**Unraveling the Threads of Decentralized Community Irrigation Systems   
on the Welfare of Rural Households in Bolivia**

Cesar Augusto Lopez[[1]](#footnote-1)†, Lina Salazar[[2]](#footnote-2)‡, and Julián Aramburu§

**April 2016**

**ABSTRACT**

*Irrigation is considered a key determinant of agricultural productivity, income and sustainable development in rural areas. This paper aims to estimate the impacts of the first phase of the National Irrigation Program with a Watershed Approach (PRONAREC) on agricultural income, productivity, and food security in rural communities in Bolivia. For this purpose, we use a unique dataset collected from a sample of 1,682 farmers (550 beneficiaries and 1,132 controls) for the agricultural cycle of 2014-2015, with the specific objective of evaluating the effects of the program. To measure program effectiveness, we exploit special features of the program design by comparing two rounds of program participants, in order to control for unobserved heterogeneity. This strategy is combined with a quasi-experimental technique of Propensity Score Matching, to control for program placement bias. The results are threefold: First, program beneficiaries become better equipped with modern complementary technologies such as agricultural machinery and certified/improved seeds. Second, as a result of investments in community irrigation systems, beneficiaries strengthen their connection to markets by increasing their likelihood of selling in a formal market and dedicating a higher proportion of their production to sales. Lastly, the estimations suggest that program beneficiaries increased total household income and value of agricultural production by 24 percent and 38 percent, respectively, compared to the control group.*

**JEL classification:**

**Keywords:** Agriculture, irrigation, productivity, propensity score matching, Bolivia

**I. Introduction**

In 2014, the agricultural sector contributed US$2,381.6 million to Bolivia’s (Plurinational State of) economy, equivalent to 9.7 percent of its gross domestic product (GDP).[[3]](#footnote-3) According to the 2013 agricultural census, there are over 871 thousand agricultural production units (UPAs) in the country, with a cultivated area of more than 2.7 million hectares (INE, 2015). Between the 2001-2002 and 2012-2013 agricultural cycles, total cultivated area and agricultural output have increased by more than 50 percent (MDRyT, 2014). Some of the major crops harvested during the 2012-2013 agricultural cycle include sugar cane, corn, sorghum, rice, wheat, quinoa, barley, coffee, oats, soy, banana, mandarin, orange, sunflower, green bean, green pea, alfalfa, coca, potato, and cassava. The value of total exports in Bolivia was approximately $12.5 billion in 2013; with agriculture, hunting, forestry, and fishing representing roughly 6.1 percent of total exports (about US$755 million). The volume of agricultural exports increased by 26 percent between 2010 and 2013 (MDRyT, 2014). The principal agricultural export commodities include brazil nuts, soybeans, chia, banana, beans, unroasted coffee, sesame seeds, groundnuts, corn, fruits and sunflower seeds (INE, 2013). With an average annual growth rate of 2.94 percent over the period 2004-2014 (3.8 percentage growth in 2014 alone) and an employment of approximately 30 percent of the labor force, agriculture remains an important and dynamic sector of the Bolivian economy (CEPALSTAT, 2015; ILO, 2014). However, agricultural yields of some of the main crops (e.g., rice, potatoes, wheat, yucca, and corn) in Bolivia have been relatively low (Ormaechea, 2009; Hameleers *et al.,* 2011; Kay, 2011; World Bank, 2011), and the country remains one of the poorest in the region.[[4]](#footnote-4)

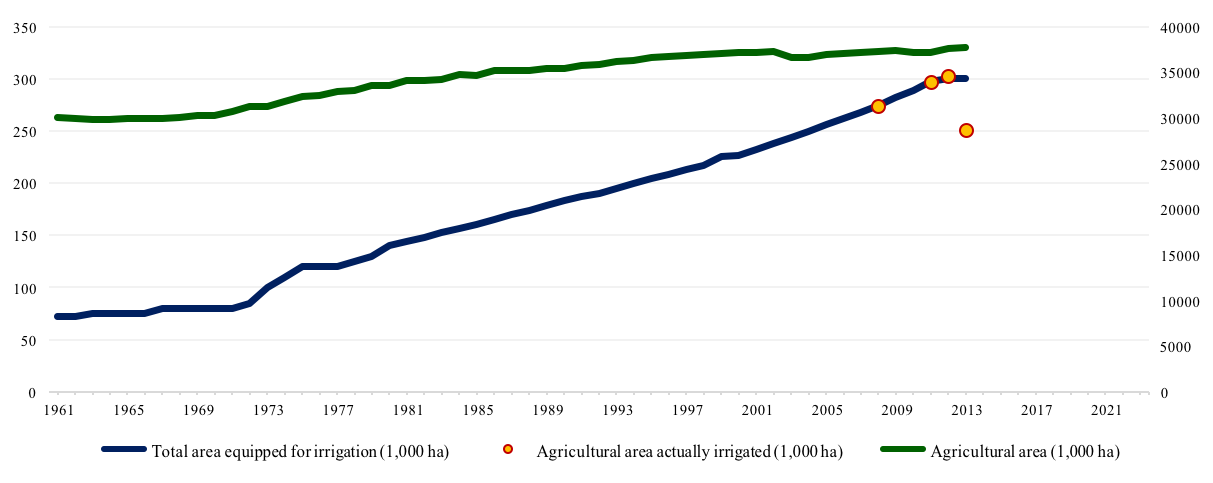
Between 1980 and 2012, agricultural labor productivity in Bolivia experienced negative growth in efficiency and a high rate of technical change (Nin-Pratt *et al.,* 2015).[[5]](#footnote-5) According to the authors, “a possible explanation (of the negative growth in efficiency) … is that Bolivia has benefited from spillovers (for example, from Brazil and Argentina) that contributed to the agricultural boom of its Western region (Santa Cruz) and the development of soybean production for export. With production in other regions lagging behind, the overall effect for the country is almost zero growth in efficiency.” Between 2009 and 2013, Bolivia’s overall (non-private) spending on agricultural research and development (R&D) increased by 3 percent, from US$57.2 million to US$ 58.9 million.[[6]](#footnote-6) Agricultural research spending represents approximately 0.93 percent of Bolivia’s agricultural GDP (US$59 million, 2011 PPI dollars in 2012/2013), and 1.1 percent of overall agricultural research spending in LAC (Stads *et al*., 2016a). In 2013, most (non-private) agricultural R&D was carried out in the country by 11 agencies with approximately 190.3 full-time equivalent (FTE) researchers—roughly 8.85 FTE researchers per 100,000 farmers—among the lowest proportional contribution of qualified (PhD) agricultural researchers in South America. (Stads *et al*., 2016b).

According to the latest data from Agrimonitor, LAC’s agricultural policy monitoring system, Bolivia’s agricultural sector received total support estimates (TSE) ranging from 12.6 percent to 22.51 percent of agricultural output (between 2.08 percent to 3.61 percent of GDP) for the period 2006-2009. Producer support estimates (PSE%) accounted for between 10.2 percent and 16.5 percent of total farm receipts, and general services support estimates (GSSE%) represented between 12.62 percent and 21.07 percent of general support from public goods over the same period.[[7]](#footnote-7) Furthermore, consumer support estimates (CSE%), at between -5.26 and -11.13, describes how “agricultural policies affect, as a percentage, the cost of the basket of agricultural products” (Agrimonitor, 2016). Recent econometric evidence suggests that the magnitude, but more importantly the composition, of rural and agricultural public expenditures have significant consequences on the performance of the sector (Lopez and Galinato, 2007; Anríquez *et al.,* 2015). The authors found evidence that increasing the share of rural and agricultural public expenditures from *private* goods to *public* goods, ceteris paribus, would lead to a large and significant effect on rural income over the long-run, and consequently on poverty reduction, food security, and sustainable rural development.[[8]](#footnote-8) Empirical evidence suggests that public expenditures in Bolivia are increasingly allocated based on needs. For instance, Cuesta *et al. (*2013) found a strong positive relationship between public agricultural spending—mainly core agricultural expenditures and capital investments, such as R&D, extension services, and rural infrastructure—and vulnerability to food insecurity at the municipality level.

Irrigation systems have been part of the agricultural practices of Andean civilizations since AD 530. Ancient civilizations developed irrigation systems (both, complex and rudimentary) adapted to climate variability and access to water around the multiple ecosystems of the Andes (Zimmerer, 1995).As a result, *campesino* and indigenous communities in the Andean region have deep-rooted cultural traditions and practices characterized by collective action, rituals and customs centered around the use of water for irrigation (Boelens and Gelles, 2005; Boelens *et al.,* 2009). The evolution of irrigation systems in the region was greatly influenced by the massive reduction in land and water use during the colonial period, and the gradual re-intensification of irrigation infrastructure over the last decades (Gutiérrez-Malaxechebarría, 2014).[[9]](#footnote-9) In Bolivia, public spending began to increase significantly in the 1970s as part of a state-driven development strategy to stimulate growth in key sectors of the economy, including agriculture (Warner, 2014). For instance, the German Development Bank (KfW) has been actively supporting the Bolivian government in the implementation of programs and projects related to the irrigation sub-sector since 1975 (Dupret *et al.,* 2009).

In 1995, a US$25.6 million loan was approved between the Inter-American Development Bank (IDB) and the Republic of Bolivia[[10]](#footnote-10) for the implementation of the National Irrigation Program (*Programa Nacional de Riego,* PRONAR) for the period 1996-2005.[[11]](#footnote-11) The program aimed at supporting the development of the irrigation sub-sector and water-resources sector by achieving the following objectives: (1) creating an institutional and legal framework for the efficient management of water-resources in the various water-use sectors, including the enactment of a new water law; (2) strengthening and reconfiguring institutions working with the irrigation sub-sector to create an appropriate institutional framework for the development of irrigation; (3) providing training to public and private institutions to enable them to offer better services in the preparation and implementation of rural irrigation projects; (4) improving the income and living conditions of rural inhabitants; (5) supporting the approach involving communities as active participants in the planning of their development strategies and improving the technical capabilities of public and private institutions pursuant to the Civic Participation Law (*Ley de Participación Popular, LPP)*;[[12]](#footnote-12) and (6) supporting the Bolivian government strategy of transferring public irrigation infrastructure to private-sector management. The goal was to create the conditions for improving the economic and social efficiency of public investments in community irrigation systems and of water use (IDB, 1995). A total of 158 small-scale irrigation projects were financed, including the rehabilitation of 8,000 hectares and extension of over 14,000 new hectares with irrigation.

By 2012, the National Inventory of Irrigation Systems (*Inventario Nacional de Sistemas de Riego*) registered a total 303,201 hectares of irrigated land out of the over 2.7 million hectares cultivated a year (winter and summer). This represents approximately 11 percent of cultivated land area. A total of 5,669 community irrigation systems were utilized by 283,427 family farmers—mostly indigenous natives (Aymara, Quechua and Guaraní)—in 215 municipalities throughout the departments of Chuquisaca, Cochabamba, La Paz, Oruro, Potosi, Santa Cruz and Tarija.[[13]](#footnote-13) An organizational feature of community irrigation systems is that users collectively agree to the distribution of water rights, which is based on the relative contribution—capital and/or labor—to the development of the irrigation infrastructure. Water rights are generally assumed by the head of household, typically men; only about 20 percent of water right holders are women. (VRHR-MMAyA, 2013).



2013

census  
(summer)

PRONAR

1994

LPP

**PRONAREC   
I II**

*Source:* FAOSTAT  
*Note:* Total area equipped for irrigation (1,000 hectares) and agricultural area actually irrigated (1,000 hectares) relates to the left scale, while agricultural area (1,000 hectares) read from the right scale.

***Figure 1****—Agricultural Area and Area Equipped for Irrigation* *in Bolivia*

More recently, the 2013 agricultural census reports 267,179 agricultural production units using irrigation, particularly in Potosi and Tarija (INE, 2015).[[14]](#footnote-14) For the 2012-2013 summer cycle, the main crops produced under irrigated agriculture were corn (42,996.6 hectares), potato (39,517.3 hectares), and alfalfa (22,464.9 hectares). In total, 2,766,779.8 hectares were cultivated during this period: 2,515,737.4 hectares under rain-fed agriculture (90.92 percent), and 251,042.5 hectares under irrigated agriculture (9.07 percent) (see Figure 1).

Following the enactment of the Water Act (*Ley de Agua*) in 2004, the National Irrigation Plan (*Plan Nacional de Riego*) aimed at increasing irrigated land area to a total of 450 million hectares by 2025 (Ministerio del Agua, 2007). Under this scenario, and based on the progress and lessons learned from PRONAR, the Plurinational State of Bolivia and the Inter-American Development Bank signed, in March 2009 and in December 2013, loan contracts 2057/BL-BO and 3060/BL-BO, respectively, to finance the first two phases of the National Irrigation Program with a Watershed Approach (*Programa Nacional de Riego con Enfoque de Cuenta—*hereinafter PRONAREC). The overall objective of the program is to promote the sustainable development of rural agricultural households by increasing agricultural income through investments in community irrigation systems. The program also provides technical assistance with a focus on gender, supports the development and implementation of management strategies to improve water use efficiency, and promotes the strengthening of the National Inventory of Irrigation Systems (BID, 2013). The entity responsible for the implementation of the program is the Ministry of Environment and Water (*Ministerio de Medio Ambiente y Agua*—MMAyA) through the Vice Ministry of Water Resources and Irrigation (*Viceministerio de Recursos Hídricos y Riego*—VRHR).

As of 2016, over a dozen irrigation-related programs have been implemented or are being implemented in the country; nevertheless, to the best of our knowledge, no rigorous empirical evaluations assessing their effectiveness have been performed. This case study evaluates the impact of the first phase of PRONAREC on agricultural agricultural income, productivity, and food security in rural communities in Bolivia, using a quasi-experimental approach. The main contribution of this paper is to provide further evidence of the effectiveness of agricultural programs promoting the adoption of irrigation technologies in developing countries.

Following this introduction, the rest of the paper is structured as follows: Section II provides a summary of the empirical evidence on market failures and the adoption of agricultural technologies in developing countries, particularly with regards to irrigation. Section III describes the structure of the program. Section IV presents the methodological framework used for the identification of program impacts. Section V presents the research hypothesis, describes the data and provides baseline comparisons of the treatment groups used in the analysis. Section VI discusses the main findings of the impact evaluation and section VII concludes.

**II. Empirical Evidence, Market Failures and the Adoption of Agricultural Technologies**

Irrigation is considered a key determinant of agricultural productivity, and consequently of food security and sustainability (Ahmed *et al.,* 2014; Nkhata, 2014). In general terms, access to irrigation has the potential of improving productivity given that farmers are able to adjust production outside of the rainy season, and are less vulnerable to weather shocks (Duflo and Pande, 2007; Zou *et al*., 2012). In turn, productivity may increase as a result of agricultural intensification, which is traditional defined as: (i) increasing yields per hectare; (ii) increasing cropping intensity per unit of input (i.e., land, water, seeds); and/or (iii) changing land use pattern from low-value (traditional) crops to higher value crops (Pretty and Bharucha, 2014).

The literature recognizes the existence of several obstacles that hinder the process of agricultural technology adoption in developing countries, including: (i) problems related to liquidity constraints and access to credit; (ii) problems of access to information and/or asymmetric information; (iii) risk aversion; (iv) input and output market inefficiencies; (v) lack of human capital; (vi) lack of infrastructure; (vii) lack of supply of complementary inputs, among others (Feder, Just and Zilberman, 1985; Jack, 2013).

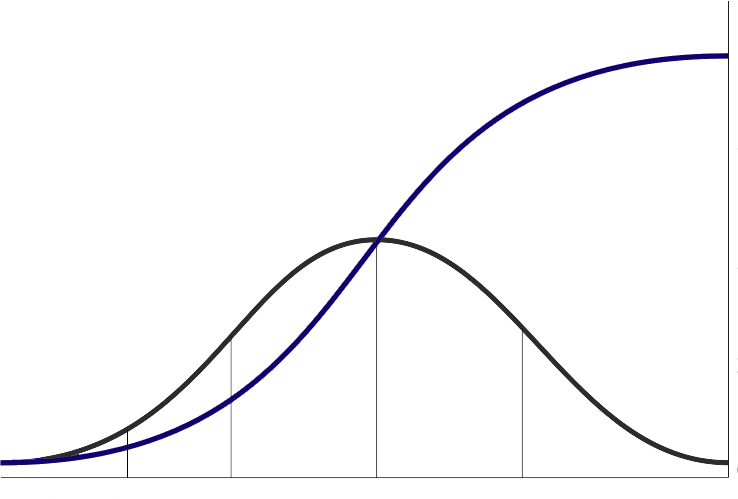
PRONAREC seeks to reduce barriers to the adoption of irrigation technologies. Specifically, we have identified three key barriers that limit technology adoption (see figure 1). First, in relation to liquidity constraints, producers do not have the financial capital that is necessary for investments in infrastructure. Several studies have shown that liquidity constraints hinder the adoption of technologies (Feder, Just and Zilberman, 1985; Simtowe and Zeller, 2006; Moser and Barrett, 2003). Eswaran and Kotwal (1990) show that the lack of financial liquidity and access to credit reduces the ability of agents to pool risk pool across time. For this reason, producers with financial liquidity and credit are more likely to embark on investments that can be considered ‘risky’ because they are aware that their consumption will not be drastically affected by fluctuations in income. This is not the case for low-income producers with financial constraints, thus affecting the propensity to invest in technologies, which could create a poverty trap. To eliminate this problem, PRONAREC will finance part of the investment in irrigation infrastructure (80% of modern irrigation-systems and 70% of traditional or conventional irrigation-systems) so that producers can have access to irrigation despite their lack of access to financial services.

|  |
| --- |
| *Figure 1—Barriers to the Adoption of Agricultural Technologies*  **CONSTRAINTS ON THE ADOPTION OF IRRIGATION SYSTEMS**  Liquidity constraints Lack of access to credit  Lack of information  Asymmetric information  Risk aversion  **REMOVING BARRIERS  LIMITING ADOPTION**  Financing part of the infrastructure  Technical assistance in the area  of water management  Agricultural technical assistance |

The second barrier is related to asymmetric information. For instance, in many cases, producers who are not familiar with a technology, and such technology is perceived as complex, are less likely to adopt. These misperceptions negatively influence the decisions to adopt (Joshi and Pandey, 2005; Adesina and Zinnah, 1993; Adesina and Baidu-Forson, 1995). To eliminate this problem, an important part of the program includes the provision of specialized technical assistance for each irrigation system, particularly focused on water management. This means that technical assistance to producers is provided from the beginning of the project construction, so that they can become familiar with the use of the system from the start. The technical assistance will include training on water management, agricultural production, commercialization, marketing and environmental issues. This technical assistance will provide the necessary knowledge and information regarding the efficient and effective management of the irrigation system, thus ensuring resource savings and improving productivity of the beneficiaries.

Lastly, we have identified risk aversion as another major barrier limiting the adoption of modern irrigation systems. Producers may prefer to grow more familiar crops using conventional farming techniques. Mainly, risk aversion limits the adoption of agricultural technologies because producers prefer to have certainty about the economic returns that will be generated by the technology prior to the incurring of any costs. Therefore, producers can postpone investment until they confirm productivity gains associated with the technology through the experience of other producers (Abadi Ghadim, Pannell and Burton, 2005; Besley and Case, 1994; Foster and Rosenzweig, 1995). For this reason, the technical assistance component of the program will also provide technical assistance related to agricultural diversification towards high-value crops that can be traded at higher prices and thereby improve their income. This technical assistance will provide information regarding crop types, crop cycle, input and output markets, etc.

|  |
| --- |
|  |



*Figure 2—Technology Adoption Curve*

**Critical  
Mass**

Time

Percent of Adoption

Innovators

*Source:* Adapted from Rogers (1983)

Early adopters

Early majority

Late majority

Laggards

The process of technology adoption has been usually described by a sigmoidal (S-shaped) adoption curve as shown in figure 2 (Cavalli-Sforza and Feldman, 1981; Rogers, 1983). The reasoning is as follows: at the beginning, technology is slowly adopted by innovators until it reaches a "critical mass" (a significant percentage of adoption), and at that point the technology begins to spread more rapidly among the population. The idea of this program is to accelerate this process so that it reaches that critical point faster.

100

0

On the other hand, in the case of the benefits associated with investments in irrigation systems, the empirical evidence shows that investments through community partnerships have the following significant impacts: (i) improvement in the quality of infrastructure maintenance; (ii) reduction in the costs of water use; (iii) improvements in the operation of the systems in terms of timing and access to the resource; (iv) increasing agricultural irrigated land; (v) greater crop diversification towards higher value crops; (vi) productivity improvements in terms of higher production; (vii) increases in revenue, (viii) efficient conflict resolution and collective action, among others (Johnson III, 1997; Vermillion, 1997; Garcés-Restrepo Muñoz and Vermillion, 2007; Urban and Wester, 2003; Salas Arredondo and Wilson, 2004; Bandyopadhyay *et al.*, 2010; Araral, 2011).

**III. The National Irrigation Program with a Watershed Approach**—**PRONAREC**

The overall objective of the program is to “increase the agricultural income of rural households through an increase in the agricultural area under irrigation and improved efficiency in the use and distribution of water resources for agricultural purposes.” By “watershed approach” the program refers to the adoption of watersheds as relevant units for planning and managing water resource development. These technologies should help enhance the capacity of rural areas to adapt to climate change. To achieve its objectives and consistent with the challenges identified in Section II, the program will finance the procurement of goods, works, and services, including: (*i*) investments for the development of sustainable community irrigation systems (e.g., studies, construction, supervision, training, operation, and maintenance); (*ii*) agricultural technical assistance with a focus on gender; (*iii*) support for the development and implementation of regulatory strategies and mechanisms for water management; and (iv) strengthening the National Irrigation Information System (*Sistema Nacional de Información de Riego,* SNIR).

Community irrigation systems (projects) were funded if they met the eligibility and feasibility criteria (e.g. social and cultural, legal, economic, environmental and technical) in accordance with policies, plans, strategies and objectives established by the Plurinational State of Bolivia and departmental prefectures.[[15]](#footnote-15) The project cycle was as follows:

1. ***Eligibility and Feasibility:***

Project submissions were first subjected to an eligibility criterion which considered the procedures and regulations established by the *Reglamento Operativo*—the internal instrument for the acquisition and management of PRONAREC (SENARI, 2009), including: Projects were assessed on the following aspects:

1. *Social and cultural criteria*: Existence of an irrigation organization and involvement of beneficiaries, including having female board members; degree of motivation, interest and initiative of the beneficiaries; social agreement to assume the project's counterpart (e.g. financing-related responsibilities and risks); commitment of self-management; understanding project scope by its beneficiaries; Smallholder producers—as defined by the *Régimen Agrario Unificado* (RAU).
2. *Legal criteria*: Rights over the user of water for irrigation; agricultural property rights over the area covered by the project; agreements, conventions and others (e.g. counterpart) for the approval of the project.
3. *Economic criteria*: Rate of return, employment generation, increase in the income of beneficiaries, market presence, poverty indicators, investment amount per hectare. Projects with an investment amount between US$300,000 and US$3,000,000, to be financed with loan resources. Projects may include construction of modern or traditional community irrigation systems, dams, and improvement or rehabilitation of existing irrigation systems.[[16]](#footnote-16)
4. *Environmental criteria*: Commitment by beneficiaries to ensure protection and sustainable use of water resources within the framework of the watershed, and soil management; projects without negative environmental impacts or with technical and economic feasibility of remediation.
5. *Technical criteria*: Agricultural use of irrigated areas as certified by municipal governments; availability of water for irrigation in the watershed.
6. ***Prioritization of Projects by the Governorates***

Once identified and approved for participation in PRONAREC, projects were prioritized by the governorates to begin implementation of activities for the preparation and execution of community irrigation systems across departments that had *Servicios Departamentales de Riego* (SEDERIs).

As mentioned above, PRONAREC consists of two components: (*1*) investments for the development of community irrigation systems; and (*2*) investments for the development of strategies and mechanisms to optimize irrigation management. Through these two components, the program seeks to increase farm income through an increase in the agricultural area under irrigation and improved efficiency in the use and distribution of water. This study will also evaluate the effect of the intervention on food security using a multi-dimensional indicator defined at the household level (Bertelli and Macours, 2014). Figure 3 outlines the intervention’s basic theory of change, describing how program activities are expected to produce a series of results and their causal effects on final outcomes.

The first component financed two types of interventions, investments in irrigation infrastructure (modern and traditional), and technical assistance. The objective of the technical assistance was to help producers diversify production towards higher value-added crops, which we hypothesize will have a significant impact on total household income (e.g., greater value of production, market access, sales, etc.). Technical assistance also included trainings on use and maintenance of irrigation systems, demonstration fields for the exchange of ideas and experiences between farmers, and a focus on gender equality to ensure equal access of women to all benefits throughout the program cycle.[[17]](#footnote-17) This component seeks to increase value of production and improve water use efficiency. The increase in value of production can be achieved in two ways: (*1*) increasing productivity by improving production per hectare—assuming producers continue to grow as usual, without any changes in cropping patters—and (2) diversification towards higher value-added crops, so that gross value added per hectare increases. Furthermore, water use efficiency refers to the volume of water used on farm relative to the volume of water collected at the source.

**IMPACTS**

* Increase value of production of program beneficiaries
* Increase farm income
* Improvement in food security

**RESULTS**

* Increase agricultural area under irrigation
* Improve water use efficiency
* Increasing crop diversification
* Improve the quality and quantity of information available for decision-making

**OUTPUTS**

* Construction and transfer of community irrigation systems
* Watershed developments
* Producers provided with technical assistance; demonstration fields for the exchange of ideas, and irrigation associations with established gender equality
* Approved sectoral diagnosis; inter-sectoral coordination strategy developed at the national and regional level; performance assessment framework
* A functional National Irrigation Information System

**ACTIVITIES**

* Investments in community irrigation systems
* Watershed activities to guarantee sustainability
* Technical assistance (i.e. irrigation infrastructure, agricultural, gender equality)
* Tools and sectoral studies to enhance regulatory policy and management
* Development of the National Irrigation Information System (SNIR)

*Figure 3—PRONAREC’s Theory of Change*

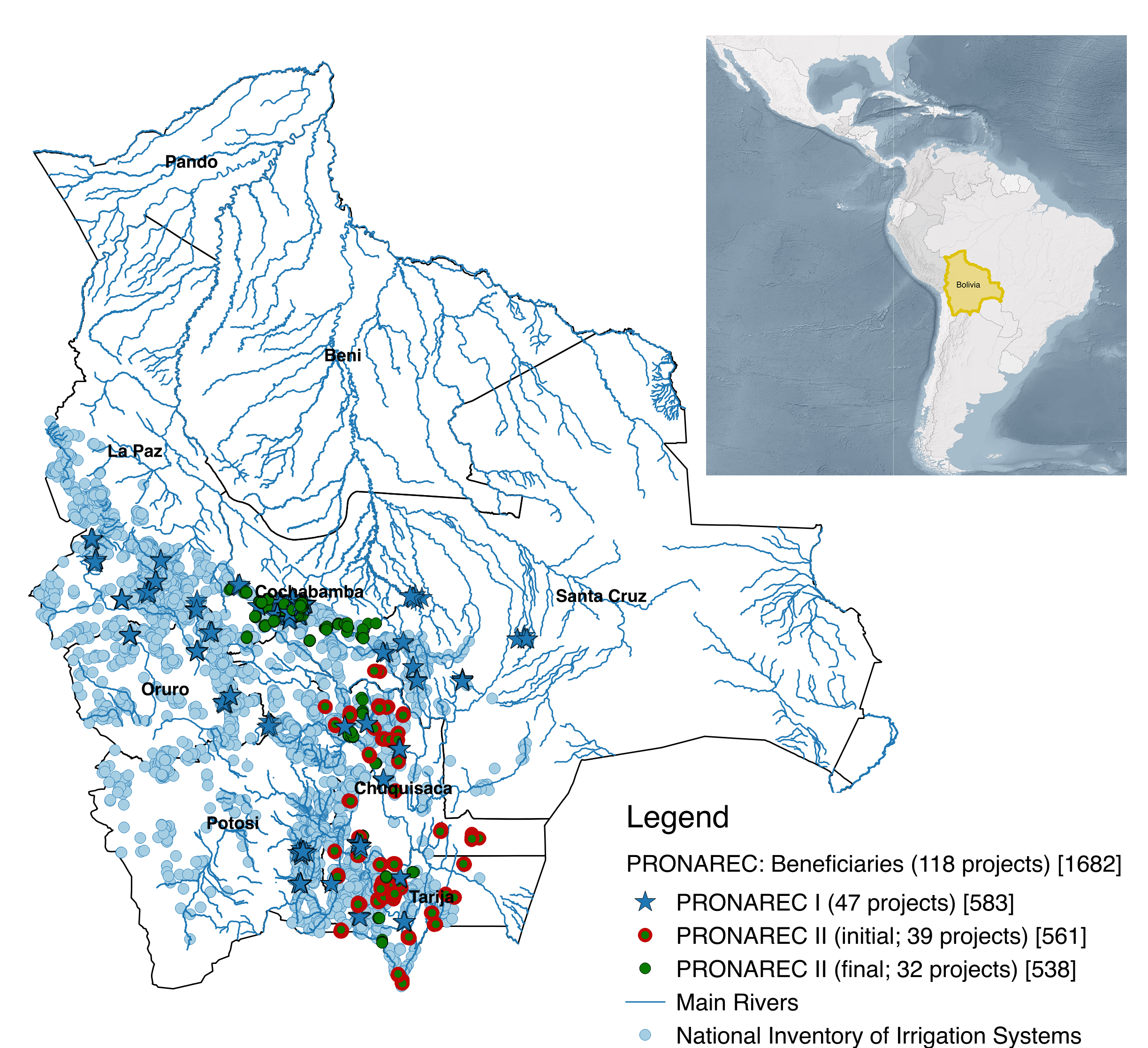
The second component provided funding to strengthen the irrigation sub-sector within the MMAyA, including: (*i*) sectoral diagnosis; (*ii*) joint strategies between the irrigation sector and the watersheds; and (*iii*) inter-sectoral coordination at the national and regional-level to develop the National Irrigation Information System. This component seeks to improve the quality and quantity of information on irrigation systems for policy making.

This impact evaluation is meant to test the following hypotheses: (1) Does access to irrigation increases agricultural income and improve food security? ; (2) Is the increase in agricultural production associated with higher yields or changes in cropping patterns? ; (3) Does access to irrigation provide enough incentives to generate changes in cropping patterns towards more marketable products and of higher value? ; and (5) Does access to irrigation generate the necessary and sufficient conditions for producers to pay their dues and maintain their own irrigation infrastructure?

**IV. Empirical Approach to the Identification of Causal Effects**

As with every impact evaluation, the main objective of this case study is to estimate the causal effect of the program on the population of beneficiaries. True causal effects, however, are difficult to estimate because ideally we would like to be able to observe the outcome with and without the project for a given agricultural producer. However, this is not possible as all beneficiaries receive the program. Thus, the *fundamental evaluation problem* is that inference about the causal effect of the program requires a control group or counterfactual that is comparable to the program beneficiaries in order identify the impact of the program. In the case of PRONAREC, the task of identifying this control group is more complex given that no baseline data is available for the first phase of the program (PRONAREC I) and there is also self-selection into the program (e.g., Governorates choose which projects will be evaluated in the feasibility phase and which projects will be prioritized). The control group should consist of producers that have not received any benefits from the program, but that are similar in terms of both, observable and non-observable characteristics, to the beneficiaries of PRONAREC I.

In order to perform a rigorous impact evaluation of PRONAREC I, we will use program beneficiaries who will receive the intervention in the second phase of the program (PRONAREC II) as the control group. These producers are enrolled in the program but have not received any benefits during the 2014-2015 agricultural cycle, and therefore, constitute an appropriate control group. At the same time, the fact that this group is composed of producers who belong to communities that have requested and been approved to participate in the program, removes any possible self-selection bias that would result from the comparison with producers who belong to communities not enrolled in PRONAREC. Hence, the idea of using producers from projects that will be benefited in the second phase of the program is to eliminate self-selection bias since we are comparing projects that have also been prioritized by the Governorates.



*Source:* Authors' own elaboration; GeoSIRH (2015)

*Figure 4—Geographic Location of Beneficiaries,*

*by Project Phase*

Specifically, most of the projects to be funded by PRONAREC II were identified during the first two years of implementation, 2014 and 2015. In 2015, construction of the first 10 projects began and will be completed by June 2016 (this group represents *initial*beneficiaries of PRONAREC II). In 2016, the construction of 20 projects will begin and are expected to be completed after July 2017 (this group represents *final* beneficiaries of PRONAREC II). Together, *initial* and *final,* beneficiaries of PRONAREC II will be used as the control group to assess the impact of PRONAREC I (see Figure 4).[[18]](#footnote-18)

For this purpose, in December 2015, we collected a representative household survey of all the projects to be financed during the five years of the program (PRONAREC I and II)[[19]](#footnote-19). This survey will allow us to identify beneficiaries of PRONAREC II that are similar, in terms of observable pre-treatment characteristic, to the beneficiaries of PRONAREC I using the Propensity Score Matching (PSM) methodology.

Matching is a quasi-experimental evaluation approach that has been widely applied in empirical research for program evaluation. Matching methods rely on observable characteristics and statistical techniques to construct a credible and rigorously defined control group in order to make cause-and-effect inferences.

The main objective of the estimation that follows is to measure the impact of PRONAREC I on the agricultural income, productivity, food security and a set of other variables of interest of beneficiaries of the program. We begin with a brief summary of the Neyman-Rubin model, a conceptual and statistical framework for analyzing causal effects within experimental and non-experimental studies.[[20]](#footnote-20)

Following the notation of Cerulli (2015), let denote the potential outcome of unit in the presence of the treatment, and let denote the potential outcome of the same unitin the absence of the treatment, wheredenotes units observed. The treatment effect (TE) of unitmay be written as:

|  |  |  |
| --- | --- | --- |
|  |  | (1) |

The empirical challenge to identifying the treatment effect of unit , commonly known as the *fundamental problem of causal inference*, is one of missing data, or more appropriately, the lack of counterfactual data (Holland, 1986). For any unit , in Eq. (1) cannot be observed directly since only one potential outcome can be observed at a given time, never both. For instance, we might be able to observe total agricultural production for a beneficiary of a modern irrigation system financed by PRONAREC I, but we would not be able to observe the agricultural production of the same beneficiary if PRONAREC I had never been implemented, and vice versa. Research has therefore focused on estimating average causal effects (Rubin, 1974). Let be a binary treatment variable equal to 1 if unit receives the treatment and 0 otherwise. The observable status of unit may be expressed as the so-called potential outcome model, that is:[[21]](#footnote-21)

|  |  |  |
| --- | --- | --- |
|  |  | (2) |

If we extend the logic from a single unit to a set of units, the population average treatment effect (hereinafter ATE) may be written as:

|  |  |  |
| --- | --- | --- |
|  |  | (3) |

Similarly, the observed outcome,, may be written in terms of potential outcomes as:

|  |  |  |
| --- | --- | --- |
|  |  | (4) |
|  |  |  |

The Neyman-Rubin framework states that, under random treatment assignment, an unbiased estimate of the average treatment effect can be calculated by taking the difference between the average outcomes of the treatment and control groups; that is, the “Difference-in-means” (DIM) estimator.[[22]](#footnote-22) Stated formally, under random treatment assignment, the expected outcome of the treatment group, is equal to the expected outcome of the control group had the control group received the treatment, , and vice-versa, . The treatment and control groups created under random treatment assignment are, on average, statistically equivalent across pretreatment observable and unobservable characteristics. Any observed differences in the outcome of interest between the treatment and the control groups may be attributed to the treatment alone.[[23]](#footnote-23) Eq. (2) may be rewritten as:

|  |  |  |
| --- | --- | --- |
|  |  | (5) |
|  | = | (6) |

Under random assignment, the estimator of ATE is consistent, asymptotically normal, and efficient (Cerulli, 2015). However, given the non-experimental nature of our study, producer beneficiaries of PRONAREC I may differ systematically from beneficiaries of PROANREC II.[[24]](#footnote-24) Thus, evaluating the impact of PRONAREC I requires a different econometric approach to find an adequate “counterfactual” scenario for beneficiaries of PRONAREC I. In line with the program evaluation literature (Imbens and Rubin, 2015), we employ the propensity score matching (PSM) methodology for estimations of average treatment effect on the treated (hereinafter ATET), .[[25]](#footnote-25) Under random assignment, ATET may be rewritten as:

|  |  |  |
| --- | --- | --- |
|  |  |  |
|  |  | (7) |

Propensity score methods are statistical techniques used in non-experimental research studies to estimate the causal effect of an intervention by reducing the bias due to confounding variables. The propensity score is formally defined as unit ’s conditional probability of being treated, given a set of exogenous and observable pretreatment covariates (Rosenbaum and Rubin, 1983):[[26]](#footnote-26)

|  |  |  |
| --- | --- | --- |
|  |  | (8) |

Further, the authors defined the propensity score as the “coarsest” balancing score , where is “a function of observed covariates such that the conditional distribution of given is the same for the treated and control units”,. Two assumptions are required to construct a valid control group using the propensity score: conditional independence or unconfoundedness, , and overlap, These assumptions are commonly referred to the assumption of “strong ignorability” (Rosenbaum and Rubin, 1983). Unconfoundedness asserts that when adjusting for differences in observable pre-treatment covariates, treatment assignment is essentially independent of the potential outcomes (Rubin, 1990). On the other hand, the overlap assumption states that for each set of pre-treatment covariates, there is a positive probability of being treated and not treated. With this in mind, Eq. (7) may be rewritten as:

|  |  |  |
| --- | --- | --- |
|  |  | (9) |
|  |  |  |
|  |  |  |

In experimental studies, the true propensity score is known and defined by the study design (Abadie and Imbens, 2016). However, in the case of non-experimental studies, such as this evaluation of PRONAREC I, the propensity score must be estimated using a logit or a probit model. This approach creates statistical balance in observable pretreatment covariates between treatment and control groups.[[27]](#footnote-27) Consequently, assuming “strong ignorability”, estimated propensity scores can be used to efficiently estimate ATET by matching treatment and control units that are as similar as possible on the basis of the propensity score.

In summary, PSM allows us to identify a comparable control group through a series of exogenous variables . This group of variables are used to predict the propensity score of producers through a probit regression model, where the propensity score represents the likelihood of participation for each producer. This prediction was carried out by estimating the following equation:

|  |  |  |
| --- | --- | --- |
|  |  | (10) |

where,

*PRONARECi* is a dummy variable equal to ‘1’ for beneficiaries of PRONAREC I;

α is a constant;

Z*i* is a vector of exogenous variables expected to affect the probability that   
producer *i* is a beneficiary of PRONAREC I;

*β* is a vector of the coefficients to be estimated;

*εi*  is the error term associated with the estimation.

Once propensity scores are estimated and balanced is achieved, we can perform different matching techniques on the basis of the propensity score for the estimation of ATETs.

**V. Data and Descriptive Statistics**

As mentioned, the data for our analysis come from a cross-sectional agricultural survey specially designed for the evaluation of PRONAREC. The survey was conducted in December 2015 to a representative sample of beneficiaries of both phases of the program, PRONAREC I and II, across seven departments of Bolivia.[[28]](#footnote-28) The survey was developed and carried out by the consulting firm *Centro de Estudios y Proyectos S.R.L.* (CEP S.R.L*.*) under the supervision of the project executing unit, UCEP-PRONAREC, of the *Viceministerio de Recursos Hídricos y Riego del Ministerio de Medio Ambiente y Agua* (VRHR-MMAyA)and the IDB.[[29]](#footnote-29)

It is worth noting that the sample calculation for the evaluation of PRONAREC took into account the fact that although interviews were conducted at the household level, program implementation was done at the community level. The implication of this in the sample design of the program is based on the assumption that producers belonging to the same community are likely to be more homogeneous relative to producers belonging to different communities. Therefore, variability of information obtained in the sample depends on the distribution of sampled units between different communities or clusters, which in the case of PRONAREC are represented by the beneficiary communities of each irrigation project. Since producers within the same community are assumed to be fairly homogenous, adding observations belonging to the same community or cluster ceases to be informative at certain point (i.e., within-cluster variance). On the other hand, the inclusion of more communities to the sample provides additional data variability. Failure to consider clustering in the sample size calculation of the design stage and ignoring clustering at the analysis stage could lead to an underpowered study (increased Type II error) and spurious declaration of significance (increased Type I error), respectively (Lipsey and Hurley, 2009; Cameron and Miller, 2015).[[30]](#footnote-30)

The sampling strategy follows a stratified clustered design. The primary sampling units (PSU), or clusters, are the beneficiary communities of an irrigation project under PRONAREC. Communities or projects were stratified by phases (PRONAREC I, *initial* beneficiaries of PRONAREC II, and *final* beneficiaries of PRONAREC II), for a total of 3 explicit strata. From each community or cluster, a sample of 12 household producers were randomly selected. All projects were included in the sample. The sample consists of 47 projects of PRONAREC I, 32 projects of *initial* beneficiaries of PRONAREC II, and 39 projects of *final* beneficiaries of PRONAREC II, with a total of 583, 561, and 538 producers surveyed (n = 1,682), by phase, respectively.

The questionnaire consists of 15 modules with a structure based on the *Living Standards Measurement Study - Integrated Surveys on Agriculture* (LSMS-ISA) surveys of the World Bank. With a total of over 200 questions, the modules cover information regarding demographic and household characteristics, identification and location of agricultural land holding, area of land holding according to land use, presence of temporary and/or permanent crops by crop type, farmland investments, livestock, agricultural machinery and equipment, technical assistance, water sources and rights for irrigation and its characteristics and practices, household participation in agricultural and/or non-agricultural organizations, migration, food security, and access to financial services (e.g., bank account, savings, credit). Questions regarding agricultural activities refers to the 2014-2015 agricultural cycle—the annual cycle of activities, between July 2014 and June 2015, related to the growth and harvest of crops.[[31]](#footnote-31)

As mentioned above, the original dataset includes a total of 1,682 observations.[[32]](#footnote-32) However, 66 observations were dropped from the dataset as they all reported not having any agricultural production.[[33]](#footnote-33) Furthermore, an additional 13 observations were excluded from the analysis as they reported working on less than 0.001 hectares of land; these observations were identified as potential input errors due to inconsistencies in the coding. The final dataset used in our analysis is composed of 1,603 observations.[[34]](#footnote-34) Tables 2-6 presents summary statistics and statistical significance of tests on equality of means for continuous variables and equality of proportions for binary variables of treated and control groups before matching. Tables 2-3 include variables related to the demographic and socioeconomic characteristics of producers. Tables 4-6 present variables related to agricultural production and food security.

Both groups share similarities in household characteristics (see Table 2). The average household is composed of 4 members, has a 60 percent dependency ratio (approximately 1.6 working-age individuals per dependent), half of the members are women, and over half of the households have at least one school-age children, of which 47 percent were enrolled and attended school in 2015. Over 85 and 60 percent of household members (5 years and older) participate in crop production and animal husbandry/processing, respectively. A smaller share of household members in the treated group work in crop production and animal husbandry/processing (6 percentage points) compared to the control group. Furthermore, a significantly larger (smaller) share of members in the treated group work in off-farm (on-farm) activities.

Looking at head of household characteristics, we observe significant differences between both groups with regards to age, marital status, ethnic background and literacy, but not in terms of the percentage of female-headed households (17 percent overall). Specifically, the treated group has a lower percentage of single-headed households (4 percentage points), a larger percentage of heads of households self-identified as indigenous peoples (10 percentage points)—NyPIOCs for its acronym in Spanish[[35]](#footnote-35)—a larger percentage of literacy (6 percentage points), and head of households in the treated group are, on average, 2 years older relative to the control group. In terms of the highest level of education achieved by household heads, we observe significant differences between treated and control groups with regards to the average percentage of heads who reported not having any formal education (5 percentage points lower for the treated group), and the average percentage of heads who reported not finishing secondary education (6 percentage points higher for the treated group). Overall, 51 percent of the household heads did not finish primary education, 6 percent completed primary education, 9 percent completed secondary education, 1 percent reported receiving technical education, and only 4 percent reported having more than secondary school education.

With the exception of flooring material, on average, both groups share similar dwelling characteristics: 83 percent of the households reported having electricity, 74 percent have a cellular phone, 12 percent have a computer, 42 percent have a fridge or freezer, and 71 percent have a television. With regards to the main construction materials of the floors, 38 percent of the households reported having a dirt floor, however, compared to the control group, the treated group has a significantly higher share (12 percentage points) of dwellings with a dirt floor. *Accessibility* of households is measured as the amount of time, in minutes, which normally takes producers to get from home to: (1) the nearest route or (paved) road reliably passable round-round, (2) the nearest market or *feria* to buy and/or sell food products, and (3) the main source of water for drinking and cooking. On average, it takes producers approximately 38.5 minutes to get to the nearest route or (paved) road, 92 minutes to get to the nearest market or *feria*, and about 3.7 minutes to get to the main source of water for drinking and cooking. There are no statistically significant differences between both groups for any of these variables.[[36]](#footnote-36)

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| ***Table 2****—Descriptive Statistics: Demographic and Socioeconomic Characteristics* | | | | | | | | | |
|  |  | **Mean** | | |  | **Mean Difference** | **t-stat** | | |
|  |  | **Total** | Treated | Control |  | t | p > | t | | |
| **Household Characteristics** | Household Size (# members) | 4.18 | 4.21 | 4.17 |  | 0.04 | 0.24 | 0.808 |  |
| Dependency Ratio1 | 59.86 | 59.58 | 60.00 |  | -0.43 | -0.99 | 0.925 |  |
| Prop. of women in household (%) | 0.49 | 0.49 | 0.49 |  | -0.005 | -0.40 | 0.693 |  |
| HH with school-age children  ( > 5 & < 17 years old) (0,1) | 0.54 | 0.52 | 0.55 |  | -0.03 | -0.87 | 0.385 |  |
| School-age children (#) | 1.14 | 1.13 | 1.14 |  | -0.01 | -0.11 | 0.912 |  |
| School-age children enrolled & attending (%) | 0.47 | 0.46 | 0.48 |  | -0.02 | -0.49 | 0.626 |  |
| **Occupation of Household Members *(> 5 years old)*** | Crop production on-farm & off-farm (%) | 0.86 | 0.83 | 0.88 |  | -0.06 | -3.06 | 0.003 | \*\*\* |
| On-farm (%) | 0.86 | 0.83 | 0.88 |  | -0.05 | -2.98 | 0.003 | \*\*\* |
| Off-farm (%) | 0.11 | 0.13 | 0.10 |  | 0.03 | 1.66 | 0.099 | \* |
| Animal husbandry & processing on-farm & off-farm (%) | 0.64 | 0.60 | 0.66 |  | -0.06 | -1.70 | 0.092 | \* |
| On-farm (%) | 0.64 | 0.60 | 0.66 |  | -0.06 | -1.77 | 0.079 | \* |
| Off-farm (%) | 0.02 | 0.02 | 0.01 |  | 0.003 | 0.42 | 0.675 |  |
| **Head of Household** | Age (years) | 52.03 | 53.41 | 51.31 |  | 2.09 | 2.03 | 0.044 | \*\* |
| Female (0,1) | 0.17 | 0.15 | 0.18 |  | -0.03 | -1.30 | 0.195 |  |
| Single (0,1) | 0.10 | 0.07 | 0.11 |  | -0.04 | -2.45 | 0.016 | \*\* |
| Indigenous - NyPIOCs (0,1) | 0.77 | 0.83 | 0.73 |  | 0.10 | 1.68 | 0.095 | \* |
| Literacy (0,1) | 0.83 | 0.87 | 0.81 |  | 0.06 | 2.21 | 0.029 | \*\* |
| **Head of Household Education Level** | Without formal education (0,1) | 0.15 | 0.11 | 0.17 |  | -0.05 | -2.34 | 0.021 | \*\* |
| Primary incomplete (0,1) | 0.51 | 0.47 | 0.52 |  | -0.05 | -1.45 | 0.150 |  |
| Primary completed (0,1) | 0.06 | 0.07 | 0.05 |  | 0.02 | 0.98 | 0.330 |  |
| Secondary incomplete (0,1) | 0.15 | 0.18 | 0.13 |  | 0.06 | 2.51 | 0.013 | \*\* |
| Secondary completed (0,1) | 0.09 | 0.09 | 0.09 |  | 0.01 | 0.39 | 0.697 |  |
| More than secondary education (0,1) | 0.04 | 0.06 | 0.04 |  | 0.02 | 1.47 | 0.145 |  |
| Technical adult education (0,1) | 0.01 | 0.01 | 0.01 |  | 0.00 | 0.42 | 0.678 |  |
| **Dwelling Characteristics** | Dirt floor (0,1) | 0.38 | 0.45 | 0.34 |  | 0.12 | 1.88 | 0.063 | \* |
| Electricity (0,1) | 0.83 | 0.86 | 0.81 |  | 0.04 | 0.86 | 0.393 |  |
| Cellular phone (0,1) | 0.74 | 0.78 | 0.72 |  | 0.06 | 1.66 | 0.100 |  |
| Computer (0,1) | 0.12 | 0.15 | 0.10 |  | 0.05 | 1.60 | 0.113 |  |
| Refrigerator or freezer (0,1) | 0.42 | 0.37 | 0.45 |  | -0.09 | -1.40 | 0.165 |  |
| Television (0,1) | 0.71 | 0.70 | 0.71 |  | -0.02 | -0.32 | 0.751 |  |
| **Accessibility *(time to)*** | Route or road reliably passable year-round (min) | 38.51 | 42.63 | 36.37 |  | 6.26 | 0.70 | 0.486 |  |
| Route or road reliably passable year-round   (min)(log) | 2.43 | 2.70 | 2.29 |  | 0.41 | 2.24 | 0.027 | \*\* |
| Closest market or feria to buy/sell food (min) | 92.04 | 99.41 | 88.22 |  | 11.19 | 0.82 | 0.415 |  |
| Closest market or feria to buy/sell food   (min)(log) | 3.91 | 3.96 | 3.88 |  | 0.09 | 0.62 | 0.540 |  |
| Main source of water for drinking/cooking (min) | 3.77 | 3.64 | 3.83 |  | -0.19 | -0.10 | 0.922 |  |
|  | Main source of water for drinking/cooking   (min)(log) | 0.90 | 1.05 | 0.82 |  | 0.23 | 3.13 | 0.002 | \*\*\* |
|  | ***n*** | **1,603** | **548** | **1,055** |  |  |  |  |  |
| *Source:* Authors' own calculations  *Note:* P-values computed from standard errors adjusted for clustering at the community level. T-test for differences in means statistically significant at the \*\*\* 1%, \*\* 5%, \* 10% level.  1 Dependency ratiorefers to the ratio of household dependents (individuals < 15 or > 65 years) per working-age member (15-64 years). | | | | | | | | | |

Over the last three decades, growing attention and recognition has been given to the concept of “social capital” and its role in the process of economic growth and sustainable development (Coleman, 1988; Putnam *et al.,* 1993; Sorensen, 2000; Winters *et al.,* 2001; Atria and Siles, 2004).[[37]](#footnote-37) This is particularly important among researchers, policymakers, and practitioners, within and across the agricultural sector, given that social capital, namely, associativism, may be one of the most important resource endowments of small-scale farmers in developing countries. For instance, empirical research has shown that the stock of social capital can positively affect the adoption of innovations and sustainable agricultural practices (Monge *et al.,* 2008; Munasib and Jordan, 2011; Beaman *et al.,* 2015, Wossen *et al.,* 2015).

For the purpose of this case study, social capital was assessed using a set of indicators for whether someone in the household participated in any organization(s), agricultural and/or non-agricultural, during the 2014-2015 agricultural cycle. Specifically, respondents reported whether someone in the household participated in a: (1) producers’ cooperative or association, (2) *patronato*, (3) syndicate, (4) neighborhood council, (5) credit or savings group, (6) other (e.g., sports club, religious group, student association, teacher association), as well as the sector associated with such organization—agriculture, livestock, agroindustry, forest, artisanal, social, tourism or other.[[38]](#footnote-38) Descriptive statistics in Table 3 show no significant differences between the average participation of the treated and control groups in agricultural (i.e., producers’ cooperative or association, *patronato*, syndicate, credit or savings group and other) and non-agricultural organizations, with the exception of participation in an agricultural-neighborhood council (significantly lower—3 percentage points—for the treated group relative to the control group).[[39]](#footnote-39)

The rest of Table 3 provide descriptive statistics of the economic characteristics of the households. For the sake of brevity, we focus our discussion on key economic characteristics. The average ‘amount’ of livestock owned, as measured by the Tropical Livestock Units (TLUs) index, is 9 units.[[40]](#footnote-40) According to average Progress of out Poverty Index (PPI) score (59.00), the average likelihood of households living below the national poverty line is 28.9 percent.[[41]](#footnote-41) Average household income and agricultural income is US$4,294.09, and US$2,748.29, respectively.[[42]](#footnote-42)

On average, agriculture is the main source of income—at least 50 percent of total income—for about 60 percent of households in the sample. With regards to access to financial services, on average, 16 percent of the households in the sample have a checking account, 16 percent reported having voluntary savings in a savings account, and 18 percent reported being credit constrained.[[43]](#footnote-43) Average land holding is significantly larger for the treated group relative to the control group (3.27 hectares), particularly in terms of the number of hectares owned (3.19), and the amount of flat land owned (3.16 hectares).[[44]](#footnote-44)

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| ***Table 3****—Descriptive Statistics: Demographic and Socioeconomic Characteristics* | | | | | | | | | |
|  |  | **Mean** | | |  | **Mean Difference** | **t-stat** | | |
|  |  | **Total** | Treated | Control |  | t | p > | t | | |
| **Associativism *(social capital)*** | Participated in an agri. cooperative or association (0,1) | 0.08 | 0.09 | 0.07 |  | 0.02 | 0.71 | 0.479 |  |
| Participated in an agri. *patronato* (0,1) | 0.003 | 0.01 | 0.002 |  | 0.004 | 1.06 | 0.291 |  |
| Participated in an agri. syndicate (0,1) | 0.33 | 0.31 | 0.35 |  | -0.04 | -0.87 | 0.387 |  |
| Participated in an agri. neighborhood council (0,1) | 0.05 | 0.03 | 0.06 |  | -0.03 | -2.38 | 0.019 | \*\* |
| Participated in an agri. credit or savings group (0,1) | 0.004 | 0.004 | 0.005 |  | -0.001 | -0.34 | 0.737 |  |
| Participated in other agri. group/org (0,1) | 0.002 | 0.002 | 0.002 |  | -0.0001 | -0.03 | 0.975 |  |
| Participated in a non-agri group/org (0,1) | 0.16 | 0.14 | 0.18 |  | -0.04 | -1.33 | 0.186 |  |
| **Economic Characteristics** | Tropical livestock units (TLUs) | 9.02 | 8.81 | 9.13 |  | -0.33 | -0.28 | 0.778 |  |
| Progress out of poverty index (PPI) score | 59.00 | 57.32 | 59.87 |  | -2.55 | -1.53 | 0.130 |  |
| Remittances (US$) | 44.42 | 23.59 | 55.25 |  | -31.66 | -1.84 | 0.068 | \* |
| Income from employment outside the HH (US$) | 1,083.40 | 946.45 | 1,154.54 |  | -208.10 | -0.90 | 0.370 |  |
| Total income (US$) | 4,294.09 | 4,837.59 | 4,011.78 |  | 825.80 | 1.23 | 0.220 |  |
| Total income p/c (US$) | 1,296.03 | 1,513.98 | 1,182.82 |  | 331.16 | 1.11 | 0.270 |  |
| Agricultural income (US$) | 2,748.29 | 3,275.55 | 2,474.41 |  | 801.14 | 1.32 | 0.190 |  |
| Agricultural income (% of total income) | 0.63 | 0.61 | 0.64 |  | -0.03 | -1.07 | 0.285 |  |
| Agriculture as main source of income (0,1) | 0.63 | 0.60 | 0.65 |  | -0.05 | -1.23 | 0.222 |  |
| Bank account with financial institution (0,1) | 0.16 | 0.17 | 0.15 |  | 0.01 | 0.45 | 0.651 |  |
| Voluntary savings (0,1) | 0.16 | 0.17 | 0.15 |  | 0.02 | 0.55 | 0.586 |  |
| Credit constrained (0,1) | 0.18 | 0.19 | 0.17 |  | 0.02 | 0.59 | 0.559 |  |
| **Total landholding (ha)** | 4.32 | 6.47 | 3.20 |  | 3.27 | 2.21 | 0.029 | \*\* |
| Land owned (ha) | 4.23 | 6.33 | 3.14 |  | 3.19 | 2.21 | 0.029 | \*\* |
| Prop. of land owned (% total landholding) | 0.96 | 0.97 | 0.96 |  | 0.001 | 0.13 | 0.898 |  |
| Flat land owned (ha) | 2.91 | 4.98 | 1.84 |  | 3.14 | 2.54 | 0.012 | \*\* |
| Prop. of flat land owned (% land owned) | 0.69 | 0.68 | 0.70 |  | -0.02 | -0.48 | 0.630 |  |
| Land rented (ha) | 0.04 | 0.07 | 0.03 |  | 0.04 | 0.91 | 0.367 |  |
| Prop. of land rented (% of total) | 0.02 | 0.02 | 0.02 |  | -0.005 | -0.59 | 0.556 |  |
| Land rented out to others (ha) | 0.05 | 0.07 | 0.03 |  | 0.04 | 1.06 | 0.290 |  |
| Prop. of land rented out to others (% of total) | 0.01 | 0.01 | 0.01 |  | 0.001 | 0.18 | 0.854 |  |
| Land - auxiliary acquired (ha) | 0.003 | 0.002 | 0.004 |  | -0.002 | -0.65 | 0.517 |  |
| Prop. of land auxiliary acquired (% of total) | 0.003 | 0.004 | 0.002 |  | 0.002 | 0.69 | 0.493 |  |
|  | ***n*** | **1,603** | **548** | **1,055** |  |  |  |  |  |
| *Source:* Authors' own calculations  *Note:* P-values computed from standard errors adjusted for clustering at the community level. T-test for differences in means statistically significant at the \*\*\* 1%, \*\* 5%, \* 10% level. | | | | | | | | | |

With regards to variables related to land use, 97 percent of the household report using at least some of their land to cultivate seasonal or annual crops, and 12 percent use at least some of their land to cultivate permanent crops such as fruits. In terms of the agro-ecological zone (AEZ) of landholdings, a significantly larger percentage of beneficiaries of PRONAREC I are located in the *altiplano* (high plateau) (24 percentage points); significantly lower percentage of beneficiaries of PRONAREC I are in the inter-Andean valleys (31 percentage points). *Traditional crop* is a dichotomous variable that takes the value of ‘1’ if producers reported harvesting either rice, barley, corn, quinoa, wheat, sorghum, oats, *oca*, potatoes, yucca, *papaliza*, tuna or beans (*frijol/poroto*), and ‘0’ otherwise.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| ***Table*** *4—Descriptive Statistics: Agricultural Production* | | | | | | | | |
|  |  | **Mean** | | |  | **Mean Difference** | **t-stat** | | |
|  |  | **Total** | Treated | Control |  | t | p > | t | | |
| **Agricultural  Land** | Physical cultivated area (ha) | 2.09 | 2.56 | 1.85 |  | 0.703 | 1.20 | 0.233 |  |
| Physical cultivated area under rainfed agriculture (ha) | 1.06 | 1.27 | 0.95 |  | 0.323 | 0.59 | 0.554 |  |
| Physical under rainfed (% physical cultivated land) | 0.35 | 0.26 | 0.39 |  | -0.131 | -2.17 | 0.032 | \*\* |
| Physical cultivated area under irrigation (ha) | 1.04 | 1.29 | 0.91 |  | 0.380 | 1.59 | 0.114 |  |
| Physical under irrigation (% physical cultivated land) | 0.65 | 0.74 | 0.61 |  | 0.131 | 2.17 | 0.032 | \*\* |
| Hectares worked: Total (ha) | 2.24 | 2.64 | 2.03 |  | 0.604 | 1.03 | 0.307 |  |
| **Land intensification**: Hectares worked (ha)  (% physical cultivated area) | 1.16 | 1.10 | 1.19 |  | -0.091 | -2.77 | 0.006 | \*\*\* |
| Hectares worked under rainfed agriculture (ha) | 1.11 | 1.28 | 1.02 |  | 0.255 | 0.47 | 0.642 |  |
| Worked under rainfed (% hectares worked) | 0.35 | 0.26 | 0.39 |  | -0.133 | -2.23 | 0.028 | \*\* |
| Hectares worked under irrigation (ha) | 1.13 | 1.36 | 1.01 |  | 0.349 | 1.42 | 0.158 |  |
| Worked under irrigation (% hectares worked) | 0.65 | 0.74 | 0.61 |  | 0.134 | 2.23 | 0.028 | \*\* |
| **Irrigation intensification:** Worked under irrigation  (% landholding equipped for irrigation) | 0.97 | 0.91 | 1.01 |  | -0.101 | -3.09 | 0.003 | \*\*\* |
| Grazing (ha) | 0.05 | 0.09 | 0.04 |  | 0.050 | 0.96 | 0.341 |  |
| Hectares planted, not harvested (ha) during 2014-2015 | 0.04 | 0.06 | 0.02 |  | 0.040 | 2.43 | 0.016 | \*\* |
| **Main  Land Use** | Cultivated with seasonal or annual crops (0,1) | 0.97 | 0.95 | 0.97 |  | -0.02 | -1.19 | 0.235 |  |
| Cultivated with permanent crops such as fruit (0,1) | 0.12 | 0.16 | 0.11 |  | 0.05 | 1.63 | 0.106 |  |
| Fallow and/or clearing (0,1) | 0.005 | 0.005 | 0.005 |  | 0.001 | 0.19 | 0.853 |  |
| Idle (uncultivated) (0,1) | 0.10 | 0.10 | 0.11 |  | -0.01 | -0.53 | 0.599 |  |
| Cultivated pasture for grazing (0,1) | 0.02 | 0.03 | 0.01 |  | 0.03 | 2.42 | 0.017 | \*\* |
| Natural grassland for grazing (0,1) | 0.04 | 0.04 | 0.04 |  | -0.002 | -0.15 | 0.878 |  |
| Forests and/or mountains (0,1) | 0.03 | 0.03 | 0.03 |  | -0.001 | -0.07 | 0.943 |  |
| **Agro-ecological Zone (AEZ)** | *Altiplano* (high plateau) (0,1) | 0.09 | 0.25 | 0.01 |  | 0.24 | 3.95 | 0.000 | \*\*\* |
| Andean valleys (0,1) | 0.85 | 0.65 | 0.96 |  | -0.31 | -4.43 | 0.000 | \*\*\* |
| Tropical (0,1) | 0.06 | 0.10 | 0.04 |  | 0.07 | 1.45 | 0.150 |  |
| **Crop Portfolio** | Traditional crops (0,1) | 0.89 | 0.90 | 0.89 |  | 0.01 | 0.27 | 0.786 |  |
| Prop. of land with traditional crops (%) | 0.71 | 0.72 | 0.71 |  | 0.01 | 0.33 | 0.742 |  |
| Produced traditional crops exclusively (0,1) | 0.37 | 0.35 | 0.39 |  | -0.04 | -0.74 | 0.464 |  |
| Non-traditional crops (0,1) | 0.62 | 0.65 | 0.61 |  | 0.04 | 0.70 | 0.488 |  |
| Prop. of land with non-traditional crops (%) | 0.33 | 0.37 | 0.31 |  | 0.06 | 1.18 | 0.242 |  |
| **Area Equipped for Irrigation** | Total landholding equipped for irrigation (ha) | 1.27 | 1.58 | 1.11 |  | 0.48 | 1.71 | 0.090 | \* |
| Prop. landholding equipped for irrigation   (% total landholding) | 0.60 | 0.68 | 0.56 |  | 0.11 | 1.93 | 0.056 | \* |
| Modern irrigation system (0,1) | 0.07 | 0.08 | 0.06 |  | 0.02 | 0.60 | 0.547 |  |
| Land equipped for modern irrigation (ha) | 0.11 | 0.12 | 0.11 |  | 0.002 | 0.03 | 0.979 |  |
| Prop. land for modern irrigation   (% ha equipped for irrigation) | 0.06 | 0.07 | 0.06 |  | 0.01 | 0.34 | 0.731 |  |
| Traditional irrigation system (0,1) | 0.67 | 0.77 | 0.62 |  | 0.15 | 2.45 | 0.016 | \*\* |
| Land equipped for traditional irrigation (ha) | 1.15 | 1.47 | 0.98 |  | 0.48 | 1.75 | 0.083 | \* |
| Prop. land for traditional irrigation  (% ha equipped for irrigation) | 0.67 | 0.77 | 0.62 |  | 0.15 | 2.45 | 0.016 | \*\* |
|  | ***n*** | **1,603** | **548** | **1,055** |  |  |  |  |  |
| *Source:* Authors' own calculations  *Note:* P-values computed from standard errors adjusted for clustering at the community level. T-test for differences in means statistically significant at the \*\*\* 1%, \*\* 5%, \* 10% level. | | | | | | | | |

Table 4 reports average agricultural characteristics of the beneficiaries of PRONAREC I and the control group, including characteristics related to agricultural land holding, land use, agro-ecological zone (AEZ), crop portfolio, and physical land area equipped for irrigation. In our study, the difference between the variables *Physical cultivated area (ha)* and *Hectares worked (ha)* is subtle yet important. *Physical cultivated area (ha)* is defined as the physical (agricultural) area cultivated during the 2014-2015 agricultural cycle, meaning that land area which is cultivated more than once in a year is counted only once. On the other hand, *Hectares worked (ha)* quantifies the total amount of land cultivated during the same cycle. For instance, if a producer reports having cultivated twice in a plot of land with 2 hectares, the variable *Physical cultivated area (ha)* would take the value of 2, while the variable *Hectares worked (ha)* would take the value of 4. Land intensification is defined as the ratio of hectares worked to physical cultivated land. A ratio of 1 indicates that total agricultural land area was cultivated only once, while a ratio greater than 1 would indicate cultivating more than once during the 2014-2015 agricultural cycle.[[45]](#footnote-45)

On average, approximately 2 hectares of physical land were cultivated during the 2014-2015 agricultural cycle, about 65 percent under irrigation. Moreover, the share of physical cultivated area under irrigation is significantly larger for the treated group relative to the control group (13 percentage points). Overall, producers in the sample have an average land intensification rate of 1.16; however, program beneficiaries have a significantly lower rate (0.9 percentage point) compared to the control group. Similarly, on average, irrigation intensification is significantly lower for program beneficiaries (10 percentage points).

Overall, there are no significant differences between both groups in terms of crop portfolio: 89 percent reported cultivating at least one traditional crop, 37 percent reported cultivating traditional crops exclusively, and 62 percent reported cultivating at least one non-traditional crop. On average, 71 percent of the land was cultivated with traditional crops between both groups. Lastly, beneficiaries of PRONAREC I have a significantly larger amount of land equipped for irrigation (0.48 hectares) than the average of the control group, especially traditional irrigation. However, future beneficiaries of the program already have at least some land equipped with modern and/or traditional irrigation (1.11 hectares, on average). On average, 68 percent of the total landholding of beneficiaries of PRONAREC I is equipped for irrigation, versus 56 percent in the control group (a significant difference of 11 percentage points).

Table 5 provides basic descriptive statistics in relation to average agricultural input use and expenditures between the treated and the control group. A significantly lower percentage of beneficiaries of PRONAREC I reported using chemical fertilizer (10 percentage points), and animal traction (oxen yoke) for production (13 percentage points). While a significantly greater number of beneficiaries of PRONAREC I reported using improved or certified seeds for production (12 percentage points) relative to the control group.[[46]](#footnote-46) On the other hand, there were no significant difference between both groups in terms of use of fungicides, herbicides, insecticide, organic fertilizer (i.e. guano, manure, chicken manure), agricultural machinery, and paid labor. With regards to input expenditures, on average, beneficiaries of PRONAREC I spent significantly more money on the use of tractor(s) for production (US$67.73), and on the irrigation of plots (US$33.50), particularly on equipment and/or maintenance of irrigation systems and energy (US$23.83 and US$7.68, respectively) compared to the control group. For the rest of the expenditures indicators, as well as investments in agricultural plots, we found no significant difference between both groups.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| ***Table 5****—Descriptive Statistics: Agricultural Input Use and Expenditures* | | | | | | | | |
|  |  | **Mean** | | |  | **Mean Difference** | **t-stat** | | | |
|  |  | **Total** | Treated | Control |  | t | p > | t | | | |
| **Input Use** | Fungicide (0,1) | 0.29 | 0.28 | 0.29 |  | -0.01 | -0.21 | 0.832 | |  |
| Herbicide (0,1) | 0.31 | 0.28 | 0.33 |  | -0.05 | -0.87 | 0.384 | |  |
| Insecticide (0,1) | 0.34 | 0.34 | 0.35 |  | -0.01 | -0.29 | 0.769 | |  |
| Chemical fertilizer (0,1) | 0.26 | 0.20 | 0.30 |  | -0.10 | -2.23 | 0.028 | | \*\* |
| Fertilizer, *guano*, manure, chicken manure (0,1) | 0.67 | 0.69 | 0.66 |  | 0.03 | 0.55 | 0.585 | |  |
| Improved or certified seeds (0,1) | 0.19 | 0.28 | 0.15 |  | 0.12 | 2.82 | 0.006 | | \*\*\* |
| Animal traction (oxen yoke) for production (0,1) | 0.65 | 0.56 | 0.69 |  | -0.13 | -2.16 | 0.033 | | \*\* |
| Tractor for production (0,1) | 0.77 | 0.81 | 0.74 |  | 0.07 | 1.38 | 0.170 | |  |
| Number of tractor used (#) | 0.79 | 0.82 | 0.77 |  | 0.05 | 0.80 | 0.423 | |  |
| Owned a tractor (0,1) | 0.05 | 0.05 | 0.05 |  | 0.01 | 0.54 | 0.588 | |  |
| Prop. of tractors owned (% of total used) | 0.05 | 0.05 | 0.04 |  | 0.01 | 0.57 | 0.571 | |  |
| Machinery and equipment (0,1) | 0.94 | 0.94 | 0.94 |  | -0.01 | -0.36 | 0.718 | |  |
| Agricultural machinery (0,1)1 | 0.78 | 0.81 | 0.76 |  | 0.05 | 1.01 | 0.314 | |  |
| Owned machinery (0,1) | 0.16 | 0.16 | 0.15 |  | 0.01 | 0.30 | 0.763 | |  |
| Paid labor (0,1) | 0.69 | 0.66 | 0.71 |  | -0.05 | -0.11 | 0.269 | |  |
| **Input Expenditures** | Inputs (US$)2 | 789.10 | 767.62 | 800.26 |  | -32.64 | -0.14 | 0.891 | |  |
| Inputs (US$/ha) | 1,349.82 | 1,756.09 | 1,138.8 |  | 617.30 | 1.08 | 0.285 | |  |
| Expenditures on animal traction yoke (US$) | 84.15 | 130.01 | 60.33 |  | 69.68 | 1.06 | 0.289 | |  |
| Expenditures on tractor for production (US$) | 129.16 | 173.73 | 106.00 |  | 67.73 | 2.56 | 0.012 | | \*\* |
| Paid labor (US$) | 684.33 | 923.88 | 559.89 |  | 363.99 | 1.03 | 0.305 | |  |
| Paid Labor (US$/ha) | 730.25 | 813.75 | 686.88 |  | 126.87 | 0.55 | 0.584 | |  |
| Expenditures on the irrigation of plots (US$) | 41.50 | 63.54 | 30.04 |  | 33.50 | 2.65 | 0.009 | | \*\*\* |
| Irrigation equipment/maintenance (US$) | 24.61 | 40.29 | 16.47 |  | 23.83 | 2.36 | 0.020 | | \*\* |
| Water service (US$) | 12.97 | 14.28 | 12.30 |  | 1.99 | 0.34 | 0.735 | |  |
| Energy (US$) | 3.91 | 8.97 | 1.28 |  | 7.68 | 1.77 | 0.080 | | \* |
| **Investments in Agricultural Plots** | Total investments in plots (US$) | 104.41 | 117.54 | 97.60 |  | 19.94 | 0.52 | 0.603 | |  |
| Investments in irrigation (US$) | 55.60 | 59.61 | 53.52 |  | 6.09 | 0.21 | 0.835 | |  |
| Other investments (e.g. *pozos,* *cercas*) (US$) | 36.71 | 42.97 | 33.46 |  | 9.52 | 0.54 | 0.588 | |  |
| Communal investments (US$) | 12.10 | 14.95 | 10.62 |  | 4.33 | 0.87 | 0.387 | |  |
|  | ***n*** | **1,603** | **548** | **1,055** |  |  |  |  | |  |
| *Source:* Authors' own calculations  *Note:* P-values computed from standard errors adjusted for clustering at the community level. T-test for differences in means statistically significant at the \*\*\* 1%, \*\* 5%, \* 10% level. 1 Tractor, tiller/cultivator, mechanical harvester, grass trimmer, chopper mill (gas and electric), irrigation pump, solar pump (surface or underwater), and other agricultural machinery. 2 Includes expenditures on herbicides, herbicides, insecticide, chemical fertilizer, manure/fertilizer, other agrochemicals, and seeds (*criollo* + improved). | | | | | | | | |

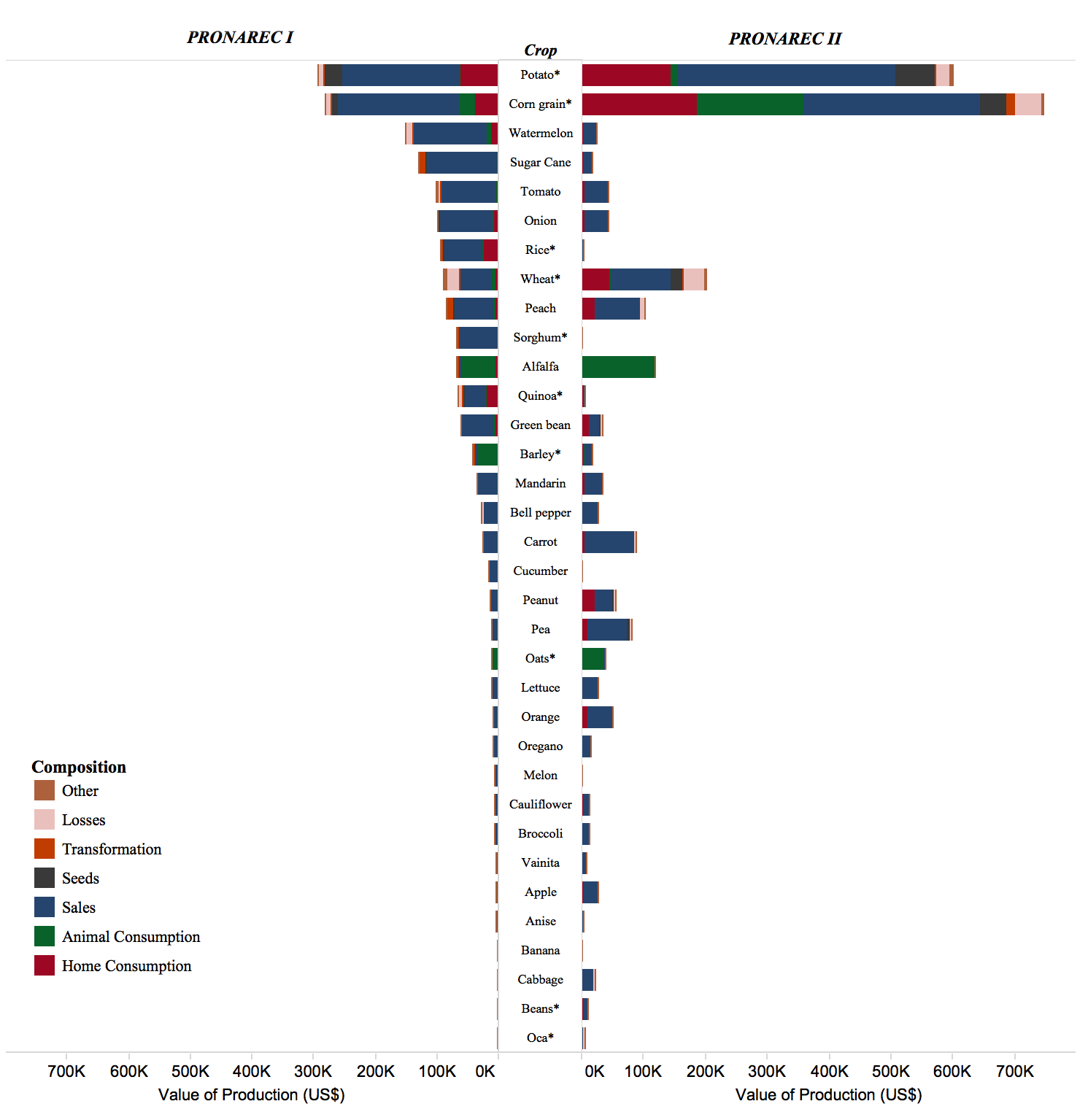
Lastly, Table 6 reports descriptive statistics related to agricultural production and food security. In summary, value of production—measured in total US$, US$ per hectare, US$ per hectare of traditional and non-traditional crops—agricultural gross margins, and gross value added (GVA) are not statistically different between both groups. However, a significantly lower percent of beneficiaries of PRONAREC I report selling to a *rescatista (*independent middle men) (11 percentage points).[[47]](#footnote-47) In turn, value of sales for beneficiaries of PRONAREC I are significantly higher relative to the control group (US$971.02). This can be observed in the composition of agricultural production between beneficiaries of PRONAREC I and II during the 2014-2015 cycle (Figure 5). Beneficiaries of PRONAREC I produced and sold more fruits, vegetables, and grains (i.e. rice and sorghum). In contrast, beneficiaries of PRONAREC II produced relatively more potatoes and corn, especially for home-consumption and to sell.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| ***Table 6****—Descriptive Statistics: Agricultural Production & Food Security* | | | | | | | | |
|  |  | **Mean** | | |  | **Mean Difference** | **t-stat** | | | |
|  |  | **Total** | Treated | Control |  | t | p > | t | | | |
| **Sales** | Household sells (0,1) | 0.74 | 0.73 | 0.75 |  | -0.02 | -0.51 | 0.609 | |  |
| Value of Sales (US$) | 1,790.98 | 2,430.04 | 1,459.03 |  | 971.02 | 1.81 | 0.073 | | \* |
| Proportion of production sold (%) | 0.43 | 0.43 | 0.43 |  | 0.01 | 0.19 | 0.849 | |  |
| Sold *most* crop in a *feria* (0,1) | 0.48 | 0.53 | 0.45 |  | 0.08 | 1.45 | 0.150 | |  |
| Sold *most* crop to *a rescatista* (0,1) | 0.30 | 0.22 | 0.33 |  | -0.11 | -2.39 | 0.018 | | \*\* |
| **Agricultural Production** | Value of home-consumption (US$) | 463.62 | 388.35 | 502.72 |  | -114.36 | -1.41 | 0.161 | |  |
| Prop. of production for home-consumption (%) | 0.29 | 0.27 | 0.31 |  | -0.03 | -1.03 | 0.305 | |  |
| Value of animal-consumption (US$) | 309.87 | 270.44 | 330.35 |  | -59.91 | -0.57 | 0.573 | |  |
| Prop. of production for animal-consumption (%) | 0.14 | 0.14 | 0.13 |  | 0.01 | 0.33 | 0.739 | |  |
| Value of losses (US$) | 125.29 | 137.81 | 118.78 |  | 19.04 | 0.33 | 0.746 | |  |
| Prop. of production losses (%) | 0.05 | 0.06 | 0.04 |  | 0.02 | 2.18 | 0.031 | | \*\* |
| Value of production transformed (sub-products)(US$) | 32.37 | 55.50 | 20.36 |  | 35.13 | 1.29 | 0.201 | |  |
| Prop. of production transformed (sub-products)(%) | 0.02 | 0.02 | 0.02 |  | 0.01 | 1.06 | 0.291 | |  |
| Value of production for seeds (US$) | 121.80 | 96.86 | 134.75 |  | -37.89 | -1.30 | 0.197 | |  |
| Prop. of production for seeds (%) | 0.06 | 0.05 | 0.06 |  | -0.01 | -1.59 | 0.115 | |  |
| **Value of Production** | Value of production (US$) | 2,882.16 | 3,429.61 | 2,597.79 |  | 831.81 | 1.31 | 0.194 | |  |
| Value of production (US$/ha) | 3,054.48 | 3,002.25 | 3,081.62 |  | -79.37 | -0.10 | 0.920 | |  |
| Value of production of traditional crops (US$) | 1,627.81 | 1,759.63 | 1,559.34 |  | 200.29 | 0.52 | 0.604 | |  |
| Value of production of traditional crops (US$/ha) | 2,268.70 | 1,940.70 | 2,439.07 |  | -498.37 | -0.88 | 0.380 | |  |
| Value of production of non-traditional crops (US$) | 1,254.35 | 1,669.98 | 1,038.46 |  | 631.52 | 1.40 | 0.163 | |  |
| Value of production of non-traditional crops (US$/ha) | 2,800.08 | 3,020.91 | 2,685.37 |  | 335.54 | 0.30 | 0.767 | |  |
| **Gross Margins** | Agricultural gross margins (US$)1 | 1,153.92 | 1,370.82 | 1,041.26 |  | 329.56 | 0.66 | 0.510 | |  |
| Agricultural gross margins (US$/ha) | 291.28 | -699.47 | 805.91 |  | -1,505.38 | -1.98 | 0.050 | | \*\* |
| **Value Added** | Gross value added (US$)2 | 2,624.51 | 3,324.67 | 2,260.83 |  | 1063.84 | 1.26 | 0.211 | |  |
| **Food Security Status  *(ELCSA)*** | Food insecure (0,1) | 0.60 | 0.62 | 0.60 |  | 0.02 | 0.66 | 0.509 | |  |
| Food insecurity: moderate & severe (0,1) | 0.20 | 0.23 | 0.18 |  | 0.05 | 1.74 | 0.084 | |  |
| Adults food insecurity (0,1) | 0.60 | 0.61 | 0.59 |  | 0.02 | 0.59 | 0.555 | |  |
| Adults food insecurity: moderate & severe (0,1) | 0.22 | 0.26 | 0.21 |  | 0.05 | 1.66 | 0.099 | | \* |
| *Q1:* Worried running out of food (0,1) | 0.55 | 0.55 | 0.55 |  | 0.01 | 0.14 | 0.885 | |  |
| *Q2:* Home run out of food (0,1) | 0.24 | 0.26 | 0.23 |  | 0.03 | 0.98 | 0.328 | |  |
| *Q3:* Unable to have nutritious food (0,1) | 0.26 | 0.28 | 0.24 |  | 0.03 | 1.04 | 0.298 | |  |
| *Q4:* Limited variety of foods (0,1) | 0.24 | 0.24 | 0.23 |  | 0.01 | 0.47 | 0.637 | |  |
| *Q5:* Skipped a meal (0,1) | 0.21 | 0.23 | 0.20 |  | 0.04 | 1.42 | 0.157 | |  |
| *Q6:* Ate less food than needed (0,1) | 0.20 | 0.23 | 0.19 |  | 0.04 | 1.53 | 0.128 | |  |
| *Q7:* Felt hungry but couldn’t eat (0,1) | 0.19 | 0.21 | 0.17 |  | 0.04 | 1.59 | 0.114 | |  |
| *Q8:* Ate only once/day or not at all (0,1) | 0.16 | 0.18 | 0.16 |  | 0.02 | 0.75 | 0.452 | |  |
| Moderate/severe food insecurity HH  with children < 18 years (0,1) | 0.11 | 0.12 | 0.10 |  | 0.02 | 0.97 | 0.333 | |  |
|  | ***n*** | **1,603** | **548** | **1,055** |  |  |  |  | |  |
| *Source:* Authors' own calculations  *Note:* P-values computed from standard errors adjusted for clustering at the community level. T-test for differences in means statistically significant at the \*\*\* 1%, \*\* 5%, \* 10% level. 1 Agricultural gross margins measured as the value of production minus agricultural inputs (fungicide, herbicide, insecticide, chemical fertilizer, organic fertilizer, other agrochemicals, and expenditures on tractors and animal traction (i.e. oxen yoke) for production). 2 Gross value added (GVA) has been considered as a parameter for the monetization of economic benefits generated on farms that have benefited from the program. VAB is defined as the wealth generated by a particular economic activity, allowing us to remunerate factors of production (e.g., own or foreign capital, labor and/or land) used in the production of goods or services. GVA was calculated by adding the cost of labor (a benefit) to agricultural gross margins. As for the “gross” nature of this aggregate, it makes reference to the fact that we are not considering consumption of fixed capital or depreciation of production units used in production. This variable was used in the economic analysis of PRONAREC. | | | | | | | | |

For the assessment of food security, this analysis concentrates on summary measures of food security status at the household level using the Latin American and Caribbean Food Security Scale (ELCSA for its acronym in Spanish) (ELCSA, 2012).[[48]](#footnote-48) ELCSA is a multi-dimensional measure of food security conceived out the combined experience with food security measures across several countries in the region (Segall-Corrêa and Marin-Leon, 2009; Melgar-Quiñonez *et al.,* 2010; Ballard *et al.,* 2013). It consists of 15 questions that capture the perception of food security (i.e., psychological perception, quality and quantity of food, and the presence of unmet hunger) in the household, using as reference the three months preceding the survey. The first eight questions consider food insecurity affecting adults in the household, while the remaining seven apply only to households with children (less than 18 years of age).

The following set of food security indicators were created using the household classification, by level of food insecurity (i.e., food secure, mild insecurity, moderate insecurity, severe insecurity), determined by the additive score of the 8 or 15 answers in the questionnaire: (1) *Food insecure* takes the value of ‘1’ if the household was classified as "food insecure" and ‘0’ otherwise; (2) *Food insecurity: moderate & severe* takes the value of ‘1’ if the household was classified as having "moderate" or "severe food insecurity" and ‘0’ otherwise; (3) *Adults food secure* only takes into account the first eight questions (Q1-Q8, as reported in the table) affecting adults in the household, taking the value of ‘1’ if classified as “food secure” and ‘0’ otherwise; (4) *Adults food insecurity: moderate & severe* takes the value of ‘1’ if adults in the household were classified as having "moderate" or "severe food insecurity" and ‘0’ otherwise; and (5) *Moderate/severe food insecurity HH w/ children < 18 years of age* takes the value of ‘1’ for households with children less than 18 years of age that were classified as having "moderate" or "severe food insecurity" and ‘0’ otherwise.

The food security status section in Table 6 provides descriptive statistics of these indicators. Overall, the indicators of food insecurity for the household, adults only, and households with children (less than 18 years of age) experiencing moderate or severe food insecurity, are not significantly different between both groups. On average, 60 percent of the households in the sample report some level of food insecurity, 20 percent report moderate and severe food insecurity. Only the indicator measuring moderate and severe food insecurity among adults is statistically significant for the treated group compared to the control group (5 percentage points).



*Figure 5—Value of Agricultural Production (US$), by Crop and Program Phase*

*Source:* PRONAREC’s 2014-2015 Agricultural Household Survey.  
*Note:* Exchange rate: 1 Bolivian Boliviano = 0.15 USD (2014-2015 average)

**VI. Results**

In this section, we present and discuss the results of the propensity score matching technique, including the participation model, assessment of the distribution of beneficiaries and non-beneficiaries in the resultant matched samples, and the effects of the program on outcomes of interests. Propensity score matching is in effect a two-stage process, the first-stage being the specification and estimation of the propensity scores using a probitor logit model to predict the likelihood of participation for each producer, and the second being estimating average treatment effects using different kinds matching algorithms on the basis of the propensity scores.

1. **First-stage: Propensity Score Model Specification and Estimation**

For the propensity score model specification, we followed the guidelines proposed in Heinrich *et al.,* (2010). In particular, the authors suggest the inclusion of variables that are explicitly part of the eligibility criteria (i.e., smallholder farmers as defined by the *Régimen Agrario Unificado*), as well as time-invariant, exogenous pre-treatment covariates (i.e., variables not affected by participation, or the anticipation of participation), and covariates that simultaneously influence treatment status and outcome variables. In the case of PRONAREC, based on the explicit characteristics of the program, it is important to consider factors associated with both, self-section and administrative selection.

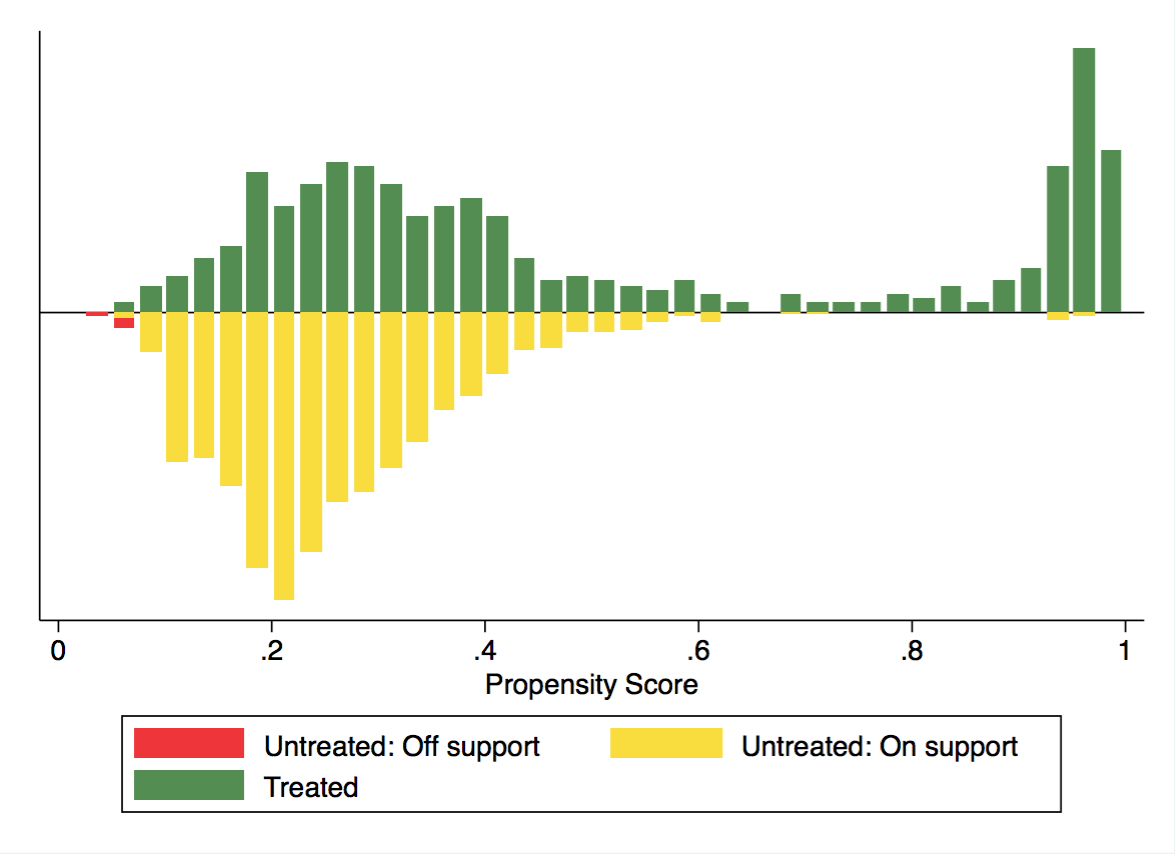
Following Rosenbaum & Rubin (1983), propensity scores were derived using a probitregression model to estimate Eq. (10), where treatment indicator (beneficiary of PRONAREC I) was regressed on the 29 pre-treatment covariates listed in Table 8. These variables are expected to be plausible predictors of the likelihood of being beneficiaries of PRONAREC I.[[49]](#footnote-49) The results for the participation model reported in Table 8 show that ethnicity, educational attainment, landholding owned, having a cellular phone, accessibility to a route or road reliably passable year-round and to the main source of water for drinking and cooking, agro-ecological zone (AEZ), and social capital influence program participation. Specifically, indigenous household heads are 8.1 percentage points more likely to participate in PRONAREC I, having a cellphone increased the likelihood of participation by 5.9 percentage points, and the probability of participation increased by 0.3 percentage points per hectare of land owned.

Interestingly, along with social capital and AEZ, educational attainment, notably higher education, where the baseline covariates that most dramatically influenced the probability of participation in PRONAREC I. With respect to farmers without formal education or incomplete primary school, farmers who completed primary education were 8.7 percentage points more likely to participate, while farmers with higher education (more than secondary education) were 20.8 percentage points more likely. Participation in agricultural cooperatives or *patronato* increased the probability of participation by 8.4 and 37.2 percentage points, respectively. Compared to producers in the *altiplano*, producers located in the inter-Andean valleys and tropical AEZ were 66.5 and 42.2 percentage points less likely to participate in the first phase of the program.

An important step in the implementation of the first stage of the propensity score matching methodology is to verify the common support and overlap conditions. Under this methodology, inferences about treatment effects are valid only if the distribution of the variables in the participation model are similar for both groups in the matched sample(s). In this regard, Figure 6 illustrates the distribution of estimated propensity scores for the treated (PRONAREC I) and untreated/control (PRONAREC II) groups before matching.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ***Table 8****—PRONAREC’s Participation Model (Probit Estimates) Dependent Variable: PRONAREC I (0,1)* | | | | |
|  | **Variable Description** | **Coefficient** | **Marginal Effects** | |
| **Household Characteristics** | Household size (# of members) | 0.011 | 0.003 |  |
| (0.021) | (0.006) |  |
| Dependency ratio | 0.0005 | 0.0001 |  |
| (0.001) | (0.0002) |  |
| Proportion of women (% household size) | 0.0409 | (0.012) |  |
| (0.184) | (0.053) |  |
| Dirt floor (0,1) | 0.0269 | 0.0078 |  |
| (0.084) | (0.024) |  |
| **Head of Household Characteristics** | Age | 0.019 | 0.005 |  |
| (0.018) | (0.005) |  |
| Age (squared) | -(0.0001) | -(0.00002) |  |
| (0.0002) | (0.00005) |  |
| Female (0,1) | -0.014 | -0.004 |  |
| (0.108) | (0.031) |  |
| Single (0,1) | -0.100 | -0.029 |  |
| (0.134) | (0.039) |  |
| Indigenous - NyPIOCs (0,1) | 0.279 | 0.081 | \*\*\* |
| (0.093) | (0.027) |  |
| **Head of Household Education Level** | No formal education & primary incomplete (0,1) | *base* | | |
| Primary completed (0,1) | 0.300 | 0.087 | \*\*\* |
| (0.096) | (0.028) |  |
| Secondary completed (0,1) | 0.228 | 0.066 |  |
| (0.139) | (0.040) |  |
| More than secondary education (0,1) | 0.719 | 0.208 | \*\*\* |
| (0.180) | (0.052) |  |
| Technical adult education (0,1) | 0.502 | 0.145 |  |
| (0.393) | (0.114) |  |
| **Economic  Characteristics** | Land owned (ha) | 0.011 | 0.003 | \*\*\* |
| (0.004) | (0.001) |  |
| Bank account with financial institution (0,1) | 0.068 | 0.020 |  |
| (0.109) | (0.032) |  |
| Credit constrained (0,1) | 0.021 | 0.006 |  |
| (0.104) | (0.030) |  |
| Household with a cellular phone (0,1) | 0.202 | 0.059 | \*\* |
| (0.090) | (0.026) |  |
| Own tractor (0,1) | -0.045 | -0.013 |  |
| (0.171) | (0.049) |  |
| **Accessibility *(time to)*** | Route or road reliably passable year-round (min)(log) | 0.055 | 0.016 | \*\* |
| (0.026) | (0.008) |  |
| Main source of water for drinking/cooking (min)(log) | 0.174 | 0.050 | \*\*\* |
| (0.054) | (0.015) |  |
| **Agro-ecological  zone (AEZ)** | *Altiplano* (high plateau) (0,1) | *base* | | |
| Andean valleys (0,1) | -2.294 | -0.665 | \*\*\* |
| (0.204) | (0.053) |  |
| Tropical (0,1) | -1.455 | -0.422 | \*\*\* |
| (0.247) | (0.070) |  |
| **Associativism *(social capital)*** | Participated in an agricultural coop (0,1) | 0.290 | 0.084 | \*\* |
| (0.136) | (0.039) |  |
| Participated in an agricultural *patronato* (0,1) | 1.283 | 0.372 | \*\* |
| (0.598) | (0.172) |  |
| Participated in an agricultural syndicate (0,1) | 0.107 | 0.031 |  |
| (0.078) | (0.023) |  |
| Participated in an agri. neighborhood council (0,1) | -0.203 | -0.059 |  |
| (0.172) | (0.050) |  |
| Participated in an agri. credit or savings group (0,1) | 0.259 | 0.075 |  |
| (0.534) | (0.155) |  |
| Participated in other agricultural group/org (0,1) | 0.548 | 0.159 |  |
| (0.767) | (0.222) |  |
| Participated in a non-agricultural group/org (0,1) | 0.003 | 0.001 |  |
| (0.100) | (0.029) |  |
| ***Constant*** |  | -0.122 |  |  |
|  | (0.548) |  |  |
|  | **Observations** | **1,603** | | |
|  | **Pseudo R2** | **0.2005** | | |
| *Source:* Authors' own calculations. *Notes:* Numbers in parentheses are standard errors. Statistically significant at the \*\*\* 1%, \*\* 5%, \* 10% level. | | | | |

*Figure 6—Distribution of Estimated Propensity Scores Across Beneficiaries   
of PRONAREC I (treated) and PRONAREC II (untreated): Before Matching*



*Source:* Authors' own elaboration  
*Note:* Region of common support is [0.06486761, 0.99897105].

The estimated propensity scores for beneficiaries of PROANREC I, before matching, range from 0.0648676 to 0.9989711, and 0.032243 to 0.9703411 for beneficiaries of PRONAREC II. The average probability to participate in PRONAREC I for all observations is 34.3 percent. As we can see in Figure 6, while there is overlap in the distribution of propensity scores between both groups, two interesting features arise. First, both distributions are right-skewed, with a large percent of propensity scores between 0.1 and 0.6. Second, there are beneficiaries of PRONAREC I with high predicted probabilities of receiving treatment given exogenous pre-treatment (measured) covariates . A total of 6 observations (0.37 percent of the sample) were dropped from the analysis as they were located outside of the region of common support [0.06486761, 0.99897105]; all 6 observations were part of the control group. However, visual inspection of the distribution of estimated propensity scores is only a basic step in the diagnosis of the appropriateness of the model in creating an adequate comparison group. A more rigorous and informative assessment of the quality of matching involves performing a set of balancing tests to verify the assumption of independence of treatment conditional on observed covariates as described in the next section.

**B. Second-stage: Propensity Score-Matching (PSM)**

For robustness, the propensity scores of producers in the treated and control groups are matched based on the nearest-neighbor, radius, Kernel, and local linear regression (LLR) matching techniques using the user-written Stata command –psmatch2–. In addition, we perform nearest-neighbor matching using the command –teffects psmatch– which implements adjustments derived by Abadie and Imbens (2016) in the calculation of standard errors, for both ATE and ATET estimators, taking into account propensity scores are estimated.[[50]](#footnote-50)

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| ***Table 9a****—Trade-offs in Terms of Bias and Efficiency* | | | | | | | | | |
|  |  |  | | |  | | |  |  |
| **Decision** |  |  | **Bias** |  | | **Variance** | | | |
| Nearest-neighbor matching: | | |  |  | | |  | | |
| multiple neighbors/single neighbor | | | (+)/(−) |  | | | (−)/(+) | | |
| with caliper/without caliper | |  | (−)/(+) |  | | | (+)/(−) | | |
|  |  |  |  |  | |  | | | |
| Use of control individuals: | |  |  |  | | |  | | |
| with replacement/without replacement | | | (−)/(+) |  | | | (+)/(−) | | |
|  |  |  |  |  | |  | | | |
| Choosing method: | |  |  |  | | |  | | |
| NN matching/Radius matching | | | (−)/(+) |  | | | (+)/(−) | | |
| KM or LLM/NN methods | |  | (+)/(−) |  | | | (−)/(+) | | |
|  |  |  |  |  | |  | | | |
| Bandwidth choice with KM: | |  |  |  | | |  | | |
| small/large |  |  | (−)/(+) |  | | (+)/(−) | | | |
|  |  |  | | |  | | |  |  |
| *Source:* Adapted from Caliendo & Kopeinig (2008).  *Note:* KM, kernel matching, LLM, local linear matching, NN, nearest-neighbor; increase (+); decrease (−) | | | | | | | | | |

The nearest-neighbor (NN) algorithm constructs the counterfactual by matching the propensity score of each treated observation to the control observation with the closest (nearest) propensity score. NN matching can be performed with or without replacement and with k-nearest neighbors (for this evaluation, we perform 1-nearest matching with and without replacement, as well as 3-nearest and 5-nearest matching with replacement). Similarly, the radius algorithm uses a specified tolerance level on the maximum propensity score distance or “caliper” to match treated observations with all control observations within the given caliper. A caliper of 0.01 was used for both, nearest-neighbor and radius matching.[[51]](#footnote-51) Lastly, the counterfactual for each treated observation is constructed using the Kernel (default bandwidth, 0.06) and LLR (default bandwidth, 0.06) matching algorithm by using the weighted average of the outcome(s) of virtually all observations in the control group. Weights are inversely proportional to the distance between each control and treated observation.[[52]](#footnote-52) The choice of matching algorithm involves a trade-off in terms of bias and efficiency, particularly in small samples, as shown in Table 9a.

Following Rosenbaum and Rubin (1985), we rely on the examination of the “standardized percentage bias” or “absolute standardized mean difference” to assess the relative balance, comparability and quality of matched samples. Unlike t-tests, absolute standardized mean differences are not sensitive to sample size. This allows researchers to compare differences in means across measured covariates between treated and control observations in the matched sample with that in the unmatched sample as a percentage of the square root of the average of the sample variances in both groups (Austin, 2009).[[53]](#footnote-53)

An average absolute standardized difference closer to 0 indicates small differences between treated and control groups in matched samples. However, exact balance in covariates is a property of randomized controlled trials (RCT) with large sample sizes. In the case of observational studies and also of RCTs with small samples, some degree of imbalance in measured covariates can be expected (Austin, 2009). Furthermore, as noted in Garrido (2014), there is no consensus in the literature on how much imbalance is acceptable when implementing PSM. Proposed maximum bias range from 10 to 25 percent (Harder *et al.,* 2010).[[54]](#footnote-54)

Table 9b reports standardized (% bias) differences in means of measured covariates between the treated and control groups in the unmatched and matched samples. A total of 15 out of the 29 covariates in the unmatched sample have an absolute standardized difference greater than 10 percent; the largest differences being 85.4 percent (AEZ valleys), 30.8 percent (time to main water source), 27.4 percent (time to route or road), and 27.2 (AEZ tropical). Only 11 covariates have an absolute % bias less than 5 percent. However, under PSM, standardized differences in measured covariates were significantly reduced across matching algorithms. Only for the 1-nearest-neighbor with replacement and local linear regression matching algorithms we observe a small imbalance in a few variables. The overall performance of the different matching techniques was satisfactory: average absolute standardized % bias of the unmatched sample is 13.8 percent, with a median of 10.4 percent. With PSM, average absolute standardized % bias range from 2.8 to 5.4 percent, and a median of 2 to 4.4 percent.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| ***Table 9b****—Standardized % Bias Across Covariates: Matched Samples* | | | | | | | | | |
|  | **%bias**(before matching) | ***-psmatch2-***with caliper (0.01) | | | | | ***-psmatch2-*** | | |
| **(I) PSM** NN(1) | **(II) PSM** NN  w/out rep. | **(II) PSM** NN(3) | **(IV) PSM** NN(5) | **(V) PSM** Radius (0.01) | | **(VI) PSM** Kernel | **(VII) PSM** LLR |
| **Baseline covariates** | **% bias** (after matching) | | | | | | | |
| Household size (# of members) | 1.1 | 9.1 | 3.4 | 6.6 | 7.0 | 8.6 | | 5.4 | 4.1 |
| Dependency ratio | -0.9 | 9.9 | 3.5 | 8.6 | 7.0 | 5.1 | | 0.6 | 0.9 |
| Age | 14.3 | -7.5 | -1.3 | -4.6 | -4.0 | -7.0 | | 3.7 | 1.1 |
| Age (squared) | 12.8 | -6.9 | -0.9 | -4.0 | -3.9 | -7.1 | | 3.9 | 1.0 |
| Prop. of women in household (%) | -2.8 | 12.6 | 1.7 | 7.5 | 9.5 | 7.1 | | 5.4 | 0.7 |
| Female (0,1) | -8.5 | 2.4 | -4.4 | -0.8 | -2.1 | -3.5 | | -9.0 | 3.3 |
| Single (0,1) | -13.5 | 4.6 | -0.9 | -4.5 | -4.4 | -3.0 | | -8.8 | 5.0 |
| Indigenous - NyPIOCs (0,1) | 23.0 | 4.8 | 6.5 | 5.5 | 6.1 | 4.9 | | 0.7 | -0.5 |
| HH Head with Primary Completed (0,1) | 17.0 | 12.2 | 2.0 | 7.8 | 9.3 | 6.7 | | 8.6 | 14.2 |
| HH Head with Secondary Completed (0,1) | 2.9 | 6.9 | 0.9 | 7.4 | 7.6 | 5.9 | | 7.4 | 7.8 |
| HH Head with more than Secondary (0,1) | 10.4 | -2.1 | -5.1 | 2.7 | 1.8 | 2.8 | | 2.3 | -2.9 |
| HH Head with Technical Adult Education (0,1) | 2.8 | 2.5 | 0.0 | 4.1 | 4.4 | -0.3 | | 0.8 | 4.6 |
| Land owned (ha) | 24.9 | -2.6 | -3.7 | -3.4 | -4.1 | -3.2 | | -8.1 | -10.9 |
| Bank account with financial institution (0,1) | 3.4 | 6.5 | 0.0 | 4.9 | 4.8 | 3.9 | | 3.2 | 9.3 |
| Credit constrained (0,1) | 4.3 | 5.7 | 0.7 | -0.4 | -1.5 | -1.9 | | -2.7 | 8.4 |
| Household with a cellular phone (0,1) | 12.5 | 1.0 | 5.0 | -3.1 | -2.8 | -1.5 | | -1.7 | -2.8 |
| Route or road reliably passable year-round (min)(log) | 27.4 | -1.5 | -2.7 | 4.9 | 4.2 | 5.5 | | 6.3 | -1.6 |
| Time to main source of water for drinking/cooking (min)(log) | 30.8 | -2.4 | -0.1 | -5.4 | -6.7 | -1.3 | | 2.3 | 5.5 |
| Dirt floor (0,1) | 23.7 | -6.3 | 3.3 | -4.0 | -2.8 | -2.1 | | -2.9 | -8.3 |
| Valleys (0,1) | -85.4 | 1.2 | 3.7 | 2.5 | 2.8 | 2.9 | | -1.5 | -4.4 |
| Tropical (0,1) | 27.2 | 0.9 | -5.3 | -1.0 | -1.5 | -1.6 | | 9.5 | 19.2 |
| Own tractor (0,1) | 3.3 | 3.0 | 1.2 | 5.4 | 3.8 | 3.3 | | 6.5 | 6.5 |
| Participated in an agricultural coop (0,1) | 4.6 | 0.8 | 2.0 | -0.3 | 0.5 | 3.9 | | 5.8 | 8.9 |
| Participated in an agricultural *patronato* (0,1) | 5.9 | 0.0 | 4.4 | 0.6 | 0.9 | 0.3 | | 0.3 | 3.3 |
| Participated in an agricultural syndicate (0,1) | -9.4 | 2.8 | 6.9 | 4.8 | 5.4 | 4.7 | | 5.7 | 5.2 |
| Participated in an agri. neighborhood council (0,1) | -12.4 | 2.0 | 1.3 | 2.4 | 1.2 | 3.1 | | 3.0 | 1.9 |
| Participated in an agri. credit or savings group (0,1) | -1.7 | 3.4 | 0.0 | 0.0 | -2.9 | -0.2 | | -0.3 | 3.1 |
| Participated in other agricultural group/org (0,1) | -0.2 | 5.0 | 0.0 | 0.0 | 0.0 | 0.0 | | 0.1 | 4.7 |
| Participated in a non-agricultural group/org (0,1) | -10.6 | 0.6 | 9.6 | -1.3 | 1.4 | -4.2 | | -4.2 | 3.9 |
| Mean Bias | 13.8 | 4.4 | 2.8 | 3.7 | 3.9 | 3.7 | | 4.2 | 5.4 |
| Median Bias | 10.4 | 3.0 | 2.0 | 4.0 | 3.9 | 3.3 | | 3.7 | 4.4 |

**C. Results**

This section presents the *short-term* effects of PRONAREC I on agricultural input use and expenditures, agricultural production, productivity, income, and food security. Tables 10-12 reports estimates of the ATETs’ derived from the different matching techniques. In Table 10, we present the impact of the program on agricultural input use and expenditures; Table 11 presents the impact of the program on indicators related to agricultural production (e.g., crop portfolio, sales, value of production, and agricultural gross margins); and Table 12 presents the effects of the program on indicators related to household income and food security.

The PSM estimates in Table 10 indicate that PRONAREC I had a positive impact on the use of improved or certified seeds and agricultural machinery during the 2014-2015 agricultural cycle. Program beneficiaries are significantly more likely to use improved or certified seeds (8-16 percentage points) and agricultural machinery (15-24 percentage points), such as a tractor (15-25 percentage points). For instance, they use significantly more tractor units (0.14-0.24) and consequently have greater expenditures on the use of tractors for production (US$60-100), representing an increase in the order of 20 percent and 65 percent, respectively, with respect to the control group. In contrast, beneficiaries are significantly less likely to use animal traction for production (14-21 percentage points). These results are robust and highly significant across specifications, except for nearest-neighbor matching without replacement and a caliper of 0.01.

Beneficiaries of the first phase of the program seem less likely to use fungicides, herbicides, chemical fertilizer and paid labor while more likely to use insecticides and organic fertilizer; however, these results are not significant. Similarly, in the short term, we do not observe an impact on the expenditures on herbicide, herbicide, insecticide, chemical fertilizer, manure/fertilizer, other agrochemicals, seeds, animal traction, and paid labor. As expected, PRONAREC I did have significant effects on aggregate expenditures dedicated to the irrigation of plots (US$27-35), especially expenditures on energy—an average gain (in the magnitude of expenditures on irrigation) of approximately 90 percent relative to the control group.[[55]](#footnote-55) Average expenditures on energy for irrigation increased six-fold, and the results are robust and significant across all specifications. In the case of expenditures on equipment, maintenance, and water service for irrigation, ATET estimators are not robust across specifications.

In summary, the results reported in Table 10 show that PRONAREC I positively affected the use and expenditures on agricultural machinery for production, particularly on tractors, for the 2014-2015 cycle. Additionally, the use of improved or certified seeds increased as a result of the intervention, and so did average expenditures allocated to irrigation for production purposes among beneficiaries of the first phase of the program.

The program is also expected to have an effect on the composition of crop portfolios of its beneficiaries, shifting their crop patterns from traditional towards high-value crops. ATET estimators in Table 11 reveal that PRONAREC I had significant positive effects on the proportion of cultivated land dedicated to the production of non-traditional crops (6-10 percentage points)—roughly a 19 percent increase in the proportion of land cultivated with non-traditional crops with respect to the control group. These results suggest farmers continue to produce at least some amount of traditional crops, perhaps for home-consumption, but they are also changing the composition of production as reflected by the increase in the proportion of land cultivated with non-traditional crops.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| ***Table 10****—Short-Term Impacts of PRONAREC on Agricultural Inputs: Use and Expenditures* | | | | | | | | | | | | | | | | | | | | | | |
|  |  | ***-psmatch2-*** with caliper (0.01)† | | | | | | | | ***-psmatch2-***† | | | | | | ***-teffects psmatch-*** without caliper | | | | | | |
| **(1) PSM** NN(1) | | **(2) PSM** NN w/out rep. | | **(3) PSM** NN(3) | | **(4) PSM** NN(5) | | **(5) PSM** Radius (0.01) | | **(6) PSM** Kernel | | **(7) PSM** LLR | | **(8) PSM** NN(1) | | **(9) PSM** NN(3) | | **(10) PSM** NN(5) | | |
| **Results** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |
| **Input Use** | Fungicide (0,1) | -0.01 |  | 0.06 | \*\* | -0.02 |  | -0.03 |  | -0.03 |  | -0.02 |  | -0.03 |  | -0.09 |  | -0.04 |  | -0.02 | |  |
| Herbicide (0,1) | -0.03 |  | -0.01 |  | -0.06 |  | -0.05 |  | -0.07 |  | -0.04 |  | -0.06 |  | -0.11 |  | -0.07 |  | -0.04 | |  |
| Insecticide (0,1) | 0.05 |  | 0.07 | \*\* | 0.03 |  | 0.03 |  | 0.03 |  | 0.03 |  | 0.04 |  | 0.06 |  | 0.02 |  | 0.03 | |  |
| Chemical fertilizer (0,1) | -0.011 |  | 0.013 |  | -0.028 |  | -0.033 |  | -0.03 |  | -0.03 |  | -0.03 |  | -0.002 |  | -0.05 |  | -0.04 | |  |
| Fertilizer/*guano*/manure/chicken manure (0,1) | 0.05 |  | 0.08 | \*\*\* | 0.03 |  | 0.03 |  | 0.02 |  | -0.008 |  | -0.02 |  | -0.07 |  | 0.02 |  | 0.004 | |  |
| Improved or certified seeds (0,1) | 0.08 | \* | 0.08 | \*\*\* | 0.08 | \*\* | 0.09 | \*\* | 0.09 | \*\*\* | 0.11 | \*\*\* | 0.12 | \*\*\* | 0.16 | \*\*\* | 0.10 |  | 0.12 | | \* |
| Animal traction (oxen yoke) for production (0,1) | -0.14 | \*\*\* | -0.08 | \*\* | -0.15 | \*\*\* | -0.14 | \*\*\* | -0.15 | \*\*\* | -0.16 | \*\*\* | -0.17 | \*\*\* | -0.20 | \*\*\* | -0.21 | \*\*\* | -0.20 | | \*\*\* |
| Tractor for production (0,1) | 0.15 | \*\*\* | 0.04 |  | 0.16 | \*\*\* | 0.16 | \*\*\* | 0.16 | \*\*\* | 0.17 | \*\*\* | 0.18 | \*\*\* | 0.25 | \*\*\* | 0.22 | \*\*\* | 0.24 | | \*\*\* |
| Number of tractor used (#) | 0.13 | \*\* | 0.02 |  | 0.14 | \*\*\* | 0.13 | \*\*\* | 0.15 | \*\*\* | 0.16 | \*\*\* | 0.16 | \*\*\* | 0.24 | \*\*\* | 0.21 | \*\*\* | 0.23 | | \*\*\* |
| Agricultural machinery (0,1) | 0.15 | \*\*\* | 0.04 |  | 0.15 | \*\*\* | 0.15 | \*\*\* | 0.16 | \*\*\* | 0.17 | \*\*\* | 0.17 | \*\*\* | 0.24 | \*\*\* | 0.21 | \*\*\* | 0.22 | | \*\*\* |
| Paid labor (0,1) | -0.02 |  | -0.02 |  | -0.02 |  | -0.03 |  | -0.02 |  | -0.02 |  | -0.01 |  | -0.12 |  | -0.01 |  | 0.004 | |  |
| **Input Expenditures** | Inputs (US$) | 68.32 |  | 111.46 |  | -32.95 |  | -55.62 |  | 44.06 |  | 81.82 |  | 128.43 |  | -10.13 |  | 53.87 |  | 69.66 | |  |
| Inputs (US$/ha worked) | 403.02 |  | 339.71 |  | 61.73 |  | 145.91 |  | 323.03 |  | 369.08 |  | 339.01 |  | 233.40 |  | 245.81 |  | 410.90 | |  |
| Expenditures on animal traction (US$) | 97.45 |  | 100.75 |  | 90.24 |  | 90.29 |  | 90.57 |  | 89.12 |  | 86.88 |  | 59.75 |  | 78.78 |  | 81.26 | |  |
| Expenditures on tractor for production (US$) | 63.87 | \*\*\* | 26.16 | \*\* | 65.96 | \*\*\* | 67.47 | \*\*\* | 68.33 | \*\*\* | 80.94 | \*\*\* | 87.98 | \*\*\* | 95.16 | \*\*\* | 99.41 | \*\*\* | 99.60 | | \*\*\* |
| Paid Labor (US$) | 250.97 |  | 286.32 |  | 276.91 |  | 175.28 |  | 170.90 |  | 321.55 |  | 342.32 |  | 540.42 | \* | 444.39 |  | 486.56 | | \* |
| Paid Labor (US$/ha worked) | 186.19 |  | 221.32 |  | 247.20 |  | 244.13 |  | 214.29 |  | 211.59 |  | 217.01 |  | 11.43 |  | 182.82 |  | 198.66 | |  |
| Expenditures on the irrigation of plots (US$) | 26.77 | \* | 46.81 | \*\*\* | 37.32 | \*\*\* | 34.11 | \*\* | 34.05 | \*\* | 32.00 | \*\*\* | 31.22 | \*\*\* | 34.78 | \* | 27.75 | \*\* | 29.34 | | \*\* |
| Irrigation equipment/maintenance (US$) | 13.02 |  | 30.17 | \*\*\* | 23.68 | \*\* | 20.52 |  | 20.17 | \* | 19.09 | \* | 18.25 |  | 21.03 |  | 12.91 |  | 16.21 | |  |
| Water service (US$) | 6.05 |  | 8.09 | \* | 5.17 |  | 5.08 |  | 5.19 |  | 4.71 |  | 5.04 |  | 6.02 | \*\* | 6.69 | \*\*\* | 4.96 | | \* |
| Energy (US$) | 7.71 |  | 8.54 | \* | 8.47 | \* | 8.51 | \* | 8.69 | \* | 8.20 | \* | 7.94 | \* | 7.73 | \* | 8.15 | \*\* | 8.17 | | \*\* |
| *Source:* Authors' own calculations. *Note:* ATET statistically significant at the \*\*\* 1%, \*\* 5%, \* 10% level (all two-tailed).  † Bootstrap standard errors with 1,000 replications. | | | | | | | | | | | | | | | | | | | | |

As mentioned in Section III, although the program did not finance on-farm irrigation infrastructure *per se*, the eligibility and feasibility criteria for the selection of projects considered the economic viability of irrigation systems. As expected, PRONAREC I had a significant positive impact on the number of hectares equipped for irrigation (0.52-0.73 hectares) for program beneficiaries, as shown in Table 11. That is, beneficiaries of PRONAREC I experienced a 46 to 66 percent increase, depending on the specification, in the number of hectares equipped for irrigation, compared to the control group. Furthermore, beneficiaries cultivated a significantly greater number of hectares under irrigation (0.57-0.57 hectares). Both impact estimates are robust to the different estimation methods.

When examining the number of hectares worked under irrigation as a percentage of total landholding equipped for irrigation, ATET estimators in Table 11 indicate a negative effect on the order of 1-9 percentage points for beneficiaries of PRONAREC I. The results are significant and robust under the *-psmatch2-* command, but not under the *-teffects psmatch-* command, yet estimated coefficients point in the same direction. These results reinforce the information available in Table 4. Even though beneficiaries of PRONAREC I have a relatively greater number of hectares equipped for irrigation, this variable suggest that usage is not optimal among beneficiaries of the program. A plausible explanation of this phenomenon is likely explained by the geographical location of irrigation systems financed by PRONAREC I. A considerable number of these systems are located in the *altiplano* (Andean plateau)(see Figure 3).During the winter time (April to October), the temperature often drops below freezing point, making land unsuitable for agriculture (Garcia *et al.,* 2007).

Our estimations suggest beneficiaries are relatively better connected to markets as a result of the program. Specifically, beneficiaries of the first phase of PRONAREC are, on average, substantially more likely to sell at least some of their production (8-14 percentage points), sold a higher proportion of their production (6-8 percentage points), and are more likely to sell the majority of at least one crop in a *feria* or market (17-23 percentage points). These results are robust and highly significant, representing an increase of about 11, 14, and 38 percent, respectively, relative to future beneficiaries of the program. On average, beneficiaries of PRONAREC I sold significantly more (US$700-US$1,2000) of their production—an increase in sales in the order of 48 to 82 percent with respect to the control group. In turn, the proportion of production for home-consumption among beneficiaries is, on average, significantly lower (11-17 percentage points). Similarly, we have statistically robust evidence to conclude PRONAREC I had a positive effect on the proportion of production dedicated to the transformation of farm products (1 percentage point).

Beneficiaries of PRONAREC I experienced a significant increase in total value of production (US$990-$1,220) caused mainly by agricultural sales. ATET estimators for this variable are highly significant across specifications, except for k-nearest-neighbor matching with caliper. On the other hand, we lack evidence of an impact of participating in PRONAREC I on agricultural productivity, measured as the value of production per hectare, and agricultural gross margins.

Overall, the results in Table 11 indicate positive effects in the composition of cropping patterns, as reflected by a higher proportion of land dedicated to the production of non-traditional crops among program beneficiaries. The program successfully increased the average number of hectares equipped for irrigation, which resulted in a higher relative number of hectares cultivated under irrigation for beneficiaries of the program. In addition, PRONAREC I had significant positive effects on the value of production of its beneficiaries, especially derived from a higher proportion of production allocated to sales—particularly in markets or *ferías*, and consequently on the value of production sold*—*and from a lower proportion of production allocated to home-consumption.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| ***Table 11****—Short-Term Impacts of PRONAREC on Agricultural Production: Sales and Value of Production* | | | | | | | | | | | | | | | | | | | | | |
|  |  | ***-psmatch2-*** with caliper† | | | | | | | | ***-psmatch2-***† | | | | | | ***-teffects psmatch-*** without caliper | | | | | |
| **(1) PSM** NN(1) | | **(2) PSM** NN w/out rep. | | **(3) PSM** NN(3) | | **(4) PSM** NN(5) | | **(5) PSM** Radius (0.01) | | **(6) PSM** Kernel | | **(7) PSM** LLR | | **(8) PSM** NN(1) | | **(9) PSM** NN(3) | | **(10) PSM** NN(5) | |
| **Results** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **Crop Portfolio** | Traditional crops (0,1) | 0.01 |  | 0.01 |  | 0.00 |  | 0.00 |  | -0.01 |  | -0.02 |  | -0.02 |  | -0.02 |  | -0.02 |  | -0.02 |  |
| Prop. of land with traditional crops (% ha worked) | 0.00 |  | 0.01 |  | 0.01 |  | 0.0129 |  | 0.006 |  | -0.01 |  | -0.01 |  | 0.02 |  | -0.02 |  | -0.02 |  |
| Non-traditional crops (0,1) | 0.03 |  | 0.04 |  | 0.02 |  | 0.01 |  | 0.02 |  | 0.05 |  | 0.04 |  | -0.04 |  | 0.05 |  | 0.05 |  |
| Prop. of land with non-traditional crops (% ha worked) | 0.08 | \*\* | 0.08 | \*\*\* | 0.07 | \*\* | 0.07 | \*\* | 0.07 | \*\* | 0.09 | \*\*\* | 0.08 | \*\*\* | 0.06 | \* | 0.10 | \*\*\* | 0.10 | \*\*\* |
| **Irrigation** | Total landholding equipped for irrigation (ha) | 0.57 | \*\*\* | 0.46 | \*\*\* | 0.52 | \*\*\* | 0.55 | \*\*\* | 0.56 | \*\*\* | 0.59 | \*\*\* | 0.59 | \*\*\* | 0.73 | \*\*\* | 0.69 | \*\*\* | 0.71 | \*\*\* |
| Hectares worked under irrigation (ha worked) | 0.51 | \*\*\* | 0.44 | \*\*\* | 0.47 | \*\*\* | 0.47 | \*\*\* | 0.49 | \*\*\* | 0.50 | \*\*\* | 0.50 | \*\*\* | 0.54 | \*\*\* | 0.55 | \*\*\* | 0.57 | \*\*\* |
| Worked under irrigation (% total landholding equipped for irrigation) | -0.11 | \*\* | -0.08 | \*\*\* | -0.09 | \*\* | -0.09 | \*\* | -0.08 | \*\*\* | -0.08 | \*\*\* | -0.09 | \*\*\* | -0.01 |  | -0.05 |  | -0.05 |  |
| **Sales** | Household Sells (0,1) | 0.09 | \*\* | 0.05 | \* | 0.08 | \*\* | 0.08 | \*\* | 0.10 | \*\*\* | 0.10 | \*\*\* | 0.11 | \*\* | 0.14 | \*\*\* | 0.10 |  | 0.12 | \* |
| Sold *most* crop in a *feria* (0,1) | 0.19 | \*\*\* | 0.14 | \*\*\* | 0.19 | \*\*\* | 0.17 | \*\*\* | 0.17 | \*\*\* | 0.19 | \*\*\* | 0.21 | \*\*\* | 0.22 | \*\*\* | 0.23 | \*\*\* | 0.23 | \*\*\* |
| Sold *most* crop to a *rescatista* (0,1) | -0.09 | \*\* | -0.09 | \*\*\* | -0.11 | \*\* | -0.08 | \*\* | -0.07 | \*\* | -0.09 | \*\* | -0.11 | \*\* | -0.07 | \* | -0.12 |  | -0.10 |  |
| **Value of Production** | Value of production (US$) | 483.60 |  | 881.30 |  | 634.66 |  | 675.83 |  | 993.91 | \*\* | 1039.36 | \*\* | 1299.79 | \*\*\* | 1037.80 | \*\*\* | 1176.73 | \*\*\* | 1221.56 | \*\*\* |
| Prop. of production: home-consumption (% total production) | -0.11 | \*\*\* | -0.05 | \*\*\* | -0.11 | \*\*\* | -0.11 | \*\*\* | -0.11 | \*\*\* | -0.11 | \*\*\* | -0.11 | \*\*\* | -0.17 | \*\*\* | -0.13 | \*\*\* | -0.13 | \*\*\* |
| Prop. of production: animal consumption (% total production) | 0.03 |  | -0.01 |  | 0.02 |  | 0.03 |  | 0.02 |  | 0.02 |  | 0.02 |  | 0.06 | \*\*\* | 0.04 | \*\* | 0.05 | \*\*\* |
| Prop. of production: losses (% total production) | 0.004 |  | 0.006 |  | 0.011 |  | 0.011 |  | 0.009 |  | 0.005 |  | 0.007 |  | 0.022 | \* | 0.012 |  | -0.0005 |  |
| Value of production: losses (US$) | 1.91 |  | -1.88 |  | -48.64 |  | -38.79 |  | -16.68 |  | 2.73 |  | 53.38 |  | 3.98 |  | 38.94 |  | 43.11 |  |
| Prop. of production: transformation (sub-products) (% total production) | 0.01 | \*\*\* | 0.01 |  | 0.01 | \*\* | 0.01 | \*\* | 0.01 | \*\* | 0.01 | \*\* | 0.01 | \*\* | 0.01 |  | 0.01 | \*\* | 0.01 | \*\* |
| Prop. of production: seeds (% total production) | -0.01 |  |  |  | -0.004 |  | -0.004 |  | 0.00 |  | -0.01 |  | -0.01 |  | 0.00 |  | -0.01 |  | -0.01 |  |
| Prop. of production: sales (% total production) | 0.06 | \* | 0.05 | \*\* | 0.06 | \*\* | 0.06 | \*\* | 0.07 | \*\*\* | 0.07 | \*\*\* | 0.08 | \*\*\* | 0.08 | \*\*\* | 0.07 | \* | 0.08 | \*\* |
| Value of production: sales (US$) | 708.61 | \* | 1,146.42 | \*\* | 869.45 | \* | 875.35 | \* | 1,150.38 | \*\*\* | 1,107.43 | \*\*\* | 1267.92 | \*\*\* | 1,144.36 | \*\*\* | 1,201.54 | \*\*\* | 1,198.36 | \*\*\* |
| Prop. of production: other (% total production) | 0.01 |  | 0.002 |  | 0.01 |  | 0.007 |  | 0.005 |  | 0.003 |  | 0.004 |  | 0.01 |  | 0.003 |  | 0.001 |  |
| Value of production (US$/ha worked) | 26.72 |  | 487.52 |  | 323.04 |  | 165.06 |  | 476.67 |  | 434.43 |  | 389.37 |  | 315.38 |  | 746.67 |  | 412.49 |  |
| Value of production of traditional crops (US$/ha worked) | 329.68 |  | -6.60 |  | -61.39 |  | -172.88 |  | -191.32 |  | -180.10 |  | -171.21 |  | -441.46 |  | 50.93 |  | -49.94 |  |
| Value of production of non-traditional crops (US$/ha worked) | 277.45 |  | 1,253.97 |  | 542.63 |  | 234.65 |  | 1,115.21 |  | 980.84 |  | 922.11 |  | 1,253.97 |  | 1,073.83 |  | 797.69 |  |
| **Agricultural Gross Margins** | Agricultural gross margins (US$/ha worked) | -821.64 |  | -24.30 |  | -144.21 |  | -355.76 |  | -243.89 |  | -581.42 |  | -553.67 |  | -458.34 |  | -210.25 |  | -693.34 |  |
| *Source:* Authors' own calculations. *Note:* ATET estimators statistically significant at the \*\*\* 1%, \*\* 5%, \* 10% level (all two-tailed).  † Bootstrap standard errors with 1,000 replications. | | | | | | | | | | | | | | | | | | | | | |

Lastly, in Table 12 we present the effects of PRONAREC on household income and food security. The output shows a significant positive ATET on total household income, mostly derived from higher agricultural sales, transformation of farm products, and consumption of livestock owned. On average, the value of consumption of livestock owned by beneficiaries is greater (U$S47-US$88) than that of the matched control groups—these results are robust and highly significant. ATET estimators of household income are significant across specifications, except for matching on the k-nearest-neighbor with a 0.01 caliper. With regards to food security, PRONAREC did not have an impact across the different dimensions of food security measured by the ELCSA.

**VII. Conclusions**

This case study evaluates the impact of the first phase of the Bolivia’s National Irrigation Program with a Watershed Approach (PRONAREC for its acronym in Spanish) on agricultural income, productivity and food security. For this purpose, we used a cross-sectional agricultural household survey specially designed for this evaluation. The survey was conducted in December 2015, to a representative sample of beneficiaries of the both phases of the program, with reference to the 2014-2015 agricultural cycle. Given the characteristics of the program, we estimate the impacts of the first phase of PRONAREC using the Propensity Score Matching (PSM) technique with multiple matching estimators. The propensity score is defined as the conditional probability of assignment to treatment given a vector of observable pre-treatment covariates (Rosenbaum and Rubin, 1983). Specifically, we used program beneficiaries who will receive the intervention in the second phase of the program (PRONAREC II) as the control group for beneficiaries of the first phase. These are producers who are enrolled in the program but have not received any benefits during the 2014-2015 agricultural cycle, and therefore, constitute an appropriate control group.

Overall, the results of the impact evaluation indicate that program beneficiaries have undergone significant changes. PRONAREC I positively affected the use of improved or certified seeds, agricultural machinery for production (i.e., tractor), and expenditures on the irrigation of agricultural plots. Access to irrigation successfully induced an increase in total household income, particularly as a result of greater agricultural production. We also found substantial evidence of greater market value of production and connection to markets. As a result, beneficiaries of PRONAREC I experienced an increase in total income of 29.5 to 35.5 percent, depending on the specification, relative to the control group. Also, beneficiaries have increased the number of hectares under irrigation (approximately 46.2 to 55.5 percent), improved the value of agricultural production (approximately 46.98 to 52.86 percent), value of sales of agricultural production (approximately 85 to 99 percent), and household income (29.5 to 35.5 percent).

As mentioned in the methodology section, PSM is a statistical approach that relies on the conditional independence assumption, reducing the effect of selection bias in the estimation of treatment effects by controlling for observable differences, thus “mimicking” some of the characteristics of randomized controlled trials (RCTs). However, this methodology is unable to control for unobservable differences that might have contributed to selection bias.[[56]](#footnote-56) The next step in the evaluation of PRONAREC is to perform a *difference-in-difference* using the scores obtained in the estimation of the propensity score in this evaluation as weights in the estimation, thus controlling for unobserved characteristics that are constant across time between treated and control groups. This is possible given that the program will be collecting follow-up surveys for all of its beneficiaries.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| ***Table 12****—Short-Term Impacts of PRONAREC on Income and Food Security* | | | | | | | | | | | | | | | | | | | | | |
|  |  | ***-psmatch2-*** with caliper† | | | | | | | | ***-psmatch2-***† | | | | | | ***-teffects psmatch-*** without caliper | | | | | |
| **(1) PSM** NN(1) | | **(2) PSM** NN w/out rep. | | **(3) PSM** NN(3) | | **(4) PSM** NN(5) | | **(5) PSM** Radius (0.01) | | **(6) PSM** Kernel | | **(7) PSM** LLR | | **(8) PSM** NN(1) | | **(9) PSM** NN(3) | | **(10) PSM** NN(5) | |
| **Results** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **Income** | Total Household Income (US$) | 352.46 |  | 888.52 |  | 770.37 |  | 743.69 |  | 971.44 | \* | 1,065.18 | \*\* | 1,296.82 | \*\* | 1,248.34 | \* | 1,100.34 | \*\* | 1,239.81 | \*\*\* |
| Off-farm employment (US$) | -105.18 |  | -112.01 |  | 46.58 |  | -3.84 |  | -77.73 |  | -55.55 |  | -33.09 |  | 66.84 |  | -75.78 |  | -36.28 |  |
| Remittances (US$) | -56.16 |  | -53.31 | \*\* | -29.68 |  | -32.08 |  | -38.02 | \* | -35.50 | \*\* | -30.71 | \* | -25.45 |  | -11.71 |  | -8.48 |  |
| Value of Production: Home Consumption (US$) | -212.95 |  | -187.30 | \*\* | -195.80 | \* | -180.17 |  | -145.68 | \*\* | -82.40 |  | -67.21 |  | -196.66 |  | -142.81 |  | -104.48 |  |
| Value of of Production: Animal Consumption (US$) | -66.87 |  | -132.90 | \* | -46.90 |  | -35.72 |  | -49.39 |  | -34.13 |  | -15.07 |  | 36.08 |  | 31.89 |  | 24.64 |  |
| Value of Agricultural Production: Transformations (US$) | 49.85 | \* | 56.99 | \* | 48.47 | \* | 47.95 | \* | 47.86 | \* | 45.35 | \* | 44.67 | \* | 35.26 | \* | 40.48 | \*\* | 42.53 | \*\*\* |
| Value of Production: Seeds (US$) | -18.40 |  | -17.50 |  | -13.63 |  | -11.40 |  | -8.82 |  | -13.79 |  | -10.06 |  | -22.12 |  | -18.39 |  | -9.19 |  |
| Value of Agricultural Production: Sales (US$) | 708.61 |  | 1,146.42 | \*\* | 869.45 | \* | 875.35 | \* | 1,150.38 | \*\*\* | 1,107.43 | \*\*\* | 1,267.92 | \*\*\* | 1,144.36 | \*\*\* | 1,201.54 | \*\*\* | 1,198.36 | \*\*\* |
| Value of Production: Other (US$) | 9.13 |  | -0.89 |  | 5.31 |  | 1.77 |  | -0.51 |  | -1.68 |  | 10.68 |  | 20.91 |  | 10.39 |  | 11.91 |  |
| Consumption of livestock owned (US$-national median) | 52.00 | \*\* | 36.01 | \* | 47.21 | \*\* | 52.70 | \*\*\* | 52.10 | \*\*\* | 57.07 | \*\*\* | 56.90 | \*\*\* | 88.18 | \*\*\* | 78.17 | \*\*\* | 74.83 | \*\*\* |
| Livestock sold (US$-national median) | -169.10 |  | 163.70 | \*\*\* | -93.20 |  | -104.73 |  | -90.47 |  | -15.44 |  | -35.03 |  | -40.48 |  | -213.18 |  | -107.60 |  |
| **Food Security Status *(ELCSA)*** | Food insecure (0,1) | -0.033 |  | 0.013 |  | -0.013 |  | -0.011 |  | 0.0003 |  | 0.005 |  | 0.017 |  | -0.005 |  | -0.005 |  | -0.018 |  |
| Adults food insecurity (0,1) | 0.033 |  | 0.02 |  | -0.016 |  | -0.013 |  | -0.001 |  | 0.004 |  | 0.014 |  | -0.009 |  | -0.007 |  | -0.021 |  |
| *Source:* Authors' own calculations. *Note:* ATET estimators statistically significant at the \*\*\* 1%, \*\* 5%, \* 10% level (all two-tailed).  † Bootstrap standard errors with 1,000 replications. | | | | | | | | | | | | | | | | | | | | | |

**REFERENCES**

Abadie, A., Drukker, D., Herr, J. L., & Imbens, G. W. (2004). Implementing Matching Estimators for Average Treatment Effects in Stata. *Stata Journal*, 4, 290-311.

Abadie, A., & Imbens, G. W. (2016). Matching on the Estimated Propensity Score. *Econometrica*, 84, 781–807.

Agrimonitor (2016). IDBAgrimonitor Platform: Agricultural Policy Monitoring System in Latin America and the Caribbean. Inter-American Development Bank.

Ahmed, B., Mume, J. and Kedir, A. (2014). Impact of Small-scale Irrigation on Farm Income Generation and Food Security Status: The Case of lowland Areas, Oromia, Ethiopia. *International Journal of Economics and Empirical Research* (IJEER), 2(10), 412-419.

Anríquez, G., Foster, W., Ortega, J., Falconi, C., & de Salvo, C. (2015). It’s Not How Much, But Where: Public Expenditures and the Performance of Latin American Agriculture. *Mimeo*, Inter-American Development Bank, Washington, DC.

Atria, R., & Siles, M. (2004). *Social Capital and Poverty Reduction in Latin America and the Caribbean: Towards a New Paradigm* (Vol. 71). United Nations Publications.

Araral, E.K. 2011. The Impact of Decentralization on Large Scale Irrigation? Evidence from the Philippines. *Water Alternatives*, 4(2), 110-123.

Austin, P. C. (2009). Balance Diagnostics for Comparing the Distribution of Baseline Covariates Between Treatment Groups in Propensity‐Score Matched Samples. *Statistics in Medicine*, 28(25), 3083-3107.

Austin, P. C. (2014). A Comparison of 12 Algorithms for Matching on the Propensity Score. *Statistics in Medicine*, 33(6), 1057-1069.

Ballard, T. J., Kepple, A. W., & Cafiero, C. (2013). *The Food Insecurity Experience Scale: Development of a Global Standard for Monitoring Hunger Worldwide.* Rome: FAO.

Bandyopadhyay, S., P. Shyamsundar and M. Xie. (2010). Transferring irrigation Management to Farmers Associations: Evidence from the Philippines*.* *Water Policy*, 12(3), 444.

Beaman, L., BenYishay, A., Fatch, P., Magruder, J. & Mushfiq A. (2015). *Making Networks Work for Policy: Evidence from Agricultural Technology Adoption in Malawi*. 3ie Grantee Final Report. New Delhi: International Initiative for Impact Evaluation (3ie).

Bertelli, O., & Macours, K. (2014). *Food Security and Agriculture in Developing Countries: Measurement and Hypotheses for Impact Evaluations.* FOODSECURE Working Paper No. 21.

BID. (2013). Programa Nacional de Riego con Enfoque de Cuenta II: Propuesta de Préstamo. Washington DC: Banco Interamericano de Desarrollo.

Boelens, R., & Gelles, P. H. (2005). Cultural Politics, Communal Resistance and Identity in Andean Irrigation Development. *Bulletin of Latin American Research*, 24(3), 311-327.

Boelens, R., Guevara-Gil, A., & Panfichi, A. (2009). Indigenous Water Rights in the Andes: Struggles Over Resources and Legitimacy. *Journal of Water Law*, 20(5-6), 268-277.

Caliendo, M., & Kopeinig, S. (2008). Some Practical Guidance for the Implementation of Propensity Score Matching. J*ournal of Economic Surveys*, 22(1), 31-72.

Cameron, A. C., & Miller, D. L. (2015). A Practitioner’s Guide to Cluster-Robust Inference. *Journal of Human Resources*, 50(2), 317-372.

Castellani, F., & Zenteno, J. (2015). *Pobreza y Movilidad Social en Bolivia en la Última Década*. Nota Técnica No. IDB-TN-899, Banco Interamericano de Desarrollo.

Cavalli-Sforza, L. L., & Feldman, M. W. (1981). *Cultural Transmission and Evolution: A Quantitative Approach*. No. 16. Princeton University Press.

CEPAL (2013). *Panorama Económico y Social de la Comunidad de Estados Latinoamericanos y Caribeños 2013*. Comisión Económica para América Latina y el Caribe, Naciones Unidas, Santiago de Chile

CEPALSTAT (2015). *Bases de Datos y Publicaciones Estadísticas: Cuentas Nacionales Anuales en Dólares.* Comisión Económica para América Latina y el Caribe. 21 Dec. 2015 <<http://estadisticas.cepal.org/cepalstat/WEB_CEPALSTAT/Portada.asp>>

Cerulli, G. (2015). *Econometric Evaluation of Socio-Economic Programs: Theory and Applications* (Vol. 49). Springer.

Coleman, J. S. (1988). Social Capital in the Creation of Human Capital. *American Journal of Sociology*, S95-S120.

Cuesta, J., Edmeades, S., & Madrigal, L. (2013). Food Security and Public Agricultural Spending in Bolivia: Putting Money Where your Mouth Is? *Food Policy*, 2013, 1-13.

Duflo, E., and Pande, R. 2007. Dams. *Quarterly Journal of Economics*, 122(2): 601–646.

Dupret, I., Heinrich, A., Keil, C., Kienle, F., Schäfer, C., & Wagenfeld, F. (2009). *30 Años de Cooperación entre Bolivia y Alemania en el Sector de Riego*. Humboldt-Universität zu Berlin, Landwirtschaftlich-Gärtnerische Fakultät.

ECLAC/FAO/IICA (2012). *The Outlook for Agriculture and Rural Development in the Americas: A Perspective on Latin America and the Caribbean 2013*. Santiago, Chile.

ELCSA, C. C. (2012). *Escala Latinoamericana y Caribeña de Seguridad Alimentaria (ELCSA): Manual de Uso y Aplicaciones*. Roma: FAO.

Eswaran, M., & Kotwal, A. (1990). Implications of Credit Constraints for Risk Behaviour in Less Developed Economies. *Oxford Economic Papers*, 42(2), 473–482.

Faguet, J. P. (2004). Does Decentralization Increase Government Responsiveness to Local nNeeds?: Evidence from Bolivia. *Journal of Public Economics*, 88(3), 867-893.

FAO (2003). *Trade Reforms and Food security: Conceptualizing the Linkages*. Rome: Food and Agricultural Organization of the United Nations.

FAO (2004). *The Ethics of Sustainable Agricultural Intensificatio*n. FAO Ethics Series, Rome: Food and Agricultural Organization of the United Nations.

FAO (2013). *Pobreza Rural y Políticas Públicas en América Latina y el Caribe Tomo II*. Santiago, Chile: FAO.

Feder, G., Just, R.E., & Sunding, D. (1985). Adoption of Agricultural Innovations in Developing Countries: A Survey. *Economic Development and Cultural Change*, 33(2), 255-298.

García, M., Raes, D., Jacobsen, S. E., & Michel, T. (2007). Agroclimatic Constraints for Rainfed Agriculture in the Bolivian Altiplano. *Journal of Arid Environments*, 71(1), 109-121.

Garrido, M. M., Kelley, A. S., Paris, J., Roza, K., Meier, D. E., Morrison, R. S., & Aldridge, M. D. (2014). Methods for Constructing and Assessing Propensity Scores. *Health Services Research*, 49(5), 1701-1720.

GeoSIRH (2015). *Nacional: Mapa Inventario de Sistemas de Riego*. (August 28). Instituto de Datos Espaciales, Viceministerio de Recursos Hídricos y Riego. Retrieved from <http://geosirh.riegobolivia.org/maps/158>

Gutiérrez-Malaxechebarría, A. (2014). Formal and Informal Irrigation in the Andean Countries. An Overview. *Cuadernos de Desarrollo Rural*, 11(74), 75-99.

Hameleers, A., Antezana, S. and Paz, B., (2011). *Agricultural Human Investment Strategies:* *Towards Strengthening the Farmers Innovation Capacity (FIC) Case Study: Bolivia.* FAO, page 33.

Harder, V. S., Stuart, E. A., & Anthony, J. C. (2010). Propensity Score Techniques and the Assessment of Measured Covariate Balance to Test Causal Associations in Psychological Research. *Psychological Methods*, 15(3), 234.

Heckman, J. J., & Robb, R. (1985). Alternative Methods for Evaluating the Impact of Interventions: An Overview. *Journal of Econometrics*, 30(1), 239-267.

Heinrich, C., Maffioli, A., & Vazquez, G. (2010). *A Primer for Applying Propensity-Score Matching.* Inter-American Development Bank, Technical Notes No. IDB-TN-161.

Holland, P. W. (1986). Statistics and Causal Inference. *Journal of the American Statistical Association*, 81(396), 945-960.

IDB (1997). National Irrigation Program (PRONAR): Loan Proposal. Inter-American Development Bank

ILO (2014). Main Statistical Indicators: Employment and labour market. International Labor Organization. Accessed 21 April 2016 <<http://www.ilo.org/>>

Imbens, G. W. (2004). Nonparametric Estimation of Average Treatment Effects Under Exogeneity: A Review. *Review of Economics and Statistics*, 86(1), 4-29.

Imbens, G. W., & Wooldridge., J. M. (2009). Recent Developments in the Econometrics of Program Evaluation. *Journal of Economic Literature*, 47(1), 5-86.

Imbens, G. W., & Rubin, D. B. (2015). *Causal Inference for Statistics, Social, and Biomedical Sciences: An Introduction*. Cambridge University Press.

INE (2013). Estadísticas Económicas: Sector Externo, Exportaciones. <<http://www.ine.gob.bo/>>

INE (2014). Estadísticas Sociales: Pobreza Desigualdad y Desarrollo Humana. <<http://www.ine.gob.bo/>>

INE (2015). *Censo Agropecuario 2013: Bolivia*. Instituto Nacional de Estadística.

Jack, B. K. (2013). *Constraints on the Adoption of Agricultural Technologies in Developing Countries.* Literature Review, Agricultural Technology Adoption Initiative, J-PAL (MIT) and CEGA (UC Berkeley).

Kay, C. (2011). Rural Poverty Reduction Policies in Honduras, Nicaragua and Bolivia: Lessons from a Comparative Analysis. *European Journal of Development Research*, 23(2), 249-265.

Kohl, B. H. (1999). *Economic and Political Restructuring in Bolivia: Tools for a Neoliberal Agenda?* PhD Dissertation, Cornell University, Ithaca, NY.

Lipsey, M., & Hurley, S. (2009). Chapter 2: Design Sensitivity: Statistical Power for Applied Experimental Research. *The SAGE Handbook of Applied Social Research Methods*, 2nd ed. Sage Publications, 44-76.

López, R., & Galinato, G. I. (2007). Should Governments Stop Subsidies to Private Goods? Evidence from Rural Latin America. *Journal of Public Economics*, 91(5), 1071-1094.

MDRyT (2014). *Plan del Sector Desarrollo Agropecuario 2014-2018*. Ministerio de Desarrollo Rural y Tierras, Dirección General de Planificación.

Melgar-Quiñonez, H., Uribe, A., Fonseca Centeno, Z. Y., Bermúdez, O., Palma de Fulladolsa, P., Fulladolsa, A., ... & Perez-Escamilla, R. (2010). Psychometric Characteristics of the Food Security Scale (ELCSA) Applied in Colombia, Guatemala y México. *Segurança Alimentar e Nutricional*, 17(1), 48-60.

Ministerio del Agua (2007). *Plan Nacional de Desarrollo del Riego “Para Vivir Mejor”.*

Monge, M., Hartwich, F., & Halgin, D. (2008). *How Change Agents and Social Capital Influence the Adoption of Innovations Among Small Farmers: Evidence from Social Networks in Rural Bolivia*. International Food Policy Research Institute, IFPRI Discussion Paper 00761.

Moser, C. y Barrett, C. (2003). *The Complex Dynamics of Smallholder Technology Adoption: the Case of SRI in Madagascar.* Working Paper WP2003-20. Department of Applied Economics and Management, Cornell University.

Munasib, A. B., & Jordan, J. L. (2011). The Effect of Social Capital on the Choice to Use Sustainable Agricultural Practices. *Journal of Agricultural and Applied Economics*, 43(2), 213.

Narayan, D. (1999). Bonds and Bridges: Social Capital and Poverty. Policy, Research Working Paper No. WPS 2167. World Bank Publications.

Nin-Pratt, A., Falconi, C., Ludena, C.E., Martel, P. (2015). *Productivity and the Performance of Agriculture in Latin America and the Caribbean: From the Lost Decade to the Commodity Boom*. IADB Working Paper No. WP-608. Inter-American Development Bank, Washington, DC.

Nkhata, R. (2014). *Does Irrigation have an Impact on Food Security and Poverty: Evidence from Bwanje Valley Irrigation Scheme in Malawi (Vol. 4).* IFPRI Working Paper No. 4, International Food Policy Research Institute.

Ormaechea, E. (2009). *Soberania y Seguridad Alimentaria en Bolivia: Politicas y Estado de la Situación.* La Paz: Centro de Estudios para el Desarrollo Laboral y Agrario.

Pinstrup-Andersen, P. (2009). Food Security: Definition and Measurement. *Food Security*, 1(1), 5–7.

Pretty, J., & Bharucha, Z. P. (2014). Sustainable Intensification in Agricultural Systems. *Annals of Botany*, 114(8), 1571-1596.

Putnam, R.D., Leonardi, R. & Nanetti, R.Y. (1993). *Making Democracy Work: Civic Traditions in Modern Italy.* Princeton University Press, Princeton.

Rogers, E. (1983). *Diffusion of Innovations*. Third Edition, The Free Press.

Rosenbaum, P. (2002). Covariance Adjustment in Randomized Experiments and Observational Studies. *Statistical Science*, 17(3), 286 - 327.

Rosenbaum, P., & Rubin, D. B. (1983). The Central Role of the Propensity Score in Observational Studies for Causal Effects. *Biometrika*, 70(1), 41-55.

Rosenbaum, P., & Rubin, D. B. (1985). Constructing a Control Group using Multivariate Matched Sampling Methods that Incorporate the Propensity Score. *The American Statistician*, 39(1), 33-38.

Rubin, D. B. (1974). Estimating Causal Effects of Treatments in Randomized and Nonrandomized Studies. *Journal of Educational Psychology*, Vol 66(5), 688-701.

Rubin, D. B. (1977). Assignment to Treatment Group on the Basis of a Covariate. *Journal of Educational and Behavioral statistics*, 2(1), 1-26.

Rubin, D. B. (1978). Bayesian Inference for Causal Effects: The Role of Randomization. *Annals of Statistics,* 6(1), 34-58.

Schavelzon, S. (2012). *El Nacimiento del Estado Plurinacional de Bolivia: Etnografía de una Asamblea Constituyente*. Consejo Latinoamericano de Ciencias Sociales (CLACSO). La Paz, Bolivia: Plural Editores.

Segall-Corrêa, A. M., & Marin-Leon, L. (2009). Food Security in Brazil: The Proposal and Application of the Brazilian Food Insecurity Scale from 2003 to 2009. *SegurançaAalimentar e Nutricional*, *16*(2), 1-19.

SENARI (2009). *Reglamento Operativo. Programa Nacional de Riego con Enfoque de Cuenca (PRONAREC)*. Servicio Nacional de Riego de Bolivia.

Sekhon, J. (2008). The Neyman-Rubin Model of Causal Inference and Estimation via Matching Methods. *The Oxford Handbook of Political Methodology*, 271-299.

Simtowe, F., & Zeller, M. (2006*). The Impact of Access to Credit on the Adoption of Hybrid Maize in Malawi: An empirical Test of an Agricultural Household Model under Credit Market Failure*. MPRA Paper N.45.

Sorensen, C. (2000). *Social Capital and Rural Development: A Discussion of Issues.* World Bank, Social Development Family, Environmentally and Socially Sustainable Development Network, Social Capital Initiative Working Paper No. 10.

Stads, G., Beintema, N., Perez, S., Flaherty, K., & Falcono, C. (2016a). *Agricultural R&D Indicators Factsheet: Bolivia*. International Food Policy Research Institute (IFPRI) and Inter-American Development Bank (IDB).

Stads, G., Perez, S., Marza, F., & Beintema, N. (2016b). *Agricultural Research in Latin America and the Caribbean: A Cross-Country Analysis of Institutions, Investment, and Capacities*. International Food Policy Research Institute (IFPRI) and Inter-American Development Bank (IDB).

Warner, A. (2014). *Public Investment as an Engine of Growth*. International Monetary Fund, Working Paper No. WP/14/148

VRHR-MMAyA. (2013). *Inventario Nacional de Sistemas de Riego 2012*. Viceministero de Recursos Hídricos y Riego del Ministerio de Medio Ambiente y Agua, Cochabamba.

Williams, R. (2012). Using the Margins Command to Estimate and Interpret Adjusted Predictions and Marginal Effects. *Stata Journal*, 12(2), 308.

Winters, P., Corral, L., & Gordillo, G. (2001). *Rural Livelihood Strategies and Social Capital in Latin America: Implications for Rural Development Projects.* University of New England, Graduate School of Agricultural and Resource Economics.

Winters, P., Salazar, L., & Maffioli, A. (2010). *Designing Impact Evaluations for Agricultural Projects*. Inter-American Development Bank, Technical Notes No. IDB-TN-198.

Winters, P., Maffioli, A., & Salazar, L. (2011). *Introduction to the Special Feature: Evaluating the Impact of Agricultural Projects in Developing Countries*. Journal of Agricultural Economics, 62(2), 393-402.

World Bank (2010). *Food Inflation: The Transmission of a Global Shock and Its Effects on the Bolivia Book*. Washington, DC.

World Bank (2011). *Plurinational State of Bolivia: Agriculture Public Expenditure Review*. Report No. 59696-BO.

Wossen, T., Berger, T., & Di Falco, S. (2015). Social Capital, Risk Preference and Adoption of Improved Farm Land Management Practices in Ethiopia. *Agricultural Economics*, 46(1), 81-97.

Zimmerer, K. S. (1995). The Origins of Andean Irrigation. *Nature*, 378, 481-483.

Zou, X., Li, Y. E., Gao, Q., & Wan, Y. (2012). How Water Saving Irrigation Contributes to Climate Change Resilience—A Case Study of Practices in China. *Mitigation and Adaptation Strategies for Global Change*, *17*(2), 111-132.

**APPENDIX A**—**Sample Design Calculations: PRONAREC**

El cálculo de muestra para el Programa PRONAREC debe tener en cuenta el hecho de que si bien las entrevistas se realizan a nivel hogar, la ejecución del programa se realizó a nivel de comunidad. La implicancia de este aspecto en el diseño muestral consiste en el hecho que, dado que los hogares pertenecientes a una misma comunidad suelen ser más homogéneos entre ellos que hogares pertenecientes a diferentes comunidades, la variabilidad de la información obtenida en una muestra depende de la distribución de las unidades muestreadas entre los diferentes clústers, que en nuestro caso son las comunidades beneficiadas de cada proyecto. Dicho de otra forma, no es lo mismo un escenario en donde se tienen 10 hogares pertenecientes a una misma comunidad versus otro en el que los 10 hogares se distribuyen uno por uno en 10 comunidades diferentes. Dado que, como se menciona anteriormente, los hogares dentro de una misma comunidad son bastante homogéneos, agregar observaciones pertenecientes a una misma comunidad o clúster deja de ser informativo a partir de un punto específico. Por otro lado, la inclusión de nuevas comunidades en la muestra provee variabilidad adicional a los datos, lo cual es siempre un aspecto positivo.

El cálculo de tamaño muestral teniendo en cuenta la presencia de clústers se puede obtener utilizando el software *Optimal Design*. Este software provee el número óptimo de unidades a encuestar dentro de cada cluster, dados los siguientes parámetros:

* α, o el nivel de significatividad estadística, que se fija en 0.05 de acuerdo a los análisis estándar de evaluación de impacto.
* ρ, la correlación intra-cluster para la variable respuesta a utilizar en el análisis.
* δ, el efecto estandarizado, , donde es la media de la variable respuesta para el grupo tratado, es la media de la variable respuesta para el grupo de control, y σ es el desvío estándar de esta variable para el total del universo.
* , el coeficiente de correlación entre las variables control incluidas en el análisis y la variable respuesta.
* J, el número de clusters en el universo (en nuestro caso comunidades).

Los parámetros ρ, δ y se obtienen en base a la variable de valor de la producción por hectárea obtenida para la evaluación de impacto del CRIAR, realizada en una zona rural de Bolivia similar a la intervenida para el PRONAREC. Si se tiene en cuenta esta variable para los beneficiarios de la tecnología de riego del programa CRIAR se obtiene ρ = 0.14, δ = 0.24, y = 0.32.

El parámetro J (número de clusters en el universo) se obtiene a partir de la información provista por la unidad ejecutora, UCEP-PRONAREC, respecto a la cantidad de comunidades beneficiadas. La tabla 1 mostró la cantidad de comunidades a beneficiarse en el PRONAREC II (72 según la información provista a agosto 2015). La Tabla A.1 debajo muestra la cantidad de comunidades beneficiadas del PRONAREC I que tienen, a julio de 2015, al menos un ciclo agrícola con riego instalado.

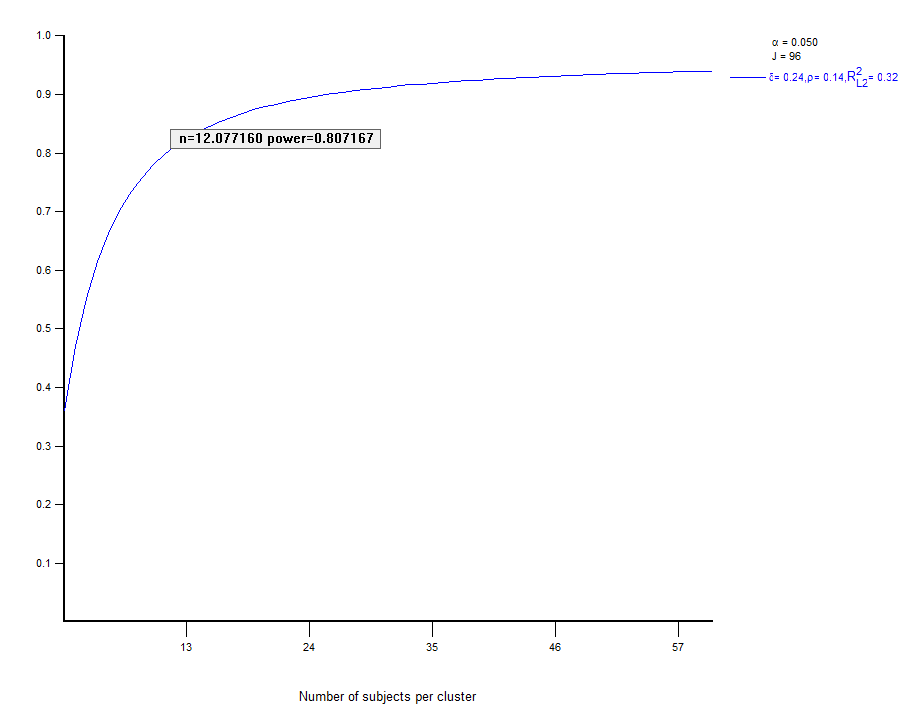
***Tabla A.1****—Comunidades PRONAREC I con al menos 1 ciclo completo con riego a julio 2015*

|  |  |
| --- | --- |
| **#** | **NOMBRE PROYECTO** |
|
|
|  | **CHUQUISACA** |
| 1 | Mejoramiento Sistema De Riego Sarufaya |
| 2 | Construcción sistema Microriego Limabamba Villca Villca |
| 3 | Ampliación de Infraestructura de Riego - AAIRC |
| 4 | Construcción sistema de distribución presa Okemayu sistema de riego Tojlasa Grande |
| 5 | Construcción sistema de riego Sajpaya |
| 6 | Mejoramiento sistema de Microriego La Fragua |
| 7 | Proyecto Construcción Sistema de Riego Manzanayuj |
|  | **LA PAZ** |
| 8 | Construcción Sistema de Riego Zona Zona |
| 9 | Construcción Sistema de Riego Jocopampa |
| 10 | Construcción Sistema de Riego Ayna |
| 11 | Construcción sistema de Riego Suriri - Capiri |
| 12 | Construcción de Sistemas de Microriego Qhunqhu Milluni |
| 13 | Construcción sistema de Microriego Qollpacanta |
|  | **COCHABAMBA** |
| 14 | Construcción sistema Riego Liriuni - La Guinda |
| 15 | Construcción sistema Microriego II Chacamayu-Chinchiro |
| 16 | Construcción Canales de Riego Aull (D1-D4) |
| 17 | Construcción Sistema Riego por aspersión Kuyoj Qhocha S. Pablo y Vertiente MELGA (Sacaba) |
| 18 | Construcción Sistema de Riego Toko (Toko) |
| 19 | Construcción Sistema de Riego Pirhuas (Sipe Sipe) |
| 20 | Implementación Pozos Para Riego German Jordán (Cliza, Toco, Tolata) |
| 21 | Perforación de Pozo Profundo Vargas Rancho Cheja Rumy |
| 22 | Mejoramiento y revestimiento de canales de riego Pachaj Kocha D-1B |
| 23 | Perforación de Pozo Profundo San Lorenzo Chullpa Mogo |
| 24 | Construcción sistema de Microriego Villa Cabot (Arbieto) |
| 25 | Construcción sistema de riego tecnificado Kaspicancha (Tiraque) |
| 26 | Construcción represa para riego Villa Barrientos (Arani) |
|  | **ORURO** |
| 27 | Construcción Sistema De Riego Vilacollo (Pazña) |
| 28 | Construcción Sistema Micro Riego Cala Cruz (Caracollo) |
| 29 | Construcción Sistema de Riego Pananoza (S. P. Totora) |
| 30 | Construcción Sistema de Riego Tolaquicta (Challapata) |
| 31 | Construcción Sistema Riego Korisiri Circapata (El Choro) |
| 32 | Construcción sistema de riego Phusuta (Pazña) |
| 33 | Construcción toma y ampliación revestimiento Canal Rey Inca (Challapata) |
| 34 | Construcción revestimiento de canales de riego Anocariri (Soracachi) |
|  | **POTOSI** |
| 35 | Construcción sistema de riego Tambillo Alto - Villa Monte Rico |
| 36 | Construcción Sistema de Riego Totora Palca, Palca Lili y Punto Suelo (Cotagaita) |
| 37 | Construcción sistema de riego Tres Cruces (Cotagaita) |
|  | **SANTA CRUZ** |
| 38 | Construcción Sistema de riego Inundado |
| 39 | Mejoramiento Sistema De Riego Mizque-San Rafael |
| 40 | Construcción sistema Riego San Juan Del Potrero |
| 41 | Construcción Sistema de Riego Buen Retiro Norte (Cabezas) |
| 42 | Construcción Sistema de Riego Buen Retiro Sur Piraicito (Cabezas) |
| 43 | Construcción Sistema de Riego San Antonio (Valle Grande) |
| 44 | Mejoramiento Sistema Riego 24 Junio (Trigal) |
| 45 | Construcción Sistema de Riego por Goteo Rosal 1 (Pailon) |
|  | **TARIJA** |
| 46 | Construcción Sistema de Riego Mecoya(PADCAYA) |
| 47 | Construcción Sistema de Microriego Presurizado San Francisco (Entre Rios) |
| 48 | Construcción Sistema de Microriego Presurizado Suaruro (Entre Rios) |

Dado que la cantidad de comunidades beneficiarias del PRONAREC I (48) resulta menor que las beneficiarias del PRONAREC II (72), se toma el escenario más conservador y se considera 48 como el número de clusters a ser tenidos en cuenta para este estudio. Esto arroja un parámetro J = 96 (48 beneficiarias y 48 controles).

Dado entonces estos parámetros, el software *Optimal Design* arroja el mínimo número de observaciones que se deben incluir por cluster para lograr un nivel de potencia deseado. Si se toma el nivel de potencia comúnmente aceptado en los análisis de evaluación de impacto de 0.80, el número mínimo de hogares a encuestar por comunidad es de 12, como lo muestra la gráfica A.1.

***Gráfica A.1****—Número óptimo de hogares por comunidad*



Esto, teniendo en cuenta la cantidad de comunidades y un ajuste de alrededor de 5% por no respuesta, arroja una muestra total de 1,800 observaciones, como se muestra en la tabla A.2.

***Tabla A.2****—Tamaño de Muestra Evaluación de Impacto PRONAREC*

|  |  |
| --- | --- |
| Hogares beneficiarios PRONAREC I | 600 |
| Hogares beneficiarios PRONAREC II  hasta junio 2016 | 600 |
| Hogares beneficiarios PRONAREC II  a partir de julio 2016 | 600 |
| Total Muestra | 1,800 |

Esta distribución de la muestra implica que para los beneficiarios del PRONAREC I se deben encuestar al menos 12 hogares por cada una de las comunidades beneficiarias (12\*48=576), más un ajuste de 24 encuestas para lograr las 600. Lo mismo deberá realizarse para los beneficiarios del PRONAREC II hasta junio 2016 y para los beneficiarios PRONAREC II a partir de julio 2016.

**APPENDIX B**—PRONAREC’s Questionnaire

**Recolección de Datos**

1. ***Periodicidad***

La evaluación del PRONAREC II requiere que se realicen tres encuestas, una de línea de base y dos de seguimiento, para así poder aplicar el método de las dobles diferencias de manera que controlemos por características no observables, tendencias en el tiempo y diferencias iniciales entre beneficiarios y no beneficiarios.

1. ***Cuestionario***

El cuestionario comprende quince módulos que fueron estructurados en base a las encuestas *Living Standards Measurement Study - Integrated Surveys on Agriculture* (LSMS-ISA) del Banco Mundial. Todas las preguntas que serán incluidas en este cuestionario son necesarias para producir la información que se requiere para medir los indicadores de la matriz de resultados y calcular el Propensity Score Matching.

***Tabla B.1****—Módulos del Cuestionario de PRONAREC*

|  |  |
| --- | --- |
| **MODULE** | **DESCRIPTION** |
| **Module 1: Household Characteristics**  Sociodemographic and educational characteristics of agricultural production units | * Module 1 includes questions about the gender, age, place of origin, education and literacy level of each household members that makes up the agricultural production unit. |
| **Módulo 2: Ocupación de los Miembros del Hogar**  Información sobre la ocupación de los miembros del hogar | * El Módulo 2 incluye preguntas sobre la ocupación de cada uno de los miembros del hogar de 4 o más años de edad que componen la unidad de producción entre julio 2014 y junio 2015. |
| **Módulo 3: Lotes**  Sección 3.1: Lista de Parcelas  Sección 3.2: Información General sobre las Parcelas propias.  Sección 3.3: Información General sobre las parcelas arrendadas  Sección 3.4: Información General sobre las parcelas rentadas o prestadas a otros  Sección 3.5: Información General sobre la compra y venta de terrenos.  Sección 3.6: Información General sobre la Inversión en parcelas y las tecnologías. | * El Módulo 3 incluye preguntas sobre todas las parcelas del hogar que fueron trabajadas por el hogar, hayan estado en descanso, tengas pastos o bosques o hayan sido rentadas a otros solo por el ciclo agrícola o un periodo corto de tiempo desde julio de 2014 a junio de 2015. * La sección 3.1 pregunta sobre las parcelas que se sembraron (propias y arrendadas). * Las secciones 3.2 a 3.6 pregunta sobre las características generales de las parcelas propias, arrendadas, rentadas a otros, vendidas y compradas así como las inversiones realizadas en finca y **tecnologías adoptadas incluyendo acceso al riego.** |
| **Módulo 4: Módulo Agrícola—Cultivos**  Sección 4.: Disposición de Cultivos  Sección 4.2a:Semilla Cultivos Anuales  Sección 4.2b: Fungicidas Cultivos Anuales  Sección 4.2c: Otros Insumos Cultivos Anuales  Sección 4.2d: Trabajo Cultivos Anuales  Sección 4.2e: Producción Cultivos Anuales  Sección 4.2f: Comercialización de Cultivos Anuales  Sección 4.3a: Producción de Cultivos Permanentes y Frutales  Sección 4.3b: Mano de Obra Cultivos Permanentes y Frutales  Sección 4.4 : Historia de la Producción Agrícola  Sección 4.5: Problemas Agrícolas  Sección 4.6: Activos Agrícolas | * La sección 4. contiene información básica sobre la disposición de cultivos tales como tipo de cultivos, ciclos, área sembrada, acceso a riego, etc. * La sección 4.2a -4.2f contiene información sobre los cultivos anuales sembrados. Principalmente información sobre área, cantidad de insumos (semilla, fertilizantes, fungicidas, insecticidas, capital y trabajo), costo de insumos, acceso a insumos, producción cosechada y comercialización. * Las secciones 4.3a y 4.3b preguntan información sobre el área sembrada, el tipo de cultivo, el costo y acceso a insumos, la producción y la venta de cultivos permanentes y frutales. * La sección 4.4 recoge información sobre la historia agrícola del productor. * La sección 4.5 recopila información relacionada a los problemas agrícolas que afrontaron en el año agropecuario antes de recibir el Programa. * La sección 4.6 recopila información relacionada sobre acceso, compra, venta y propiedad de los activos agrícolas. |
| **Módulo 5: Inversión en Parcelas**  Inversiones en parcelas, ya sea en riego, comunales u otras inversiones. | * El Módulo 5 recoge información sobre las inversiones en parcelas propias o adquiridas en arrendamiento o préstamo por el hogar entre julio de 2014 y junio de 2015. |
| **Módulo 6: Ganadería**  Sección 6.1: Contabilidad Ganadera  Sección 6.2: Productos Ganaderos | * La sección 6.1 recoge información sobre las compras, ventas, valor y gastos relacionados con la ganadería. * La sección 6.2 recoge información sobre la compra, venta, costos y autoconsumo de productos ganaderos. |
| **Módulo 5: Actividades Económicas**  Sección 6.1: Ocupación y Trabajo  Sección 6.2: Microempresa  Sección 6.3: Empleo por cuenta Propia | * Las secciones 6.1-6.4 recogen información sobre las actividades económicas fuera de finca de los miembros de la unidad de producción. Esto incluye información sobre la ocupación, el ingreso, la distribución del tiempo, etc. |
| **Módulo 7: Cuenca y Junta de Regantes**  Sección 7.1: Fuentes de Agua en la Comunidad  Sección 7.2: Organizaciones de Regantes en la Comunidad | * El Módulo 7 recoge información sobre las acciones relacionadas con las fuentes de agua que existen en la comunidad y las organizaciones de regantes que existieron en la comunidad entre julio de 2014 a junio de 2015. |
| **Módulo 8: Asistencia Técnica**  Asistencia técnica riego y actividades agrícolas | * El Módulo 8 recoge información sobre la asistencia técnica para temas de riego y actividades agrícolas que algún miembro del hogar haya recibido entre julio de 2014 a julio de 2015. |
| **Módulo 9: Riego**  Sistemas de Riego en la comunidad | * El Módulo 9 recoge información referida a las características y la gestión del sistema de riego de la comunidad. |
| **Módulo 10: Participación en Organizaciones**  Sección 10.1: Acceso a Capital Social | * Este módulo recoge información sobre la participación en organizaciones sociales (agrícolas y no agrícolas) tales como asociaciones de regantes, productores, etc. |
| **Módulo 11: Migración**  Sección 11.1a: Migración  Sección 11.1b: Migración  Sección 11.2: Microempresa | * Las secciones 11.1 y 11.2 recogen información sobre las migraciones domesticas e internacionales, los destinos, las remesas, etc., de los miembros de la unidad de producción. |
| **Módulo 12: Crédito y Ahorro**  Sección 12.1: Ahorros del Hogar  Sección 12.2: Prestamos a Otros  Sección 12.3: Préstamos Solicitados | * Las secciones 12.1-12.3 recogen información sobre los ahorros de la unidad de producción, los créditos ofrecidos a otros y los solicitados. |
| **Módulo 13: Seguridad Alimentaria**  Situación alimentaria | * El Módulo 13 recoge información sobre la situación alimentaria en los últimos 3 meses con el propósito de construir el indicador de seguridad alimentaria ELCSA. |
| **Módulo 14: Maquinaria y Equipos**  Maquinaria y equipos agrícolas | * El Módulo 14 recoge información sobre la maquinaria y equipos agrícolas que fueron utilizados para el trabajo de cultivos desde junio 2014 a julio 2015. |
| **Módulo 15: Activos del Hogar, Vivienda y Accesibilidad** | * Esta sección recopila información sobre el tipo de vivienda, la distancia a lugares importantes, los materiales, el acceso a servicios públicos, y las condiciones de vida del hogar. |

1. † Consultant, Inter-American Development Bank, Division of Environment, Rural Development and Disaster Risk Management (INE/RND), ([clopezrivas@iadb.org](mailto:clopezrivas@iadb.org)) [↑](#footnote-ref-1)
2. ‡ Sr. Economist, Inter-American Development Bank, Division of Environment, Rural Development and Disaster Risk Management (INE/RND), ([lsalazar@iadb.org)](mailto:lsalazar@iadb.org))

   § Consultant, Inter-American Development Bank, Division of Environment, Rural Development and Disaster Risk Management (INE/RND), ([jaramburu@iadb.org)](mailto:jaramburu@iadb.org)) [↑](#footnote-ref-2)
3. In PPP, constant 2010 prices (CEPALSTAT, 2015). [↑](#footnote-ref-3)
4. There has been significant progress in the last decade in terms of poverty reduction. According to the latest available official data, out of a population of 10.5 million people, roughly 32 percent live in the rural sector, and almost 80 percent are employed in agriculture (ECLAC/FAO/IICA, 2012; INE, 2014). Between 2000 and 2013, rural poverty declined from 87 percent to 60 percent, while extreme poverty fell from 60 percent to 39 percent (INE, 2014; Castellani and Zenteno, 2015). However, significant disparities remain between rural and urban areas. A larger share of the rural population lives below the poverty line. Indigenous communities, women and young people in the rural sector are among the most vulnerable groups to poverty and food insecurity. [↑](#footnote-ref-4)
5. Agricultural labor productivity measured as agricultural growth in output per worker. The authors analyze the contribution of agricultural inputs and total factor productivity (TFP)—composed of efficiency and technical change—to growth in output per worker. [↑](#footnote-ref-5)
6. In PPP, constant 2011 prices. [↑](#footnote-ref-6)
7. Producer support estimates (PSE%) defined as the “percentage of producer’s revenue due to the support provided by agricultural policies,” and general services support estimates (GSSE%) defined as the “percentage of total support that is provided to agricultural producers (as a group and not individually) through general support (this refers to research, agricultural health services, infrastructure, among others)” (Agrimonitor, 2016). [↑](#footnote-ref-7)
8. Both studies, Lopez and Galinato (2007) and Anríquez *et al.* (2015), define *public goods* as “both pure public goods as well as subsidies (mixed public goods) directed to mitigating the effects of market failure(s),” for instance, public financing of agricultural R&D, extension services, rural infrastructure, plant and animal health, and major irrigation development projects such as PRONAREC. [↑](#footnote-ref-8)
9. Gutiérrez-Malaxechebarría (2014) defines two types of irrigation systems that can be found in the Andes: formal and informal. “The formal systems are those, public or private, that have been developed with universally accepted technical standards under the state institution and, for their characteristics, have been reported in national statistics. On the other hand, the informal irrigation systems are those developed by farmers themselves, without meeting the state’s formal requirements, which are not reported in national statistics.” [↑](#footnote-ref-9)
10. Complying with the newly established constitution of 2009, Decree No 0048 was signed on March 18, 2009, changing the official name of the country from the Republic of Bolivia to the Plurinational State of Bolivia (Schavelzon, 2012). [↑](#footnote-ref-10)
11. The total amount of the project was estimated at US$32.9 million, which included a loan for US$26.5 million from the IDB (Loan 964/SF-BO), US$ 5.3 million of local counterpart funding, and US2 million in co-financing from the Federal Republic of Germany (IDB, 1995). [↑](#footnote-ref-11)
12. The LLP decentralization reform was established in 1994 to foster community participation in development projects. The law transferred 20 percent of national tax revenues from central governments to municipalities along with responsibilities for the administration, maintenance and investments in public infrastructure (i.e. health, education, roads, irrigation, culture and sports) (Faguet, 2004). Further, the reform mandates that 85 percent of the revenues must be spend on the implementation of projects, and only 15 percent to administration (Kohl, 1999). [↑](#footnote-ref-12)
13. Data from the 2012 National Inventory of Irrigation Systems relate mainly to community irrigation systems (traditional, newly build or improved/rehabilitated) under an autonomous and collective administration known as *Gestión Campesina del Agua*. Approximately 70 percent of families in the system irrigated less than 1 hectare of land. No such systems were identified in the departments of Beni and Pando. These departments are located in a region with significantly greater rainfall compared to the rest of the country (VRHR-MMAyA, 2013). The 2013 agricultural census reports a relatively small number of UPAs using irrigation in both departments: 1,376 out of 20,762 UPAs in Beni (6.6 percent of total in the country), and 504 out of 7,537 UPAs in Pando (6.7 percent) (INE, 2015). [↑](#footnote-ref-13)
14. In terms of irrigation methods, the 2013 agricultural census shows that 235,935 UPAs use gravity fed irrigation, 42,932 UPAs use sprinklers, and 7,669 UPAs use drip irrigation (INE, 2015). [↑](#footnote-ref-14)
15. Irrigation systems are provided at the community level and each system represents a project, therefore, the phrase ‘community irrigation system(s)’ and the term ‘project(s)’ will be used synonymously throughout this paper. [↑](#footnote-ref-15)
16. Modern irrigation systems include drip, micro and sprinkler irrigation, while the traditional systems include gravity-fed, submersion and flood irrigation. [↑](#footnote-ref-16)
17. According to the latest statistics from the International Labor Organization (ILO), women represent 44.28 percent of total agricultural labor force in the country (ILO, 2014). The average wage of women in the country is approximately 80 percent of the salary of men, and roughly 52.2 percent of rural women do not have income of their own (CEPAL, 2013). [↑](#footnote-ref-17)
18. Bolivian agriculture is highly heterogeneous, reflecting both its diverse agro-ecological diversity and production orientation. The western highlands and valleys are characterized by small-scale and traditional agriculture oriented towards national production while the eastern lowlands (Chuquisaca, Santa Cruz, Beni, Pando) are characterized by commercial, export-led farming, with a mixture of both large and small-scale producers (World Bank, 2011). [↑](#footnote-ref-18)
19. At the same time, this survey represents the baseline for PRONAREC II, and will be used in the future to assess the effectiveness of the second phase of the program using a different quasi-experimental impact evaluation approach. [↑](#footnote-ref-19)
20. See Sekhon (2008) for a more in-depth discussion of the Neyman-Rubin model, and Cerulli (2015) for a detailed review of the theoretical and applied econometrics for the assessment of socio-economic programs. [↑](#footnote-ref-20)
21. Both potential outcomes, and , are assumed to be independent and identically distributed (i.i.d.) random variables (Holland, 1986). [↑](#footnote-ref-21)
22. For the estimate to be unbiased, the Neyman-Rubin model implicitly assumes that the *stable unit treatment value assumption* (SUTVA) holds. SUTVA assumes treatment status of unit will not affect the potential outcomes of the other units, and that treatment is homogeneous across units (Rubin, 1978). [↑](#footnote-ref-22)
23. For each unit , we observe the triple , where is a vector of [observable and unobservable] characteristics or covariates. On average, random assignment balances all potential confounding factors between treatment and control groups, eliminating bias in treatment assignment. [↑](#footnote-ref-23)
24. Cerulli (2015) states that “nonrandomness is inherent to a policy for two distinct reasons: (1) the *self-selection* into the program operated by individuals (in the case of PRONAREC, it concerns the choice of individual communities to apply and participate in the program), and (2) the *selection mechanism* of the agency managing the program.” [↑](#footnote-ref-24)
25. The ATET is the average effect of the treatment on those who actually get the treatment, calculated as the average difference between participants and their matches. See Rubin (1977), Heckman and Robb (1985), Rosembaum (2002), and Imbens (2004) for a more in-depth discussion on estimating average treatment effects. [↑](#footnote-ref-25)
26. It is assumed that given the set of pretreatment covariates , treatment is independent:

    |  |  |  |
    | --- | --- | --- |
    |  |  |  |

    [↑](#footnote-ref-26)
27. Rosenbaum (2005) shows that an important task of propensity scores is to minimize unit heterogeneity, as it reduces both sampling variability and sensitivity to unobserved bias. However, PSM cannot adjust for unobserved differences between groups. [↑](#footnote-ref-27)
28. Chuquisaca, Cochabamba, La Paz, Oruro, Potosí, Santa Cruz, and Tarija. [↑](#footnote-ref-28)
29. Team members from the Environment, Rural Development & Disaster Risk Management Division of the Inter-American Development Bank (INE/RND) provided technical support and capacity building with regards to the analysis and design of the project. See Winters *et al.,* (2010, 2011) for a set of guidelines on designing impact evaluations for agricultural projects. [↑](#footnote-ref-29)
30. See Appendix A for more details of the power calculations conducted for the evaluation of PRONAREC. [↑](#footnote-ref-30)
31. See Appendix B for a more detailed description of the information collected in each of the 15 modules of the questionnaire. [↑](#footnote-ref-31)
32. The initial dataset (received on December 23, 2015) included 1,701 observations; however, 19 surveys were discarded from the dataset by the consulting firm in charge of the data collection as a results of significant inconsistencies and missing data. [↑](#footnote-ref-32)
33. These 66 observations (27 from PRONAREC I, 27 from PRONAREC II *initial*, and 12 from PRONAREC II *final)* reported either "*No sembró,*" "*No cosechó*" and/or "*Pastoreó*" for all plots, and therefore have zero value of production (US$). They were excluded from the analysis given we are particularly interested in evaluating the impact of PRONAREC I on production-related indicators. Also, we have only taken into account costs of production associated with land cultivated and harvested during the 2014-2015 agricultural cycle, excluding any costs of production associated with plots of land reported as "*No cosechó*" (cultivated but not harvested). [↑](#footnote-ref-33)
34. 548 beneficiaries of PRONAREC I, 534 *initial* beneficiaries of PRONAREC II, and 521 *final* beneficiaries of PRONAREC II. [↑](#footnote-ref-34)
35. NyPIOCs based on the Bolivian constitutional definition of Indigenous Peoples as "*naciones y pueblos indígena originario campesinos*". [↑](#footnote-ref-35)
36. For the probit model used in the first step of the PSM methodology, we will use the natural log transformation of all three variables of *accessibility* (by adding a constant value of “1” prior to applying the log transformation). Basic descriptive statistics of these log-transformed variables are reported in Table 2. [↑](#footnote-ref-36)
37. While marginal differences might exist in the literature with regards to the definition, interpretation, and measurement of social capital, the concept is generally defined as “the norms and social relations embedded in social structures of society that enable people to coordinate action and achieve desired goals” (Narayan, 1999). [↑](#footnote-ref-37)
38. A *patronato* is a governing board appointed/elected to manage agricultural-related policies among an association of commercial and/or communal farmers. [↑](#footnote-ref-38)
39. The dummy variable for participation in non-agricultural organization(s) takes the value of ‘1’ if someone in the household participated in any organization(s) in the livestock, agroindustry, artisanal, social, tourism and/or other sectors, and ‘0’ otherwise. [↑](#footnote-ref-39)
40. TLUs are livestock numbers, across species and geographical regions, converted to a common unit, where 1 TLU is commonly taken to represent 1 mature cow of 250kg. Conversion factors are: cattle = 0.7, pigs = 0.25, sheep = 0.1, goats = 0.1, birds = 0.01, horses = 0.8, donkeys = 0.7, oxen = 0.7, beehives = 0.001. [↑](#footnote-ref-40)
41. The PPI is a statistically-sound poverty measurement tool created by the Grameen Foundation to estimate the likelihood that a household is living below a poverty line (either national or international). The PPI is specially designed, by country, based on the most recent national household expenditure or income surveys. So far, 45 PPIs have been developed for 45 countries. The PPI score is derived from the answers to 10 questions regarding the characteristics and asset ownership of households. All of the questions from the 2007 PPI for Bolivia were incorporated in PRONAREC’s survey. [↑](#footnote-ref-41)
42. Total household income derived from off-farm employment/income, remittances, agricultural income (i.e., home consumption, animal consumption, transformation, seeds, and sales), and livestock revenue (i.e., home consumption and sales). It is important to note that the variable *agricultural income* does not consider agricultural production losses as part of the "income" of producers. On the other hand, the variable *value of* (agricultural) *production*, which will be analyzed later in the study, does consider production losses as part of total agricultural production. [↑](#footnote-ref-42)
43. Rural credit markets can be classified into formal and informal. Informal credit markets include lending from family/friends/relatives and private lending by unregulated individuals, while formal credit markets include all (regulated) financial institutions. For the purpose of this study, credit constrained is defined as a household that requested a credit/loan from a formal financial institution, but the request was either denied or the amount of credit/loan offered to the household was lower than the amount requested. [↑](#footnote-ref-43)
44. Total landholding, in hectares, includes land owned, land leased/loaned to the household, land leased/loaned by the household, and auxiliary land, whether the land was used for agricultural activities during the 2014-2015 agricultural cycle or not. [↑](#footnote-ref-44)
45. Intensification is generally defined as an increase in agricultural production that results from higher productivity of inputs (e.g. land, labor, capital (FAO, 2004). [↑](#footnote-ref-45)
46. The variable *Improved or certified seeds* takes the value of ‘1’ if the producer reports using any amount of “improved or certified” seeds during the 2014-2015 harvest, and ‘0’ otherwise. [↑](#footnote-ref-46)
47. From the data, it is not possible to identify the proportion of production was sold in a *feria* (market)vs *rescatista*. More specifically, by crop sold, producers were asked whether *most* of the production was sold in a *feria* (within and outside the community), a *rescatista*, or other. Therefore, both variables, *Sold most crop in a feria* and *Sold most crop to a rescatista*, are unable to capture the actual magnitude and composition of agricultural sales by source. For instance, if a producer reported harvesting corn and wheat, but selling *most* of the wheat in a *feria* while consuming all the corn at home, the variable *Sold most of a crop in a feria* would take a value of ‘1’ for this producer. [↑](#footnote-ref-47)
48. Food security is a complex concept, both in development theory and practice, encompassing several sectors (e.g. agriculture, education, health, rural development, social protection). It is generally defined as the condition in which “all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life” (FAO, 2003; Pinstrup-Andersen, 2009). In the Bolivian context, several factors have been identified as potential threats to food security, including the composition of agricultural and rural public expenditures (e.g. underdeveloped rural roads), reduced cultivated land area, high levels of income inequality, environmental shocks, changes in diets or food intake, reductions in the national supply of food products combined with increasing demand for agricultural imports (e.g. meat, sugar and oil) and greater export-driven agro-industrial production (Ormaechea, 2009; World Bank, 2010; Cuesta *et al.*, 2013). [↑](#footnote-ref-48)
49. This process was performed using the user-written command –pscore– in Stata 14.1, restricting the analysis of the balancing property to all treated and untreated observations within the region of common support, and a significance level of 0.01. We used the command –margins– to calculate average marginal effects to further analyze PRONAREC I’s participation model (Williams, 2012). [↑](#footnote-ref-49)
50. According to Abadie and Imbens (2016), propensity score estimators have “approximately normal distributions in large samples … (and the estimation of the propensity score in the first stage) affects the large sample distribution of propensity score matching estimators.” With this in mind, the command –teffects psmatch– incorporates adjustments to the estimators of the ATE and ATET as derived in Abadie and Imbens (2016). The authors conclude that “for the ATET estimator, the sign of the adjustment depends on the data generating process, and ignoring the estimation error in the propensity score may lead to confidence intervals that are either too large or too small.” [↑](#footnote-ref-50)
51. The caliper (0.01) option was specified only for nearest-neighbor matching using –psmatch2–, not with the command –teffects psmatch–. Also, we used the –ties– option for all matching algorithms in –psmatch2– following the recommendation of Abadie *et al.* (2004, pg 293). [↑](#footnote-ref-51)
52. See Caliendo and Kopeinig (2008), and Imbens and Wooldridge (2009) for a more detailed discussion of each matching algorithm. [↑](#footnote-ref-52)
53. For continuous variables, standardized percent difference for covariate X is defined as , where and are the sample means in the treated and matched control group, and and are the sample variances in the treated group and control reservoir (Rosenbaum and Rubin, 1985). For dichotomous variables, standardized percent difference is defined as , where and are the prevalence or mean of the dichotomous variable in the treated and matched control group (Austin, 2014). [↑](#footnote-ref-53)
54. A reasonably accurate or exact balance in covariates can be assured by randomized controlled trials (RCT) with large sample sizes. However, for observational studies and RCTs with small samples, some degree of imbalance in some covariates can be expected (Austin, 2009). [↑](#footnote-ref-54)
55. Aggregate expenditures on the irrigation of plots does not take into account expenditures on labor for irrigation. [↑](#footnote-ref-55)
56. Cerulli (2015) elaborates on the issue of *exogeneity* in a counterfactual framework by stating that “the ‘true’ causal effect of *xi*(treatment in the two states for the same individual; *x1* for the treated and *x0* for the untreated status) on *Yi* (outcomes in the two states for the same individual; *Y1* for the treated and *Y0* for the untreated status) can be identified, as long as independent changes of *xi* only produce a *direct* effect on *Yi*, by ruling out any potential *indirect* effect of *xi* on *Yi*, via the relation of unobservable factors”. [↑](#footnote-ref-56)