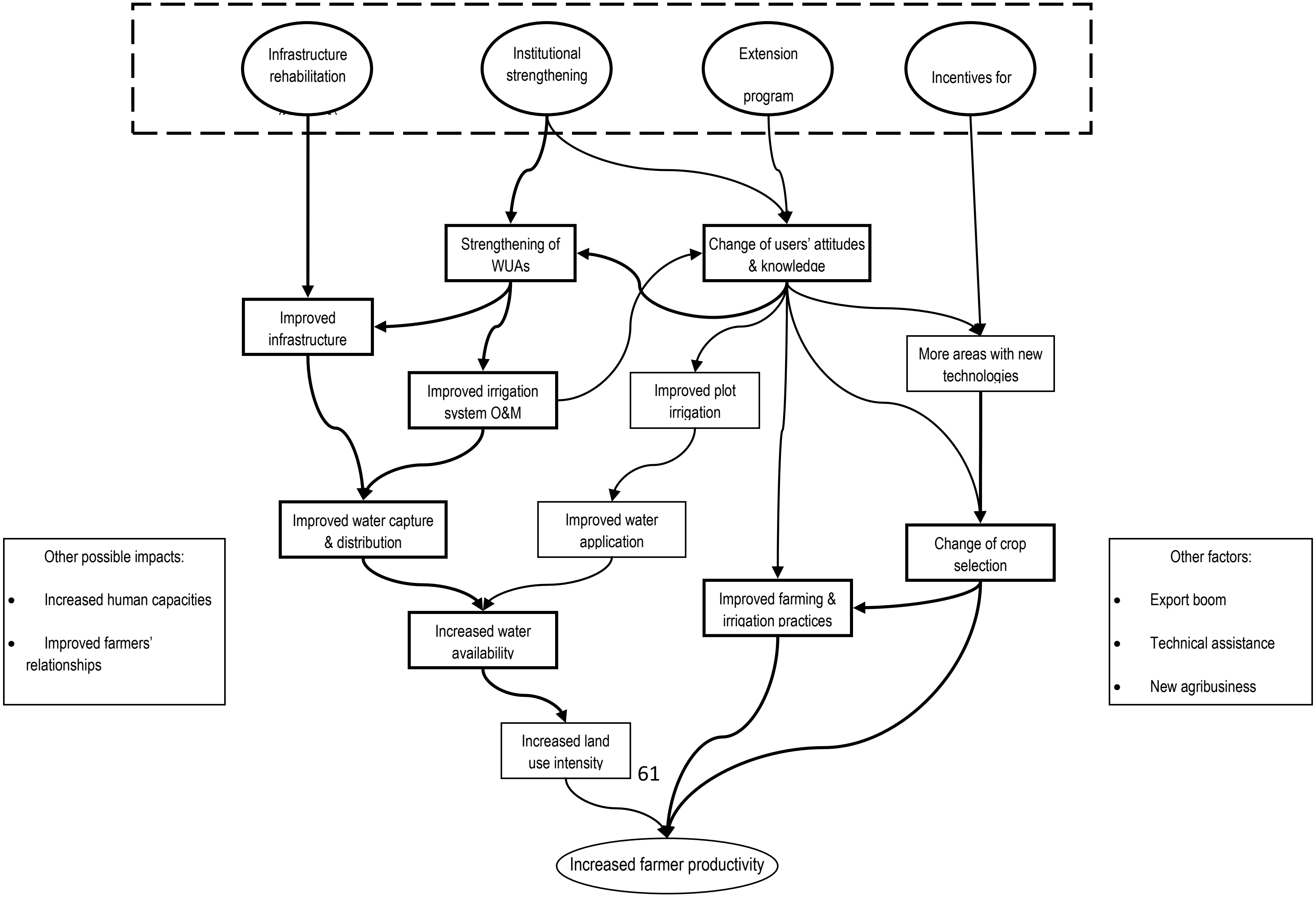


Table A.1: List of Evaluated Infrastructure Rehabilitation Projects

	Region	Completion date
1	Ica	3/15/00
2	Lambayeque	12/15/00
3	Lima	12/31/00
4	Lambayeque	12/31/00
5	Lambayeque	12/31/00
6	Lambayeque	12/31/00
7	Lambayeque	12/31/00
8	Lambayeque	12/31/00
9	Tacna	5/22/01
10	La Libertad	6/24/01
11	Ica	2/22/02
12	Arequipa	5/12/02
13	Tacna	10/1/02
14	La Libertad	11/25/02
15	La Libertad	12/2/02
16	Arequipa	12/22/02
17	Lambayeque	1/25/03
18	Arequipa	3/11/03
19	Lima	3/13/03
20	Piura	5/10/03
21	Ica	6/9/03
22	Arequipa	7/8/03
23	Arequipa	8/13/03
24	Lima	8/21/03
25	La Libertad	9/2/03
26	Lima	9/3/03
27	Arequipa	9/25/03
28	Arequipa	9/30/03
29	Arequipa	11/28/03
30	Lima	12/6/03
31	Piura	12/8/03
32	Ica	1/1/04
33	Lambayeque	1/1/04
34	Lima	1/11/04
35	La Libertad	1/24/04
36	Ica	1/28/04
37	La Libertad	2/3/04
38	Piura	2/4/04
39	Lima	2/7/04
40	Arequipa	2/12/04
41	Lima	2/18/04
42	Tacna	2/25/04
43	Arequipa	3/2/04
44	Piura	3/10/04
45	Lambayeque	3/14/04
46	La Libertad	3/31/04
47	Lambayeque	4/13/04
48	Arequipa	5/7/04
49	Lima	5/12/04
50	Piura	5/14/04
51	Piura	5/23/04
52	La Libertad	6/13/04
53	La Libertad	6/13/04
54	La Libertad	6/13/04
55	Arequipa	6/23/04
56	Lima	6/26/04
57	Arequipa	6/30/04
58	Piura	6/30/04
59	Arequipa	6/30/04
60	Piura	6/30/04
61	Tacna	6/30/04
62	Tacna	6/30/04
63	Tacna	6/30/04

Table A.2: Summary Statistics for ENAHO Infrastructure Data

Variable	Observations	Mean	Std. Dev.	Minimum	Maximum
Outcome variables					
Total value of production per capita	662	2,084.38	3,447.59	0.00	25,670.00
Total agro income per capita	627	1,932.91	3,239.85	0.00	29,355.67
Total agro costs per capita	679	642.52	1,284.06	0.00	10,707.00
Total agro profit per capita	622	12,26.32	2,274.04	–1,297.00	18,648.67
Fruit production	671	408.53	1,975.15	0.00	18,090.00
Industrial crop production	673	1,500.16	4,216.08	0.00	26,250.00
Bean production	675	318.96	1,078.23	0.00	8,016.00
Root vegetable production	674	48.01	212.44	0.00	2,600.00
Number of crops	675	2.72	1.99	0.00	10.00
Hire peon	680	0.63	0.48	0.00	1.00
Work as manual	680	0.75	0.43	0.00	1.00
Total expenditures per capita	661	1,302.99	1,052.05	115.75	5,702.67
Total income per capita	668	2,272.05	2,469.07	76.44	1,5531.00
Dependent income per capita	668	400.83	653.97	0.00	3,687.00
Independent income per capita	669	1,076.11	1,497.11	4.71	1,1136.50
Other variables included as controls					
Distance to Infrastructure	680	8.36	5.31	0.16	22.72
River flow	643	26.50	13.09	–25.95	110.50
Male household head	680	0.93	0.26	0.00	1.00
Household head age	680	53.44	14.24	20.00	92.00
Household head age squared	680	3,058.37	1,569.97	400.00	8,464.00
Household head years education	678	5.02	3.96	0.00	17.00
Treatment variables					
Treat (within radius of influence)	680	0.72	0.45	0.00	1.00
Post (after work completed)	680	0.54	0.50	0.00	1.00
Post-treat	680	0.34	0.47	0.00	1.00

Table A.3: Summary Statistics for ENAPROVE—PIRT

Variable	Observations	Mean	Std. Dev.	Minimum	Maximum
Outcome variables					
Total value of production	22,660	14,141.41	27,672.11	0	194,726.6
Productivity	22,660	2,093.00	3,646.06	0	178,788.2
Proportion of production sold	13,436	0.47	0.44	0	1
Probability of export crop	24,274	0.06	0.24	0	1
Probability of permanent crop	24,274	0.22	0.41	0	1
Proportion of land cultivated	24,274	0.43	0.43	0	1
Rice production	24,274	0.09	0.29	0	1
Cotton production	24,274	0.10	0.30	0	1
Maize production	24,274	0.14	0.35	0	1
Asparagus production	24,274	0.01	0.11	0	1
Sugarcane production	24,274	0.04	0.20	0	1
Mango production	24,274	0.02	0.12	0	1
Grape production	24,274	0.02	0.14	0	1
Onion production	24,274	0.01	0.11	0	1
Mandarin production	24,274	0.01	0.11	0	1
Orange production	24,274	0.01	0.08	0	1
Potato production	24,274	0.03	0.17	0	1
Tomato production	24,274	0.01	0.09	0	1
Other variables used as controls					
Hectares	22,660	7.55	8.14	0.01	41.83
North	24,274	0.50	0.50	0	1
South	24,274	0.36	0.48	0	1
Treatment variables					
PIRT commission	24,274	0.62	0.48	0	1
PERAT commission	24,274	0.38	0.48	0	1
Infrastructure	24,274	0.24	0.43	0	1
PIRT commission*infrastructure	242,74	0.19	0.40	0	1

Table A.4: Summary Statistics for ENAPROVE—PERAT

Variable	Observations	Mean	Std. Dev.	Minimum	Maximum
Outcome variables					
Total value of production	18,963	12,713.44	24,286.47	0	192,930.9
Productivity	18,963	2,024.15	3,340.52	0	87,672.45
Proportion of production sold	10,859	0.47	0.44	0	1
Probability of export crop	20,471	0.07	0.25	0	1
Probability of permanent crop	20,471	0.19	0.39	0	1
Proportion of land cultivated	20,471	0.42	0.42	0	1
Rice production	20,471	0.17	0.38	0	1
Cotton production	20,471	0.05	0.23	0	1
Maize production	20,471	0.14	0.34	0	1
Asparagus production	20,471	0.01	0.08	0	1
Sugarcane production	20,471	0.02	0.14	0	1
Mango production	20,471	0.02	0.14	0	1
Grape production	20,471	0.04	0.19	0	1
Onion production	20,471	0.01	0.10	0	1
Mandarin production	20,471	0.00	0.04	0	1
Orange production	20,471	0.00	0.04	0	1
Potato production	20,471	0.01	0.10	0	1
Tomato production	20,471	0.01	0.07	0	1
Other variables used as controls					
Hectares	18,963	7.51	8.21	0.02	41.83
North	20,471	0.72	0.45	0	1
South	20,471	0.22	0.42	0	1
Treatment variables					
PERAT commission	20,471	0.71	0.45	0	1
PIRT commission	20,471	0.08	0.28	0	1
Infrastructure	20,471	0.20	0.40	0	1
PERAT commission*infrastructure	20,471	0.16	0.36	0	1

Appendix B: Secondary Analysis—Centro Peruano de Estudios Sociales

Data

This data source comes from the program itself. PSI I.2 undertook an overall evaluation of its achievements and outcomes at the end of its execution period (CEPES 2004) in November 2003. This survey covered multiple topics, including some measures of socioeconomic characteristics and a rich agricultural module. It was conducted in program localities and administered to beneficiaries and nonbeneficiaries living in the same commissions or villages; however, the survey was conducted only after much of the program had been implemented and thus does not allow for a before–and-after comparison. The Centro Peruano de Estudios Sociales (CEPES) surveyed 460 households treated under PIRT and PERAT (component C). Of these, 268 households were in villages where there were demonstration plots and capacity training was given (PERAT), and 192 households were in villages where at least one household received a grant for pressurized irrigation (PIRT). These households are all in 20 WUAs treated up to that time.

The empirical strategy to evaluate the impact of farmer capacity building and pressurized drip irrigation subsidies used a combination of CEPES and ENAHO data. The variables used in the analysis are limited to those common to both survey instruments and comparable in terms of definition and unit of measurement. These variables focus on the welfare of households, as the format of the agriculture module in CEPES is not comparable to that of ENAHO. Given that the CEPES data were collected ex post in 2003, ENAHO data were also used to construct a comparable baseline and control group. To construct a baseline for the treatment districts, districts in the 2003 CEPES data were identified and then located in the ENAHO data at baseline (defined as 1999 and 2000, before the program was implemented). Other, comparable coastal districts at baseline were then identified through propensity score matching to serve as controls, and these same comparable districts were located in the 2003 ENAHO survey. Regressions were first run on each of the outcome variables at baseline to ensure that treated districts were not different from nontreated districts, and the regressions were then run at follow-up to estimate the impact of PIRT and PERAT. As no household received both PIRT and PERAT, and the qualitative work indicated that beneficiaries of PIRT and PERAT were generally quite different, the matching and analysis were done separately for the two interventions. This methodology is illustrated in table B.1.

Empirical Strategy

This strategy used a constructed pseudo-panel dataset that combines the two sources of data, CEPES and ENAHO. The CEPES data were collected in November-December 2003 and included data on households that benefited from either PIRT or PERAT in 20

WUAs.[13] The lack of experimental data presented a causal inference problem because the group exposed to the treatment would be compared with a nonexperimental comparison group, which introduces biases that necessitate econometric manipulation. In other words, calculating a simple difference between the treated and the nontreated groups is likely to misestimate the impact of the program, because there may be specific reasons why beneficiaries were selected or took up the program.

Table B.1: Matching Methodology for PIRT and PERAT Using CEPES/ENAHO Data

	Treatment	***Control***
Baseline (1999-2000)	ENAHO 12/18 of the treated districts 1 ↑	ENAHO Comparable districts → 2. Kernel matched → 3 ↓
Followup (2003)	CEPES and ENAHO 18 CEPES districts	ENAHO Households from the comparable districts

Note: Data for this analytical strategy come from two sources, ENAHO and the PSI. However, as the program data were only collected on beneficiaries at follow-up, without surveying a control group or baseline groups, this process creates a pseudo-panel. First, districts were identified that contained households from the program data, and these districts were then located in the 1999-2000 ENAHO survey (arrow 1). Comparable districts at baseline were then identified by propensity score kernel matching (arrow 2). Finally, households from these districts in the 2003 ENAHO survey were found (arrow 3). Table B.4 reports results of tests validating that the baseline districts were comparable, and thus that the households from treated districts could be compared with the households from control districts at follow-up.

Formally, h indexes the group considered, Y_{h1} is the variable to be estimated when h is subject to the treatment, and Y_{h0} is the same variable when the subject is not treated. The treatment effect for one household τ_h is defined as $\tau_h = Y_{h1} - Y_{h0}$. In a nonexperimental setting such as this one, one wants to estimate the treatment effect on the treated or $\tau \mid_{T=1} = E(Y_{h1} \mid T_h = 1) - E(Y_{h0} \mid T_h = 1)$, where $T_h = 1$ or $T_h = 0$ if the h_{th} unit was assigned to treatment (1) or control (0). As one cannot measure treatment and nontreatment outcomes for the same unit at the same time, a counterfactual scenario of two groups that accounts for the potential systematic differences between treated and the nontreated households had to be created. For this reason it was necessary to find a set of covariates ($\mathbf{X}_h$) for each observation in both populations, not necessarily deriving from the same source, that could be compared at the pre-treatment stage. These observable covariates determine the propensity score. Identification assumptions were that treatment was not driven by other, unobservable covariates and that outcomes in the nontreated state were independent of assignment to the program. In other words, it was assumed that, before the program, both groups had an equal chance of participation in the program. Given this assumption, households were matched on the vector of selected covariates ($\mathbf{X}_h$).[14] Details on the merits of propensity score matching and the mechanics of how matches are determined are described in the seminal work by Heckman, Ichimura, and Todd (1997).

First, the eventually treated districts in the baseline years 1999 and 2000 combined were located. Second, a set of covariates was chosen to be included in a standard regression for PIRT-treated households, where per capita expenditure was the dependent variable and the independent variables were whether the household was in an urban area, whether the household had a female head, whether the household head was employed, the age of the household head and its square, the education level of the household head, and the number of household members. These covariates were selected using qualitative insight and standard variables identified in the literature for similar programs. Third, all variables showing significant coefficients were kept as covariates in calculating the propensity scores for each district. Fourth, after the control districts were identified at baseline, balancing tests were run across the treatment group and the matched control group to ensure that outcomes were not significantly different from zero at baseline. As covariates were balanced, the matched localities were used post-treatment.

Qualitative work shows that PIRT and PERAT beneficiaries were slightly different from each other. Those who received PIRT were not generally the poorest, as the program required them to contribute 20–30 percent of the cost of the technology from their own funds. This means that some people were unable to benefit from the plot irrigation subsidy because of liquidity constraints. Informants stated that PERAT beneficiaries were more likely to be poor than PIRT beneficiaries and were more representative of the general farm household population. This concern was addressed by matching for each subcomponent separately and taking this factor into account by including wealth-related covariates.

Outcome variables—PIRT and PERAT

To assess the impact of these subcomponents of the program, five outcome variables were examined and are described in table B.2. Data limitations prevented looking at more agricultural productivity variables.

Table B.2. Outcome Variables for Component C

Variable	Description
% Income from agriculture	The percentage of household income that comes from agricultural activities
Expenditures per Capita	Expenditures on health, education, and food (soles per capita monthly)
Nonagricultural income	Income from nonagricultural sources (soles, monthly)
Hire worker	1 if the household hired a farm worker to conduct agricultural work, 0 otherwise
Work as manual laborer	1 if a household member was hired to work in manual labor (agro and nonagro) elsewhere, 0 otherwise

Control variables—PIRT and PERAT

In each of the specifications, as with the estimations for component A, controls included the sex of the household head, the age of the household head and its square, a dummy variable for whether the household head had completed secondary school, whether the household lived in an urban area or shantytown (as opposed to a rural area), and the number of household members.

Treatment variables and specifications—PIRT

The qualitative assessment showed that households that did not directly receive PIRT or PERAT still benefited indirectly from the subsidy component, either by observing beneficiary practices or through the increased economic activity in the community. Therefore, both the district-level and the household-level effects of PIRT and PERAT (subscript *D* stands for district level, subscript *h* for household level) were examined. The first specification focused on the district-level effects, enabling a comparison with baseline districts, and the next incorporated both household- and district-level effects. Errors in all specifications were clustered by WUA, as these errors were likely to be correlated.

The effect of PIRT at the district level was analyzed first in order to compare it with the baseline effects. The first specification included a control for whether the district received an infrastructure project (component A) as well as the household controls listed above:

$$Y_h = a + \beta_1(PIRT_D) + \beta_2(PERAT_D) + \gamma(INFR) + \mathbf{X}_h + \varepsilon_h \qquad (1)$$

As PIRT and PERAT do not appear to be independent at the district level, with a chi-square value of 84.0071 ($p < 0.001$), a variable for PERAT was included to separate the effects of the treatments. Although no individual household received both treatments, the overlap at the district level was significant: out of the 30 districts treated for either PIRT or PERAT, 15 were treated for both.

Individual-level treatment variables were then incorporated into the regression, to examine both public (district-level treatment) and private (household-level treatment) effects.

The next specification examined only the private effects of PIRT, controlling for whether the household was in a district that received the infrastructure treatment and including the household controls. Next, the district-level effect was included in addition to the private effect, to investigate the additional impact of the treatment on indirect beneficiaries. The next estimation included a variable for the district-level treatment of PERAT; as no household was treated for both PIRT and PERAT, the household-level impact of PIRT was only potentially confounded with the district-level effect of PERAT:

$$Y_h = a + \beta_1(PIRT_h) + \beta_2(PIRT_D) + \beta_3(PERAT_D) + \gamma(INFR) + \mathbf{X}_h + \varepsilon_h \qquad (2)$$

Treatment variables and specifications—PERAT

The specifications for PERAT follow those of PIRT closely. However, as PERAT focused on training farmers to irrigate more effectively, rather than giving them a new irrigation technology directly as did PIRT, access to water was an extremely important factor in PERAT's potential for impact. As described in the text of the report, PIRT technology includes a reservoir that provides water for an extended period, so that access to water is less volatile and less relevant to PIRT's success. The qualitative work emphasized that the rehabilitated infrastructure increased the *distribution* of water, whereas PERAT, the farmer capacity-building element, improved the *effectiveness* of water use. To account for this multiplier effect, an interaction term identifying whether a household was in a district that received an infrastructure treatment as well as whether the household received PERAT was included. The effect of the simultaneous interventions is captured in the coefficient on this interaction variable. Specification 1 includes an interaction term of PERAT and infrastructure at the district level:

$$Y_h = a + \beta_1(PERAT_D) + \beta_2(PIRT_D) + \delta(PERAT_D{*}INFR) + \gamma(INFR) + \mathbf{X}_h + \varepsilon_h \qquad (1)$$

Specification 2 looks at the household-level impact of PERAT, as opposed to only the district-level impact as in specification 1. Specification 3 is the same as specification 2, except that it includes a public interaction effect as well as an individual interaction effect between PERAT and infrastructure:

$$Y_h = a + \beta_1(PERAT_h) + \beta_2(PERAT_D) + \gamma(INFR) + \beta_3(PIRT_D) + \delta_1(PERAT_h{*}INFR) + \mathbf{X}_h + \varepsilon_h \qquad (2)$$

$$Y_h = a + \beta_1(PERAT_h) + \beta_2(PERAT_D) + \gamma(INFR) + \beta_3(PIRT_D) + \delta_1(PERAT_h{*}INFR) + \delta_2(PERAT_D{*}INFR) + \mathbf{X}_h + \varepsilon_h \qquad (3)$$

Results

As described in the empirical strategy section, regressions were first run on the baseline data to ensure that those districts that were eventually treated were not statistically different from those that were not subsequently treated. In other words, if treated districts had, on average, higher consumption at baseline, the coefficient on *treat* in the consumption regression would have been significant and positive at baseline. If the coefficients on the *treat* variable are significant at baseline and also at follow-up, then it is likely that other, unobservable factors are influencing the results. This was a particularly important test to run because this part of the analysis did not use difference-in-differences techniques (because of data constraints) and instead relied on the success of the matching exercise. The qualitative work indicated that households receiving the irrigation grant or subsidy tended to be wealthier than those participating in the demonstration or training component. Therefore, matching techniques for PIRT and PERAT beneficiaries were used separately to find households in comparable districts at baseline for each group. The results of the baseline analysis of PIRT and PERAT are reported in table B.5. This table also includes results of the same regression run at follow-up. Generally, households that were eventually treated were not significantly different at baseline from those that were not treated. The one exception is with respect to expenditure per capita for the PIRT districts: districts treated under PIRT had significantly lower consumption than those not treated, and among the PIRT districts, those treated under PERAT had significantly higher consumption than those not treated. Therefore, in looking at the follow-up results for PIRT, the impact of PIRT is likely to be understated and the impact of PERAT is likely to be overstated.

As demonstrated in table B.6, PIRT shows generally positive results. PIRT households derived 35 percent more of their income from agriculture than did nonbeneficiaries, and those in PIRT-treated districts increased their agricultural income by 11.3 percent. Additionally, labor trends shifted significantly; beneficiaries were 17 percent more likely to hire agricultural workers, and 46 percent less likely to work as manual laborers. The coefficient on nonagricultural income sources was negative (although insignificant) for direct beneficiaries, which is logical, as they are likely to shift their income sources toward agriculture, and the significant effect of the district-level PIRT treatment disappears when PERAT is included. As PIRT and PERAT treatments were not independently distributed, this indicates that PERAT was the bigger driver of increased nonagricultural income. However, it is important to note that this represents only the effect of PERAT on slightly wealthier beneficiary districts—PIRT districts and those matched with PIRT districts—as PIRT beneficiaries had the means to invest in and benefit from the drip irrigation technology. Together, this evidence suggests that farmers significantly increased agricultural economic activity on their land, as more of their income came from agriculture than before, more of them hired others to help on their own land, and fewer were working elsewhere.

The results for PERAT (table B.7) were extremely positive. The private effect on the share of income from agriculture was significantly positive: PERAT beneficiaries derived 45 percent more of their income from agriculture than did nonbeneficiaries. The public effect of PERAT (seen in specification 1) disappeared when the public effect of the pressurized irrigation subsidy component was included; having PIRT at the district level increased the share of income from agriculture by almost 20 percent. There does not appear to be an additional gain from having an infrastructure rehabilitation project in a district that also benefited from having demonstration work at the plot level.

The outcomes for welfare and labor indicators are also very positive. Both public and private increases in consumption were found among those receiving the PERAT treatment, as well as significantly positive public effects on nonagricultural income. Additionally, there were very strongly positive private impacts of capacity building on hiring workers and strongly negative private impacts on working for a wage as a manual laborer. The public effect of PERAT on hiring workers was negligible, and the effect on working as a manual laborer was weak. None of these indicators showed any additional effects of having both infrastructure improvements and demonstration capacity training. All of these results are consistent with the PIRT analysis above, even though the analysis was conducted on different districts, due to the fact that they were matched separately.

Table B.3: Summary Statistics for PERAT

Variable	Observations	Mean	Std. Dev.	Minimum	Maximum
Dependent variables					
Percent income from agriculture	1,003	26.59	38.84	0	100
Expenditures per capita	1,003	92.99	86.99	0	725.8
Nonagricultural income	1,011	280.26	700.53	0	9,000
Hire worker	1,011	0.7	0.46	0	1
Work as manual laborer	1,003	0.65	0.48	0	1
Control variables					
Male household head	1,003	0.9	0.3	0	1
Household head age	1,003	52.9	14.66	19	93
Household head age^2	1,003	3,012.88	1,596.19	361	8,649
Household secondary school	1,003	0.29	0.45	0	1
Household in nonrural area	1,041	0.73	0.44	0	1
Number of household members	1,003	4.54	2.22	1	15
Treatment variables					
PERAT_HH	1,041	0.21	0.41	0	1
PERAT_District	1,041	0.92	0.28	0	1
Infrastructure	1,041	0.19	0.39	0	1
PIRT_District	1,041	0.71	0.46	0	1
PERAT_HH*Infrastructure	1,041	0.04	0.19	0	1
PERAT_District*Infra	1,041	0.17	0.37	0	1

Table B.4: Summary Statistics for PIRT

Variable	Observations	Mean	Std. Dev.	Minimum	Maximum
Dependent variables					
Percent income from agriculture	1,010	31.36	40.36	0	100
Expenditures per capita	1,010	101.14	91.50	0	725.8
Nonagricultural income	1,018	310.09	760.93	0	9000
Hire worker	1,018	0.75	0.43	0	1
Work as manual laborer	1,010	0.58	0.49	0	1
Control variables					
Male household head	1,010	0.90	0.31	0	1
Household head age	1,010	53.22	14.40	19	93
Household head age	1,010	3,039.82	1,572.12	361	8,649
Household head education	1,010	0.32	0.47	0	1
Household in nonrural area	1,048	0.71	0.45	0	1
Number of household members	1,010	4.43	2.16	1	15
Treatment variables					
PIRT_HH	1,048	0.27	0.44	0	1
PIRT_District	1,048	0.91	0.29	0	1
Infrastructure	1,048	0.24	0.43	0	1
PERAT_District	1,048	0.92	0.28	0	1

Table B.5: Baseline Comparison of Treated and Matched Control Districts

a. PERAT

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	% Income from Agriculture		**Expenditures Per Capita**		**Non-Agricultural Income**		**Hire Peon**		**Work as Manual**	
	1999	2003	1999	2003	1999	2003	1999	2003	1999	2003
PERAT District	-0.00	4.15	6.57	27.70*	493.42	345.46**	-0.01	0.01	-0.02	-0.22***
	(0.28)	(6.50)	(7.39)	(15.44)	(674.29)	(132.86)	(0.07)	(0.11)	(0.02)	(0.07)
Infrastructure	0.07	1.61	1.47	-6.26	769.32	58.21	-0.00	0.03	-0.01	-0.05
	(0.30)	(1.26)	(6.06)	(9.77)	(901.73)	(149.41)	(0.09)	(0.11)	(0.02)	(0.05)
PIRT District	-0.10	21.92***	-7.07	13.88	-223.24	9.27	0.04	0.19**	0.02	-0.20**
	(0.30)	(7.15)	(7.67)	(12.19)	(649.09)	(45.77)	(0.07)	(0.07)	(0.03)	(0.08)
PERAT District *Infra	-0.03	-10.70	-1.11	18.68	-1076.32	60.45	-0.07	-0.08	-0.01	0.01
	(0.34)	(11.35)	(7.41)	(16.36)	(1093.16)	(160.38)	(0.10)	(0.11)	(0.03)	(0.17)
Constant	-0.42	-61.52***	13.17	11.16	336.30	-273.52	-0.08	0.40	0.62***	1.52***
	(0.49)	(20.31)	(24.69)	(22.43)	(1634.45)	(238.34)	(0.14)	(0.26)	(0.19)	(0.25)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1339	1003	1339	1003	1339	1003	1339	1003	1339	1003
R-squared	0.135	0.151	0.191	0.178	0.110	0.165	0.145	0.098	0.151	0.219

b. PIRT

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	% Income from Agriculture		**Expenditures Per Capita**		**Non-Agricultural Income**		**Hire Peon**		**Work as Manual**	
	1999	2003	1999	2003	1999	2003	1999	2003	1999	2003
PIRT District	-0.17	24.20***	-11.41***	20.10	-24.40	56.79	-0.02	0.11	-0.04	-0.24***
	(0.13)	(5.71)	(4.20)	(15.16)	(437.70)	(88.80)	(0.03)	(0.10)	(0.03)	(0.08)
Infrastructure	0.05	-8.81	1.82	9.99	12.20	114.37**	-0.05	-0.05	-0.02	-0.04
	(0.17)	(10.47)	(3.47)	(11.56)	(509.78)	(56.20)	(0.05)	(0.04)	(0.01)	(0.15)
PERAT District	0.04	-3.99	10.83**	15.71	210.45	286.20***	0.04	0.03	0.04	-0.12
	(0.17)	(6.51)	(5.08)	(13.11)	(552.29)	(95.06)	(0.05)	(0.11)	(0.03)	(0.10)
Constant	-0.09	-57.49**	-1.16	4.17	-762.52	-421.17	-0.04	0.34	0.56***	1.59***
	(0.44)	(22.73)	(22.85)	(26.65)	(1687.54)	(295.53)	(0.12)	(0.25)	(0.19)	(0.28)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1348	1010	1348	1010	1348	1010	1348	1010	1348	1010
R-squared	0.126	0.115	0.188	0.151	0.095	0.158	0.156	0.070	0.147	0.180

Table B.6: PIRT Focus Using CEPES and ENAHO Data

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	% Income from Agriculture		**Expenditures Per Capita**		**Non-Agricultural Income**		**Hire Peon**		**Work as Manual**	
PIRT HH	35.40***	35.41***	11.55	11.85	-76.03	-71.26	0.17**	0.17**	-0.45***	-0.46***
	(3.02)	(3.10)	(8.53)	(8.71)	(71.69)	(73.06)	(0.07)	(0.07)	(0.07)	(0.07)
PIRT District	11.83***	11.34*	28.29	15.80	282.77*	82.67	0.09	0.05	-0.21***	-0.08
	(3.47)	(6.36)	(18.25)	(14.43)	(150.87)	(99.84)	(0.05)	(0.11)	(0.07)	(0.06)
Infrastructure	-8.62	-8.58	8.91	10.07	95.24	113.89**	-0.05	-0.05	-0.03	-0.04
	(6.32)	(6.61)	(12.05)	(11.53)	(58.30)	(49.42)	(0.04)	(0.04)	(0.09)	(0.09)
PERAT District		0.68		17.27		276.81***		0.05		-0.18***
		(7.78)		(12.65)		(95.59)		(0.12)		(0.06)
Constant	-35.86**	-36.03**	15.70	11.36	-394.78	-464.37	0.46**	0.44*	1.26***	1.31***
	(14.76)	(14.46)	(26.22)	(27.09)	(298.47)	(296.99)	(0.22)	(0.23)	(0.21)	(0.20)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1010	1010	1010	1010	1010	1010	1010	1010	1010	1010
R-squared	0.257	0.257	0.153	0.154	0.157	0.160	0.097	0.097	0.335	0.338

Note: * p<0.10 ** p<0.05 *** p<0.01.

Table B.7: PERAT Focus Using CEPES and ENAHO Data

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
	% Income from Agriculture			**Expenditures Per Capita**			**Non-Agricultural Income**			**Hire Peon**			**Work as Manual**		
PERAT HH	43.13***	42.31***	44.75***	15.98**	15.43**	16.06*	118.25	118.02	74.26	0.25***	0.24***	0.25***	-0.29***	-0.28***	-0.28***
	(6.65)	(6.12)	(6.95)	(7.84)	(7.53)	(9.09)	(91.25)	(91.51)	(85.33)	(0.05)	(0.04)	(0.05)	(0.05)	(0.05)	(0.06)
PERAT District	9.81**	-7.65	-6.21	40.30*	28.37*	23.99	337.48**	332.43**	329.07**	0.10	-0.06	-0.04	-0.32***	-0.15	-0.15*
	(4.31)	(5.39)	(5.04)	(21.03)	(14.10)	(16.30)	(151.53)	(133.49)	(132.06)	(0.07)	(0.10)	(0.11)	(0.09)	(0.10)	(0.09)
Infrastructure	-1.36	-6.63	1.66*	14.47*	10.86	-6.25	117.23**	115.70*	57.98	0.01	-0.03	0.03	-0.10	-0.05	-0.05
	(9.57)	(9.34)	(0.92)	(8.00)	(10.98)	(9.99)	(52.12)	(57.13)	(151.18)	(0.05)	(0.04)	(0.11)	(0.14)	(0.14)	(0.05)
PIRT District		19.99***	19.90***		13.65	13.18		5.77	9.40		0.18***	0.18***		-0.19**	-0.19**
		(5.38)	(5.40)		(11.38)	(11.46)		(45.30)	(45.89)		(0.06)	(0.06)		(0.08)	(0.09)
PERAT HH*Infra			-13.43			-3.12			239.31			-0.01			-0.04
			(12.00)			(8.94)			(305.08)			(0.09)			(0.12)
PERAT District*Infra			-6.11			19.94			7.86			-0.07			0.01
			(13.03)			(16.35)			(176.03)			(0.12)			(0.19)
Constant	-42.07**	-35.01*	-38.22*	11.07	15.88	19.85	-221.37	-219.33	-184.39	0.49**	0.56**	0.54*	1.43***	1.36***	1.36***
	(18.59)	(19.29)	(19.77)	(22.18)	(22.64)	(24.13)	(254.99)	(254.27)	(273.99)	(0.24)	(0.26)	(0.27)	(0.24)	(0.22)	(0.24)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1003	1003	1003	1003	1003	1003	1003	1003	1003	1003	1003	1003	1003	1003	1003
R-squared	0.281	0.320	0.324	0.178	0.182	0.183	0.169	0.169	0.172	0.117	0.138	0.139	0.246	0.269	0.269

Note: * p<0.10 ** p<0.05 *** p<0.01.

Appendix C: Estimations

Treatment Variables and Specifications: Off-Farm Irrigation Rehabilitation and WUA Strengthening

Specification tests were first run on four key outcome variables—total value of production per capita, probability of hiring a farm laborer, total expenditure per capita, and total income per capita—to determine the most appropriate specification for the rest of the outcome variables. The results of these specification tests are presented in table C.3. The key variable of interest is *post-treat,* a variable identifying a household that both received the infrastructure treatment(rehabilitation of an irrigation canal) and was a member of a downstream community within the area of influence. (The *post-treat* variable is an interaction of two variables: *post,* a dummy variable for whether the rehabilitation had taken place yet, regardless of whether the household was in a treatment or a control community, and *treat,* a dummy variable for whether the household was in a downstream community, within the appropriate radius and WUA, regardless of whether the rehabilitation had taken place or not.)

The first specification included only these variables and an error term (with errors clustered by water users' association [WUA] and weighted by the expansion factor):

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

All of these estimations are restricted to farm households.

The next specification added to the previous one the following variables: river flow, distance from the rehabilitation site, and year fixed effects to account for unobservable variables that change over time. Including these variables changes the point estimation of *post_treat* in some cases, signaling that outcomes likely varied across these dimensions:

$$Y_h = \alpha + \beta_1(post) + \beta_2(treat) + \beta_3(post\_treat) + River\ Flow + Distance + TimeFE + \varepsilon_h \qquad (2)$$

The third specification included a vector of household characteristics that are expected to be orthogonal to the treatment effect. As the addition of these control variables altered neither the sign nor significance of the point estimation, there is reason to believe that treatment was not confounded by these other nonobservables:

$$Y_h = \alpha + \beta_1(post) + \beta_2(treat) + \beta_3(post\_treat) + River\ Flow + Distance + TimeFE + \mathbf{X}_h + \varepsilon_h \qquad (3)$$

The fourth specification controlled for whether a district also received the plot-level treatment (component C.1 or component C.2), by including a dummy variable (*PPtreat*) that takes a value of 1 if the district had been treated under PIRT or PERAT. As this control only minimally changes the point estimates of *post-treat,* there is reason to believe that the treatments were implemented independently, and that the impact of component

C does not confound that of component A. This is not surprising given that the staff, the processes, and the implementation period for the on-farm and off-farm components were all different. Because this dataset does not have enough variation to allow accurate estimation of whether there were complementarities between components A and C, the interaction is not included. This final specification was used for the rest of the outcome variables:

$$Y_h = \alpha + \beta_1(post) + \beta_2(treat) + \beta_3(post\_treat) + \gamma_1(PPtreat) + River\ Flow + Distance + TimeFE + \mathbf{X}_h + \varepsilon_h \tag{4}$$

Treatment Variables and Specifications: On-Farm Irrigation Technology and Farmer Extension Services

Impacts were calculated by looking at the difference in each outcome variable between 2001 and 2004. Within this span of time, either PIRT or PERAT, or both, had been administered, and thus, if the impact on the outcome variables was large, the difference between 2001 and 2004 for the treated water commissions would be larger than that for the matched control commissions. Therefore, the coefficients on the treatment terms (represented by β below) are the average difference-in-differences.

The specifications all included the infrastructure treatment and the controls discussed above. Because treatment was at the commission level, errors for each regression were clustered by commission. The commission-level treatment also means that the treatment coefficients represent the commission-level effects, rather than the on-farm (private) effects on individual beneficiaries. As the propensity score matching was done separately for PIRT and PERAT, a separate set of regressions was run for each. The PIRT specifications are as follows:

$$Y_{p1} - Y_{p0} = a + \beta_1(PIRT) + \beta_2(PERAT) + \gamma(INFR) + \mathbf{X}_p + \varepsilon_p \tag{5}$$

$$Y_{p1} - Y_{p0} = a + \beta_1(PIRT) + \beta_2(PERAT) + \gamma(INFR) + \delta(PIRT^*INFR) + \mathbf{X}_p + \varepsilon_p \tag{6}$$

The specification in equation 5 measures the impact of PIRT, controlling for infrastructure and PERAT. The specification in equation 6 interacts the PIRT treatment with the infrastructure treatment. As the PIRT technology requires a substantial amount of water to initially fill the reservoir, its effectiveness depends on good access to water, and thus, there may be complementarities between PIRT and infrastructure. In these estimations, Y_{p1} is the outcome Y for plot level p at time 1 (after treatment) and Y_{p0} the outcome at time 0 (before treatment).

The specifications for PERAT parallel those of PIRT exactly. Synergies are also likely between PERAT and infrastructure, as infrastructure improves access to water, whereas PERAT improves the effectiveness of water use:

$$Y_{p1} - Y_{p0} = a + \beta_1(PERAT) + \beta_2(PIRT) + \gamma(INFR) + \mathbf{X}_p + \varepsilon_p \tag{7}$$

$$Y_{p1} - Y_{p0} = a + \beta_1(PERAT) + \beta_2(PIRT) + \gamma(INFR) + \delta(PERAT^*INFR) + \mathbf{X}_p + \varepsilon_p \tag{8}$$

Table C.1: Time Trend Tests for Infrastructure

	(1) Total Value of Output Per Capita	(2) Total Agro Income Per Capita	(3) Total Agro Costs Per Capita	(4) Total Agro Profit Per Capita	(5) Fruit Production	(6) Industrial Crop Production	(7) Beans Production	(8) Roots Production	(9) Number of Crops	(10) Hire Peon	(11) Work as Manual	(12) Total Expend Per Capita	(13) Total Income Per Capita	(14) Dependent Income Per Capita	(15) Indep Income Per Capita
Time	33.44	35.33	20.32**	17.87	4.31	8.94	25.73*	-0.85	0.01	0.01	-0.01*	17.25**	23.57***	3.16	13.50***
	(20.62)	(19.88)	(7.56)	(14.59)	(4.58)	(17.96)	(12.16)	(0.48)	(0.02)	(0.01)	(0.00)	(5.46)	(5.84)	(1.76)	(3.41)
Treat	1431.84*	1309.82*	751.37**	497.54	92.85	-1997.72	66.82	65.53	0.53	0.16	0.03	300.31*	256.84	-141.25	325.14**
	(609.12)	(569.72)	(258.76)	(313.09)	(71.75)	(2496.98)	(82.90)	(55.65)	(0.42)	(0.18)	(0.10)	(126.60)	(157.08)	(93.61)	(126.68)
Time*Treat	**-27.70**	**-21.10**	**-15.73^**	**-13.67**	**15.78**	**-0.95**	**-24.04**	**-2.52**	**-0.01**	**-0.01**	**0.00**	**-11.25**	**-6.30**	**-1.36**	**-6.74**
	(22.03)	**(23.38)**	**(8.14)**	**(13.03)**	**(20.04)**	**(22.56)**	**(14.31)**	**(3.05)**	**(0.02)**	**(0.01)**	**(0.00)**	**(6.33)**	**(6.81)**	**(1.94)**	**(4.66)**
Constant	1016.98**	902.12***	215.24	776.70**	3.69	2554.56	112.45	56.27***	1.91***	0.41**	0.72***	322.50***	646.55***	231.01**	255.79**
	(298.04)	(240.81)	(114.41)	(224.31)	(12.29)	(2575.64)	(82.88)	(14.18)	(0.37)	(0.15)	(0.10)	(63.43)	(114.38)	(79.67)	(75.80)
Observations	294	312	311	310	310	307	309	310	312	312	312	299	308	312	308
R-squared	0.009	0.010	0.016	0.003	0.055	0.043	0.054	0.030	0.007	0.029	0.021	0.086	0.059	0.072	0.023

Note: ^ p<.12 * p<0.10 ** p<0.05 *** p<0.01.

Table C.2: Baseline Tests for Infrastructure

	(1) Total Value of Output Per Capita	(2) Total Agro Income Per Capita	(3) Total Agro Costs Per Capita	(4) Total Agro Profit Per Capita	(5) Fruit Production	(6) Industrial Crop Production	(7) Beans Production	(8) Roots Production	(9) Number of Crops	(10) Hire Worker	(11) Work as Manual	(12) Total Expend Per Capita	(13) Total Income Per Capita	(14) Dependent Income Per Capita	(15) Indep Income Per Capita
treat	708.38	557.70	435.66	-85.76	314.29	-3238.12	-204.41	26.92*	0.63	0.08	0.03	217.60	137.50	-110.43	147.82
	(1088.82)	(1027.04)	(508.47)	(539.32)	(351.86)	(2037.22)	(197.72)	(12.46)	(0.54)	(0.11)	(0.11)	(122.72)	(206.69)	(88.98)	(146.01)
HH Head Gender	1033.02	1005.03	327.36	647.60	353.11	1365.17	141.84*	50.55*	0.40**	-0.11	0.08	-178.50	-37.74	-2.12	188.17
	(651.82)	(725.84)	(303.59)	(479.41)	(326.26)	(795.84)	(68.72)	(25.03)	(0.13)	(0.16)	(0.06)	(124.51)	(264.21)	(63.29)	(202.56)
HH Head Age	99.04	89.79	31.30	43.65	53.46*	43.54	-3.23	1.67	0.13	-0.03	0.01	12.38	40.65	4.85	32.17
	(242.55)	(204.49)	(79.94)	(113.83)	(24.98)	(92.93)	(15.12)	(3.33)	(0.14)	(0.02)	(0.02)	(25.94)	(56.40)	(6.16)	(38.72)
HH Head Age2	-0.75	-0.54	-0.18	-0.23	-0.57^	0.02	0.01	-0.00	-0.00	0.00	-0.00	-0.05	-0.26	-0.04	-0.22
	(1.94)	(1.60)	(0.64)	(0.86)	(0.30)	(0.71)	(0.12)	(0.04)	(0.00)	(0.00)	(0.00)	(0.24)	(0.47)	(0.06)	(0.30)
HH Head Educ	-40.23	-42.54	30.29	-69.00	-31.42	-6.86	3.30	4.41	0.01	-0.00	-0.02**	42.60**	30.59	11.58^	2.99
	(181.39)	(169.15)	(70.59)	(98.08)	(52.97)	(92.19)	(6.55)	(3.06)	(0.02)	(0.01)	(0.01)	(15.87)	(40.53)	(6.31)	(26.37)
HH Members	-212.72*	-162.76	-70.96	-75.08	-55.42	376.67	25.65	4.93	-0.01	0.00	0.01	-50.65***	-93.10***	16.50*	-55.64**
	(95.38)	(111.55)	(50.23)	(90.34)	(58.85)	(247.89)	(14.69)	(6.63)	(0.07)	(0.01)	(0.01)	(10.95)	(15.67)	(6.89)	(15.02)
Distance to Infra	-52.79	-59.17	-17.21	-51.65	25.18	-90.69	42.58	0.64	0.03	0.03	-0.02**	29.14**	36.56*	12.46**	5.01
	(96.71)	(103.70)	(52.74)	(70.26)	(23.63)	(86.99)	(26.65)	(2.36)	(0.02)	(0.02)	(0.01)	(9.55)	(16.77)	(3.86)	(13.30)
River Flow	-23.14	-32.80	-7.87	-21.88	9.61	49.15	-3.34	-1.01**	-0.01	0.00	-0.00	0.48	-0.19	3.22***	-3.90
	(45.98)	(48.18)	(17.60)	(31.05)	(8.62)	(36.56)	(3.56)	(0.30)	(0.01)	(0.00)	(0.00)	(2.69)	(9.16)	(0.57)	(8.13)
Constant	58.27	21.27	-306.17	811.04	-1375.91*	-2414.79	66.55	-123.50	-1.88	1.08**	0.77	-40.73	-331.19	-219.17	-388.86
	(5735.28)	(4760.89)	(1895.99)	(2716.06)	(701.90)	(3277.58)	(630.51)	(83.46)	(3.13)	(0.41)	(0.72)	(680.48)	(1709.98)	(184.77)	(1067.12)
Observations	263	274	273	273	272	270	272	273	274	274	274	262	271	274	271
R-squared	0.045	0.051	0.039	0.056	0.042	0.213	0.085	0.028	0.047	0.088	0.133	0.163	0.067	0.171	0.050

Note: ^ p<.12 * p<0.10 ** p<0.05 *** p<0.01

Table C.3: Specification Tests for Infrastructure Focus

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
	Total Value of Output Per Capita				Hire Peon				Total Expend Per Capita				Total Income Per Capita			
treat	900.49	787.27	1073.66	1044.63	0.00	0.02	0.01	0.02	61.19	-82.91	91.97	92.30	9.86	-214.14	17.37	-14.38
	(877.40)	(1563.57)	(1487.15)	(1444.59)	(0.09)	(0.08)	(0.09)	(0.09)	(53.85)	(125.20)	(115.96)	(94.85)	(134.48)	(300.56)	(261.10)	(242.67)
post	1120.54*	1610.19	1831.23^	1966.95^	-0.09	-0.01	-0.02	-0.05	1292.22***	127.15	214.87*	213.32	2483.71***	137.74	258.25	404.86
	(503.02)	(999.93)	(996.02)	(1037.96)	(0.12)	(0.19)	(0.20)	(0.20)	(258.71)	(116.78)	(99.99)	(120.26)	(471.98)	(274.35)	(264.63)	(321.53)
post_treat	-1232.46**	-1571.03	-1735.98	-1704.23	0.19	0.28**	0.28**	0.27**	7.86	-13.42	-115.38	-115.74	-68.15	-126.01	-252.87	-218.84
	(485.63)	(1350.94)	(1208.43)	(1183.40)	(0.15)	(0.10)	(0.10)	(0.10)	(194.51)	(188.32)	(139.14)	(158.15)	(388.08)	(389.65)	(315.59)	(308.80)
PIRT/PERAT				-365.77				0.09				4.17				-394.23
				(780.44)				(0.08)				(315.94)				(535.42)
Distance to Infra		-89.44	-56.18	-62.90		0.01	0.01	0.02		-28.31^	-16.40	-16.32		-55.66**	-31.53	-38.64
		(52.84)	(59.94)	(58.12)		(0.01)	(0.01)	(0.01)		(14.96)	(16.99)	(12.17)		(20.75)	(24.57)	(22.19)
River Flow		-22.68	-22.30	-22.02		0.00	0.00	0.00		0.55	0.56	0.56		3.57	2.91	3.23
		(32.53)	(36.28)	(36.16)		(0.00)	(0.00)	(0.00)		(2.39)	(3.91)	(3.88)		(8.36)	(11.32)	(11.14)
HH Head Gender			488.79	470.88			-0.08	-0.07			-173.07	-172.88			-201.48	-210.89
			(425.78)	(423.23)			(0.10)	(0.10)			(129.68)	(124.06)			(325.49)	(329.04)
HH Head Age			185.29	184.98			-0.01	-0.01			47.47^	47.48^			97.85*	97.45*
			(162.28)	(163.12)			(0.01)	(0.01)			(24.95)	(25.06)			(42.05)	(43.87)
HH Head Age2			-1.36	-1.35			0.00	0.00			-0.35	-0.35			-0.62	-0.61
			(1.33)	(1.34)			(0.00)	(0.00)			(0.23)	(0.23)			(0.38)	(0.40)
HH Head Educ			78.16	80.17			0.00	0.00			58.64***	58.61***			87.20*	88.90*
			(106.75)	(107.09)			(0.01)	(0.01)			(14.89)	(14.24)			(42.53)	(42.74)
HH Members			-320.54**	-319.01**			0.01	0.01			-90.45**	-90.46**			-194.14**	-192.55**
			(104.16)	(101.43)			(0.01)	(0.01)			(34.03)	(33.85)			(65.68)	(64.07)
Year Fixed Effects		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes
Constant	1601.62***	1838.01	-1981.83	-1925.62	0.58***	0.64**	0.54	0.54	607.88***	825.42***	382.90	382.91	1036.59***	1257.26***	-1656.12	-1600.84
	(426.24)	(2076.48)	(5279.94)	(5299.32)	(0.09)	(0.19)	(0.44)	(0.43)	(54.61)	(157.51)	(543.49)	(542.59)	(153.29)	(277.00)	(1244.86)	(1297.22)
Observations	662	632	631	631	680	643	642	642	661	625	624	624	668	632	631	631
R-squared	0.005	0.041	0.103	0.103	0.014	0.114	0.120	0.122	0.357	0.453	0.546	0.546	0.242	0.337	0.422	0.423

Note: ^ p<.12 * p<0.10 ** p<0.05 *** p<0.01.

Table C.4: Infrastructure Focus Using ENAHO Data

	(1) Total Value of Output Per Capita	(2) Total Agro Income Per Capita	(3) Total Agro Costs Per Capita	(4) Total Agro Profit Per Capita	(5) Fruit Production	(6) Industrial Crop Production	(7) Beans Production	(8) Roots Production	(9) Number of Crops	(10) Hire Worker	(11) Work as Manual	(12) Total Expend Per Capita	(13) Total Income Per Capita	(14) Dependent Income Per Capita	(15) Indep Income Per Capita
treat	1044.63	1076.66	610.60	319.45	234.76	-2691.90	-308.14	8.44	0.44	0.02	0.08	92.30	-14.38	-146.71	121.73
	(1444.59)	(1436.89)	(588.89)	(862.39)	(253.37)	(1856.17)	(174.96)	(10.55)	(0.25)	(0.09)	(0.09)	(94.85)	(242.67)	(82.72)	(212.14)
post	1966.95^	2045.68^	943.27	1022.26	-527.81	-134.26	-974.48**	-34.36**	-0.30	-0.05	0.21**	213.32	404.86	38.52	696.62***
	(1037.96)	(1120.89)	(554.37)	(740.91)	(409.47)	(1368.46)	(319.66)	(13.35)	(0.32)	(0.20)	(0.07)	(120.26)	(321.53)	(50.70)	(175.64)
post_treat	-1704.23	-1661.22	-826.36	-433.95	-102.73	1669.48	374.92*	21.49	-0.35	0.27**	-0.18	-115.74	-218.84	171.60**	-200.22
	(1183.40)	(1173.50)	(525.40)	(717.13)	(180.11)	(1440.46)	(163.38)	(14.88)	(0.41)	(0.10)	(0.14)	(158.15)	(308.80)	(66.60)	(342.38)
PIRT/PERAT	-365.77	-438.37	61.74	-506.12	-508.82	3526.14	279.59	49.24	0.68	0.09	0.12*	4.17	-394.23	107.76	-467.43
	(780.44)	(881.25)	(222.29)	(722.25)	(607.78)	(2031.16)	(269.97)	(41.25)	(0.83)	(0.08)	(0.05)	(315.94)	(535.42)	(120.93)	(415.99)
River Flow	-22.02	-25.62	-7.99	-13.84	13.12	71.12	-3.03	-0.96***	-0.01	0.00	-0.00	0.56	3.23	3.20***	-2.82
	(36.16)	(37.51)	(13.07)	(23.56)	(12.98)	(51.54)	(2.61)	(0.22)	(0.01)	(0.00)	(0.00)	(3.88)	(11.14)	(0.81)	(8.12)
Distance to Infra	-62.90	-62.25	-18.67	-42.62	-19.38	-88.74	15.11	1.63	0.08**	0.02	-0.01**	-16.32	-38.64	5.95	-29.96*
	(58.12)	(64.13)	(32.37)	(36.16)	(35.18)	(91.12)	(16.89)	(1.04)	(0.02)	(0.01)	(0.00)	(12.17)	(22.19)	(5.32)	(13.79)
HH Head Gender	470.88	606.80^	214.14*	338.37	319.12	579.63	-506.50	17.52	0.41	-0.07	0.20**	-172.88	-210.89	17.49	240.87
	(423.23)	(333.65)	(89.69)	(296.75)	(261.96)	(431.37)	(523.95)	(20.97)	(0.25)	(0.10)	(0.08)	(124.06)	(329.04)	(62.67)	(250.74)
HH Head Age	184.98	139.94	51.07	92.84	56.11	49.88	4.68	2.12	0.08	-0.01	0.02	47.48^	97.45*	15.98	66.37**
	(163.12)	(162.78)	(54.32)	(99.22)	(36.35)	(70.06)	(9.78)	(2.13)	(0.09)	(0.01)	(0.01)	(25.06)	(43.87)	(13.22)	(21.75)
HH Head Age2	-1.35	-0.91	-0.36	-0.62	-0.53	-0.17	-0.07	-0.01	-0.00	0.00	-0.00*	-0.35	-0.61	-0.17	-0.49**
	(1.34)	(1.34)	(0.46)	(0.80)	(0.40)	(0.59)	(0.08)	(0.03)	(0.00)	(0.00)	(0.00)	(0.23)	(0.40)	(0.12)	(0.18)
HH Head Educ	80.17	49.67	48.45	10.94	-20.50	-18.29	22.52***	1.89	-0.04**	0.00	-0.02**	58.61***	88.90*	5.12	33.94
	(107.09)	(98.53)	(42.41)	(60.94)	(43.41)	(78.02)	(4.91)	(1.92)	(0.01)	(0.01)	(0.01)	(14.24)	(42.74)	(8.50)	(21.68)
HH Members	-319.01**	-257.77**	-91.83**	-145.93*	-75.32	206.46	7.36	0.33	0.01	0.01	0.01	-90.46**	-192.55**	26.66***	-118.09*
	(101.43)	(89.29)	(36.04)	(66.24)	(56.74)	(137.82)	(20.16)	(4.70)	(0.05)	(0.01)	(0.01)	(33.85)	(64.07)	(6.53)	(49.73)
Constant	-1925.62	-1189.82	-1287.13	-832.65	-1350.36^	-1398.61	1052.01	-68.89	-1.99	0.54	0.70*	382.91	-1600.84	-444.71	-1150.21
	(5299.32)	(5354.73)	(1567.38)	(3318.80)	(715.16)	(2373.69)	(648.66)	(66.47)	(2.08)	(0.43)	(0.34)	(542.59)	(1297.22)	(398.93)	(950.34)
Observations	631	589	641	585	633	636	638	637	637	642	642	624	631	630	632
R-squared	0.103	0.098	0.109	0.125	0.074	0.229	0.086	0.043	0.119	0.122	0.173	0.546	0.423	0.218	0.255

Note: ^ p<.12 * p<0.10 ** p<0.05 *** p<0.01.

Table C.5: Infrastructure Focus using ENAHO Data: Poor and Nonpoor Segmentation (Agricultural Outcomes)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
	Total Value of Output Per Capita		Total Agro Income Per Capita		Total Agro Costs Per Capita		Total Agro Profit Per Capita		Fruit Production		Industrial Crop Production		Beans Production		Roots Production		Number of Crops	
	Poor	Not Poor	Poor	Not Poor	Poor	Not Poor	Poor	Not Poor	Poor	Not Poor	Poor	Not Poor	Poor	Not Poor	Poor	Not Poor	Poor	Not Poor
treat	-424.11	1991.84	-492.44*	2183.98	137.05	980.33	-637.93*	994.81	352.70	45.01	-297.24	-5257.54*	-264.43***	-282.24	-47.88**	32.28	-0.11	0.70*
	(287.71)	(2638.83)	(241.12)	(2722.36)	(102.83)	(1021.44)	(284.24)	(1740.80)	(389.81)	(262.45)	(1079.61)	(2351.58)	(69.14)	(244.45)	(19.34)	(20.94)	(0.26)	(0.33)
post	-215.46	3063.87	-203.70	3414.38	163.71	1261.84	-353.61	2044.06	-595.33	-311.80	-195.55	-842.53	-556.50	-1334.12**	-101.50***	15.13	-0.67^	-0.07
	(584.93)	(2022.14)	(553.15)	(2080.04)	(272.32)	(943.80)	(401.89)	(1348.72)	(471.23)	(341.46)	(1067.84)	(1501.79)	(366.68)	(438.04)	(20.29)	(27.54)	(0.36)	(0.44)
post_treat	713.12	-3090.28	769.80	-3398.40	-11.47	-1452.27	760.69	-1241.88	-303.68	335.68	1031.13	3152.47*	257.77*	410.07	67.35**	-4.01	0.05	-0.16
	(464.00)	(2136.53)	(493.64)	(2347.89)	(116.42)	(1028.76)	(427.19)	(1591.48)	(287.63)	(454.85)	(1036.01)	(1613.41)	(109.43)	(231.66)	(19.87)	(44.66)	(0.71)	(0.57)
PIRT/PERAT	143.75	-1086.18	220.95	-1523.56	64.85	-70.36	139.85	-1453.30	170.27***	-1231.52	1982.19	4241.38**	256.03	253.17	104.88*	22.19	1.05	0.63
	(181.17)	(1147.26)	(190.81)	(1154.32)	(130.17)	(279.95)	(119.15)	(965.83)	(45.16)	(1154.90)	(1728.35)	(1633.08)	(170.04)	(475.08)	(46.69)	(27.12)	(0.75)	(0.75)
River Flow	-31.42**	-13.53	-29.87**	-23.43	-5.65	-7.25	-24.10***	-12.93	22.01	12.66	17.74	88.40**	-1.24	-3.18	-3.03**	-0.03	0.02	-0.01
	(10.17)	(61.48)	(10.37)	(60.05)	(4.78)	(20.16)	(6.50)	(40.44)	(29.19)	(11.99)	(15.42)	(34.76)	(3.65)	(3.40)	(0.92)	(0.41)	(0.02)	(0.01)
Distance to Infra	22.62	-119.17	20.84	-123.92	3.88	-36.66	15.98	-95.17*	0.18	-42.14	53.67*	-218.77^	12.03	21.11	0.45	1.36	0.05	0.14**
	(26.18)	(84.82)	(25.17)	(90.35)	(8.52)	(54.26)	(19.08)	(47.49)	(15.06)	(75.42)	(25.27)	(116.62)	(15.00)	(14.32)	(0.89)	(2.27)	(0.04)	(0.04)
HH Head Gender	-267.21	1632.94	-342.00	2051.49*	-37.94	574.96**	-301.86	1319.69	168.94	634.83	1321.57^	-153.70	185.85*	-807.52	-34.07	41.54*	0.06	0.68^
	(461.07)	(1316.56)	(453.41)	(997.81)	(97.42)	(161.64)	(426.26)	(887.72)	(190.57)	(521.64)	(698.83)	(734.73)	(91.80)	(880.32)	(33.79)	(20.22)	(0.56)	(0.36)
HH Head Age	21.67	153.68	25.94	76.50	23.28	4.78	0.09	79.94	43.40	55.69	-37.63	89.16	-33.50	0.81	1.54	4.12^	-0.09	0.21*
	(36.26)	(258.97)	(42.90)	(230.98)	(13.50)	(82.36)	(37.36)	(143.08)	(34.16)	(34.37)	(54.36)	(71.19)	(21.43)	(24.62)	(1.77)	(2.27)	(0.08)	(0.09)
HH Head Age2	-0.19	-1.21	-0.22	-0.51	-0.19	-0.05	-0.01	-0.57	-0.44	-0.56	0.52	-0.57	0.32^	-0.05	-0.02	-0.02	0.00	-0.00^
	(0.35)	(2.06)	(0.39)	(1.83)	(0.12)	(0.68)	(0.33)	(1.11)	(0.36)	(0.38)	(0.55)	(0.59)	(0.18)	(0.18)	(0.01)	(0.02)	(0.00)	(0.00)
HH Head Educ	34.39	-34.40	34.04*	-113.95	25.89**	-2.03	6.68	-91.39	-24.48	-33.05	-0.81	-110.24	-3.94	28.85*	-0.04	1.34	-0.02	-0.09
	(20.82)	(166.66)	(17.50)	(157.04)	(9.86)	(64.47)	(14.42)	(97.48)	(42.60)	(52.80)	(41.30)	(111.59)	(3.55)	(13.83)	(1.53)	(3.18)	(0.06)	(0.05)
HH Members	-28.78	-281.57	-27.05	-117.95	-2.08	-48.92	-24.95	-30.07	-48.41	-67.44	249.21	349.46^	28.05^	21.47	-1.51	-1.03	0.04	-0.03
	(37.76)	(356.77)	(32.70)	(394.48)	(10.73)	(137.55)	(25.92)	(293.79)	(48.13)	(48.95)	(161.59)	(196.00)	(15.31)	(24.56)	(1.21)	(10.17)	(0.07)	(0.08)
Constant	2441.24	-3014.18	2376.67	214.65	-485.50	178.93	2421.01*	-3674.74	-1591.68	-1244.93	-2252.08	434.58	966.64	1661.60	227.40	-210.70**	4.31*	-5.57**
	(1459.07)	(6577.17)	(1539.28)	(6564.61)	(461.30)	(2183.29)	(1233.67)	(3648.07)	(1213.40)	(1242.76)	(2102.19)	(3726.10)	(574.29)	(1234.68)	(162.25)	(70.78)	(1.96)	(1.88)
Observations	321	310	311	278	326	315	311	274	325	308	325	311	325	313	325	312	322	315
R-squared	0.218	0.088	0.220	0.113	0.217	0.122	0.240	0.163	0.137	0.095	0.162	0.351	0.091	0.134	0.141	0.049	0.182	0.220

Note: ^ p<.12 * p<0.10 ** p<0.05 *** p<0.01.

Table C.6: Infrastructure Focus Using ENAHO Data: Poor and Nonpoor Segmentation (Welfare Outcomes)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Hire Worker		Work as Manual		Total Expend Per Capita		Total Income Per Capita		Dependent Income Per Capita		Indep Income Per Capita	
	Poor	Not Poor	Poor	Not Poor	Poor	Not Poor	Poor	Not Poor	Poor	Not Poor	Poor	Not Poor
treat	0.20^	-0.09	0.20^	0.06	-11.84	64.05	-168.71	-174.86	-116.71	-128.12	-185.00**	159.97
	(0.10)	(0.15)	(0.11)	(0.11)	(32.03)	(126.31)	(177.79)	(515.90)	(120.81)	(72.04)	(54.48)	(472.66)
post	0.27	-0.25	0.20	0.23**	41.64	143.60	-172.74	547.87	-20.63	74.43	149.96	865.01**
	(0.19)	(0.16)	(0.13)	(0.08)	(113.31)	(207.98)	(244.38)	(614.98)	(109.45)	(158.55)	(275.14)	(324.49)
post_treat	0.16**	0.33*	-0.32***	-0.07	-27.07	-107.12	343.15	-361.16	152.77	107.99	219.38*	-258.50
	(0.06)	(0.14)	(0.04)	(0.16)	(96.56)	(200.23)	(195.07)	(586.50)	(182.74)	(98.94)	(98.94)	(496.82)
PIRT/PERAT	0.03	0.08	0.10	0.11	14.16	-152.49	-49.96	-863.87	2.69	226.44*	-251.54	-792.54
	(0.13)	(0.07)	(0.06)	(0.09)	(71.50)	(365.40)	(152.33)	(785.99)	(105.16)	(114.04)	(183.25)	(523.52)
River Flow	-0.00	0.00	0.01^	-0.00	-1.06	3.08	-11.53*	14.59	2.14	1.67	-7.65**	3.90
	(0.00)	(0.00)	(0.00)	(0.00)	(1.21)	(4.36)	(4.76)	(13.89)	(1.33)	(1.53)	(2.67)	(12.19)
Distance to Infra	0.02**	0.02	-0.00	-0.02*	-8.34*	-12.92	0.69	-57.71^	-6.54	20.69**	-0.93	-47.72**
	(0.00)	(0.01)	(0.01)	(0.01)	(3.44)	(8.44)	(9.92)	(30.39)	(6.99)	(8.25)	(9.51)	(17.04)
HH Head Gender	-0.10	0.07	0.21**	0.21**	-40.31	-9.07	-683.98**	574.57	102.46	-46.82	-83.67	813.47
	(0.06)	(0.16)	(0.07)	(0.07)	(84.38)	(247.74)	(241.46)	(772.44)	(81.02)	(132.38)	(263.97)	(502.35)
HH Head Age	-0.03*	-0.00	0.03**	0.01	14.03*	29.63	73.98***	72.94	32.72**	-1.46	11.99^	70.68*
	(0.01)	(0.02)	(0.01)	(0.02)	(6.91)	(28.18)	(11.79)	(62.53)	(11.28)	(6.18)	(6.34)	(35.53)
HH Head Age2	0.00**	0.00	-0.00**	-0.00	-0.14*	-0.21	-0.59***	-0.40	-0.31**	-0.02	-0.09	-0.57*
	(0.00)	(0.00)	(0.00)	(0.00)	(0.07)	(0.27)	(0.12)	(0.55)	(0.10)	(0.06)	(0.06)	(0.28)
HH Head Educ	0.01	-0.01	-0.01	-0.02^	1.62	51.12**	48.19**	64.13	-8.67	6.31	8.70	8.05
	(0.01)	(0.01)	(0.01)	(0.01)	(6.88)	(18.31)	(15.44)	(74.38)	(9.93)	(10.70)	(7.40)	(34.46)
HH Members	0.01	0.01	0.00	0.01	-8.99^	-76.36	-29.46	-251.30^	5.92	54.32**	10.37	-164.88
	(0.01)	(0.01)	(0.01)	(0.02)	(4.81)	(56.08)	(17.15)	(131.75)	(7.91)	(21.20)	(23.77)	(97.24)
Constant	0.72	0.57	0.03	0.88	175.65	1167.01	-471.37	-1693.71	-373.35	-42.95	499.48	-516.08
	(0.67)	(0.65)	(0.31)	(0.55)	(172.18)	(751.29)	(571.65)	(1666.13)	(331.73)	(222.60)	(364.40)	(909.79)
Observations	326	316	326	316	315	309	322	309	323	307	323	309
R-squared	0.142	0.242	0.236	0.168	0.746	0.634	0.534	0.466	0.245	0.262	0.270	0.290

Note: ^ p<.12 * p<0.10 ** p<0.05 *** p<0.01.

Table C.7: PIRT Focus Using ENAPROVE Data

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Change in Total Value of Production		Change in Productivity		Change in Proportion of Production Sold		Change in Probability of Export Crop		Change in Probability of Permanent Crop		Change in Proportion of Land Cultivated	
PIRT Commission	1820.92	-1335.55	67.79	-522.61	0.12***	0.11***	0.02	0.02	0.15**	0.09	0.16	0.01
	(5144.29)	(6165.33)	(819.07)	(967.35)	(0.04)	(0.04)	(0.03)	(0.03)	(0.07)	(0.07)	(0.13)	(0.14)
PERAT Commission	-12499.79**	-11389.10*	-1082.13	-874.38	0.05	0.05	-0.02	-0.02	-0.18**	-0.16*	-0.21	-0.16
	(5761.21)	(6103.22)	(839.94)	(902.00)	(0.04)	(0.04)	(0.04)	(0.04)	(0.09)	(0.10)	(0.16)	(0.17)
Infrastructure	4678.50	-5700.15*	527.02	-1414.26**	0.03	0.02	0.05	0.04	0.15	-0.04	0.06	-0.43***
	(5636.31)	(3135.44)	(816.77)	(549.64)	(0.07)	(0.04)	(0.04)	(0.03)	(0.10)	(0.08)	(0.16)	(0.12)
PIRT Commission		15151.75*		2834.07*		0.01		0.02		0.28^		0.71**
*Infra		(9064.35)		(1497.46)		(0.14)		(0.07)		(0.18)		(0.29)
Hectares	1056.87*	1059.89*	-58.65	-58.08	0.01*	0.01*	-0.00	-0.00	0.01**	0.01**	-0.01	-0.01
	(599.13)	(593.81)	(57.64)	(56.09)	(0.01)	(0.01)	(0.00)	(0.00)	(0.01)	(0.00)	(0.01)	(0.01)
Hectares^2	-28.34^	-28.59*	0.51	0.46	-0.00	-0.00	0.00	0.00	-0.00	-0.00	0.00	0.00
	(17.22)	(17.29)	(1.55)	(1.53)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
North	-3673.01	-5590.09	-440.69	-799.27	0.22***	0.22***	-0.01	-0.02	0.09	0.05	0.12	0.03
	(8035.69)	(8557.15)	(1408.82)	(1452.84)	(0.07)	(0.07)	(0.04)	(0.04)	(0.11)	(0.11)	(0.20)	(0.20)
South	4668.73	4682.87	-193.84	-191.20	0.38***	0.38***	0.09*	0.09*	0.30***	0.30***	-0.01	-0.01
	(8270.04)	(8061.87)	(1507.05)	(1466.32)	(0.06)	(0.06)	(0.05)	(0.05)	(0.11)	(0.11)	(0.25)	(0.24)
Constant	4248.30	6319.34	2212.93*	2600.30**	-0.35***	-0.35***	-0.01	-0.00	0.00	0.04	0.12	0.22
	(6599.25)	(6825.91)	(1229.27)	(1216.94)	(0.06)	(0.06)	(0.03)	(0.03)	(0.09)	(0.09)	(0.18)	(0.17)
Observations	9546	9546	9546	9546	3342	3342	9546	9546	9546	9546	9546	9546
R-squared	0.040	0.044	0.020	0.028	0.099	0.099	0.023	0.023	0.093	0.100	0.053	0.086

Note: ^ p<.12 * p<0.10 ** p<0.05 *** p<0.01.

Table C.8: PERAT Focus Using ENAPROVE Data

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Change in Total Value of Production		Change in Productivity		Change in Proportion of Production Sold		Change in Probability of Export Crop		Change in Probability of Permanent Crop		Change in Proportion of Land Cultivated	
PERAT Commission	313.02	2051.83	490.57^	722.38**	0.08*	0.04	0.07*	0.08*	0.05	0.08	0.00	0.05
	(1759.23)	(1842.29)	(301.99)	(311.06)	(0.04)	(0.05)	(0.04)	(0.05)	(0.05)	(0.06)	(0.08)	(0.09)
PIRT Commission	2306.94	1724.68	505.26	427.63	0.13***	0.14***	-0.01	-0.01	0.19**	0.18**	0.32**	0.30**
	(3875.71)	(3395.83)	(599.81)	(551.85)	(0.05)	(0.05)	(0.03)	(0.03)	(0.10)	(0.09)	(0.15)	(0.14)
Infrastructure	-6489.73***	1770.97	-1183.69***	-82.38	0.00	-0.11*	0.02	0.07	-0.06	0.07	-0.34***	-0.10
	(1611.75)	(3560.19)	(293.36)	(736.70)	(0.04)	(0.07)	(0.02)	(0.06)	(0.05)	(0.10)	(0.09)	(0.14)
PERAT Commission*In		-10361.43**		-1381.37*		0.15*		-0.07		-0.16		-0.31*
		(4067.57)		(798.00)		(0.08)		(0.06)		(0.12)		(0.17)
Hectares	-917.29***	-893.60***	-126.20***	-123.04***	-0.00	-0.00	-0.01***	-0.01***	-0.02***	-0.02***	-0.03***	-0.03***
	(318.60)	(318.38)	(25.56)	(25.72)	(0.01)	(0.01)	(0.00)	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)
Hectares^2	16.04*	15.53^	2.89***	2.83***	-0.00	-0.00	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***
	(9.65)	(9.62)	(0.65)	(0.66)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
North	-29794.68***	-30072.90***	-6754.39***	-6791.48***	0.18	0.21*	-0.16***	-0.16***	-0.31***	-0.31***	-0.72***	-0.73***
	(2010.53)	(1860.82)	(665.77)	(616.70)	(0.12)	(0.12)	(0.04)	(0.03)	(0.06)	(0.06)	(0.12)	(0.11)
South	-18685.80***	-18808.64***	-5592.56***	-5608.94***	0.39***	0.41***	-0.00	-0.00	-0.12**	-0.12**	-0.84***	-0.84***
	(2911.21)	(2757.36)	(738.88)	(691.31)	(0.12)	(0.12)	(0.04)	(0.03)	(0.06)	(0.06)	(0.16)	(0.15)
Constant	30472.08***	29420.95***	6918.20***	6778.07***	-0.27**	-0.27**	0.09***	0.08***	0.37***	0.36***	0.80***	0.77***
	(2078.74)	(2168.98)	(648.63)	(606.98)	(0.12)	(0.12)	(0.03)	(0.03)	(0.05)	(0.05)	(0.12)	(0.11)
Observations	7910	7910	7910	7910	2427	2427	7910	7910	7910	7910	7910	7910
R-squared	0.096	0.099	0.147	0.149	0.035	0.037	0.054	0.055	0.069	0.072	0.189	0.195

Note: ^ p<.12 * p<0.10 ** p<0.05 *** p<0.01.

Table C.9: PIRT Focus Using ENAPROVE Data: Poor and Nonpoor Segmentation

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)
	Change in Total Value of Production				Change in Productivity				Change in Proportion of Production Sold				Change in Probability of Export Crop				Change in Probability of Permanent Crop				Change in Proportion of Land Cultivated			
	Poor		Not Poor		Poor		Not Poor		Poor		Not Poor		Poor		Not Poor		Poor		Not Poor		Poor		Not Poor	
PIRT Commission	1309.28	570.17	-3424.61*	-3920.91	87.48	192.54	-628.94**	-737.12*	-0.05	-0.06	0.11**	0.07*	-0.01	-0.01	0.03	0.04	0.08*	0.11**	0.14***	0.16***	0.17***	0.15***	0.14***	0.10
	(2265.15)	(3617.21)	(1948.51)	(2884.18)	(203.86)	(242.64)	(308.73)	(383.91)	(0.07)	(0.06)	(0.04)	(0.04)	(0.02)	(0.02)	(0.02)	(0.03)	(0.04)	(0.05)	(0.05)	(0.06)	(0.05)	(0.06)	(0.05)	(0.07)
PERAT Commission	2542.18	2713.22	11504.82***	11622.43***	510.06*	485.74^	1216.95***	1242.58***	0.05	0.05	0.03	0.04	0.05**	0.05**	0.06*	0.06*	0.16***	0.15***	0.11*	0.10^	0.09	0.10^	0.07	0.08^
	(2639.49)	(2878.64)	(2446.22)	(2441.69)	(305.86)	(297.76)	(321.70)	(341.08)	(0.08)	(0.08)	(0.04)	(0.03)	(0.02)	(0.02)	(0.03)	(0.03)	(0.04)	(0.03)	(0.06)	(0.06)	(0.06)	(0.06)	(0.05)	(0.05)
Infrastructure	-1153.59	-3569.45	-7695.90**	-8849.25***	-661.58***	-318.17	-727.56**	-978.97***	0.09	0.08	0.13**	0.03	0.01	0.02	0.04	0.06*	-0.12***	-0.03	-0.10**	-0.04	-0.16***	-0.23***	-0.16***	-0.27***
	(4002.81)	(2787.68)	(3287.78)	(2674.51)	(166.81)	(287.54)	(300.82)	(351.23)	(0.15)	(0.07)	(0.05)	(0.04)	(0.02)	(0.02)	(0.02)	(0.03)	(0.03)	(0.08)	(0.04)	(0.07)	(0.05)	(0.07)	(0.06)	(0.07)
PIRT Commission		3500.76		2031.41		-497.62^		442.81		0.02		0.21**		-0.01		-0.05		-0.12		-0.10		0.10		0.19*
*Infra		(7322.75)		(5638.90)		(317.84)		(555.91)		(0.39)		(0.09)		(0.03)		(0.03)		(0.09)		(0.08)		(0.08)		(0.11)
Hectares	-608.01*	-612.89*	-2253.21***	-2252.38***	38.27	38.97	-77.57*	-77.39*	0.02*	0.02*	0.02*	0.01^	-0.00	-0.00	-0.01*	-0.01*	0.01	0.01	-0.00	-0.00	-0.00	-0.00	0.01	0.01
	(347.09)	(349.95)	(543.27)	(545.59)	(100.26)	(100.22)	(42.53)	(42.50)	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)	(0.01)	(0.01)
Hectares^2	5.06	5.15	49.70***	49.60***	-0.99	-1.00	2.49**	2.47**	-0.00	-0.00	-0.00**	-0.00**	0.00	0.00	0.00*	0.00*	0.00	0.00	0.00**	0.00**	0.00	0.00	0.00	0.00
	(17.56)	(17.42)	(17.06)	(17.28)	(2.41)	(2.40)	(1.09)	(1.08)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
North	-7296.73	-7747.45	-8713.87**	-9064.96**	3014.69	3078.75	-700.93	-777.46	-0.16	-0.16	0.02	-0.00	0.00	0.00	-0.07	-0.06	-0.01	0.01	0.01	0.03	-0.07	-0.08	0.15*	0.11
	(8849.74)	(9273.95)	(4097.90)	(4231.30)	(3076.64)	(3068.74)	(558.60)	(576.84)	(0.11)	(0.11)	(0.06)	(0.06)	(0.15)	(0.15)	(0.05)	(0.05)	(0.11)	(0.11)	(0.07)	(0.08)	(0.10)	(0.10)	(0.08)	(0.09)
South	6927.53	6823.36	6572.43*	6479.58*	3264.89	3279.70	307.75	287.51	-0.02	-0.03	0.23***	0.22***	0.08	0.08	0.04	0.04	0.38***	0.38***	0.43***	0.43***	-0.25***	-0.25***	-0.01	-0.02
	(7849.92)	(7859.22)	(3844.12)	(3819.51)	(3062.66)	(3059.28)	(554.35)	(563.57)	(0.09)	(0.09)	(0.05)	(0.05)	(0.14)	(0.14)	(0.05)	(0.05)	(0.10)	(0.10)	(0.08)	(0.08)	(0.10)	(0.10)	(0.06)	(0.06)
Constant	-1731.37	-1051.13	4291.37	4705.48	-4081.90	-4178.60	-551.38	-461.12	0.47***	0.47***	-0.43***	-0.40***	-0.06	-0.06	-0.03	-0.04	-0.21*	-0.23*	-0.18***	-0.20***	-0.27**	-0.25*	-0.50***	-0.46***
	(8834.23)	(9520.01)	(3553.67)	(3894.72)	(3270.75)	(3262.98)	(502.56)	(539.47)	(0.09)	(0.08)	(0.07)	(0.06)	(0.15)	(0.14)	(0.04)	(0.04)	(0.12)	(0.12)	(0.06)	(0.07)	(0.13)	(0.13)	(0.07)	(0.07)
Observations	2207	2207	4067	4067	2207	2207	4067	4067	1044	1044	2298	2298	2207	2207	4067	4067	2207	2207	4067	4067	2207	2207	4067	4067
R-squared	0.078	0.079	0.098	0.098	0.045	0.046	0.022	0.023	0.050	0.051	0.096	0.101	0.030	0.030	0.037	0.038	0.217	0.219	0.227	0.228	0.129	0.131	0.079	0.085

Note: ^ p<.12 * p<0.10 ** p<0.05 *** p<0.01.

Table C.10: PERAT Focus Using ENAPROVE Data: Poor and Nonpoor Segmentation

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)
	Change in Total Value of Production				Change in Productivity				Change in Proportion of Production Sold				Change in Probability of Export Crop				Change in Probability of Permanent Crop				Change in Proportion of Land Cultivated			
	Poor		Not Poor		Poor		Not Poor		Poor		Not Poor		Poor		Not Poor		Poor		Not Poor		Poor		Not Poor	
PERAT Commission	4067.31**	4205.33*	3450.32**	4452.57**	709.69**	776.58***	789.74***	828.47***	-0.01	-0.01	0.04	0.03	0.08	0.08	0.09	0.10	0.14**	0.14**	0.13^	0.13	-0.01	-0.01	-0.01	-0.00
	(2047.22)	(2133.28)	(1592.15)	(2050.38)	(275.48)	(291.70)	(242.98)	(268.51)	(0.04)	(0.04)	(0.03)	(0.04)	(0.05)	(0.06)	(0.07)	(0.09)	(0.06)	(0.06)	(0.08)	(0.10)	(0.06)	(0.06)	(0.05)	(0.05)
PIRT Commission	2101.91	2113.43	6731.74	6565.59	274.54	280.13	333.70	327.28	-0.01	-0.01	0.15***	0.15***	-0.01	-0.01	0.02	0.02	0.14	0.14	0.27**	0.27**	0.26***	0.26***	0.35***	0.35***
	(5394.92)	(5396.22)	(6603.75)	(6358.86)	(317.53)	(314.81)	(460.29)	(451.92)	(0.06)	(0.06)	(0.05)	(0.05)	(0.03)	(0.03)	(0.04)	(0.05)	(0.11)	(0.11)	(0.13)	(0.13)	(0.06)	(0.06)	(0.08)	(0.08)
Infrastructure	-4706.84**	-3085.70	-5286.22***	-1736.81	-501.40*	284.23	-642.01**	-504.86	0.07	0.11	0.05	0.03	0.00	0.06	0.06	0.07	-0.06	-0.01	-0.01	0.00	-0.16**	-0.14*	-0.14**	-0.11**
	(1996.03)	(2288.34)	(1930.70)	(1891.03)	(268.19)	(270.87)	(258.02)	(509.36)	(0.05)	(0.08)	(0.04)	(0.04)	(0.02)	(0.05)	(0.04)	(0.08)	(0.06)	(0.05)	(0.06)	(0.08)	(0.07)	(0.08)	(0.06)	(0.05)
PERAT Commission*In		-1750.72		-4551.47		-848.43**		-175.87		-0.05		0.03		-0.06		-0.02		-0.05		-0.02		-0.03		-0.04
		(2868.52)		(3210.55)		(401.89)		(579.32)		(0.09)		(0.07)		(0.05)		(0.10)		(0.08)		(0.11)		(0.11)		(0.09)
Hectares	-1860.58***	-1861.66***	-1973.68***	-1955.40***	-98.05***	-98.57***	-73.97***	-73.27***	0.01*	0.01*	-0.00	-0.00	-0.01***	-0.01***	-0.01***	-0.01***	-0.01***	-0.01***	-0.02***	-0.02***	-0.01**	-0.01**	-0.00	-0.00
	(477.85)	(478.84)	(241.66)	(238.91)	(31.63)	(31.84)	(27.83)	(27.67)	(0.00)	(0.00)	(0.01)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)	(0.00)
Hectares^2	34.71**	34.74**	31.71***	31.27***	2.42***	2.43***	2.13***	2.12***	-0.00*	-0.00*	0.00	0.00	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***
	(16.57)	(16.60)	(10.60)	(10.54)	(0.79)	(0.80)	(0.71)	(0.70)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
North	-34278.35**	-34194.40**	-22856.11***	-23597.95***	-3677.72	-3637.04	-3963.17***	-3991.83***	-0.16	-0.16	-0.02	-0.01	-0.10*	-0.10*	-0.14*	-0.14*	-0.29*	-0.29*	-0.14*	-0.14*	-0.13	-0.13	-0.14*	-0.15**
	(17142.90)	(17174.38)	(8000.10)	(8068.25)	(2981.44)	(2990.27)	(1023.97)	(1026.62)	(0.11)	(0.11)	(0.10)	(0.10)	(0.06)	(0.05)	(0.08)	(0.09)	(0.17)	(0.17)	(0.07)	(0.08)	(0.20)	(0.20)	(0.07)	(0.08)
South	-29259.71*	-29221.63*	-18011.35**	-18563.45**	-3864.39	-3845.93	-3829.45***	-3850.78***	0.06	0.06	0.16*	0.16*	-0.00	0.00	0.00	0.00	-0.08	-0.08	0.08	0.08	-0.50**	-0.50**	-0.54***	-0.55***
	(17172.24)	(17195.65)	(8214.92)	(8210.68)	(2986.41)	(2993.14)	(1052.47)	(1053.60)	(0.11)	(0.11)	(0.10)	(0.10)	(0.04)	(0.04)	(0.06)	(0.07)	(0.16)	(0.17)	(0.06)	(0.07)	(0.20)	(0.20)	(0.09)	(0.09)
Constant	35284.09**	35111.88**	22966.60***	22902.95***	3167.48	3084.02	2736.57***	2734.11***	0.53***	0.53***	-0.32***	-0.32***	0.04***	0.03**	0.02	0.02	0.21	0.21	0.05	0.05	-0.03	-0.03	-0.10	-0.10
	(17120.70)	(17157.16)	(7449.92)	(7443.65)	(2982.62)	(2992.76)	(976.72)	(976.59)	(0.10)	(0.10)	(0.09)	(0.09)	(0.01)	(0.02)	(0.04)	(0.04)	(0.16)	(0.16)	(0.04)	(0.04)	(0.20)	(0.20)	(0.07)	(0.07)
Observations	1874	1874	3072	3072	1874	1874	3072	3072	835	835	1592	1592	1874	1874	3072	3072	1874	1874	3072	3072	1874	1874	3072	3072
R-squared	0.087	0.087	0.121	0.122	0.021	0.022	0.032	0.032	0.053	0.053	0.038	0.038	0.040	0.041	0.059	0.059	0.070	0.070	0.092	0.092	0.165	0.165	0.194	0.194

Note: ^ p<.12 * p<0.10 ** p<0.05 *** p<0.01.

Table C.11: Crop Results: ENAPROVE Data

Crop	PIRT	PERAT	PIRT and Infrastructure	PERAT and Infrastructure
Rice	-	+	-	+
Cotton	+	+	+	+
Maize	-	+	-	-
Asparagus	+	-	+	+
Sugar Cane	+	-	+	+
Mangoes	-	-	-	-
Grapes	+	+	+	+
Onions	-	+	-	-
Mandarins	-	-	-	-
Oranges	+	-	+	-
Potatoes	-	+	-	-
Tomatoes	-	-	-	-

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Endnotes

Chapter 1

1. The main functions of a WUA are to represent member irrigation commissions before the local water authority and the government; to levy and collect water charges; to ensure the irrigation commissions' compliance with their obligations and to audit their financial accounts; to prepare, implement, and monitor irrigation plans that have been adopted by the General Assembly; and to acquire, operate, and maintain equipment.

2. The original cost estimate was $172 million (World Bank 1996).

3. Informally, there was a third phase due to the El Niño of 1997–98, which postponed the first phase.

4. The PSI was featured in a World Bank technical briefing on water titled "Technical and Institutional Modernization of Irrigated Agriculture: Peru's Irrigation Sub-sector Project and Irrigation" (World Bank 2008a).

Chapter 2

5. The survey uses a three-stage, stratified, rotating sample of 22,000 households (8,800 in the rural areas of the country, 2,300 of which are on the rural coast) and is representative at the urban, rural, and regional levels. The first stage uses the census to derive randomly selected primary sampling units (conglomerates) with probability proportional to size. Once the conglomerates are selected, samples of seven to ten households are selected at random. These households are surveyed over the course of a year, and in the next year seven to ten different households from the same sampling unit are randomly chosen to be surveyed. Although the sampled communities (and households within them) rotate, preventing the creation of household- or community-level panels, districts stay in the sampling units over the course of years, which allowed district panels to be constructed.

6. The sampling framework is composed of all plots in the cadastre, and samples are taken from stratified groups in each valley according to historical production records. The samples are representative for each valley and stratum and can be aggregated at different coastal levels. The survey has a temporal structure, allowing both annual and seasonal data to be captured. The first round of the survey, conducted in 2002, took recall information for the preceding 12 months and thus captured data since 2001. For each valley there were generally two annual survey rounds, and each round would collect information from the point at which it left off in the previous round. Sampling units are cadastre plots that are visited each year, resulting in a panel. From the full sample, 8,564 plots were treated for component A, and 3,112 for component C. Variables and their change over time allow the evaluation to assess whether the program had an impact on variables related to crop selection and productivity.

Chapter 3

7. The three criteria were reaching a minimum water fee collection rate of 75 percent, contracting the services of a technical manager, and proposing an O&M budget.

8. 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.

9. All estimations used the appropriate expansion factors; these are weights that account for the sampling strategy and were calculated by the statistical institute that collected the data. For all estimations the standard errors were clustered by WUA: because outcomes within a cluster are likely to be correlated, it is important to allow for unobserved cluster effects; appendix C presents details on the econometric specifications estimated.

10. Commissions are smaller administrative units of a WUA. They are designated by primary water source.

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11. PIRT beneficiaries were required to pay for 30 percent of the cost of the drip irrigation technology, which means that these beneficiaries were likely to be wealthier or have greater access to savings. PERAT beneficiaries were selected in a more random fashion and thus had characteristics closer to the average.

Chapter 4

12. Complementarities between components are measured by adding a multiplicative term in the econometric specifications. The result represents the additional impact of receiving both components, beyond the components' individual effects.

Appendix B

13. For more information on the CEPES evaluation methodology, see the final report (CEPES 2004).

14. A kernel match with common support was conducted to minimize the propensity score distance of the treated household from its control match.