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FOOD SECURITY AND PRODUCTIVITY:

IMPACTS OF TECHNOLOGY ADOPTION IN SMALL SUBSISTENCE FARMERS IN BOLIVIA

Lina Salazar[1], Julián Aramburu[2], Mario González-Flores[3] and Paul Winters[4].

ABSTRACT

This paper presents the impact evaluation of CRIAR program, implemented in rural areas in Bolivia. The objective of CRIAR is to increase smallholders' agricultural income and food security through productivity improvements triggered by technological adoption. In this study, we use data from a sample of 1,287 households-817 beneficiaries and 470 controls- interviewed specifically for this evaluation. The econometric approach to estimate the program's impact is an instrumental variable model. This approach addresses possible endogeneity and self-selection issues that might arise from program's implementation. The results present evidence that program participation increased agricultural productivity, household income and improved food security. Overall, this study confirms the importance of considering the role of productive programs as policy tools to address vulnerability to food insecurity.

Keywords: Technology Adoption; Food Security; Productivity; Instrumental Variables; Bolivia.

JEL Classifications: O13, O33, Q12, Q16, Q18.

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I. Introduction

The agricultural sector plays a fundamental role in the Bolivian economy. This sector represents about 9% of the Gross Domestic Product (GDP) and employs about 40.3% of the labor force at the national level (FAOSTAT, 2014). The agricultural area in Bolivia is 3.1 million hectares of cultivated land which has been increasing significantly, expanding more than 20% from 2005 (Finance Ministry of Bolivia, 2014). This cultivated land represents about 3% of the total area of the country.

Bolivia presents a wide gap between the different productive systems that characterize the agricultural sector. Specifically, out of the 775,000 productive agricultural units in the country, 6% belong to medium and large producers while 94% belong to smallholder producers who use their land for family farming[5]. On one hand, large and medium producers rely on modern agricultural systems characterized for being capital intensive with high levels of mechanization, access to modern technologies and credit, and oriented towards exports. These units of production are mainly located in the eastern side of the country cultivating crops such as soy, rice, sugar cane and livestock. In contrast, the family farming systems are characterized for having small parcels oriented towards home consumption, low access to credit and lack of modern productive technologies. These units of production are mainly located in the Valleys and the Altiplano producing staple crops such as potatoes, corn and cereals.

Despite the increasing expansion and the high potential of the agricultural sector, Bolivia is one of the countries with the lowest levels of agricultural productivity in the Latin America and Caribbean (LAC) region. The agricultural yields from cereal production, for example, correspond to only 57% of the average yields in South America and for the case of tubers; it reaches only 39% (FAO, 2012). Moreover, for the period from 2006 to 2011, Bolivia was the only country in the region that presented a negative growth in total factor productivity[6] (IFPRI, 2013). The low levels of agricultural productivity leads to low income and food insecurity,

[5]Jornadanet.com. 2013. "Bolivia se insertara en actividades por Año de Agricultura Familiar". La Paz, November 2013. URL: http://www.jornadanet.com/n.php?a=97329-1.

[6] Economic Research Service's International Agricultural Productivity database (2012) shows an agricultural total factor productivity growth for Bolivia that is positive but close to zero (0.0005) for the period from 2002 to 2011. According to this source, Bolivia is still the country with the lowest growth of TFP in the region, followed by Venezuela with an index of 0.0138.

particularly in rural areas. With respect to income, Bolivia is one of the countries with the lowest per capita income in the LAC region, 51% of the total population is below the poverty line and 66% in rural areas (National Institute of Statistic-INE- 2009). On the other hand, Bolivia is the second country with the highest rate of malnutrition in South America at 21% (IFPRI, 2013)[7] and 89% of the municipalities are classified by the Ministry of Agriculture as having high or medium levels of vulnerability to food insecurity (Ministry of Rural Development and Land, 2013)[8].

In this context, the Government of Bolivia requested a loan from the Inter-American Development Bank in 2009, to implement the "*Programa de Apoyos Directos para la Creación de Iniciativas Agroalimentarias Rurales*[9]" (CRIAR). This program targeted smallholder rural producers with the objective to improve agricultural income and food security triggered by productivity increases due to technological adoption.

This study builds on a previous paper by Aramburu, Salazar, González-Flores and Winters (2014) and sheds light on the role of productive agricultural programs on food security and welfare by assessing the impact of the CRIAR program. This analysis relies on a quasi-experimental approach to identify the effects of program participation in productivity[10], income and food security. Given the period of program execution, beneficiary producers were able to use their newly acquired technology during one agricultural cycle. Therefore, the impacts of technological adoption that can be attributed to program participation correspond mainly to short-term and medium-term effects. The value added of this study is threefold: (i) presents rigorous empirical analysis on the effectiveness of technology adoption programs on productivity and income; (ii) provides evidence that agricultural programs play an important role as policy instruments to enhance food security; and (iii) delivers deeper insight into the causal link through which agricultural programs enhance food security (income vs. home-consumption).

[7] International Food Policy Research Institute (IFPRI) en base al Global Hunger Index 2013.
[8] Based on the Vulnerability Assesment Map (VAM) of the Bolivian Ministry of Rural Development and Land (MDRyT). This is a methodology developed by the World Food Program of the United Nations to establish the degree of vulnerability to food insecurity for a given population or geographic area. This scale categorized the municipalities in three levels of food insecurity: (VAM=1: low; VAM=2: medium; VAM=3:high).
[9] In English, "Direct Support Program for the Creation of Rural Agrifood Initiatives."
[10] Productivity will be measured as the value of production per hectare, see section V and VII for further details.

The remainder of this paper is structured as follows. Section II presents a review of the literature that analyzes the effectiveness of different policy instruments that have been recognized and implemented in different settings in order to reduce vulnerability to food insecurity. Section III describes the CRIAR program. Section IV and V present the counterfactual identification and the econometric methodology used to identify the program's impact respectively. Section VI provides descriptive statistics of the data used in the analysis. Section VII provides the main results of the impact evaluation in the outcomes of interest and section VIII concludes.

II. Policy Tools for Food Security Improvements: A Literature Review

Three types of policy instruments have been acknowledged as tools to improve access to food and food security, including: (i) targeted direct feeding programs; (ii) food for work programs; and (iii) income transfer programs (Stamoulis and Zezza, 2003). Direct feeding programs supply food to targeted households either through direct transfers of food or coupons for food purchase. Food-for-work programs provide in-kind payment in the form of food in exchange for public work. Finally, income transfer programs provide cash transfers to poor households based upon fulfillment of certain conditions that might include age limits for adults, health visits for pregnant women or educational attainment for children, with the goal to increase households' food consumption and nutritional status. Less frequently discussed and analyzed is the role of productive programs in food security, particularly agricultural programs. Specifically, agricultural programs have been mainly studied from a productive and income perspective without much emphasis on the link with food security. This section presents a review of studies that aim to provide evidence on the impact of different policy instruments on food security using different proxies to measure this outcome. Furthermore, advantages and disadvantages for each policy instrument are mentioned followed by a discussion on the role of productive programs on food security.

The literature presents mixed evidence on the impact of **direct feeding programs** on food security indicators. For instance, Stifel and Alderman (2006), assess the impact of the *Vaso de Leche* (Glass of Milk) food transfer program on children's nutritional status in Peru. This program provides milk, milk substitutes and other dietary needs to households with children under eleven years old from eligible communities. The results do not provide compelling

evidence that the magnitude of program expenditures at the community level had a positive impact on children's nutritional outcomes. On the other hand, Ahmed and del Ninno (2002) analyze the impact of a food for education program in Bangladesh. The program provides a ration of grains to poor families with the condition that children attend primary school. The authors find some evidence that beneficiary households present a higher caloric intake than non-beneficiary households and children show better nutritional status. Similar programs were implemented and evaluated in Laos, Burkina Faso and Uganda. In Uganda and Burkina Faso randomized impact evaluations were conducted to analyze the impact of in-school meals and take-home rations programs. In Burkina Faso, Kazianga, Walque and Alderman (2014) show that in-school meals increased beneficiary children's weight-for-age while take-home rations did not have any impact. However, take-home rations increased weight-for-age of beneficiaries' younger siblings who were not directly treated. In Uganda, similar results were found in regards to spillover impacts on non-treated siblings. However, in this particular case, only beneficiary girls between 10 to 13 years old seemed to receive a positive effect from program participation. Finally, in the case of a school feeding program in Laos, Buttenheim, Alderman and Friedman (2011) do not find effects on children's nutritional status.

Food-for-work programs were extremely popular during the 1990s (Devereux 2001, von Braun et al. 1999), especially in Sub-Saharan Africa. However, rigorous evidence on the impacts of these programs is scarce and when present is inconclusive. For instance, The World Food Program implemented a group of food-for-work programs to meet food consumption needs of vulnerable people in exchange for labor. These labor resources were employed to build infrastructure projects in their own communities. Evidence from Bangladesh and Guatemala suggests that these programs did not improve household's ability to consume three meals per day. Also, the authors do not find a significant impact on dietary diversity or food consumption scores in beneficiary households (WFP 2012 & 2014). On the other hand, an evaluation of a similar program in Nepal found small improvements in food consumption scores and reduced food shortage for beneficiary households (WFP 2013). These studies, however, recognize their methodological shortcomings limiting the scope of their analysis.

Gilligan and Hoddinot (2007) used a more rigorous approach to estimate the effects of a food-for-work program implemented in Ethiopia after the drought of 2002. The authors find that

program participation increased total consumption and food consumption of beneficiary households. However, the authors find that targeting of food-for-work programs only benefited households in the middle and upper tails of the consumption distribution as they did not find any effects for the poorest households.

The literature on **conditional cash transfers** presents ample empirical evidence that assess the impact of this type of programs on food security indicators. For instance, Behrman and Hoddinott (2005) evaluate the impact of *PROGRESA* in Mexico, on children's nutritional status. The results show a positive impact on children aged 12-36 months. However, it is not clear whether the impact is due to the cash transferred or the nutritional supplement delivered by program administrators. Attanasio et. al (2004) evaluate the impact of *Familias en Acción*, a cash transfer program established in Colombia, on children's nutritional status. The results show that program participation decreased the probability of being undernourished, particularly for children under two years old. The authors do not find any effect for older children. Also, program participation increased children's food intake of proteins and vegetables. In Nicaragua, Maluccio and Flores (2005) find that the *Red de Protección Social* program increased per capita annual food expenditures and share of food expenditures for beneficiary households. Furthermore, program participation reduced stunting prevalence on children under five years of age. In Honduras, IFPRI (2003) analyze the impact of *Programa de Asignación Familiar* on different welfare outcomes including food consumption and children's nutritional status. The authors do not find a significant impact of program participation on these indicators.

Similar programs were evaluated in Africa. For instance, Duflo (2000) analyzes the impact of the *South African Old Age Pension* program on children's nutrition status. The program provides a pension payment to women older than 60 years and men older than 65. The results show a positive impact of the program on children's nutritional status, particularly in girls. In Malawi, Miller, Tsoka and Reichert (2011) also find a positive impact of the *Social Cash Transfer Scheme* on household food consumption, expenditures and dietary diversity.

Overall, the literature on the impact of safety net programs that aim to improve food security is inconclusive and limited from a rigorous empirical perspective. This is particularly true for direct feeding and food-for-work programs. On the other hand, in the case of conditional cash transfers, the literature presents robust and rigorous empirical evidence although mixed results

still in place. In addition to the lack of conclusive empirical evidence, advantages and shortcomings in regards to targeting and implementation of these policy instruments must be considered. In the case of direct feeding programs, beneficiaries can be accurately targeted through schools and communities. However, the logistics involved in food distribution are extremely complex and costly with respect to other types of programs such as conditional cash transfers. Moreover, provision of free food might create market distortions with unintended consequences (Rogers and Coates, 2002). In the case of food-for-work programs, targeting issues are twofold. First, targeting errors caused by imperfect labor markets are common in low-income countries and second, participation depends highly on having a household member who is physically capable of working, leaving aside the poorest and most vulnerable households (von Braun, 1995). Moreover, under certain conditions, food-for-work programs can distort labor allocation and/or crowd-out private investments (Barret et. al., 2002 and Holden et. al., 2006). Finally, while conditional cash transfer programs present easier logistics for treatment distribution and targeting, there are transaction costs associated with exchanging cash for food that might limit their impact on food consumption (Bryson et al, 1991). Additionally, concerns in regards to the sustainability and lack of exit mechanisms associated with these programs are rising rapidly (Stampini and Tornarolli, 2012).

Despite increasing interest on the impact of safety net programs on food security, little attention has been given to the impact of productive programs on food security and even less on the link through which this relationship takes place. While there is literature suggesting a positive link between agricultural production and food security (Maxwell, 1998), productive agricultural programs are not yet widely recognized as policy tools to enhance food security. Also, very few studies have focused on addressing the impact of such programs on food security outcomes (Ruiz-Arranz et. al, 2006). This paper aims at providing some empirical evidence to reduce this gap of knowledge and analyze the channels through which agricultural productive programs can have an impact on food security. In particular, there are two channels through which agricultural productive programs that aim at increasing productivity could reduce household vulnerability to food insecurity. First, higher levels of productivity could be due to higher yields and therefore, more food available for home-consumption. Second, higher productivity could be due to higher production value and therefore, higher income available to purchase food. This paper aims to gain more insights into this process.

III. The CRIAR Program

The program to be analyzed in this study is the "*Programa de Apoyos Directos para la Creación de Iniciativas Agroalimentarias Rurales*" (CRIAR). Specifically, this paper aims to provide rigorous empirical evidence of its impact on productivity, income and food security. This program was implemented by the Ministry of Rural Development and Land (MDRyT) in Bolivia with a total cost of US$25 million dollars, partly financed by the Inter-American Development Bank (IDB). Program execution started in 2011 with a peak in 2012-2013.

The program targeted smallholder producers located in rural areas in Bolivia with the overall objective to improve their agricultural income and food security through productivity increases. The program provided non-reimbursable vouchers that financed 90% of the total cost of an agricultural technology chosen by the producer. The voucher also covered personalized technical assistance on the use of the selected technology in the field. To this date, the program has given 17,663 non-reimbursable vouchers to finance one of the following technologies: modern irrigation systems[11], traditional irrigation, fruit dehydrators, mills, pulp machines, silos, weed cutters, destemmers, electric fences, greenhouses and livestock technologies.

The CRIAR program was implemented in five departments of Bolivia (La Paz, Cochabamba, Chuquisaca, Tarija and Potosí), focusing on 33 municipalities and 1,355 communities. The targeting of the program was based on the following criteria: (i) vulnerability to food insecurity measured with the "Vulnerability Assessment Map" (VAM); (ii) productive agricultural capacity[12]; and (iii) territorial continuity to simplify program execution. The cost of the technology covered by the program amounts to US$900, the remaining US$100 was covered by the producer. The technologies offered by the program could be divided into five groups: greenhouses, planting, harvest, post-harvest and livestock technologies. The most highly demanded were planting technologies (76%) which mainly included modern irrigation equipment and post-harvest technologies (12%) that included mills, fruit dehydrators and silos.

The implementation of CRIAR was focused at the community level. As a first step in the implementation process, the program's executing unit contacted community leaders from the different areas to evaluate the producers' interest to participate in the program. Next, once the

[11] Modern irrigation systems comprise sprinkler irrigation, micro-sprinkler irrigation and drip irrigation systems.
[12] Under this criterion, mining communities were excluded from the program.

communities expressed their interest to participate in CRIAR, the community leader provided a list of potential beneficiaries from the community with relevant information (community roster). The executing unit then implemented technological *ferias*[13] in the field. In these *ferias* smallholder producers who were included in the community roster could approach different technology providers. Overall, 33 *ferias* were organized –one per benefited municipality- that lasted about three days each. These *ferias* were located within the municipalities in order to be accessible for the different participant communities. During the *ferias,* the executing unit verified the eligibility of each producer and then delivered the vouchers. The producers used the vouchers during the *feria* to sign a contract of purchase with the selected provider for the chosen technology. The private provider selected by the producer had 45 working days to deliver the technology to the producer in the field. The producers were eligible based on the following criteria: (i) to present a valid identification card; (ii) to belong to the community roster; (iii) to have agriculture as the principal economic activity; and (iv) to be a smallholder producer with less than 35 hectares of land[14].

Once the producers received the technology, the executing unit provided a personalized training in the field regarding the use and operation of the purchased technologies. This training aimed to foster an appropriate and effective use of the technology among farmers. Ultimately, an in-situ verification of the process of delivery and technical assistance was conducted by a private company to all benefited producers. The full cost of the technology was paid to the private provider once the verification company certified the process of delivery by the executing unit of the program.

In the specific case of CRIAR, the implementation of the program was focused on addressing the market failures that limit technological adoption for smallholder producers without creating market distortions. Specifically, the provision of a voucher that partially covers the cost of an agricultural technology aims to ease liquidity and credit constraints. On the other hand, the provision of technical assistance to farmers in the field aims to reduce the barriers

[13] Fairs.

[14] The Ministry of Rural Development and Land of Bolivia defines a smallholder as any farmer who works 35 hectares of land or less. However, the average plot size worked by the CRIAR beneficiaries is 2.11 hectares (43% of farmers work in one hectare or less of land), with a maximum of 15.75 hectares. Although there is an eligibility criterion that requires farmers to own less than 35 hectares of land, the CRIAR program finally targets even smaller –subsistence- producers. See section V for a description of beneficiary households.

related to risk aversion and low levels of human capital that limit the effective use of the technologies. Lastly, the implementation of technology ferias aimed to reduce information asymmetries and eliminate problems related to shortage of supply and thin markets by providing a physical space where demand (small farmers) and supply (technology private providers) could carry out the commercial exchange.

As mentioned, the main objectives of the program were to increase income and food security for beneficiary households through improvements in agricultural productivity. The channel through which increases in agricultural productivity are expected to increase food security is twofold. First, higher agricultural productivity translates into higher agricultural yields increasing food production for home-consumption. Second, higher agricultural productivity will increase agricultural income from production sales which will improve household's purchasing power and therefore, food consumption. The following sections will focus on measuring the program's impact on productivity, income and food security as well as in understanding the channel through which these relationships occur.

IV. Counterfactual Identification

As with every impact evaluation, the principal problem to identify the causal effect of the program is the lack of information. Specifically, it is impossible to observe the outcome indicator (*Y*), at the same moment in time (*t=1*) for beneficiaries (*i*) with and without treatment (*CRIAR=1; CRIAR=0*) because by definition, all the beneficiaries received the program.

$$Impact = [Yi\ (t = 1, CRIAR = 1) - Yi(t = 1, CRIAR = 0)] \quad (1)$$

Therefore, the term $Yi(t = 1, CRIAR = 0)$ is not observable because there is only information about the beneficiaries with the program $Yi\ (t = 1, CRIAR = 1)$. Consequently, the principal challenge consists in the identification of a proper counterfactual or control group composed by non-beneficiary households comparable to treated households in all their characteristics. The identification of a counterfactual will allow us to measure the average impact of the program for the treated households by comparing them with the control households.

The ideal scenario to create a control group consists on a random assignment to treatment. Unfortunately, this scenario must be ruled out because participation in CRIAR was not randomly

assigned. Moreover, lack of baseline information makes it more difficult to identify a control group for CRIAR.

Therefore, the identification strategy for this evaluation includes the following procedures: (i) replicating the selection process into CRIAR at the community and the household levels; (ii) careful data collection strategy in the field; and (iii) rigorous econometric methodology. First, to replicate the selection process into CRIAR at the community level, we identified the communities that fulfilled all the initial eligibility conditions with regards to high vulnerability to food insecurity, agricultural productive capacity, territorial continuity and that belonged to the treated municipalities. These criteria correspond to the original conditions that determine eligibility of participant communities. Also, using administrative data and local knowledge from the program's executing unit, we identified control communities that fulfilled the eligibility criteria, did not reject participation into the program and were located within a radius of 5 kilometers from benefited communities. This proximity criterion used to select the control communities resembled the decision-making of the executing unit that was considered for selection of beneficiary communities to facilitate the logistics of program implementation (territorial continuity). Moreover, it assures that beneficiary and control communities have similar geographic, climatic and productive characteristics as well as access to markets and infrastructure.

Second, to determine comparability at the household level, we perform a careful analysis of the administrative data collected by the executing unit during the creation of the roster of beneficiary households at the technology *ferias*. The administrative data contains information regarding land extension, cultivated crops and other general characteristics of the treated households. The analysis of these variables allowed us to identify a prototype of beneficiary households and elaborate a short list of questions that determined whether control households fulfilled these characteristics ex-ante and therefore, could be comparable. The administration of this list of questions was part of the data collection process which allowed us to have a pre-screening of the control households and determine at first glance, their comparability to treatment households.

Third, once the pre-screening was confirmed, the interviewer proceeded with the administration of a comprehensive agricultural household survey. The questionnaire was

administered to a representative sample of beneficiary and non-beneficiary households that fulfilled the eligibility criteria at the community level and the pre-screening at the household level. The questionnaire includes all the possible variables needed to identify a proper counterfactual, including key variables that capture the process of socialization and dissemination of CRIAR as these could have determined the participation of beneficiary producers to a great extent. For instance, variables that capture participation in agricultural associations were included because the socialization of the program included these organizations as part of their dissemination strategy. Also, information that captures distance to the *feria* location was measured using GPS, as the *ferias* were the physical place were vouchers were delivered and exchanged.

Lastly, the data collected in the field was later used to apply an Instrumental Variable (IV) methodology in order to control by those unobservable characteristics of beneficiary farmers that might have affected both program participation and outcomes of interest (self-selection bias). Applying this methodology will allow us to measure the causal effects of program participation.

Summarizing, the identification of a proper counterfactual consisted on three basic strategies: (i) identifying non-beneficiary communities comparable to beneficiary communities by replicating the original process of selection into CRIAR; (ii) identifying control households that fulfilled all the eligibility criteria, were located in comparable communities and exhibit similar characteristics to the prototype of beneficiary households; and (iii) implementing a rigorous econometric methodology to control for program self-selection bias.

V. Data and Descriptive Statistics

This section presents the descriptive statistics of the data collected for the impact evaluation of CRIAR. This analysis provides an overview of the socio-demographic, economic and agricultural background of sampled households. It also presents a comparison between the beneficiaries and control group.

The data used for this study was collected in the departments of Chuquisaca, La Paz, Cochabamba, Tarija and Potosí between November 2013 and January 2014[15]. The agricultural

[15] The data was collected by *CIES Internacional*.

household survey was administered in the field to 1,287 households located in 35 [16] municipalities and 176 communities (see Annex A). The sample interviewed for this purpose included a total of 817 beneficiary and 470 control households, selected from a list of beneficiary and non-beneficiary communities which met the program eligibility criteria.

The questionnaire applied to the sample of treated and control households included 11 modules and 215 questions containing socio-demographic information, education, occupation and income, information about agricultural land, crops, input use, agricultural production, access to associations or cooperatives, housing conditions, poverty and food security. The information collected in this survey refers to the agricultural cycle comprised between July 2012 and June 2013. The questions covered information about the whole agricultural cycle – land preparation, sowing and harvesting- for all the different crops planted by the farmers. In addition, community-level questionnaires were applied to 170 community leaders that included 11 modules and 150 questions. This questionnaire contained information regarding population, basic community services, infrastructure and communication, accessibility to markets and nearby towns, sources of community income, seasonality of the agricultural activities, and main characteristics of agricultural and livestock production

Tables 1 and 2 present the descriptive statistics for both the beneficiary and control households. Table 1 presents the descriptive statistics of variables related to socio-economic status, household demographics, access to social capital and distance to important places.

Regarding the demographic composition of the sample, households have an average of 4 household members, 50% of which are age dependents (under 15 or over 65 years old). The heads of household are mostly men (89%) who considered themselves indigenous or native (74%). The average education for the heads of household is 4.7 years; 14% do not have any formal education, 41% have incomplete primary, 22% have completed primary education, 14% have incomplete secondary education and 9% have completed secondary education or above.

With respect to the household dwelling characteristics, most of them have dirt floor (63%), access to electricity is rather widespread (76%) and only 15% have a refrigerator.

[16] The two additional municipalities (just 33 municipalities participated in CRIAR, see section 3) are due to households that, when surveyed, were located in neighbor municipalities.

Regarding access to social capital, only 8% of the households have a member who belongs to an agricultural association. This differs significantly between treated and control households. Specifically, the treated group has a higher percentage of households who belong to a cooperative or an agricultural association (11%) compared with control households (4%).

Table 1: Descriptive Statistics – Socio-Economic Status of Households

	Variables (units)	Total	Treated	Control	Diff. in Means
Household	Household Size (# members)	4.23	4.39	3.97	0.42**
	Dependency Ratio	1.05	1.04	1.08	0.04
Head of Household	Age (years)	50.39	48.97	52.86	3.89***
	Female (0,1)	0.11	0.09	0.15	0.06**
	Single (0,1)	0.21	0.16	0.27	0.11***
	Indigenous or native (0,1)	0.74	0.76	0.71	0.05
Education of the Head of Household	HH without formal education (0,1)	0.14	0.11	0.21	0.10***
	HH with primary incomplete (0,1)	0.41	0.43	0.42	0.01
	HH with primary complete (0,1)	0.22	0.22	0.22	0.01
	HH with secondary incomplete (0,1)	0.14	0.16	0.1	0.06***
	HH with secondary incomplete (0,1)	0.07	0.09	0.04	0.05**
	HH with more than secondary (0,1)	0.02	0.03	0.01	0.01
Dwelling Characteristics	Dirt floor (0,1)	0.63	0.6	0.68	0.08
	House with electric energy (0,1)	0.76	0.78	0.72	0.06
	House with freezer (0,1)	0.15	0.15	0.14	0.01
Associativity	Household belongs to an agric. cooperative (0,1)	0.08	0.11	0.04	0.07***
Economic Characteristics	Agriculture as main source of income (0,1)	0.7	0.71	0.67	0.05
	Agricultural income (% of total income)	0.56	0.57	0.56	0.01
	Access to formal credit (0,1)	0.08	0.09	0.07	0.02
	Voluntary savings (0,1)	0.06	0.07	0.04	0.03
	Remittances (USD year/HH)	394.5	369.28	438.34	69.06
	TLU	4.89	4.8	5.06	0.26
	Household with land tenure (0,1)	0.99	0.99	0.99	0.01
	PPI Score	29.32	29.6	28.84	0.76
Accessibility	Time to paved road (mins)	24.85	27.57	20.14	7.42
	Distance to CRIAR ferias (km)	13.78	12.62	15.82	3.2***
Land	Land owned by HH (Has)	2.35	2.29	2.45	0.16
	Hectares worked (Has)	2.11	2.09	2.16	0.07
	Prop. of hectares worked (Has/total Has)	0.82	0.83	0.81	0.02
	N	**1,287**	**817**	**470**	

Difference in means is significant at the *** 1%, ** 5%, * 10% level. P-values for t-tests are obtained controlling for clusters at the community level.

With respect to households' economic characteristics and welfare, 70% of the households use agriculture as the main source of income which represents about 56% of the total household income. The index number of cattle in *TLU* (*Total Livestock Units*) shows that, on average, households own 5 livestock units. Regarding access to credit and financial services, only 8% of households reported having received formal credit and 6% reported having voluntary savings in financial institutions. The remittances received by households in the sample amounted to US$394 per year, about 7% of their annual income. The *Progress out of Poverty Index* (*PPI* index; see Annex B for details) shows that the probability that a household, in this sample, has an income below the poverty line is 83%. None of the economic characteristics differ significantly between treated and control groups.

The average extent of land owned by the households in this sample is 2.35 hectares, while the average extent of the plots worked by these farmers reaches 2.11 hectares (43% of farmers work in one hectare or less of land). None of the variables related to extension of agricultural land show significant differences between treatment and control groups. Finally, distance from the household to the CRIAR *ferias* is about 14 kms and traveling distance to a paved road is about 25 minutes (walking equivalence). Treated households are 3.2 km closer to the technology ferias than control households.

The descriptive analysis suggests the presence of various types of barriers that potentially limit technological adoption by small farmers in Bolivia. In particular, the inaccessibility to credit markets, the lack of access to information, the presence of liquidity constraints and the low level of education are the most important.

The context described above also confirms that ex- ante counterfactual identification strategy at the household level was successful. Most of the observable variables analyzed are not significantly different between treated and control households and when different, the magnitude of this difference is not large enough to cause concern. This corroborates that treated and control households are similar in most observable characteristics. Any differences in the remaining variables between treated and control groups, will be addressed by including them in the econometric estimations.

Table 2 presents variables related to agricultural production including measures for productivity and food security. Given the nature of the program, it is expected to find statistical significant differences in these variables between treated and control groups. In fact, most of these are our outcomes of interest and therefore, the econometric analysis will corroborate whether these differences are directly attributable to program participation.

Table 2: Descriptive Statistics – Agricultural Production and Food Security

	Variables (unit)	Total	Treated	Control	Diff. in Means
Crop Portfolio	Traditional Crops (0,1)	0.28	0.24	0.36	0.12***
	Proportion of land with traditional crops (%)	0.66	0.62	0.74	0.13***
Irrigation	Modern Irrigation (0,1)	0.19	0.23	0.11	0.12***
	Proportion of land with modern irrigation	0.10	0.13	0.05	0.07***
Input Expenditures	Inputs - FIHF (US$/HA)	553	644	397	247***
	Machinery and equipment (US$/HA)	18.96	20.26	16.69	3.56
	Paid labor (US$/HA)	281	318	218	100 **
	Value of household labor (US$/HA)	1433	1418	1459	41
Sales	HH sells (0,1)	0.74	0.77	0.69	0.08***
	Proportion of production sold (%)	0.24	0.25	0.21	0.05***
	HH sales in the market (0,1)	0.50	0.52	0.47	0.05**
	Proportion of production sold in the market	0.32	0.33	0.30	0.03**
	HH sells in farm (0,1)	0.50	0.53	0.46	0.07**
	Proportion of production sold on-farm (%)	0.20	0.20	0.19	0.01
	Value of Sales (US$)[17]	2232	2529	1716	812***
	Value of Sales (logs)	5.05	5.30	4.61	0.69***
Home Consumption	Proportion home-consumption (%)	0.36	0.34	0.39	0.05***
	Value of home consumption (US$)	1907	2000	1746	254
	Value of home consumption (US$) (logs)	6.464	6.443	6.501	0.057
Value of Production	Value of production US$/HA	4679	4941	4223	718***
	Value of production US$/HA (logs)	7.69	7.79	7.52	0.28***
	Value of production US$	6579	7121	5638	1483**
	Value of production US$ (logs)	7.73	7.79	7.62	0.17*
Household Income	Household Income (US$)	5544	6070	4630	1441**
	Household Income (logs)	10.26	10.28	10.23	0.05**
	Household Income p/c (US$)	1627	1786	1354	432**
	Household Income p/c (logs)	9.28	9.29	9.27	0.02
Food Insecurity	Food Insecurity (FAO Index)	0.58	0.57	0.59	0.02*
	N	**1,287**	**817**	**470**	

Difference in means is significant at the *** 1%, ** 5%, * 10% level. P values for the t-tests are obtained controlling for clusters at the community level.

[17] The medians for the treated and control groups are 520 and 343 respectively which suggests that the difference between means is not driven by outliers.

In regards to the portfolio of crops cultivated by the farmers, 28% of households reported working on traditional crops exclusively[18]. The average proportion of land allocated to traditional crops is 66% of total land cultivated. With respect to input use, farmers in this sample spend on average, US$553 per hectare in fungicides, insecticides and fertilizers, US$19 per hectare in machinery and US$281 per hectare in contracted labor. The value of household labor used for agricultural production valued at market prices is US$1433 per hectare. Lastly, only 19% of the households have access to modern irrigation systems that cover about 10% of the total land. Compared with the control group, beneficiary households present better access to modern irrigation, larger proportion of land allocated to non-traditional crops and a higher use of inputs and machinery. With respect to labor, treated households spent more on contracted labor than control households while there are not significant differences with respect to household labor.

Households in this sample allocate 36% of their agricultural production for home consumption and 24% for sales. The remaining is distributed among seeds (10%), losses (10%), animal consumption (8%) and other uses (12%). Treated households assign a higher proportion of production to sales and lower proportion to home consumption compared with control households. At the same time, while the value of home consumption does not differ significantly between treated and control groups, the value of the production sold is US$812 higher for beneficiary households. In regards to agricultural output, we used value of agricultural production valued at market prices per hectare as a proxy for productivity. We also include the value of agricultural production valued at market prices per household to corroborate that the results obtained for productivity are not mainly driven by the distribution of hectares, especially by small values of this variable. For agricultural income we calculated the net agricultural household and per capita income based on the value of production and the input costs per hectare[19]. On average, the value of production for these households equals US$4,679 per hectare and the value of production per household is US$6,579. Regarding income and income per capita, the households in the sample earn an average of US$5,544 and US$1,627 per year, respectively. The differences for treated and control households are statistically significant with better outcomes for beneficiary households.

[18] Traditional crops are rice, barley, corn, quinoa, wheat, *oca*, potato and cassava.
[19] The following input costs were included: fungicides, insecticides, fertilizer, machinery and equipment. The income variable includes home consumption valued at market prices.

To measure food security at the household level we use the FAO index based on the Latin American and Caribbean Food Security Scale (ELCSA by the Spanish acronym). This index consists of a list of 15 questions that capture the degree of households' accessibility to food[20]. According to this index, 58% of households in the sample are food insecure. The difference between both groups is about 2% lower for the treated households compared to the control group.

Table 3 shows the descriptive statistics at the community level from the questionnaire applied to community leaders. The variables related to basic infrastructure and public services indicate that only 8% of the communities in the sample have access to public hospital or health center, 84% have primary school and only 1% have a formal financial institution within the community. With respect to communication and transportation, 41% of communities have public transportation and 12% have a paved road that connects with the provincial capital. The average travel time from these communities to the largest market in the area is 133 minutes (2.2 hours)[21]. Finally, variables referring to agricultural and productive activities show that 98% of the communities consider agriculture as their main source of income, 15% have an association or agricultural cooperative, 58% have access to water for irrigation and 46% have water for irrigation continuously throughout the year.

Table 3: Descriptive Statistics – Communities Characteristics

Variables (unit)	Total	Treated	Control	Diff. in Means
Community with hospital or health center (0,1)	0.08	0.09	0.07	0.02
Community with primary school (0,1)	0.84	0.84	0.85	0.01
Community with formal financial institution (0,1)	0.01	0.01	0.00	0.01
Community with public transportation (0,1)	0.41	0.40	0.48	0.09
Community with paved road (0,1)	0.12	0.13	0.09	0.04
Time between community and nearest market (min.)	132.78	129.63	145.61	15.98
Community with agricultural cooperative (0,1)	0.15	0.17	0.06	0.11
Community with agriculture as main source of income (0,1)	0.98	0.98	0.97	0.01
Community has access to water for irrigation (0,1)	0.58	0.60	0.48	0.12
Community has access to water for irrigation throughout the year (0,1)	0.46	0.46	0.45	0.01
N	**167**	**134**	**33**	

Difference in means is significant at the *** 1%, ** 5%, * 10% level

[20] This index consists of a list of 15 questions that capture the degree of households' accessibility to food by capturing objective) and subjective assessments. This index was chosen as the most robust, reliable and scientifically valid at an international symposium organized by the FAO in 2012. Also, the index is one of the most cost-effective when collecting information in the field. See Annex C for details.

[21] This is considering the most common means of transportation within each community.

The last column of table 3 presents the difference in means between treated and control communities. The evidence shows that the selection process was successful as control communities are comparable to the treated ones. The differences in means between treated and controls are small in magnitude, and none of them is statistically significant.

VI. Econometric Approach: Instrumental Variables

As mentioned, it is expected that households' participation in CRIAR would improve food security through increases in agricultural income and/or home-consumption that take place due to higher agricultural productivity. However, there are two main issues that need to be considered when estimating the effect of CRIAR on these outcomes. First, participation in CRIAR might be endogenous as well as correlated with the outcomes of interest. For instance, highly productive farmers, with higher income and food security, might be more inclined to participate in the program. Also, farmers with higher agricultural income are more likely to have the economic resources to pay the remaining 10% of the cost of the technology and therefore, to participate in the program. Second, there might be some unobservable characteristics or omitted variables that might influence both participation in CRIAR and the outcome of interest, such as leadership skills or levels of risk aversion. Therefore, comparisons of treated and untreated households are unlikely to provide the causal impact effect and estimating "Ordinary Least Squares" (OLS) will generate biased estimates (Angrist, 2001). Hence, to assess the impact of CRIAR in productivity, income and food security, we use an Instrumental Variable approach (IV) where the first stage estimates the participation equation and the second stage estimates the impact of CRIAR on the outcomes of interest. However, in order to apply this methodology, it is necessary to identify one or more variables that affect participation in CRIAR but are unlikely to affect the outcome variables. These variables needed to identify the participation equation (first stage) are the instruments.

The instrumental variables used in this analysis are distance from the household dwelling to the location where the CRIAR *ferias* took place and its quadratic term. The intuition behind choosing these variables as an instrument is that households located further from the technology *ferias* are less likely to participate in the program because of higher transaction costs. It is important to mention that technology *ferias* where the physical place where CRIAR vouchers were delivered and technologies were purchased. Therefore, it was necessary for farmers to

mobilize themselves to the *ferias* in order to receive the vouchers and therefore, the technologies. The quadratic term of the distance variable was included to capture any non-linear relations.

To apply the IV methodology, the instruments chosen must be valid, relevant and exogenous to the outcome of interest (Stock and Watson, 2007). However, in the case of exogeneity, instruments cannot be tested and the assumption must be justified. In other words, it is important to understand how distance from the household to the *feria* does not affect the outcomes of interest other than by its effect on program participation, after controlling for other variables (Angrist, 2001; Attanasio y Vera-Hernandez, 2004).

Following Attanasio and Vera-Hernandez (2004), two problems can be of concern when using distance to the *ferias* as an instrument: (i) endogeneity of *ferias* placement; and (ii) endogeneity of producer's households. The first problem would be troublesome if *ferias* location was determined based on characteristics that might affect the outcomes of interest. For instance, *ferias* could have been located in communities with lower income or less productive households that might have benefited from the program to a greater extent. However, interviews with program officials and local authorities confirm this was not the case. First of all, the *ferias* were organized in the capital of the municipality and not within specific communities. This was implemented as a measure of fairness to guarantee accessibility to all communities in the municipality. Using the capital of the municipalities as the physical place to locate the *ferias* allowed program executors to reach as many communities as possible within the municipality. Therefore, the criterion to locate a specific feria was purely administrative, without considering specific household or producer characteristics. Within the capital, the ferias took place in schools, indoor sports facilities, community centers, etc., without following a particular pattern from one municipality to the next.

To corroborate that communities located closer to the *ferias* are not systematically different from those communities located further away, we performed t-tests of difference in means for different variables both at the community (for all the variables in Table 3) and at the household level (economic status, land and associativity, among other variables). These tests were applied within different distance bandwidths. For all the bandwidths chosen, none of the variables show a statistically significant difference in means. This confirms that *ferias* location

was not based on specific community or producer characteristics that might have been correlated with the outcomes of interest (see Appendix). Furthermore, measures for distance to the closest road and closest market were included in all specifications in order to assure that the instrumental variable (distance to *ferias*) was not capturing other location characteristics of the households that could affect the outcomes of interest.

The second problem of instrument endogeneity would arise if producer households' location was endogenously determined based on the location of the *ferias*. In other words, if producers who might benefit from the program to a greater extent (i.e. poorest households), would have moved to benefited municipalities in order to participate in the *ferias*. However, this problem is of less concern in short term, one-shot-phase interventions like CRIAR as *ferias* lasted from three to five days only. During this period producers must have reached the location, obtain their voucher and purchase their technology. This process was done within one day and producers would then return to their respective communities. To this extent, it is difficult to consider that program benefits (US$900) were enough to compensate farmers for purchasing land in a different community outside their municipality. Besides, the lack of strong property rights, the presence of customary land rights and the short time available between program dissemination and implementation (two to three months) suggest this was rather implausible. On the other hand, it is worth mentioning that communities in Bolivia are not only based on geographical proximity but mainly on strong social ties and sense of belonging. Therefore, the cost of moving to a different community within a different municipality would imply high social and economic costs.

In addition, to support the identification strategy, we performed some placebo tests on variables related to the outcomes of interest (productivity, income and food security) but on which the program should have not had an impact (i.e. flat land, education of the head of the household and Total Livestok Units). The estimations do not show any program's impact on these variables. This suggests that any effects found on the real equations are not driven by a correlation between the error term of the outcome equation and the instruments (Attanasio and Vera-Hernandez, 2004)[22].

[22] Estimations are available upon request.

Finally, the literature of impact evaluation presents other studies that used distance in order to predict program participation mainly due to the exogeneity associated with this type of variable (Attanasio y Vera-Hernandez, 2004).

In the case of a binary endogenous regressor such as in this analysis (participation in CRIAR), using a "Two Stage Least Square" (2SLS) linear probability model is appropriate as long as we are concerned about estimating causal effects rather than structural coefficients (Angrist, 2001). Also, it is important to mention that using this methodology allows us to predict the effect of treatment on the treated for those whose treatment (participation in CRIAR) is influenced by the instrument also known as Local Average Treatment Effect (LATE) (Angrist, 2001). This means that predictions are valid for the treated households whose participation in CRIAR is affected by the distance to the technology *ferias*.

Hence, the first stage is estimated as follows:

$$Prob(CRIAR|\, xi) = \alpha + \beta_2 \sum HH_i + \beta_3 \sum W_i + \beta_4 \sum A_i + \beta_5 \sum M_i + \beta_6 \sum D_i + \varepsilon_1$$

Where,

HH_i is a vector of head of the household and household demographic characteristics that include gender, age, age square, indigenous origin, marital status and education of the head of the household as well as household size, dependency ratio and travel time to a paved road;

W_i is a vector of variables that capture household wealth and economic status including access to credit, savings, number of hectares of land worked, number of parcels worked, access to nonagricultural income, remittances, livestock owned and a poverty indicator;

A_i is a vector of agricultural variables related with the production process such as inputs, share of flat land, share of irrigated land and access to technical assistance from other sources than CRIAR;

M_i is a vector of fixed effects at the municipality level to control for geographic characteristics such as climate and soil;

D_i is a vector that includes the instruments to identify the participation equation including distance from the household dwelling to the CRIAR ferias and its square term;

ε_1 is the error term; and

$\alpha, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6$ are the coefficients to be estimated.

The second stage corresponds to the estimation of the impact of CRIAR on the outcomes of interest including agricultural productivity, income and food security. For this purpose, the following equation is estimated:

$$Y_i = \varphi + \lambda_2 \sum HH_i + \lambda_3 \sum W_i + \lambda_4 \sum A_i + \lambda_5 \sum M_i + \lambda_6 CRIAR_i + \varepsilon_2$$

Where,

Y_i represents the outcomes of interest. Productivity is measured through value of production, agricultural income through net agricultural household income and food security through the FAO index of food security);

$CRIAR_i$ is the predicted participation from the first stage;

HH_i, W_i, A_i, M_i are defined previously;

$\varphi, \lambda_2, \lambda_3, \lambda_4, \lambda_5, \lambda_6$ are the coefficients to be estimated; and

ε_2 is the error term.

The hypothesis that CRIAR has a positive effect on productivity, income and food security is verified if the coefficient λ_6 is positive and significant.

VII. The Results

The results to the first stage participation equation are presented in Table 4. As expected, the coefficient of distance from the household dwelling to the *ferias* is negative and statistically significant[23]. Specifically, being located one kilometer further away from the CRIAR *ferias* reduces the probability of participation by 2.3%. The magnitude of this coefficient is rather large

[23] The results to the first stage estimation using a LPM, municipality fixed effects and robust standard errors clustered at the community level are presented in Annex D.

as the average household is located about 14 kms. away from the technology *ferias*. Also, it suggests that transaction costs associated with transportation and time-use influence participation in CRIAR. The squared term of the distance is positive and significant suggesting a nonlinear relationship between distance and program participation. The instruments pass the underidentification and weak identification tests. The under-identification test confirms that the equation is identified and the excluded instruments are relevant[24].

Table 4: First Stage

	First Stage: Specification	
Variable (Units)	**Productivity/ Income**	**Food Security**
Distance	-0.023***	-0.022***
	(0.008)	(0.008)
Distance Squared	0.001***	0.001***
	(0.000)	(0.000)
Covariates		
Household Characteristics	Yes	Yes
Head of Household Characteristics	Yes	Yes
House Characteristics	Yes	Yes
Associativity	Yes	Yes
Economic Status	Yes	Yes
Irrigation	Yes	No
Input Expenditures	Yes	No
Technical Assistance	Yes	No
Land	Yes	Yes
Municipality Fized Effects	Yes	Yes
N	***1287***	***1264***
F Stat	*9.57 [0.000]*	*10.78 [0.000]*
Kleibergen-Paap rk Wald F stat	*84.9 [0.000]*	*82.2 [0.000]*
Hansen J Stat	*1.118 [0.2903]*	*0.013 [0.908]*

Standard errors clustered at the community level in parentheses
P values for the test statistics are in brackets
**** Significant at 1 percent level*

The second stage estimations examine the impact of program participation in productivity -measured as the log value of production per hectare-, agricultural income –measured as

[24] The F-statistic of join significance, the chi-square values for the Kleibergen-Paap test of under-identification and the Hansen J test of validity of the instruments are presented at the bottom of the table. The estimations pass the test of relevance and identification tests. The Hansen-J test confirms that the instruments are valid and correctly excluded from the second stage and the Kleibergen-Paap test suggests that the equation is identified. The F-statistic of join significance for the instruments is 9.04.

household income and household income per capita -, and food security –measured with the FAO index of food security-. The results show that participation in CRIAR has a positive significant impact on productivity, household income and food security. The summary of the results are presented in Table 5[25].

The results for agricultural productivity show that participation in CRIAR increased annual value of production per hectare by 92% in average[26]. This represents an increase of US$1,870, based on the median value of production per hectare for the control group (US$2,032). The program effect for value of production at the household level is also positive, significant and similar in magnitude: participation in the program increased annual value of production by 113%. In addition, in order to reduce noise from price volatility, the value of production was also calculated using the average price for each crop at the municipality level instead of using the average price reported by the farmer. The coefficient becomes more significant and the impact increases to about 148%.

The possible causes for this result are twofold: (i) adopted technologies increased production per hectare significantly; and/or (ii) farmers engaged in crop substitution from traditional to high-value crops. The data provides some evidence suggesting the presence of both effects, particularly for the case of high-value crops. Farmers in the sample cultivate a mix of traditional and high-value crops. Potatoes (80%) and corn (45%) are the main traditional crops, while green beans (21%) and green peas (14%) are the main high-value crops. Compared to the control group, beneficiary households have statistically similar production yields for potatoes but greater production yields for corn, green peas and green beans (the difference in means for yields per hectare is statistically significant). On the other hand, the average price of potatoes equals US$301 dollars per ton, while prices for peas and beans reach US$525 and US$376[27] dollars per ton respectively (74% and 25% higher than potatoes). Therefore, the large magnitude in the productivity coefficient derives from higher yields with a significantly higher value. Furthermore, the data shows that 76% of the beneficiary farmers cultivate high-value crops compared with 64% of non-beneficiaries. Also, beneficiary farmers allocate 13% more land to high-value crops

[25] Tables with full 2SLS results for each outcome of interest are presented in Annex E

[26] Value of production was calculated with prices reported by farmers. In the case where sales were not reported, the average price at the community level for a particular crop was used instead.

[27] Prices per ton were obtained using the average price reported by farmers for each crop at the provincial level. These are very similar to the prices reported by FAO in Bolivia (year 2012).

versus non beneficiaries. This suggests that high-value crops represent a most important proportion of the crop portfolio for beneficiary farmers than for non-beneficiaries farmers.

With regards to variables that capture production use and allocation, we do not find any significant impact on production allocated for home consumption. On the other hand, beneficiaries are more likely to sell their production either in the market, to intermediaries or on-farm (17%). The results also show a significant impact of the program on the value of production sales. Specifically, as a result of the program, the value of the production sold by beneficiary farmers increases by 360% (the median value of sales for the control group is 343 US$ per hectare). The large magnitude of this coefficient can be justified twofold. First, program participation increased the probability of farmers engaging in commercialization of agricultural production. Therefore, households that did not sell any production before the program are more likely to sell after program participation. Consequently, any small change in production sold is a large impact for these small producers. In fact, 30% of the households in the control group do not sell any production and for those who sell, only 25% of their production is sold. Second, as mentioned previously, beneficiary farmers produce more and engage in crop substitution from traditional to high-value crops. This can account for a significant increase in the value of the production sold.

With respect to net agricultural income, the results show that participation in CRIAR increased net agricultural household income by 36% and per capita income by 19%. The coefficients are both positive and significant. Specifically, this represents an increase of US$1,667 in net household income and US$257 per capita with respect to the average income of the control group (US$4630 and US$1354). These findings suggest that beneficiary households not only became more productive with their participation in CRIAR but also were able to increase their net purchasing power with respect to control households.

Finally, the estimations show that participation in CRIAR improved food security. Specifically, using a LPM, the estimated coefficient of the FAO Index presents an increase of 32% in the probability of being food secure. Likewise, using a Bivariate Probit model, the results suggest an increase of 20% in the probability of being food secure which can be used as a lower bound estimate (see Annex E, Table E10). Hence, beneficiary households are 20% to 30% more likely to be food secure than their control counterparts. In order to understand which specific

aspects of food security were driving the overall results, the FAO Index was disaggregated into the fifteen questions that composed this indicator[28]. These questions aimed to capture the concern and the actual food shortage due to lack of money or other resources in the household during the last 3 months. These questions are divided into two sections. The first section corresponds to questions related to food insecurity among adults (questions 1 to 8) and the second section to questions related to food insecurity among children under 18 years of age in the household (questions 9 to 15). The results show that program participation increased food security for adults. Specifically, with respect to the control group, adults from beneficiary households reduced their concern in regards to lack of food at home by 22%, increased the probability of eating nutritious food by 14% and reduced the probability of having a diet based on low food variety by 17%. Also, participation in CRIAR reduced the probability of adults missing a meal by 14% and adults not eating during the whole day by 10%. In the case of food security for children under 18 years of age, the coefficients had the expected signs but were not significant, which might be due to lack of sample representativeness with respect to this segment of households (68% of the total households in the sample)[29].

In regards to the link through which program participation enhances food security, the results confirm that reduction of vulnerability to food insecurity by program participants was driven by an income increase as the coefficient for the regression of home consumption was positive but non-significant. This finding suggests that beneficiary households are less food insecure due to an increase in their purchasing power which allows them to obtain more food outside their farms.

[28] The response to these questions were binary answers (Yes/No) replied by the head of household for adults and children under 18 years separately. See Annex C for more details.
[29] Table 5 presents the coefficients obtained for adults only as non-significance was found in the case of children under 18 years of age.

Table 5. Results and Placebo Tests

	Dependent Variables (Unit)	Impact
Productivity	Value of production US$/HA (logs)	0.654**
		(0.347)
	Value of production US$ (logs)	0.762*
		(0.019)
	Value of production - Valued at mean prices in the municipality US$/HA (logs)	0.915**
		(0.363)
Home Consumption	Home Consumption US$ (logs)	0.301
		(0.500)
Sales	Household sells production (0,1)	0.172***
		(0.094)
	Household sales US$ (logs)	1.539*
		(0.833)
Income	Household income (US$-logs)	0.311***
		(0.115)
	Household income per capita (US$-logs)	0.179**
		(0.086)
Food Security	Food Security (FAO Index - 1=Food Security, 0=Food Insecurity)	0.316***
		(0.104)
	In the last 3 months, was concern about lack of food at home? (yes/no)	*-0.219**
		(0.114)
	In the last 3 months, the household ran out of food? (yes/no)	*-0.043*
		(0.066)
	In the last 3 months, any adult was unable to eat healthy and nutritious food? (yes/no)	*-0.142***
		(0.065)
	In the last 3 months, any adult ate only a few kinds of foods? (yes/no)	*-0.168**
		(0.089)
	In the last 3 months, any adult had to skip a meal? (yes/no)	*-0.144***
		(0.064)
	In the last 3 months, any adult ate less than he/she you should? (yes/no)	*-0.114*
		(0.078)
	In the last 3 months, any adult was hungry but did not eat? (yes/no)	*-0.093*
		(0.071)
	In the last 3 months, any adult went without eating for a whole day? (yes/no)	*-0.103**
		(0.059)
Placebo Tests	TLU Index for cows	1.140
		(0.809)
	TLU Index for bulls	-0.193
		(0.137)
	Head of the household education (years)	0.087
		(0.189)
	Share of flat land	0.000
		(0.104)
	N	**1,287**

Notes: All models are estimated by 2SLS and include municipality fixed effects
Robust standard errors clustered at the community level are in parentheses
*Significant at *** 1 percent level, ** 5 percent level, * 10 percent level*

The last panel of table 5 presents the placebo tests performed on *Total Livestock Units* for cows and bulls, education of the head of the household and share of flat land. As mentioned in section VI, the idea behind this placebo tests is to run the estimations for variables related to the outcomes of interest (productivity, income and food security) but on which the program should not have an impact. As long as the coefficient for program participation is not significant, these placebo tests allow us to corroborate that any effects found in previous estimations are not driven by a correlation between the error term of the outcome equations and the instruments (Attanasio and Vera-Hernandez, 2004). The estimations for these placebo tests do not show any program's impact on these variables, which confirms the validity of the results.

Finally, it is worth mentioning that even though the data generation process does not correspond to a randomized control trial and there are some initial differences in variables between treated and control groups (Table 1), the identification strategy used in this paper (IV) correctly addresses potential identification problems that might take place due to observable and unobservable characteristics[30].. This, together with the placebo tests described in the preceding paragraph, ensure that the coefficients obtained are consistent estimators of the causal effect of the CRIAR program and correspond to the LATE.

VIII. Conclusions

This paper aims to provide deeper insight into the role of productive agricultural programs as policy tools to enhance food security. Specifically, this study focuses on the effects of the CRIAR program, an agricultural program implemented in Bolivia with the objective to increase smallholders' food security and income through productivity increases triggered by technological adoption. This program provided non-reimbursable vouchers to finance 90% of the total cost of an agricultural technology selected by the farmer. Considering that program participation can be endogenous, as there might be unobservable characteristics that might influence participation in CRIAR and the outcomes of interest, an instrumental variable methodology was applied.

The results from the empirical analysis confirmed that, with respect to the control group, program participants increased annual value of production per hectare by 92% and the value of

[30] See Section VI: Econometric Approach, Instrumental Variables.

the production sold by 360%. With respect to income, the results show that participation in CRIAR increased net annual agricultural household income by 36% and per capita household income by 19%. Moreover, results from different estimations confirmed that CRIAR participation increased the probability of a household being food secure by 32%. Deeper analysis suggests that food security gains from program participation are mainly driven by better outcomes obtained by adults. It is worth mentioning, however, that results obtained in these estimations correspond to local average treatment effects (LATE). This implies that the coefficients represent the causal effects for households whose decision to participate is affected by the instrument considered (distance from the dwelling to the CRIAR ferias).

Last but not least, the paper delivers deeper insight into the causal link through which agricultural programs enhance food security (income versus home-consumption). For the case of the CRIAR program, results provide evidence that reduction on vulnerability to food insecurity was entirely driven by an increase in income rather than by higher levels of home-consumption.

Summarizing, the evidence presented in this paper is valuable both for its contribution to the literature on the effectiveness of agricultural technological programs as well as for the policy implications regarding the role of productive agricultural programs as policy instruments to reduce vulnerability to food insecurity. The study presents rigorous empirical analysis on the effectiveness of technology adoption programs on productivity and income. It also provides evidence that agricultural programs play a crucial role as policy instruments to enhance food security. This is of special interest, since the literature on agricultural productive programs has not deeply explored the effects of this type of policy tools and its links with food security.

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ANNEX A: LIST OF MUNICIPALITIES

MUNICIPALITY	NUMBER OF HOUSEHOLDS
Alalay	42
Alcalá	4
Anzaldo	52
Aucapata	20
Ayata	29
Bermejo	38
Chuma	4
Colquechaca	51
Colquiri	63
Combaya	39
El Puente	33
El Villar	8
Ichoca	56
Icla	33
Inquisivi	76
Malla	21
Mizque	94
Mocomuco	30
Mojocoya	85
Ocurí	36
Padilla	8
Pocoata	26
Quiabaya	30
Quime	49
Ravelo	45
San Lorenzo	4
Sopachuy	24
Tarabuco	5
Tarija	58
Tarvita	27
Tomina	16
Uriondo	61
Vila Vila	22
Yaco	57
Zudañez	41
Total	**1,287**

ANNEX B: PPI SCORECARD FOR BOLIVIA

INDICATOR	ANSWER	POINTS
1. How many household members are there?	A. Seven or more	0
	B. Six	7
	C. Five	11
	D. Four	16
	E. Three	17
	F. Two	26
	G. One	35
2. How many household members ages 6 to 17 currently attend school at the level and grade that they enrolled in for this calendar year?	A. Not all	0
	B. All	2
	C. No children ages 6 to 17	4
3. What is the main construction material of the floors of the residence?	A. Earth, bricks, or other	0
	B. Wooden planks, cement, hardwood floors, parquet, rugs or carpets	4
	C. Tile (mosaic, stone, or ceramic)	10
4. What is the main fuel used for cooking?	A. Firewood, dung/manure, kerosene, LPG in a cylinder, or other	0
	B. Piped-in natural gas, electricity, or does not cook	7
5. Does the household own, have, or use a refrigerator or freezer?	A. No	0
	B. Yes	5
6. Does the household own, have, or use a dining-room set (table and chairs)?	A. No	0
	B. Yes	5
7. Does the household own, have, or use a television?	A. No	0
	B. Yes	10
8. Does the household own, have, or use a VCR or DVD player?	A. No	0
	B. Yes	6
9. Does the household own, have, or use a stereo or hi-fi system?	A. No	0
	B. Yes	5
10. Are any household members employed in blue-collar or white-collar jobs?	A. No	0
	B. Yes	13

ANNEX C: CONSTRUCTION OF THE FAO FOOD INSECURITY INDEX

In order to obtain a measure of food security for the households we used the food security index developed by the FAO and based on the Latin American and Caribbean Food Security Scale (ELCSA by the Spanish acronym). This index consists of a list of 15 questions that capture the degree of households' accessibility to food capturing objective (number of meals per day, variety of food) and subjective assessments (concern for food deprivation).

These 15 questions are divided into two sections: one with 8 questions relating to food insecurity experienced by adults; and a second section (questions 9 to 15) with the same questions relating to conditions affecting specifically children under 18 years of age in the household. The first 8 questions are the following:

During the last 3 months, because of a lack of money or other resources, was there a time when:

1. You were worried you would run out of food?
2. Your household ran out of food because?
3. You or any adult in the household were unable to eat healthy and nutritious food?
4. You or any adult in the household ate only a few kinds of foods?
5. You or any adult in the household had to skip a meal?
6. You or any adult in the household ate less than you thought you should?
7. You or any adult in the household were hungry but did not eat?
8. You or any adult in the household went without eating for a whole day?

According to this index, the levels of food insecurity raise as positive responses are given. The classification of households within each category of food (in)security is performed taking into account the cutoffs shown in the following table:

Type of Household	Food (in)Security Status – Number of Positive Responses			
	Security	Mild Insecurity	Moderate Insecurity	Severe Insecurity
Households with adults only (they answer the first 8 questions only)	0	1 to 3	4 to 6	7 to 8
Households with adults and children under 18 years of age(they answer 15 questions)	0	1 to 5	6 to 10	11 to 15

In general, regardless the level of food insecurity, a household is considered food insecure if it shows mild, moderate or severe food insecurity.

The cutoff points were determined given the conceptual basis of ELCSA along with the use of statistical models applied to check for the external validity of the scale (FAO 2012).

ANNEX D: FIRST STAGE REGRESSIONS

Table D1: First Stage for Productivity and Income Specifications

	Variable (Units)	Coefficient	Robust Std. Error
Household	Household Size (# members)	0.011	0.010
	Dependency Ratio	-0.005	0.014
	Members in agricultural work (%)	0.071***	0.028
Head of Household	Age (years)	-0.003	0.005
	Age (squared)	0.000	0.000
	Female (0,1)	0.060	0.042
	Single (0,1)	-0.106***	0.035
	Indigenous or native (0,1)	-0.013	0.030
Education of the Head of Household	HH with primary incomplete (0,1)	-0.002	0.039
	HH with primary complete (0,1)	-0.032	0.045
	HH with secondary incomplete (0,1)	0.030	0.057
	HH with secondary complete (0,1)	0.033	0.071
	HH with more than secondary (0,1)	0.039	0.086
	HH without formal education (0,1)	Base	
House Characteristics	Dirt floor (0,1)	-0.004	0.028
	House with electric energy (0,1)	-0.027	0.054
	House with freezer (0,1)	-0.065	0.044
Associativity	Household belongs to an agric. cooperative (0,1)	0.155***	0.052
Economic Status	Remittances (US$ year/HH)	0.000	0.000
	Access to formal credit (0,1)	0.031	0.046
	TLU	0.000	0.002
	PPI Score	0.003*	0.002
Modern Irrigation	Proportion of land with modern irrigation	0.032	0.057
	Modern Irrigation (0,1)	0.109**	0.046
Input Expenditures / Value	Inputs - FIHF (US$/HA (logs))	0.008	0.006
	Machinery and equipment (US$/HA (logs))	0.017	0.011
	Unpaid labor (US$/HA (logs))	-0.042***	0.011
	Paid labor (US$/HA (logs))	0.004	0.005
Technical Assistance	Technical Assistance non CRIAR (0,1)	0.033	0.058
Land	Hectares worked (Has)	0.000	0.007
	Proportion of flat hectares worked	0.006	0.037
	Household with 2 plots	0.056	0.049
	Household with 3 plots	0.099**	0.049
	Household with 4 plots	0.132**	0.053
	Household with 5 plots	0.115**	0.055
	Household with more than 5 plots	0.111*	0.058
	Household with one plot	Base	
Access to Ferias	Time to paved road (logs)	-0.012	0.011
Instruments	Distance	-0.023***	0.008
	Distance Squared	0.001***	0.000
	Municipality Fixed Effects	Yes	
	Constant	1.148***	0.198
	N	**1,264**	
	F Stat: 9.57 [0.0001]		
	Kleibergen-Paap rk Wald F stat: 84.937 [0.000]		
	Hansen J Stat: 1.118 [0.2903]		

Notes: Robust standard errors are clustered at the community level
P values for the F and Hansen J statistics are in brackets

Table D2: First Stage for Food Security

	Variable (Units)	Coefficient	Robust Std. Error
Household	Household Size (# members)	0.012	0.010
	Dependency Ratio	-0.010	0.014
	Members in agricultural work (%)	0.053*	0.027
Head of Household	Age (years)	-0.005	0.006
	Age (squared)	0.000	0.000
	Woman (0,1)	0.051	0.044
	Single (0,1)	-0.110***	0.037
	Indigenous or native (0,1)	-0.021	0.032
Education of the Head of Household	HH with primary incomplete (0,1)	0.009	0.040
	HH with primary complete (0,1)	-0.015	0.045
	HH with secondary incomplete (0,1)	0.036	0.057
	HH with secondary complete (0,1)	0.048	0.072
	HH with more than secondary (0,1)	0.061	0.090
	HH without formal education (0,1)	Base	
Technical Assistance	Technical Assistance non CRIAR (0,1)	0.036	0.056
Associativity	Household belongs to an agric. cooperative (0,1)	0.161***	0.053
Economic Status	Remittances (US$ year/HH)	0.000**	0.000
	Access to formal credit (0,1)	0.060	0.045
	TLU	-0.001	0.001
	PPI Score	0.004**	0.002
House Characteristics	Dirt floor (0,1)	-0.023	0.028
	House with electric energy (0,1)	-0.020	0.055
	House with freezer (0,1)	-0.041	0.043
Access to Ferias	Time to paved road (logs)	-0.008	0.012
Land	Hectares worked (Has)	0.013**	0.007
	Household with one plot	Base	
	Household with 2 plots	0.074	0.048
	Household with 3 plots	0.104**	0.049
	Household with 4 plots	0.149***	0.052
	Household with 5 plots	0.128***	0.057
	Household with more than 5 plots	0.122**	0.059
	Proportion of flat hectares worked	0.032	0.037
Instruments	Distance	-0.023***	0.008
	Distance Squared	0.001***	0.000
	Municipality Fixed Effects	Yes	
	Constant	1.019***	0.199
	N	**1,264**	
	F Stat: 10.78 [0.0002]		
	Kleibergen-Paap rk Wald F stat: 82.291 [0.000]		
	Hansen J Stat: 0.013 [0.9082]		

Notes: Robust standard errors are clustered at the community level

P values for the F and Hansen J statistics are in brackets

ANNEX E: FULL REGRESSION RESULTS FOR EACH OUTCOME OF INTEREST

Table E1: Impact of CRIAR - Value of production US$/HA (logs)

	Variable (Units)	Coefficient	Robust Std. Error
Treatment	CRIAR Beneficiary (0,1)	0.654**	0.347
Household	Household Size (# members)	0.009	0.035
	Dependency Ratio	-0.031	0.055
	Members in agricultural work (%)	0.293***	0.109
Head of Household	Age (years)	0.016	0.018
	Age (squared)	0.000	0.000
	Woman (0,1)	-0.094	0.179
	Single (0,1)	0.009	0.146
	Indigenous or native (0,1)	0.008	0.102
Education of the Head of Household	HH with primary incomplete (0,1)	0.266**	0.130
	HH with primary complete (0,1)	0.279**	0.150
	HH with secondary incomplete (0,1)	0.465**	0.182
	HH with secondary complete (0,1)	0.276	0.221
	HH with more than secondary (0,1)	0.303	0.267
	HH without formal education (0,1)	Base	
House Characteristics	Dirt floor (0,1)	0.189**	0.094
	House with electric energy (0,1)	-0.220**	0.117
	House with freezer (0,1)	-0.092	0.172
Associativity	Household belongs to an agric. cooperative (0,1)	0.393***	0.129
Economic Status	Remittances (US$ year/HH)	0.000	0.000
	Access to formal credit (0,1)	0.219	0.156
	TLU	0.006*	0.003
	PPI Score	0.005	0.006
Modern Irrigation	Proportion of land with modern irrigation	0.057	0.161
	Modern Irrigation (0,1)	0.374***	0.128
Input Expenditures / Value	Inputs - FIHF (US$/HA (logs))	0.105***	0.031
	Machinery and equipment (US$/HA (logs))	-0.044	0.031
	Unpaid labor (US$/HA (logs))	0.252***	0.050
	Paid labor (US$/HA (logs))	0.030*	0.016
Technical Assistance	Technical Assistance non CRIAR (0,1)	0.233	0.158
Land			
	Proportion of flat hectares worked	0.223**	0.113
	Household with 2 plots	0.533***	0.202
	Household with 3 plots	0.549**	0.222
	Household with 4 plots	0.704**	0.229
	Household with 5 plots	0.884***	0.239
	Household with more than 5 plots	1.210***	0.220
	Household with one plot	Base	
Access to Ferias	Time to paved road (logs)	-0.015	0.030
	Municipality Fixed Effects	Yes	
	Constant	3.381***	0.861
	N	**1,264**	

Notes: Robust standard errors are clustered at the community level
*Significant at *** 1 percent level, ** 5 percent level, * 10 percent level*

Table E2: Impact of CRIAR - Value of production per household US$ (logs)

	Variable (Units)	Coefficient	Robust Std. Error
Treatment	CRIAR Beneficiary (0,1)	0.762*	0.429
Household	Household Size (# members)	0.010	0.036
	Dependency Ratio	-0.053	0.056
	Members in agricultural work (%)	0.367***	0.113
Head of Household	Age (years)	0.015	0.019
	Age (squared)	0.000	0.000
	Woman (0,1)	-0.164	0.163
	Single (0,1)	-0.180	0.148
	Indigenous or native (0,1)	0.022	0.106
Education of the Head of Household	HH with primary incomplete (0,1)	0.379***	0.137
	HH with primary complete (0,1)	0.433***	0.156
	HH with secondary incomplete (0,1)	0.419**	0.209
	HH with secondary complete (0,1)	0.186	0.219
	HH with more than secondary (0,1)	0.244	0.238
	HH without formal education (0,1)	Base	
House Characteristics	Dirt floor (0,1)	0.036	0.102
	House with electric energy (0,1)	-0.235*	0.122
	House with freezer (0,1)	0.042	0.171
Associativity	Household belongs to an agric. cooperative (0,1)	0.404***	0.144
Economic Status	Remittances (US$ year/HH)	0.000*	0.000
	Access to formal credit (0,1)	0.082	0.188
	TLU	0.004	0.004
	PPI Score	0.002	0.006
Modern Irrigation	Proportion of land with modern irrigation	0.041	0.118
	Modern Irrigation (0,1)	0.354***	0.128
Input Expenditures / Value	Inputs - FIHF (US$/HA (logs))	0.124***	0.032
	Machinery and equipment (US$/HA (logs))	-0.057	0.041
	Unpaid labor (US$/HA (logs))	0.278***	0.043
	Paid labor (US$/HA (logs))	0.041*	0.013
Technical Assistance	Technical Assistance non CRIAR (0,1)	0.236	0.172
Land	Hectares worked (Has)	0.287***	0.022
	Proportion of flat hectares worked	0.050	0.126
	Household with 2 plots	0.955***	0.225
	Household with 3 plots	1.052***	0.225
	Household with 4 plots	1.314***	0.225
	Household with 5 plots	1.606***	0.225
	Household with more than 5 plots	1.916***	0.224
	Household with one plot	Base	
Access to Ferias	Time to paved road (logs)	0.004	0.032
	Municipality Fixed Effects	Yes	
	Constant	4.418***	0.804
	N	**1,264**	

Notes: Robust standard errors are clustered at the community level
*Significant at *** 1 percent level, ** 5 percent level, * 10 percent level*

Table E3: Impact of CRIAR - Value of production - Valued at mean prices in the municipality US$/HA (logs)

	Variable (Units)	Coefficient	Robust Std. Error
Treatment	CRIAR Beneficiary (0,1)	0.915**	0.363
Household	Household Size (# members)	0.006	0.035
	Dependency Ratio	-0.032	0.054
	Members in agricultural work (%)	0.257**	0.113
Head of Household	Age (years)	0.008	0.018
	Age (squared)	0.000	0.000
	Woman (0,1)	-0.106	0.186
	Single (0,1)	-0.018	0.144
	Indigenous or native (0,1)	-0.017	0.104
Education of the Head of Household	HH with primary incomplete (0,1)	0.310**	0.132
	HH with primary complete (0,1)	0.330**	0.152
	HH with secondary incomplete (0,1)	0.399**	0.198
	HH with secondary complete (0,1)	0.318*	0.193
	HH with more than secondary (0,1)	0.279	0.225
	HH without formal education (0,1)	Base	
House Characteristics	Dirt floor (0,1)	0.265**	0.104
	House with electric energy (0,1)	-0.260**	0.128
	House with freezer (0,1)	-0.054	0.178
Associativity	Household belongs to an agric. cooperative (0,1)	0.299**	0.126
Economic Status	Remittances (US$ year/HH)	0.000	0.000
	Access to formal credit (0,1)	0.098	0.182
	TLU	0.006*	0.003
	PPI Score	0.005	0.006
Modern Irrigation	Proportion of land with modern irrigation	0.001	0.157
	Modern Irrigation (0,1)	0.273**	0.125
Input Expenditures / Value	Inputs - FIHF (US$/HA (logs))	0.121***	0.033
	Machinery and equipment (US$/HA (logs))	-0.044	0.032
	Unpaid labor (US$/HA (logs))	0.258***	0.052
	Paid labor (US$/HA (logs))	0.020	0.017
Technical Assistance	Technical Assistance non CRIAR (0,1)	0.152	0.166
Land	Hectares worked (Has)	-0.032	0.028
	Proportion of flat hectares worked	-0.198*	0.114
	Household with 2 plots	0.524**	0.205
	Household with 3 plots	0.536**	0.220
	Household with 4 plots	0.703***	0.227
	Household with 5 plots	0.865***	0.226
	Household with more than 5 plots	1.136***	0.219
	Household with one plot	Base	
Access to Ferias	Time to paved road (logs)	-0.032	0.032
	Municipality Fixed Effects	Yes	
	Constant	3.378***	0.871
	N	**1,264**	

Notes: Robust standard errors are clustered at the community level
*Significant at *** 1 percent level, ** 5 percent level, * 10 percent level*

Table E4: Impact of CRIAR - Home Consumption US$ (logs)

	Variable (Units)	Coefficient	Robust Std. Error
Treatment	CRIAR Beneficiary (0,1)	0.301	0.500
Household	Household Size (# members)	-0.019	0.037
	Dependency Ratio	-0.048	0.062
	Members in agricultural work (%)	-0.184	0.106
Head of Household	Age (years)	0.004	0.020
	Age (squared)	0.000	0.000
	Female (0,1)	-0.018	0.222
	Single (0,1)	-0.028	0.152
	Indigenous or native (0,1)	-0.014	0.114
Education of the Head of Household	HH with primary incomplete (0,1)	0.020	0.129
	HH with primary complete (0,1)	0.100	0.163
	HH with secondary incomplete (0,1)	-0.170	0.216
	HH with secondary complete (0,1)	-0.278	0.242
	HH with more than secondary (0,1)	-0.080	0.317
	HH without formal education (0,1)	Base	
House Characteristics	Dirt floor (0,1)	0.129	0.102
	House with electric energy (0,1)	-0.127	0.128
	House with freezer (0,1)	-0.055	0.176
Associativity	Household belongs to an agric. cooperative (0,1)	0.228	0.191
Economic Status	Remittances (US$ year/HH)	0.000	0.000
	Access to formal credit (0,1)	0.058	0.221
	TLU	0.005	0.005
	PPI Score	-0.007	0.006
Modern Irrigation	Proportion of land with modern irrigation	0.053	0.210
	Modern Irrigation (0,1)	0.337**	0.167
Input Expenditures / Value	Inputs - FIHF (US$/HA (logs))	0.098***	0.034
	Machinery and equipment (US$/HA (logs))	-0.040	0.040
	Unpaid labor (US$/HA (logs))	0.314***	0.073
	Paid labor (US$/HA (logs))	-0.016	0.020
Technical Assistance	Technical Assistance non CRIAR (0,1)	0.317	0.200
Land	Hectares worked (Has)	-0.026	0.036
	Proportion of flat hectares worked	-0.193	0.143
	Household with 2 plots	0.606***	0.216
	Household with 3 plots	0.558**	0.237
	Household with 4 plots	0.618**	0.276
	Household with 5 plots	0.823***	0.270
	Household with more than 5 plots	1.111***	0.252
	Household with one plot	Base	
Access to Ferias	Time to paved road (logs)	-0.015	0.031
	Municipality Fixed Effects	Yes	
	Constant	3.421***	0.972
	N	**1,264**	

Notes: Robust standard errors are clustered at the community level
*Significant at *** 1 percent level, ** 5 percent level*

Table E5: Impact of CRIAR - Household sells production (0,1)

	Variable (Units)	Coefficient	Robust Std. Error
Treatment	CRIAR Beneficiary (0,1)	0.172 ***	0. 094
Household	Household Size (# members)	0. 005	0. 009
	Dependency Ratio	0. 006	0.016
	Members in agricultural work (%)	-0.188	0.030
Head of Household	Age (years)	0.004	0.005
	Age (squared)	0.000	0.000
	Female (0,1)	-0.123**	0.049
	Single (0,1)	0.010	0.038
	Indigenous or native (0,1)	-0.046	0.030
Education of the Head of Household	HH with primary incomplete (0,1)	0.044	0.042
	HH with primary complete (0,1)	0.030	0.046
	HH with secondary incomplete (0,1)	0.029	0.051
	HH with secondary complete (0,1)	0.014	0.062
	HH with more than secondary (0,1)	-0.003	0.095
	HH without formal education (0,1)	Base	
Technical Assistance	Technical Assistance non CRIAR (0,1)	0.092	0.045**
Associativity	Household belongs to an agric. cooperative (0,1)	-0.002	0.045
Economic Status	Remittances (US$ year/HH)	0.000	0.000
	Access to formal credit (0,1)	0.065	0.041
	TLU	0.000	0.003
	PPI Score	0.002	0.002
House Characteristics	Dirt floor (0,1)	0.020	0.030
	House with electric energy (0,1)	0.030	0.040
	House with freezer (0,1)	0.017	0.039
Access to Ferias	Time to paved road (logs)	0.000	0.008
Land	Hectares worked (Has)	0.014**	0.006
	Household with one plot	Base	
	Household with 2 plots	0.120**	0.060
	Household with 3 plots	0.201***	0.060
	Household with 4 plots	0.204***	0.065
	Household with 5 plots	0.300***	0.063
	Household with more than 5 plots	0.363***	0.063
	Proportion of flat hectares worked	0.063*	0.034
	Municipality Fixed Effects	Yes	
	Constant	0.175	0.201
	N	**1,264**	

Notes: Robust standard errors are clustered at the community level
*Significant at *** 1 percent level, ** 5 percent level, * 10 percent level*

Table E6: Impact of CRIAR - Household sales US$ (logs)

	Variable (Units)	Coefficient	Robust Std. Error
Treatment	CRIAR Beneficiary (0,1)	1.539*	0.832
Household	Household Size (# members)	0.026	0.067
	Dependency Ratio	0.031	0.111
	Members in agricultural work (%)	1.383***	0.068
Head of Household	Age (years)	0.049	0.037
	Age (squared)	0.000	0.000
	Female (0,1)	-0.825**	0.343
	Single (0,1)	-0.068	0.273
	Indigenous or native (0,1)	-0.370*	0.207
Education of the Head of Household	HH with primary incomplete (0,1)	0.532**	0.265
	HH with primary complete (0,1)	0.654**	0.296
	HH with secondary incomplete (0,1)	0.623*	0.350
	HH with secondary complete (0,1)	0.513	0.409
	HH with more than secondary (0,1)	0.161	0.608
	HH without formal education (0,1)	Base	
Technical Assistance	Technical Assistance non CRIAR (0,1)	0.641*	0.347
Associativity	Household belongs to an agric. cooperative (0,1)	0.351	0.312
Economic Status	Remittances (US$ year/HH)	0.000	0.000
	Access to formal credit (0,1)	0.691***	0.264
	TLU	-0.006	0.016
	PPI Score	0.015	0.011
House Characteristics	Dirt floor (0,1)	0.172	0.206
	House with electric energy (0,1)	0.006	0.287
	House with freezer (0,1)	0.307	0.262
Access to Ferias	Time to paved road (logs)	0.019	0.060
Land	Hectares worked (Has)	0.000	0.043
	Household with one plot	Base	
	Household with 2 plots	1.004***	0.382
	Household with 3 plots	1.340***	0.373
	Household with 4 plots	1.461***	0.428
	Household with 5 plots	2.105***	0.408
	Household with more than 5 plots	2.078***	0.420
	Proportion of flat hectares worked	0.471**	0.235
	Municipality Fixed Effects	Yes	
	Constant	0.032	1.442
	N	**1,264**	

Notes: Robust standard errors are clustered at the community level
*Significant at *** 1 percent level, ** 5 percent level, * 10 percent level*

Table E7: Impact of CRIAR - Household income (US$-logs)

	Variable (Units)	Coefficient	Robust Std. Error
Treatment	CRIAR Beneficiary (0,1)	0.311***	0.114
Household	Household Size (# members)	-0.012*	0.006
	Dependency Ratio	0.004	0.013
	Members in agricultural work (%)	0.055***	0.016
Head of Household	Age (years)	0.011***	0.003
	Age (squared)	0.000	0.000
	Female (0,1)	-0.060**	0.027
	Single (0,1)	0.083*	0.046
	Indigenous or native (0,1)	0.040**	0.016
Education of the Head of Household	HH with primary incomplete (0,1)	0.060	0.053
	HH with primary complete (0,1)	0.106*	0.060
	HH with secondary incomplete (0,1)	0.089	0.058
	HH with secondary complete (0,1)	0.060	0.056
	HH with more than secondary (0,1)	-0.008	0.057
	HH without formal education (0,1)	Base	
House Characteristics	Dirt floor (0,1)	-0.032	0.037
	House with electric energy (0,1)	-0.035	0.024
	House with freezer (0,1)	0.070	0.044
Associativity	Household belongs to an agric. cooperative (0,1)	0.014	0.042
Economic Status	Remittances (US$ year/HH)	0.000	0.000
	Access to formal credit (0,1)	0.028	0.029
	TLU	0.000	0.000
	PPI Score	-0.002*	0.001
Modern Irrigation	Proportion of land with modern irrigation	-0.024	0.032
	Modern Irrigation (0,1)	0.015	0.030
Technical Assistance	Technical Assistance non CRIAR (0,1)	0.043	0.033
Land	Hectares worked (Has)	0.050***	0.006
	Proportion of flat hectares worked	0.003	0.016
	Household with 2 plots	0.023	0.026
	Household with 3 plots	-0.009	0.027
	Household with 4 plots	-0.043	0.059
	Household with 5 plots	0.039	0.035
	Household with more than 5 plots	0.102***	0.038
	Household with one plot	Base	
Access to Ferias	Time to paved road (logs)	-0.001	0.006
	Municipality Fixed Effects	Yes	
	Constant	9.617***	.148
	N	**1,264**	

Notes: Robust standard errors are clustered at the community level
*Significant at *** 1 percent level, ** 5 percent level, * 10 percent level*

Table E8: Impact of CRIAR - Household income per capita (US$-logs)

	Variable (Units)	Coefficient	Robust Std. Error
Treatment	CRIAR Beneficiary (0,1)	0.179**	0.086
Household	Household Size (# members)	-0.025***	0.005
	Dependency Ratio	0.010	0.007
	Members in agricultural work (%)	0.023	0.015
Head of Household	Age (years)	0.003	0.003
	Age (squared)	0.000	0.000
	Female (0,1)	-0.064	0.039
	Single (0,1)	0.063	0.050
	Indigenous or native (0,1)	0.032	0.022
Education of the Head of Household	HH with primary incomplete (0,1)	0.002	0.023
	HH with primary complete (0,1)	0.041**	0.017
	HH with secondary incomplete (0,1)	0.034	0.022
	HH with secondary complete (0,1)	0.014	0.023
	HH with more than secondary (0,1)	0.003	0.054
	HH without formal education (0,1)	Base	
House Characteristics	Dirt floor (0,1)	-0.014	0.015
	House with electric energy (0,1)	-0.032	0.026
	House with freezer (0,1)	0.022	0.028
Associativity	Household belongs to an agric. cooperative (0,1)	-0.066	0.102
Economic Status	Remittances (US$ year/HH)	0.000	0.000
	Access to formal credit (0,1)	0.048	0.036
	TLU	0.000	0.000
	PPI Score	-0.001	0.001
Modern Irrigation	Proportion of land with modern irrigation	-0.070	0.053
	Modern Irrigation (0,1)	0.030	0.026
Technical Assistance	Technical Assistance non CRIAR (0,1)	0.071	0.069
Land	Hectares worked (Has)	0.038***	0.004
	Proportion of flat hectares worked	-0.019	0.025
	Household with 2 plots	-0.085	0.105
	Household with 3 plots	-0.051	0.074
	Household with 4 plots	-0.053	0.079
	Household with 5 plots	-0.018	0.077
	Household with more than 5 plots	0.036	0.082
	Household with one plot	Base	
Access to Ferias	Time to paved road (logs)	0.002	0.004
	Municipality Fixed Effects	Yes	
	Constant	9.089***	0.133
	N	**1,264**	

Notes: Robust standard errors are clustered at the community level
*Significant at *** 1 percent level, ** 5 percent level*

Table E9: Impact of CRIAR - FAO Food Security Index (1=Food Security, 0=Food Insecurity)[31]

	Variable (Units)	Coefficient	Robust Std. Error
Treatment	CRIAR Beneficiary (0,1)	0.316***	0.104
Household	Household Size (# members)	-0.013	0.012
	Dependency Ratio	-0.040**	0.016
	Members in agricultural work (%)	-0.021	0.031
Head of Household	Age (years)	0.000	0.006
	Age (squared)	0.000	0.000
	Female (0,1)	-0.066	0.052
	Single (0,1)	0.028	0.048
	Indigenous or native (0,1)	0.127***	0.036
Education of the Head of Household	HH with primary incomplete (0,1)	-0.003	0.041
	HH with primary complete (0,1)	0.007	0.044
	HH with secondary incomplete (0,1)	-0.037	0.056
	HH with secondary complete (0,1)	0.015	0.074
	HH with more than secondary (0,1)	0.180	0.118
	HH without formal education (0,1)	Base	
Technical Assistance	Technical Assistance non CRIAR (0,1)	-0.039	0.050
Associativity	Household belongs to an agric. cooperative (0,1)	-0.064	0.053
Economic Status	Remittances (US$ year/HH)	0.000	0.000
	Access to formal credit (0,1)	-0.160***	0.051
	TLU	0.000	0.001
	PPI Score	-0.001	0.001
House Characteristics	Dirt floor (0,1)	0.018	0.035
	House with electric energy (0,1)	0.054	0.038
	House with freezer (0,1)	0.150***	0.054
Access to Ferias	Time to paved road (logs)	-0.006	0.010
Land	Hectares worked (Has)	.024***	0.007
	Household with one plot	Base	
	Household with 2 plots	0.095*	0.052
	Household with 3 plots	0.024	0.056
	Household with 4 plots	0.035	0.059
	Household with 5 plots	0.005	0.066
	Household with more than 5 plots	0.052	0.063
	Proportion of flat hectares worked	0.151***	0.041
	Municipality Fixed Effects	Yes	
	Constant	-0.074	0.201
	N	**1,264**	

Notes: Robust standard errors are clustered at the community level
*Significant at *** 1 percent level, ** 5 percent level, * 10 percent level*

[31] Full regression results for each of the 15 questions of the FAO index are available upon request.

Table E10: Impact of CRIAR - FAO Food Security Index (1=Food Security, 0=Food Insecurity) – Bivariate Probit

	Variable (Units)	Coefficient	Robust Std. Error
Treatment	CRIAR Beneficiary (0,1)	0.194**	0.307
Household	Household Size (# members)	-0.007	0.035
	Dependency Ratio	-0.126**	0.051
	Members in agricultural work (%)	-0.060	0.099
Head of Household	Age (years)	0.007	0.019
	Age (squared)	0.000	0.000
	Female (0,1)	-0.138	0.149
	Single (0,1)	-0.008	0.137
	Indigenous or native (0,1)	0.382***	0.118
Education of the Head of Household	HH with primary incomplete (0,1)	-0.006	0.122
	HH with primary complete (0,1)	0.022	0.129
	HH with secondary incomplete (0,1)	-0.113	0.168
	HH with secondary complete (0,1)	0.103	0.223
	HH with more than secondary (0,1)	0.525	0.338
	HH without formal education (0,1)	Base	
Technical Assistance	Technical Assistance non CRIAR (0,1)	-0.114	0.152
Associativity	Household belongs to an agric. cooperative (0,1)	-0.124	0.158
Economic Status	Remittances (US$ year/HH)	0.000	0.000
	Access to formal credit (0,1)	-0.409**	0.162
	TLU	-0.003	0.005
	PPI Score	0.007	0.005
House Characteristics	Dirt floor (0,1)	0.018	0.035
	House with electric energy (0,1)	0.054	0.038
	House with freezer (0,1)	0.150***	0.054
Land	Hectares worked (Has)	0.070***	0.021
	Household with one plot	Base	
	Household with 2 plots	0.310*	0.160
	Household with 3 plots	0.140	0.180
	Household with 4 plots	0.184	0.194
	Household with 5 plots	0.057	0.208
	Household with more than 5 plots	0.210	0.200
	Proportion of flat hectares worked	0.473***	0.118
Access to Ferias	Time to paved road (logs)	-0.033	0.030
	Municipality Fixed Effects	Yes	
	Constant	-1.665***	0.574
	N	**1,264**	

Notes: Robust standard errors are clustered at the community level
*Significant at *** 1 percent level, ** 5 percent level, * 10 percent level*

Table E11: Placebo test 1: TLU Index for cows

	Variable (Units)	Coefficient	Robust Std. Error
Treatment	CRIAR Beneficiary (0,1)	-0.193	0.138
Household	Household Size (# members)	0.060***	0.017
	Dependency Ratio	-0.038	0.028
	Members in agricultural work (%)	-0.025	0.044
Head of Household	Age (years)	-0.009	0.007
	Age (squared)	0.000	0.000
	Female (0,1)	-0.057	0.082
	Single (0,1)	0.008	0.078
	Indigenous or native (0,1)	0.005	0.056
Education of the Head of Household	HH with primary incomplete (0,1)	-0.031	0.053
	HH with primary complete (0,1)	0.084	0.066
	HH with secondary incomplete (0,1)	-0.002	0.088
	HH with secondary complete (0,1)	-0.007	0.111
	HH with more than secondary (0,1)	0.060	0.127
	HH without formal education (0,1)	Base	
Technical Assistance	Technical Assistance non CRIAR (0,1)	-0.031	0.090
Associativity	Household belongs to an agric. cooperative (0,1)	-0.034	0.075
Economic Status	Remittances (US$ year/HH)	0.000	0.000
	Access to formal credit (0,1)	0.046	0.058
	TLU	0.019*	0.011
	PPI Score	0.006**	0.003
House Characteristics	Dirt floor (0,1)	0.040	0.055
	House with electric energy (0,1)	0.046	0.051
	House with freezer (0,1)	-0.110	0.073
Access to Ferias	Time to paved road (logs)	0.011	0.015
Land	Hectares worked (Has)	0.028**	0.012
	Household with one plot	Base	
	Household with 2 plots	0.200*	0.062
	Household with 3 plots	0.147**	0.063
	Household with 4 plots	0.205**	0.080
	Household with 5 plots	0.204**	0.080
	Household with more than 5 plots	0.524***	0.105
	Proportion of flat hectares worked	-0.008	0.047
	Municipality Fixed Effects	Yes	
	Constant	-0.162	0.280
	N	**1,264**	

Notes: Robust standard errors are clustered at the community level
*Significant at *** 1 percent level, ** 5 percent level, * 10 percent level*

Table E12: Placebo test 2: TLU Index for bulls

	Variable (Units)	Coefficient	Robust Std. Error
Treatment	CRIAR Beneficiary (0,1)	1.140	0.809
Household	Household Size (# members)	-0.069	0.078
	Dependency Ratio	0.028	0.091
	Members in agricultural work (%)	-0.073	0.124
Head of Household	Age (years)	0.003	0.030
	Age (squared)	0.000	0.000
	Female (0,1)	-0.502**	0.210
	Single (0,1)	0.238	0.234
	Indigenous or native (0,1)	0.033	0.251
Education of the Head of Household	HH with primary incomplete (0,1)	0.103	0.171
	HH with primary complete (0,1)	0.104	0.227
	HH with secondary incomplete (0,1)	-0.114	0.254
	HH with secondary complete (0,1)	-0.647**	0.306
	HH with more than secondary (0,1)	0.009	0.417
	HH without formal education (0,1)	Base	
Technical Assistance	Technical Assistance non CRIAR (0,1)	-0.060	0.410
Associativity	Household belongs to an agric. cooperative (0,1)	0.046	0.329
Economic Status	Remittances (US$ year/HH)	0.000	0.000
	Access to formal credit (0,1)	-0.225	0.236
	TLU	0.105*	0.062
	PPI Score	-0.014	0.012
House Characteristics	Dirt floor (0,1)	-0.420**	0.192
	House with electric energy (0,1)	-0.143	0.197
	House with freezer (0,1)	0.031	0.321
Access to Ferias	Time to paved road (logs)	0.019	0.053
Land	Hectares worked (Has)	0.030	0.051
	Household with one plot	Base	
	Household with 2 plots	0.487	0.333
	Household with 3 plots	0.295	0.209
	Household with 4 plots	0.377	0.266
	Household with 5 plots	0.793***	0.297
	Household with more than 5 plots	0.906**	0.355
	Proportion of flat hectares worked	-0.244	0.156
	Municipality Fixed Effects	Yes	
	Constant	-0.395	0.701
	N	**1,264**	

Notes: Robust standard errors are clustered at the community level
*Significant at *** 1 percent level, ** 5 percent level, * 10 percent level*

Table E13: Placebo test 3: Head of the household education (years)

	Variable (Units)	Coefficient	Robust Std. Error
Treatment	CRIAR Beneficiary (0,1)	-0.882	0.834
Household	Household Size (# members)	0.167*	0.087
	Dependency Ratio	0.017	0.122
	Members in agricultural work (%)	0.096***	0.002
Head of Household	Age (years)	-0.122***	0.037
	Age (squared)	0.000	0.000
	Female (0,1)	-1.534***	0.295
	Single (0,1)	-0.564*	0.294
	Indigenous or native (0,1)	-0.036	0.223
Technical Assistance	Technical Assistance non CRIAR (0,1)	0.697*	0.419
Associativity	Household belongs to an agric. cooperative (0,1)	0.480	0.468
Economic Status	Remittances (US$ year/HH)	0.000	0.000
	Access to formal credit (0,1)	-0.131	0.370
	TLU	0.029*	0.017
	PPI Score	0.065***	0.016
House Characteristics	Dirt floor (0,1)	0.122	0.244
	House with electric energy (0,1)	0.336	0.270
	House with freezer (0,1)	0.308	0.346
Access to Ferias	Time to paved road (logs)	-0.100	0.068
Land	Hectares worked (Has)	-0.053	0.049
	Household with one plot	Base	
	Household with 2 plots	-0.668**	0.304
	Household with 3 plots	-0.230	0.347
	Household with 4 plots	-0.768**	0.366
	Household with 5 plots	-0.596*	0.351
	Household with more than 5 plots	-0.434	0.385
	Proportion of flat hectares worked	0.007	0.219
	Municipality Fixed Effects	Yes	
	Constant	8.201***	1.596
	N	**1,264**	

Notes: Robust standard errors are clustered at the community level
*Significant at *** 1 percent level, ** 5 percent level, * 10 percent level*

Table E14: Placebo test 4: Share of flat land

	Variable (Units)	Coefficient	Robust Std. Error
Treatment	CRIAR Beneficiary (0,1)	0.000	0.104
Household	Household Size (# members)	-0.012	0.009
	Dependency Ratio	0.008	0.013
	Members in agricultural work (%)	-0.039	0.026
Head of Household	Age (years)	-0.010*	0.005
	Age (squared)	0.000	0.000
	Female (0,1)	0.017	0.046
	Single (0,1)	0.007	0.039
	Indigenous or native (0,1)	-0.136	0.034
Education of the Head of Household	HH with primary incomplete (0,1)	0.041	0.035
	HH with primary complete (0,1)	0.068*	0.038
	HH with secondary incomplete (0,1)	-0.021	0.043
	HH with secondary complete (0,1)	0.015	0.046
	HH with more than secondary (0,1)	0.122	0.075
	HH without formal education (0,1)	Base	
Technical Assistance	Technical Assistance non CRIAR (0,1)	-0.021	0.060
Associativity	Household belongs to an agric. cooperative (0,1)	0.030	0.042
Economic Status	Remittances (US$ year/HH)	0.000	0.000
	Access to formal credit (0,1)	-0.019	0.054
	TLU	0.001	0.001
	PPI Score	-0.002	0.001
House Characteristics	Dirt floor (0,1)	-0.042	0.026
	House with electric energy (0,1)	0.078**	0.033
	House with freezer (0,1)	0.108**	0.045
Access to Ferias	Time to paved road (logs)	0.002	0.007
Land	Hectares worked (Has)	-0.003	0.005
	Household with one plot	Base	
	Household with 2 plots	-0.021	0.056
	Household with 3 plots	0.008	0.051
	Household with 4 plots	-0.025	0.051
	Household with 5 plots	-0.006	0.059
	Household with more than 5 plots	-0.049	0.053
	Municipality Fixed Effects	Yes	
	Constant	0.599***	0.182
	N	**1,264**	

Notes: Robust standard errors are clustered at the community level
*Significant at *** 1 percent level, ** 5 percent level, * 10 percent level*