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Sowing for food security: A case study of smallholder farmers in Bolivia

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ABSTRACT

This paper explores the role that agriculture can play in the food security agenda. To meet this objective, this study measures the impact of the "Programa de Apoyos Directos para la Creación de Iniciativas Agroalimentarias Rurales" (CRIAR), an agricultural technology adoption program implemented in highly food insecure areas of rural Bolivia. The paper analyzes whether changes in food security are due to improved food availability (production and local sales) and/or greater food access (income and production used for home consumption). To this end, data from a sample of 1287 households-817 beneficiaries and 470 controls – interviewed specifically for this purpose are used. To address self-selection issues, the program's impact is estimated using an instrumental variable model. The results present evidence that program participation improved food security. Specifically, positive impacts on agricultural productivity, agricultural sales and household income are found. These findings confirm the importance of considering agricultural programs as policy tools to address food insecurity.

1. Introduction

Food security exists when all people, at all times, have physical and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life (FAO, 2002). Food security has three key dimensions: (i) food availability, (ii) food access, and (iii) food use (World Bank, 2008; FAO, 2006).[1] *Food availability* refers to the supply of food at the national or regional level which ultimately determines the price of food. Enhanced food availability can be obtained through greater domestic production or through imports. Despite significant advances in global agricultural production and productivity, and even with improvements in caloric intake per capita across the globe (Wik et al., 2008; Fuglie and Nin-Pratt, 2012), hunger, malnutrition, and poor health remain widespread (IFPRI, 2012; WHO, 2014). Improved availability of food is necessary to reduce food insecurity and hunger but is insufficient to completely end malnutrition, particularly because access to other services such as potable water, sanitation and health services is also required.

Food access refers to the ability to obtain food and it requires households to have adequate resources. This can be achieved through increases in income that allow food to be purchased, through direct food production or through other sources such as transfers, or in-kind payments for labor. Even if food is available at the national, regional and local level, it does not mean that all households have the ability to access it since they may be constrained in their capacity to command food through income, own production, wage earnings, transfers or other means. Given that a large portion of the poor worldwide are farmers, there remains considerable attention to promoting agriculture as a means to

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[1] A fourth consideration often included is food stability, which incorporates the idea of having food access at all times.

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enhance food access (Levitt et al., 2011; FAO, 2012b; IFPRI, 2012; Herforth et al., 2012; Fan and Pandya-Lorch, 2012). The emphasis on an agricultural pathway to increase food access is twofold, since increased agricultural production provides income to purchase food as well as direct access to food for consumption obtained from own production.

Lastly, *food use* refers to the level of nutrition obtained through food consumption. Specifically, nourishments must be of high quality, safe and diverse in order to provide an adequate diet in terms of energy and nutrients. Carletto et al. (2015) analyze pathways to improved nutritional status by systematically measuring the impact of eight agricultural interventions implemented in Asia and Africa. The general conclusions from this analysis provide evidence of association between increased agricultural production and positive nutrition outcomes. However, causality is not always established.

Given the limitations of agricultural growth to address food security on its own, the most effective strategy appears to be a multi-sector approach (FAO, 2014; IFPRI, 2014; IDB, 2015; Timmer, 2015) that combines the promotion of broad-based, agricultural growth and rural development with programs that directly target the food insecure (Devereux and Guenther, 2009; de Janvry and Sadoulet, 2009; IFPRI, 2014; Timmer, 2015), as well as programs focused on nutrition with a gender approach (IFPRI, 2014; Talukder et al., 2010). Generally, agriculture plays a significant role in improving food systems and nutrition (FAO, 2013; Carletto et al., 2015) but its scope can be broaden to reach full potential (Ruel and Alderman, 2013).

Despite hundreds of agricultural programs and policies implemented to address food insecurity, and the high expectations on the potential of agriculture, there is limited rigorous empirical evidence on the best way to achieve this (Berti et al., 2004; Girard et al., 2012; Masset et al., 2012; Ruel and Alderman, 2013; Webb, 2013). Meta-reviews of the literature on agriculture and its link to food security come to similar conclusions (Webb, 2013).

Much of the problem then seems to be a general lack of rigorous evaluations of agricultural programs. In 2011, the World Bank (2011) identified only 86 articles that can be defined as proper impact evaluations of agricultural interventions; that is, those which attempt to establish causality through a clearly defined counterfactual. A recent review of impact evaluations over the last decade shows that while the number of impact evaluations of agricultural and rural development programs s have grown in recent years, less than 10% of overall evaluations are linked to agriculture and rural development—compared to 65% for health, 23% for education and 15% for social protection (Cameron et al., 2015). Further, the tendency is for evaluations of agricultural programs to consider broader agricultural indicators of impact (value of production, yields) and in some cases final outcomes resulting from food use such as child anthropometrics. Few papers, however, explore food accessibility and availability as pathways to link agriculture to improved food security. In sum, agricultural programs have been primarily assessed on their productive impact without much emphasis on their link with food security.

This paper aims to provide evidence on the link between agricultural interventions and food security as well as on the mechanisms through which this relationship takes place. To date, most of the literature addresses the impact of agricultural interventions on income and productivity, assuming that such findings are translated into food security improvements. This paper addresses this research gap using specific measures to identify such an impact as well as to establish the channels through which food security is improved. For this purpose, we analyze the effects of an agricultural technology adoption program "*Programa de Apoyos Directos para la Creación de Iniciativas Agroalimentarias Rurales*" (CRIAR), implemented in highly food insecure areas of rural Bolivia.

The remainder of this paper is structured as follows. Section 2 provides the conceptual framework to identify the pathways by which we should expect agricultural interventions to improve food security. Section 3 describes the CRIAR program. Sections 4 and 5 present the counterfactual identification and the econometric methodology, respectively. Section 6 provides descriptive statistics of the data. Section 7 presents the main results, and Section 8 concludes.

2. Agriculture as a pathway to food security

Policies designed to improve food security generally target one of the three aforementioned dimensions of food security: (i) food availability, (ii) food access, or (iii) food use. Since food availability refers to the aggregate food supply, agricultural policies that enhance productivity and increase production are often used to expand the supply and ensure relatively low food prices. While increasing domestic production and lowering prices can enhance food availability, such actions do not ensure access since they do not guarantee that individuals have the means to command food. Therefore, improving food access requires policies that enhance the capacity of households to obtain food through income, production, wage earnings, transfers or other means. Further, having food access does not always ensure the proper utilization of food since this requires that food provides not only an acceptable amount of calories, but also sufficient nutrition. Policies can also focus on improving food use through interventions designed to ensure adequate nutrition such as trainings or access to public services.

This paper focuses on assessing the dimensions of food availability and access by evaluating an agricultural program that was designed with the objective of increasing food supply through greater production and productivity as well as to improve the ability of households to acquire food through higher income.

While the literature suggests a positive link between agricultural production and food security (Maxwell, 1998), productive agricultural programs are not widely assessed as policy tools to enhance food security and even less so to understand the pathways through which food security can be improved. The majority of agricultural programs seek to enhance productivity, increase output, reduce output loss, and/or improve quality of output. These objectives are aligned with increasing food production which is one of the pathways for enhancing food availability, particularly when targeting smallholder producers (FAO, 2006). However, although many agricultural interventions have been evaluated from a productive perspective, the link with improved food security through *food availability* is often ignored.

In the case of policies that enhance *food access* for the food insecure, these can be direct or indirect. Three types of policy instruments that improve direct access to food are: (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 payments in the form of food in exchange for public work. Income transfer programs provide cash transfers to poor households often based upon fulfillment of certain conditions, with the goal to increase households' food consumption and nutritional status. Overall, the literature on the impact of these programs in improving food security is inconclusive. [2] In the case of direct feeding and food-for-work programs this is partly due to lim-

[2] For evaluations of direct feeding programs see Stifel and Alderman (2006), Ahmed and del Ninno (2002), Kazianga et al. (2014). For food for work programs see Gilligan and Hoddinott, 2007 (2007). The literature on cash transfers is more substantial and some examples include Behrman and Hoddinott (2005), Attanasio and Vera-Hernández (2004), Duflo (2000), and Miller et al. (2011).

ited rigorous impact evaluations. In the case of cash transfers, robust and rigorous empirical evidence is more widespread although results on the impact of transfer programs on food security are still somewhat mixed.

Food access can be promoted indirectly by interventions that allow households to produce for their own consumption or earn income through the use of their labor. While there are multiple means to promote self-employment and wage employment earnings, agricultural production represents a key option as a large percent of the food insecure remain in rural areas. However, the role of productive agricultural programs in food security through higher food access is less frequently analyzed.

Technology adoption programs that target smallholder producers are interventions that aim primarily at improving agricultural production through productivity increases. Hence, these are productive programs that must be assessed from a productive perspective. However, there are two channels by which these interventions may also reduce households' vulnerability to food insecurity. First, greater production or improved output quality can lead to higher home-consumption[3] or income, therefore improving *food access*. Second, higher levels of productivity lead to higher yields that will be sold in local markets, increasing food supply and therefore, improving *food availability*.

The Bolivian CRIAR program seeks to enhance food security through higher food access and availability by promoting technologies to improve agricultural output and income. This paper assesses whether this approach has been successful.

3. The CRIAR program

The agricultural sector plays a fundamental role in the Bolivian economy representing 13% of the Gross Domestic Product (GDP). Yet, from 2006 to 2011, Bolivia was the only country in Latin America that presented a negative growth in total factor productivity (IFPRI, 2013). The low levels of agricultural productivity increase vulnerability to food insecurity by limiting the supply of food (*availability*). Bolivia also has one of the lowest levels of per capita income in Latin America with 45% of the total population below the poverty line and with 61% in rural areas (National Institute of Statistic – INE – 2011). Low income levels increase vulnerability to food insecurity by limiting the capacity to acquire food (*accessibility*). Further, 89% of the municipalities in Bolivia are classified as having high or medium levels of vulnerability to food insecurity (Ministry of Rural Development and Land, 2014). Also, the country has the second highest rate of malnutrition in South America at 21% (IFPRI, 2013). Given this background of low productivity and high food insecurity, Bolivia represents an ideal case in which to explore the role that agriculture can play in the food security agenda.

To this end, we evaluate the CRIAR program, which targeted smallholder rural producers with the objective of improving food security and income through productivity increases that result from technological adoption. Along with identifying the impact of an agricultural program in enhancing food security, the causal link through which the program enhances food security is assessed. Fig. 1 presents the theory of change by which CRIAR is expected to have an impact on food security.

The CRIAR program began implementation in 2011 by the Ministry of Rural Development and Land (MDRyT), in five departments in Bolivia – La Paz, Cochabamba, Chuquisaca, Tarija and Potosí – including 33 municipalities and 1355 communities. The program followed a twin-track approach by financing an agricultural technology as well as technical assistance. Specifically, CRIAR offered non-reimbursable vouchers that covered 90% of the total cost of an agricultural technology chosen by the producer. It also covered personalized technical assistance on the use of the selected technology in the field. The maximum price of the technologies offered was US$1000 and these included: irrigation systems, fruit dehydrators, mills, pulp machines, silos, weed cutters, destemmers, electric fences, greenhouses and livestock technologies. The most highly demanded technologies were irrigation systems (62%), and post-harvest technologies (12%). The program benefited 20,269 producers.

CRIAR targeted rural communities. As a first step, the program's executing unit contacted community leaders to assess interest in participation. Once communities expressed their interest, a list of potential beneficiaries was constructed (community roster). During this process, farmers were informed of the participation requirements including the amount of the co-payment necessary to cover the remaining cost of the technology[4]. Next, the executing unit implemented technology *ferias* (fairs) in selected municipalities. The *ferias* were the actual place for market exchange where producers met technology providers, gathered information and purchased their selected technologies. During the *ferias*, the executing unit verified the eligibility of producers and delivered the vouchers. Producers used their vouchers to sign a contract of purchase with the selected provider for their chosen technology. Overall, 33 *ferias* were organized, one per targeted municipality. The *ferias* were held in a central location of a municipality to facilitate access to potential participating communities and lasted three days on average. At the producer level, the program used the following eligibility criteria: (i) to present a valid identification card; (ii) to belong to the community roster; (iii) to have agriculture as their principal economic activity; and (iv) to be a smallholder producer with less than 35 ha of land[5].

Once producers received their technology, the executing unit provided personalized technical assistance in the field for its use, operation and maintenance. Finally, in-situ verification was done to guarantee proper installation of technologies and technical training.

Given its design, CRIAR aimed at addressing market failures that limit technology adoption by smallholder producers without creating market distortions. The provision of a voucher that partially covers the cost of the technology aims to ease liquidity constraints. The provision of technical assistance aims to address low educational levels and reduce risk aversion that limit the effective use of the technologies. Lastly, the implementation of technology *ferias* aimed to reduce information asymmetries and reduce shortage of supply by providing a physical space where market exchange took place.

The key hypothesis to be tested is whether program participation led to increased food security. Further, we aim to understand the mechanisms by which food security is improved. First, food access is assessed by analyzing the program's impact on household income and production used for home consumption. Second, food availability is assessed by analyzing the program's impact on production and sales. This analysis is a short-term assessment of the program's impact that corresponds to one agricultural cycle (the amount of time that farmers have implemented the technology).

[3] Home consumption refers to agricultural production used for household consumption.

[4] Farmers used different sources to cover the remaining 10% of the cost of the technology including informal and formal loans, private savings and remittances.

[5] The Ministry of Rural Development and Land of Bolivia defines a smallholder as any farmer who works 35 ha of land or less. However, the average land size worked by the CRIAR beneficiaries is 2.11 ha with a maximum of 15.75 ha.

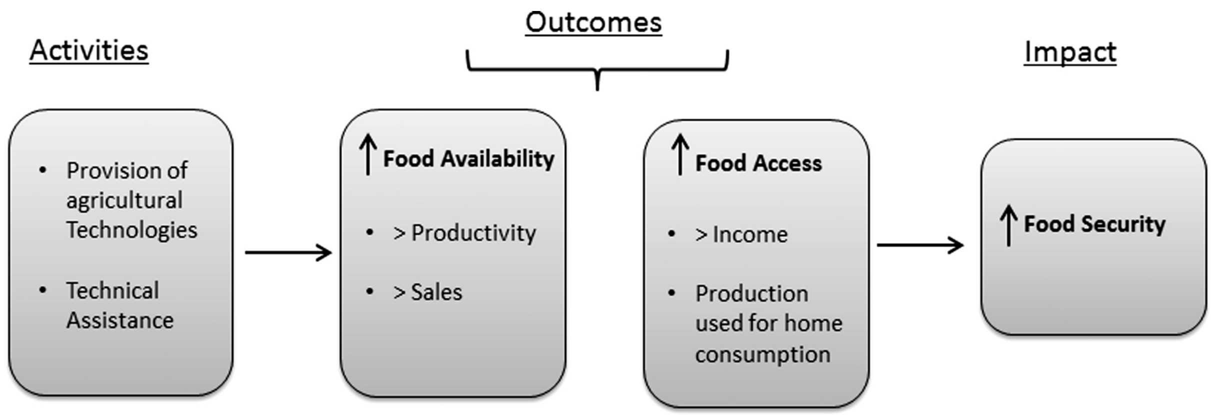

Fig. 1. CRIAR-theory of change.

4. Identification strategy

As with every impact evaluation, the principal problem in identifying a causal effect of a program is the lack of information. It is impossible to observe the outcome indicator at a given moment in time for beneficiaries with and without treatment because, by definition, all beneficiaries received the program. Given this, the true counterfactual is unobservable. Hence, the principal challenge consists in identifying a control group composed of non-beneficiary households comparable to treated households. If properly identified, a counterfactual allows an unbiased estimate of the average impact of the program.

The ideal approach to create a counterfactual consists of randomly assigning eligible households to treatment and control groups. However, this was not feasible for CRIAR. The identification strategy for this evaluation includes: replicating the selection process into CRIAR at the community and household levels; a careful data collection strategy in the field and a rigorous econometric methodology. This multi-step approach as well as robustness tests, support the identification of an unbiased estimate of impact.

To replicate the community-level selection process, we identified potential control communities that fulfilled all the initial eligibility conditions: (i) vulnerability to food insecurity measured with the "Vulnerability Assessment Map" (VAM); (ii) productive agricultural capacity; and (iii) territorial continuity to simplify program execution. Next, using administrative data and the local knowledge of the program's executing unit, we identified control communities that did not reject participation into the program and were located within a 5 km radius from beneficiary communities. This proximity criterion resembled the decision-making of the executing unit when selecting 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 similar access to markets and infrastructure.

To determine comparability at the household level, we performed a careful analysis of the administrative data collected during the technology *ferias*. The administrative data contains information regarding land extension, cultivated crops and other general characteristics of treated households. The analysis of these variables allowed identification of a prototype of beneficiary households that was used to construct a short list of questions to ensure comparability of the control group. The administration of these few questions was part of the data collection process and allowed for a pre-screening of the control households to determine at first glance, their comparability to treatment households.

If the pre-screening yielded a control household with comparable characteristics to beneficiary households, the interviewer proceeded with the implementation 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 as well as the pre-screening at the household level. The questionnaire includes all the 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 participation. For instance, variables that capture participation in agricultural associations were included because the program targeted these organizations as part of the dissemination strategy. The data collection strategy was then one in which great efforts were made to identify a reasonable counterfactual.

Building on this data collection strategy, an instrumental variable (IV) approach is used to control for unobservable characteristics of beneficiary farmers that might have affected both program participation and the outcomes of interest (primarily as a result of self-selection bias). This methodology allows measurement of the causal effects of program participation.

Summarizing, the overall identification strategy is threefold: (i) identifying non-beneficiary communities comparable to *beneficiary communities* by replicating the original process of selection; (ii) identifying control *households* that fulfilled all the eligibility criteria, were located in comparable communities and exhibit similar characteristics as the prototype of treated households; and (iii) implementing a rigorous econometric methodology to control for possible program self-selection bias.

5. Data and descriptive statistics

To corroborate the validity of the identification strategy, this section presents a preliminary assessment of comparability between treated and control groups by discussing differences/similarities in observable characteristics at the household and community levels. The data used for this study was collected between November 2013 and January 2014[6]. The agricultural household survey was administered to 1287 households in 176 communities, located in 35municipalities[7]. The final sample includes 817 beneficiary and 470 control households that fulfilled the program's eligibility criteria.

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

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

The questionnaire included 11 modules capturing information on socio-demographic indicators, education, income, agricultural land, agricultural production, access to associations, housing conditions, poverty and food security. The information collected covers the complete agricultural cycle from July 2012 to June 2013. In addition, community-level questionnaires were applied in 170 communities, with information on population, basic community services, infrastructure and communication, and accessibility to markets, among others.

Table 1 presents descriptive statistics for treatment and control households regarding socio-economic status, household demographics, access to social capital and distance to important places. Households have an average of 4 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, 14% have incomplete secondary and only 9% have completed secondary education. Regarding access to social capital, this differs between treated and control households: treated households have a higher percentage of producers who belong to a cooperative or an agricultural association (11%) compared to control households (4%).

With respect to households' economic characteristics, 70% of households have agriculture as the main source of income which represents about 56% of total household income. Household income also comprises off-farm income (34%), livestock production (8%) and transformed products (2%).

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 (7% of their annual income). Last, the *Progress out of Poverty Index* (*PPI*) shows that the probability that a household has an income below the poverty line is 83% (PPI, Bolivia). None of the economic characteristics differ significantly between treated and control groups.

The average amount of land owned is 2.35 ha, while the average amount of land worked is 2.11 ha. No variables related to land show significant differences between treatment and control groups. Finally, information that captures distance to the *feria* was obtained using GPS to measure the Euclidean distance (vector distance) from the household dwelling to the *ferias* location. The average distance is about 14 km and treated households are, on average, 3.2 km closer to the technology *ferias* than control households. As expected, this difference is statistically significant. Also, traveling distance to a paved road is about 25 min (walking equivalence).

The results of Table 1 confirm that the counterfactual identification strategy at the household level was largely successful. Any possible differences between treated and control groups are addressed by including key variables in the econometric estimations.

Table 2 presents variables related to agricultural production including measures of productivity and food security. Given the nature of the program and the timing of the data collection (about one year after beneficiary households received their technology) we expect to find statistical significant differences between treated and control groups for these variables. Importantly, most of these are outcomes of interest and therefore, the econometric analysis will corroborate whether these differences are attributable to program participation.

With regards to the portfolio of crops cultivated, 28% of households reported producing traditional crops exclusively[8]. The average proportion of cultivated land allocated to traditional crops is 66%. Compared with the control group, beneficiary households have better access to modern irrigation, a larger proportion of land with non-traditional crops and a greater use of inputs and machinery. With respect to labor, treated households spend more on hired labor than control households while no significant differences are found with respect to household labor.

Households use 36% of their agricultural production for home consumption and 24% for sales[9]. Treated households assign a higher proportion to sales and a lower proportion to home consumption compared with control households. While the value of production for 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. On average, the annual value of production is US$4679 per hectare[10]. Annual income is calculated based on the net agricultural income (value of production net of input costs[11]) off-farm income, livestock production and transformed products. Households' earnings average US$5544 per year. The differences for treated and control households are statistically significant with better outcomes for treated households.

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) (FAO, 2012a), which consists of 15 questions that capture the degree of households' accessibility to food (see Appendix B)[12]. These questions were administered directly to women, irrespective of whether they were considered heads of household, to capture female's perspective and avoid bias that might arise when income is male-controlled. According to this index, 58% of households are food insecure while the difference between both groups is about 2% lower for treated households compared to the control group.

Table 3 shows descriptive statistics at the community level. The last column presents the difference in means between treated and control communities. The evidence shows that the selection process was successful as control communities are highly comparable to treated communities while no statistical significant differences are found.

Overall, by assessing similarity on observable characteristics, the descriptive statistics presented in Tables 1–3 corroborate the validity of the identification strategy discussed in Section 4. Nevertheless, possible bias from unobservable heterogeneity due to self-selection will be considered in the econometric analysis. .

6. Econometric approach

Given that unobservable heterogeneity due to self-selection might play a major role, it is not a sufficient condition to guarantee comparability solely based on observable characteristics (Section 5). This section focuses on describing the econometric approach implemented to address this potential source of bias.

There are two main issues that need to be considered when estimating the impact of CRIAR. First, participation might be endogenous as well as correlated with the outcomes of interest.

[8] Traditional crops are rice, barley, corn, quinoa, wheat, *oca*, potato and cassava.

[9] Households also allocate their production for animal feed (8%), seeds (5%), presents and barter (16%), and transformation (2%). The remaining 10% of the production correspond to losses.

[10] Annual value of production is calculated by multiplying the yields per hectare by the price of the crop.

[11] The following input costs were included: fungicides, insecticides, fertilizer, machinery and equipment. The income variable includes home consumption valued at market prices.

[12] This index consists of 15 questions that capture the degree of households' accessibility to food and was chosen as the most robust, reliable and scientifically valid at an international symposium organized by the FAO in 2012.

Table 1
Descriptive statistics – socio-economic status of households.

	Variables (units)	Total	Treated	Control	Diff. in means
Household	HH size (# members)	4.23	4.39	3.97	0.42** *[0.012]*
	Dependency ratio (%)	1.05	1.04	1.08	0.04 *[0.521]*
Head of household	Age (years)	50.39	48.97	52.86	3.89*** *[0.001]*
	Female (0, 1)	0.11	0.09	0.15	0.06** *[0.015]*
	Single (0, 1)	0.21	0.16	0.27	0.11*** *[0.001]*
	Indigenous or native (0, 1)	0.74	0.76	0.71	0.05 *[0.489]*
Education of the head of household	HH without formal education (0, 1)	0.14	0.11	0.21	0.10*** *[0.002]*
	HH with primary incomplete (0, 1)	0.41	0.43	0.42	0.01 *[0.558]*
	HH with primary complete (0, 1)	0.22	0.22	0.22	0.01 *[0.965]*
	HH with secondary incomplete (0, 1)	0.14	0.16	0.1	0.06*** *[0.009]*
	HH with secondary incomplete (0, 1)	0.07	0.09	0.04	0.05** *[0.013]*
	HH with more than secondary (0, 1)	0.02	0.03	0.01	0.01 *[0.191]*
Dwelling characteristics	Dirt floor (0, 1)	0.63	0.6	0.68	0.08 *[0.239]*
	House with electric energy (0, 1)	0.76	0.78	0.72	0.06 *[0.417]*
	House with freezer (0, 1)	0.15	0.15	0.14	0.01 *[0.776]*
Associativity	HH belongs to agric. cooperative (0, 1)	0.08	0.11	0.04	0.07*** *[0.002]*
Economic characteristics	Agriculture as main source of income (0, 1)	0.7	0.71	0.67	0.05 *[0.349]*
	Agricultural income (% of total income)	0.56	0.57	0.56	0.01 *[0.480]*
	Access to formal credit (0, 1)	0.08	0.09	0.07	0.02 *[0.418]*
	Voluntary savings (0, 1)	0.06	0.07	0.04	0.03 *[0.616]*
	Remittances (USD year/HH)	394.5	369.28	438.34	69.06 *[0.447]*
	TLU	4.89	4.8	5.06	0.26 *[0.726]*
	HH owns land (0, 1)	0.99	0.99	0.99	0.01 *[0.602]*
	PPI Score	29.32	29.6	28.84	0.76 *[0.666]*
Accessibility	Time to paved road (mins)	24.85	27.57	20.14	7.42 *[0.168]*
	Distance to CRIAR ferias (km)	13.78	12.62	15.82	3.2*** *[0.003]*
Land	Land owned by HH (Has)	2.35	2.29	2.45	0.16 *[0.515]*
	Hectares worked (Has)	2.11	2.09	2.16	0.07 *[0.817]*
	Prop. of hectares worked (Has/total Has)	0.82	0.83	0.81	0.02 *[0.520]*
	N	1287	817	470	

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

For instance, highly productive farmers, with higher income and food security, might be more inclined 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 risk aversion. Therefore, comparisons of treated and control households may not provide the causal effects of participation and estimating ordinary least squares may generate biased estimates (Angrist, 2001). While careful data collection can help overcome these concerns, there remain concerns about the potential for bias. Hence, we use an Instrumental Variable (IV) approach where the first stage estimates the participation equation and the second stage

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*** *[0.004]*
	Prop. of land with traditional crops (%)	0.66	0.62	0.74	0.13*** *[0.000]*
Irrigation	Modern irrigation (0, 1)	0.19	0.23	0.11	0.12*** *[0.002]*
	Proportion of land with modern irrigation (%)	0.10	0.13	0.05	0.07*** *[0.004]*
Input expenditures	Inputs – FIHF (US$/HA)	553	644	397	247** *[0.013]*
	Machinery and equipment (US$/HA)	18.96	20.26	16.69	3.56 *[0.350]*
	Paid labor (US$/HA)	281	318	218	100 ** *[0.042]*
	Value of household labor (US$/HA)	1433	1418	1459	41 *[0.891]*
Sales	HH sells (0, 1)	0.74	0.77	0.69	0.08** *[0.021]*
	Proportion of production sold (%)	0.24	0.25	0.21	0.05** *[0.025]*
	HH sells in the market (0, 1)	0.50	0.52	0.47	0.05** *[0.026]*
	Proportion of production sold in the market (%)	0.32	0.33	0.30	0.03** *[0.044]*
	HH sells in farm (0, 1)	0.50	0.53	0.46	0.07** *[0.040]*
	Proportion of production sold on-farm (%)	0.20	0.20	0.19	0.01 *[0.753]*
	Value of sales (US$)[a]	2232	2529	1716	812*** *[0.001]*
	Value of sales (logs)	5.05	5.30	4.61	0.69** *[0.017]*
Home consumption	Proportion home-consumption (%)	0.36	0.34	0.39	0.05** *[0.040]*
	Value of home consumption (US$)	1907	2000	1746	254 *[0.773]*
	Value of home consumption (US$) (logs)	6.464	6.443	6.501	0.057 *[0.581]*
Value of production	Value of production US$/HA	4679	4941	4223	718*** *[0.009]*
	Value of production US$/HA (logs)	7.69	7.79	7.52	0.28*** *[0.002]*
	Value of production US$	6579	7121	5638	1483** *[0.048]*
	Value of production US$ (logs)	7.73	7.79	7.62	0.17* *[0.068]*
Household income	Household income (US$)	5544	6070	4630	1441** *[0.048]*
	Household income (logs)	10.26	10.28	10.23	0.05** *[0.021]*
	Household income p/c (US$)	1627	1786	1354	432** *[0.033]*
	Household income p/c (logs)	9.28	9.29	9.27	0.02 *[0.198]*
Food insecurity	Food insecurity (FAO index)	0.58	0.57	0.59	0.02* *[0.081]*
	N	1287	817	470	

P values for the *t*-tests are in brackets. Standard errors clustered at the community level.
[a] 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.
* Difference in means is significant at the 10% level.
** Difference in means is significant at the 5% level.
*** Difference in means is significant at the 1% level.

estimates the impact of CRIAR on the outcomes of interest. To apply this methodology, it is necessary to identify one or more variables that affect participation in CRIAR (the first stage) but do not affect the outcome variables (the second stage).

The instrumental variables used in this analysis are distance from the household dwelling to the location of the CRIAR *ferias* and its quadratic term. The intuition suggests that households located further from the technology *ferias* are less likely to participate in the program because of higher transaction costs. Since the technology *ferias* were the physical place where vouchers were delivered and technologies were purchased, it was necessary for farmers to reach the *ferias*. The quadratic term of the distance vari-

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 *[0.332]*
Community with primary school (0, 1)	0.84	0.84	0.85	0.01 *[0.860]*
Community with formal financial institution (0, 1)	0.01	0.01	0.00	0.01 *[0.483]*
Community with public transportation (0, 1)	0.41	0.40	0.48	0.09 *[0.353]*
Community with paved road (0, 1)	0.12	0.13	0.09	0.04 *[0.571]*
Time between community and nearest market (min.)	132.78	129.63	145.61	15.98 *[0.636]*
Community with agricultural cooperative (0, 1)	0.15	0.17	0.06	0.11 *[0.110]*
Community with agriculture as main source of income (0, 1)	0.98	0.98	0.97	0.01 *[0.791]*
Community has access to water for irrigation (0, 1)	0.58	0.60	0.48	0.12 *[0.214]*
Community has access to water for irrigation throughout the year (0, 1)	0.46	0.46	0.45	0.01 *[0.933]*
N	167	134	33	

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

able was included to capture any non-linear relations. As mentioned in Section 5, this distance was obtained with GPS and represents the vector distance.

To apply the IV methodology, the chosen instruments must be relevant and exogenous to the outcome of interest (Stock and Watson, 2007). In the case of exogeneity, instruments cannot be tested and the assumption must be justified. This requires a clear explanation of 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 and Vera-Hernández, 2004). Following Attanasio and Vera-Hernández (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 location of producers' household.

The first problem would be troublesome if the location of *ferias* 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. The *ferias* were held in the capital of the municipality to guarantee accessibility to all communities. Therefore, the criterion to hold a *feria* in a particular location was purely administrative, without considering specific household or producer characteristics. Within the capital, the *ferias* took place in schools, indoor sports facilities or community centers without following a particular pattern.

To corroborate that communities located closer to the *ferias* are not systematically different from those communities located further away, we performed tests of difference in means between treatment and control households 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). Tests were applied within different distance bandwidths. For all the bandwidths chosen, none of the variables show a statistically significant difference in means[13]. This confirms that the location of *ferias* was not based on specific community or producer characteristics that might have been correlated with the outcomes of interest. Furthermore, measures for distance to the closest road and closest market were included to assure that the instrumental variable (distance to *ferias*) was not capturing other location characteristics that could affect the outcomes of interest.

The second problem of instrument endogeneity would occur if 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 three to five days only. During this period, producers must have reached the location, obtained their voucher, and purchased their technology. 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. Moreover, 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 implausible. Further, communities in Bolivia are bonded by strong social ties and a sense of belonging. Therefore, the cost of moving to a different community would imply high social and economic costs.

To corroborate the identification strategy, we performed 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. % of flat land, education of the head of the household and Total Livestock Units (TLU)). The estimations do not show any impact of the program on these variables. This suggests that impacts found are not driven by a correlation between the error term of the outcome equation and the instruments (Attanasio and Vera-Hernández, 2004)[14]. Finally, the impact evaluation literature provides precedence of other studies using distance in order to predict program participation mainly due to the exogeneity associated with this type of instrumental variable (Attanasio and Vera-Hernández, 2004).

In the case of a binary endogenous regressor (participation in CRIAR), a linear probability model is appropriate in the first stage of the IV as long as we are concerned about estimating causal effects rather than structural coefficients (Angrist, 2001). Note that

[13] These results are available upon request.

[14] Estimations are available upon request.

using this approach predicts the effect of treatment on the treated for those whose treatment (participation in CRIAR) is influenced by the instrument; which is known as the 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*.

To summarize, the first stage is estimated as follows:

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

where

HH_i is a vector of head of the household and household demographic characteristics including gender, age, age square, indigenous origin, marital status and education of the head of 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 to the production process such as inputs, share of flat land, share of irrigated land and access to technical assistance from sources other 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_i 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:

$$Y_i = \varphi + \lambda_2 \sum HH_i + \lambda_3 \sum W_i + \lambda_4 \sum A_i + \lambda_5 \sum M_i + \lambda_6 \widehat{CRIAR}_i + \omega_i$$

where

Y_i represents the outcomes of interest;
$\widehat{CRIAR}_i$ 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
ω_i 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.

7. Results

The results of the first stage participation equation are presented in Table 4. As expected, the coefficient of distance from the household to the *ferias* is negative and statistically significant[15], being located a kilometer further away from the *ferias* reduces the probability of participation by 2.3%. The squared term of distance is positive and significant suggesting that each additional kilometer has less of an influence on program participation. The magnitude of this linear coefficient is relatively large as the average household is located about 14 km away from the technology *ferias* suggesting that transaction costs associated with transportation and time-use influence participation. The instruments pass the underidentification and weak identification tests. The underidentification test confirms that the equation is identified and the excluded instruments are relevant[16].

Table 4
First stage – participation into CRIAR (linear probability model).

Instruments	Dependent variable: participation into CRIAR (0, 1)	
	(1)	(2)
Distance	-0.023^{***} (0.008)	-0.022^{***} (0.008)
Distance squared	0.001^{***} (0.000)	0.001^{***} (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 fixed 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]*

Notes: These results correspond to the OLS estimation for the first stage using a linear probability model. Column (1) presents the first stage specification for the analysis of productivity and income. Column (2) presents the first stage specification for the analysis of Food Security. Standard errors clustered at the community level in parentheses. P values for the test statistics are in brackets.
*** Significant at 1% level.

The second stage estimations examine the impact of program participation on food security (measured with the FAO index), income (measured as household income and household income per capita), household home consumption (measured as the log of value of production used for home consumption), productivity (measured as the log value of production per hectare) and agricultural household sales (measured as the log value of sales per household). The impacts of program participation on the outcome variables are presented in Tables 5 and 6.[17]

First and foremost, participation in CRIAR improved food security via greater *food access* – positive impact on household income – and *food availability* – increased agricultural productivity and sales. Specifically, the coefficient of the FAO Index indicates an increase of 32% in the probability of being food secure by beneficiary households. 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.[18] Also, beneficiaries are 22% less likely to be concerned about lack of food at home (Table 5).

In order to understand which specific aspects of food security were driving this result, the FAO Index was disaggregated into

[15] Full results to the first stage estimation are available upon request.

[16] 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 joint significance for the instruments is 9.04.

[17] Appendix A contains the tables with full 2SLS results for each outcome of interest.

[18] Results available upon request.

Table 5
Impacts of CRIAR on outcome variables – food security.

Dependent variables (unit) – outcome variables	Impact of CRIAR
Impact: food security	
Whole sample (N = 1287)	
Food security (FAO index – 1 = Food security, 0 = Food insecurity)	0.316***
	(0.104)
In the last 3 months, was there concern about lack of food at home? (yes/no)	*−0.219**
	(0.114)
In the last 3 months, did the household run out of food? (yes/no)	*−0.043*
	(0.066)
In the last 3 months, was the household unable to eat healthy and nutritious food? (yes/no)	*−0.142***
	(0.065)
In the last 3 months, did any adult eat only a few types of foods? (yes/no)	*−0.168**
	(0.089)
In the last 3 months, did any adult have to skip a meal? (yes/no)	*−0.144***
	(0.064)
In the last 3 months, did any adult eat less than he/she should? (yes/no)	*−0.114*
	(0.078)
In the last 3 months, was any adult hungry but did not eat? (yes/no)	*−0.093*
	(0.071)
In the last 3 months, did any adult go without eating for a whole day? (yes/no)	*−0.103**
	(0.059)
Households with children under 18 years of age (N = 860)	
Any children in the household were unable to eat healthy and nutritious food? (yes/no)	−0.087
	(0.122)
Any children in the household ate only a few kinds of foods? (yes/no)	0.006
	(0.082)
Any children in the household had to skip a meal? (yes/no)	−0.098
	(0.083)
Any children in the household ate less than you thought they should? (yes/no)	−0.093
	(0.098)
You had to reduce the amount of food served to the children in the household? (yes/no)	−0.092
	(0.086)
Any children in the household were hungry but did not eat? (yes/no)	−0.081
	(0.054)
Any children in the household did not eat for a whole day? (yes/no)	−0.070
	(0.069)

Notes: All models are estimated by 2SLS and include municipality fixed effects. Covariates for Food Security regressions include household characteristics, head of the household characteristics, dwelling characteristics, associativity variables, economic status variables, and land variables. Annex A presents the results of the full regressions. Robust standard errors clustered at the community level are in parentheses.
* Significant at 10% level.
** Significant at 5% level.
*** Significant at 1% level.

the fifteen questions that make up this indicator.[19] These questions aim to capture household food access, availability and use during the previous 3 months for adults and children under 18 years of age.

The results show that participation increased food security for adults. Specifically, adults from beneficiary households are less likely to face unavailability of healthy and nutritious food (14%), skip a meal (14%), not eat for an entire day (10%) or have a diet based on low food variety (17%). In the case of children, the coefficients have the expected sign, but are not statistically significant. This might be explained by the following reasons: First, adults might have "sheltered" food insecurity faced by children and therefore, food insecurity in this region is mainly faced by adults. Second, the lack of statistical significance may be due to reduced sample size and lack of statistical power, since 33% of the sample is composed by households without children, therefore only 77% of the sample answered questions regarding children's food insecurity. Third, mothers might be reluctant or feel ashamed to openly accept that children faced food shortages, which in turn might have caused an underestimation of children's food insecurity.

As mentioned, in regards to the mechanisms through which program participation enhances food security, the results confirm that both *food access and availability* are improved (Table 6). Specifically, *food access* is improved by higher income rather than increases in production used for home consumption purposes. The results show that participation in CRIAR increased net household income by 36% and per capita income by 19%. The coefficients are both positive and significant. This represents an increase of US $1667 in net household income and US$257 per capita with respect to the average income of the control group (US$4630 and US$1354). In regards to the value of production used for home consumption, we do not find any significant impact. These findings suggest that beneficiary households have greater access to food due to enhanced purchasing power.

On the other hand, *food availability* is improved by higher productivity and sales that increase food supply at the local level (as most of these farmers sell their production in local markets). The results for agricultural productivity show that participation in CRIAR increased the annual value of production per hectare by 92%, on average.[20] This represents an increase of US$1870, based on the median value of production per hectare for the control group (US$2032).[21] The possible causes for this result are twofold: (i)

[19] The response to these questions were binary answers (Yes/No) replied by the women of the household, for adults and children under 18 years separately. See Appendix B.

[20] 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.

[21] As a robustness check and 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 price reported by the farmer. The coefficient becomes more significant and the impact increases to about 148%.

Table 6
Impacts of CRIAR on outcome variables – continued – mechanisms and placebo tests.

	Dependent variables (unit) – outcome variables	Impact of CRIAR
	Mechanism #1: food access	
Income	Household income (US$-logs)	0.311***
		(0.115)
	Household income per capita (US$-logs)	0.179**
		(0.086)
Home consumption	Home Consumption (US$-logs)	0.301
		(0.500)
	Mechanism #2: food availability	
Sales	Household sells production (0, 1)	0.172***
		(0.094)
	Household sales US$ (logs)	1.539*
		(0.833)
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)
	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	1287

Notes: All models are estimated by 2SLS and include municipality fixed effects. Covariates for the following dependent variables-income, home consumption, sales and productivity, are the same as in the food security specification plus input expenditures, irrigation, and technical assistance. Annex A presents the results of the full regressions. Robust standard errors clustered at the community level are in parentheses.
* Significant at 10% level.
** Significant at 5% level.
*** Significant at 1% level.

adopted technologies increased the value of production significantly; and (ii) farmers engaged in crop substitution to higher-value crops. The data provides evidence suggesting the presence of both effects. 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. 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[22] dollars per ton, respectively (74% and 25% higher than potatoes, respectively). Therefore, the large magnitude of the coefficient derives from higher yields with a significantly higher value. Indeed, the data shows that 76% of beneficiary farmers cultivate higher-value crops compared with 64% of non-beneficiaries. Also, beneficiary farmers allocate 13% more land to high-value crops versus non beneficiaries. This suggests that high-value crops represent a more important proportion of the crop portfolio for beneficiary farmers.

In addition, beneficiaries are more likely to sell their production either in the market, to intermediaries or on-farm (17%). The results also show that value of production sold by beneficiary farmers increased by 360% (the median value of sales for the control group is US$343 per hectare). The large magnitude of this coefficient can be justified based on two reasons. 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. In fact, 30% of 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 higher-value crops. This can account for a significant increase in the value of the production sold.

The last panel of Table 6 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 6, placebo tests are estimated 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-Hernández, 2004). The estimations confirm the validity of the results.

Finally, note that even though there are a few initial differences in some variables between the treated and control groups, the identification strategy used in this paper (IV) addresses potential identification problems that might take place due to observable and unobservable characteristics. Together with the placebo tests, this ensures that coefficients obtained are consistent estimators of the causal effect of the program and correspond to the Local Average Treatment Effect (LATE).

8. Conclusions

This paper provides deeper insight into the role of productive agricultural programs as policy tools to enhance food security. Specifically, this study focuses on the CRIAR, 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 cover 90% of the total cost of an agricultural technology and technical assistance. Considering that program participation can be endogenous, as there might be unobservable characteristics that might influence participation and the outcomes of interest, an instrumental variable methodology was applied.

The results confirmed that, with respect to the control group, beneficiary households are 20–30% more likely to be food secure than the control group and 22% less likely to be concerned about lack of food. This increase was driven both by food availability – the annual value of production per hectare increased by 92% and the value of production sold by 360% – and food access – the results show that participation in CRIAR increased net annual agricultural household income by 36% and per capita household income by 19%. Three caveats must be considered when interpreting these results. First, the estimates measure short-term effects, therefore issues of sustainability and durability of program's impact must be addressed in future studies. Second, in regards to extrapolation of results, estimates correspond to local average treatment effects which limit their external validity. Despite this limitation, agricultural production systems in the Andes are likely comparable due to similar geographic characteristics and altitude conditions. Hence, results obtained in this paper might be valid

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

for farmers living in rural areas of the Andes with similar contexts, cropping patterns, endowments, and socio-economic characteristics. Lastly, this paper does not study in great detail the nutritional aspects that might have resulted from this intervention (*food use*). Therefore, further research on this area is needed to deepen our understanding on the potential impacts of this type of interventions on outcomes related to food diversity, consumption and nutrition as well as its interactions with gender aspects such as women's empowerment, work and child care practices.

The evidence presented in this paper is valuable for its contribution to the literature on the effectiveness of agricultural technology programs, its policy implications regarding the role of agricultural programs as policy instruments to reduce vulnerability to food insecurity, and for identifying the pathways by which these programs can have a positive effect on food security.

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Appendix A. Full regressions for outcome variables

See Tables A1–A4.

Table A1
Impact of CRIAR on food security outcomes – whole sample (includes households with children less than 18 years of age).

	Variables (unit)	(1) Food security (1 = Security, 0 = Insecurity)	(2) Concern about lack of food at home (1 = yes)	(3) Household runs out of food (1 = yes)	(4) Unable to eat healthy and nutritious food (1 = yes)
Treatment	CRIAR (0, 1)	0.316***	−0.219*	−0.043	−0.142**
		(0.104)	(0.114)	(0.066)	(0.065)
Household	Size (# members)	−0.013	0.012	0.009	0.015
		(0.012)	(0.013)	(0.008)	(0.010)
	Dep. ratio (%)	−0.040**	0.051***	0.020	0.018
		(0.017)	(0.017)	(0.013)	(0.015)
	Members in ag. work (%)	−0.021	0.013	−0.034	0.055*
		(0.031)	(0.031)	(0.027)	(0.033)
Head of household	Age (years)	0.001	0.004	0.003	0.005
		(0.006)	(0.007)	(0.005)	(0.006)
	Age squared	0.000	0.000	0.000	0.000
		(0.000)	(0.000)	(0.000)	(0.000)
	Female (0, 1)	−0.066	0.086	0.000	0.024
		(0.053)	(0.055)	(0.043)	(0.054)
	Single (0, 1)	0.028	−0.046	−0.018	−0.018
		(0.048)	(0.050)	(0.034)	(0.046)
	Indigenous or native (0, 1)	0.130***	−0.130**	−0.190***	−0.010***
		(0.036)	(0.036)	(0.031)	(0.035)
Education of the head of household	Primary incomplete. (0, 1)	−0.003	−0.027	−0.011	−0.05*
		(0.042)	(0.044)	(0.033)	(0.041)
	Primary complete (0, 1)	0.007	0.000	0.029	−0.098**
		(0.045)	(0.048)	(0.037)	(0.045)
	Secondary incomplete (0, 1)	−0.037	0.013	0.013	−0.093*
		(0.056)	(0.061)	(0.051)	(0.056)
	Secondary complete (0, 1)	0.015	−0.003	0.015	−0.102*
		(0.074)	(0.074)	(0.063)	(0.059)
	More than secondary (0, 1)	0.181	−0.189	−0.119*	−0.240***
		(0.118)	(0.120)	(0.068)	(0.071)
Technical assistance	Tech. assistance non CRIAR (0, 1)	−0.040	0.046	−0.024	−0.026
		(0.051)	(0.048)	(0.050)	(0.044)
Associativity	HH belongs to an agric. coop. (0, 1)	−0.064	0.045	0.043	0.058
		(0.054)	(0.056)	(0.044)	(0.044)
Economic status	Remittances (US$ year/HH)	−0.000	0.000	0.000	0.000**
		(0.000)	(0.000)	(0.000)	(0.000)
	Access to formal credit (0, 1)	−0.160***	0.082	0.058	0.129***
		(0.051)	(0.055)	(0.042)	(0.042)
	TLU	−0.001	0.001	0.001	0.002
		(0.002)	(0.002)	(0.001)	(0.002)
	PPI score	−0.001	0.001	0.001	0.003*
		(0.002)	(0.002)	(0.002)	(0.002)
House characteristics	Dirt floor (0, 1)	0.018	−0.032	0.026	−0.006
		(0.036)	(0.034)	(0.027)	(0.029)
	Electric energy (0, 1)	0.054	−0.030	−0.059*	−0.026
		(0.038)	(0.039)	(0.034)	(0.032)
	House with freezer (0, 1)	0.151***	−0.137**	−0.14***	−0.150***
		(0.055)	(0.055)	(0.039)	(0.039)
Access to ferias	Time to paved road	−0.007	0.004	−0.011	0.012

(*continued on next page*)

Table A1 (*continued*)

	Variables (unit)	(1) Food security (1 = Security, 0 = Insecurity)	(2) Concern about lack of food at home (1 = yes)	(3) Household runs out of food (1 = yes)	(4) Unable to eat healthy and nutritious food (1 = yes)
	(logs)	(0.010)	(0.010)	(0.007)	(0.008)
Land	Hectares worked (Has)	0.024***	−0.020***	−0.011*	−0.010***
		(0.007)	(0.007)	(0.005)	(0.005)
	Household with 2 plots (1, 0)	0.096*	−0.088	−0.032	−0.062
		(0.053)	(0.054)	(0.044)	(0.044)
	Household with 3 plots (1, 0)	0.025	−0.030	0.014	−0.029
		(0.056)	(0.062)	(0.046)	(0.052)
	Household with 4 plots (1, 0)	0.036	−0.058	−0.044	0.002
		(0.060)	(0.061)	(0.046)	(0.051)
	Household with 5 plots (1, 0)	0.006	−0.070	−0.027	−0.054
		(0.066)	(0.068)	(0.048)	(0.060)
	Household with >5 plots (1, 0)	0.052	−0.105	−0.037	0.002
		(0.064)	(0.066)	(0.049)	(0.059)
	Flat hectares worked (%)	0.152***	−0.120***	−0.063**	−0.052*
		(0.042)	(0.038)	(0.032)	(0.027)
	Constant	−0.075	0.845***	0.393**	0.334*
		(0.201)	(0.207)	(0.157)	(0.178)
	Observations	1264	1264	1264	1264
	R-squared	0.182	0.176	0.131	0.120

Notes: The dependent variable is the Food Security Index (FAO Index: 1 = Food Security, 0 = Food Insecurity) in column (1). Dummy variables that take the value of 1 if: there was concern about the lack of food at home (column (2)), the household ran out of food (column (3)), any adult was unable to eat healthy and nutritious food (column (4)). All models are estimated by 2SLS and include municipality fixed effects. Robust standard errors clustered at the community level are in parentheses.

	Variables (unit)	(5) Ate only few types of food (1 = yes)	(6) Skipped a meal (1 = yes)	(7) Ate less than he/she should (1 = yes)	(8) Was hungry but did not eat (1 = yes)	(9) Did not eat for a whole day (1 = yes)
Treatment	CRIAR (0, 1)	−0.168*	−0.144**	−0.114	−0.093	−0.103*
		(0.089)	(0.064)	(0.078)	(0.070)	(0.060)
Household	Size (# members)	0.002	−0.005	−0.011	−0.007	−0.011
		(0.011)	(0.010)	(0.010)	(0.009)	(0.007)
	Dep. ratio (%)	0.026*	0.021	0.007	0.020	0.011
		(0.015)	(0.014)	(0.013)	(0.013)	(0.012)
	Members in ag. work (%)	0.030	−0.004	0.081***	0.009	−0.012
		(0.028)	(0.027)	(0.029)	(0.025)	(0.024)
Head of household	Age (years)	−0.002	0.001	−0.005	−0.003	−0.003
		(0.006)	(0.004)	(0.005)	(0.004)	(0.004)
	Age squared	0.000	0.000	0.000	0.000	0.000
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
	Female (0, 1)	0.0143	−0.060	−0.105**	−0.052	−0.027
		(0.047)	(0.044)	(0.046)	(0.040)	(0.045)
	Single (0, 1)	0.032	0.019	0.098**	0.001	−0.031
		(0.040)	(0.040)	(0.046)	(0.031)	(0.040)
	Indigenous or native (0, 1)	−0.007	−0.043	−0.027	−0.011	−0.053*
		(0.036)	(0.030)	(0.039)	(0.029)	(0.030)
Education of the head of household (HH)	Primary incomplete (0, 1)	−0.038	−0.048	−0.034	−0.059	−0.017
		(0.039)	(0.037)	(0.036)	(0.036)	(0.029)
	Primary complete (0, 1)	−0.067	−0.071*	−0.017	−0.100***	−0.057*
		(0.042)	(0.038)	(0.042)	(0.040)	(0.035)
	Secondary incomplete (0, 1)	−0.100*	−0.112***	−0.061	−0.067	−0.056
		(0.054)	(0.042)	(0.046)	(0.042)	(0.039)
	Secondary complete (0, 1)	−0.150**	−0.101**	−0.113**	−0.091	−0.075*
		(0.063)	(0.052)	(0.053)	(0.056)	(0.042)
	More than secondary (0, 1)	−0.115	−0.138**	−0.180***	−0.160***	−0.091*
		(0.084)	(0.069)	(0.060)	(0.056)	(0.052)
Technical assistance	Tech. assistance non CRIAR (0, 1)	0.038	0.075	0.028	0.035	0.032
		(0.057)	(0.055)	(0.051)	(0.057)	(0.055)
Associativity	HH belongs to an agric. coop. (0, 1)	0.003	−0.006	0.044	0.005	0.021
		(0.047)	(0.040)	(0.047)	(0.038)	(0.037)
Economic status	Remittances (US$ year/HH)	0.000	0.000**	0.000	0.000*	0.000
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
	Access to formal credit (0, 1)	0.145***	0.078*	0.074*	0.011	0.027
		(0.043)	(0.040)	(0.043)	(0.039)	(0.040)
	TLU	0.001	0.004**	0.003*	−0.000	0.001
		(0.002)	(0.002)	(0.001)	(0.001)	(0.001)
	PPI Score	−0.001	−0.000	−0.004**	−0.001	0.000
		(0.002)	(0.002)	(0.002)	(0.001)	(0.001)
House characteristics	Dirt floor (0, 1)	−0.031	−0.045	−0.048	−0.014	0.001

Table A1 (*continued*)

	Variables (unit)	(5) Ate only few types of food (1 = yes)	(6) Skipped a meal (1 = yes)	(7) Ate less than he/she should (1 = yes)	(8) Was hungry but did not eat (1 = yes)	(9) Did not eat for a whole day (1 = yes)
		(0.033)	(0.027)	(0.029)	(0.028)	(0.030)
	Electric energy (0, 1)	−0.053	−0.082***	−0.046	−0.007	−0.005
		(0.037)	(0.030)	(0.033)	(0.031)	(0.029)
	House w freezer (0, 1)	−0.050	−0.028	0.002	0.029	−0.039
		(0.047)	(0.049)	(0.049)	(0.048)	(0.041)
Access to ferias	Time to paved road (logs)	0.008	−0.090	0.001	0.005	0.009
		(0.008)	(0.008)	(0.008)	(0.008)	(0.007)
Land	Hectares worked (Has)	−0.010***	−0.017***	−0.010***	−0.010**	−0.010***
		(0.005)	(0.005)	(0.005)	(0.005)	(0.004)
	Household with 2 plots (0, 1)	0.041	−0.068*	−0.016	−0.020	0.003
		(0.045)	(0.038)	(0.042)	(0.037)	(0.035)
	Household with 3 plots (0, 1)	0.040	−0.031	0.021	0.043	0.004
		(0.050)	(0.052)	(0.047)	(0.042)	(0.041)
	Household with 4 plots (0, 1)	0.073	−0.011	−0.005	0.036	0.022
		(0.051)	(0.050)	(0.049)	(0.044)	(0.043)
	Household with 5 plots (0, 1)	0.066	0.001	0.017	0.079	0.065
		(0.060)	(0.055)	(0.054)	(0.051)	(0.051)
	Household with >5 plots (0, 1)	0.097*	0.008	0.011	0.011	0.034
		(0.056)	(0.056)	(0.052)	(0.044)	(0.045)
	Flat hectares worked (%)	−0.040	−0.057*	−0.080**	−0.058*	−0.038
		(0.029)	(0.030)	(0.033)	(0.032)	(0.030)
	Constant	0.601***	0.598***	0.778***	0.514***	0.489***
		(0.202)	(0.152)	(0.167)	(0.147)	(0.142)
	Observations	1264	1264	1264	1264	1264
	R-squared	0.103	0.079	0.105	0.090	0.068

Notes: The dependent variable is a dummy that takes the value of 1 if: any adult ate only few types of food (column (5)); any adult had to skip a meal (column (6);, any adult ate less than he/she should have eaten (column (7); any adult was hungry but did not eat (column (8)); any adult did not eat for a whole day (column (9)). All models are estimated by 2SLS and include municipality fixed effects. Robust standard errors clustered at the community level are in parentheses.

* Significant at 10% level.
** Significant at 5% level.
*** Significant at 1% level.

Table A2
Impact of CRIAR on food security outcomes – sample of households with children less than 18 years of age.

	Variables (unit)	(1) Were any of the children unable to eat healthy and nutritious food (1 = yes)	(2) Did any children eat only few types of food (1 = yes)	(3) Did any children skip a meal (1 = yes)	(4) Did any children eat less than he/she should (1 = yes)
Treatment	CRIAR (0, 1)	−0.087	0.006	−0.098	−0.093
		(0.122)	(0.082)	(0.083)	(0.098)
Household	Size (# members)	−0.007	0.011	0.007	0.008
		(0.009)	(0.011)	(0.009)	(0.008)
	Dep. ratio (%)	0.000	0.003	0.024*	−0.000
		(0.013)	(0.015)	(0.015)	(0.013)
	Members in ag. work (%)	−0.047*	−0.051**	−0.039	0.002
		(0.026)	(0.026)	(0.025)	(0.026)
Head of household	Age (years)	−0.001	0.002	0.005	0.008
		(0.007)	(0.008)	(0.005)	(0.006)
	Age squared	0.000	−0.000	−0.000	−0.000
		(0.000)	(0.000)	(0.000)	(0.000)
	Female (0, 1)	−0.076	−0.057	0.052	0.002
		(0.061)	(0.061)	(0.062)	(0.048)
	Single (0, 1)	0.022	0.037	−0.007	0.020
		(0.060)	(0.059)	(0.060)	(0.044)
	Indigenous or native (0, 1)	−0.073*	−0.072**	−0.102***	−0.064*
		(0.038)	(0.035)	(0.034)	(0.035)
Education of the head of household	Primary incomplete. (0, 1)	−0.002	0.005	0.047	−0.014
		(0.047)	(0.048)	(0.033)	(0.037)
	Primary complete (0, 1)	−0.011	−0.009	0.065*	−0.058
		(0.048)	(0.052)	(0.038)	(0.037)
	Secondary incomplete (0, 1)	0.021	−0.043	0.045	−0.016
		(0.056)	(0.062)	(0.044)	(0.046)
	Secondary complete (0, 1)	0.017	−0.037	0.063	−0.043
		(0.068)	(0.068)	(0.056)	(0.054)
	More than secondary (0, 1)	0.065	−0.036	−0.054	−0.015
		(0.098)	(0.105)	(0.053)	(0.093)

(*continued on next page*)

Table A2 (*continued*)

	Variables (unit)	(1) Were any of the children unable to eat healthy and nutritious food (1 = yes)	(2) Did any children eat only few types of food (1 = yes)	(3) Did any children skip a meal (1 = yes)	(4) Did any children eat less than he/she should (1 = yes)
Technical assistance	Tech. assistance non CRIAR (0, 1)	−0.012 (0.063)	−0.016 (0.060)	−0.052 (0.046)	0.037 (0.057)
Associativity	HH belongs to an agric. coop. (0, 1)	−0.057 (0.037)	−0.108*** (0.033)	−0.008 (0.031)	−0.022 (0.037)
Economic status	Remittances (US$ year/HH)	0.000* (0.000)	0.000 (0.000)	0.000 (0.000)	−0.000 (0.000)
	Access to formal credit (0, 1)	0.065* (0.038)	−0.016 (0.035)	−0.002 (0.038)	−0.017 (0.032)
	TLU	−0.002** (0.001)	0.001 (0.002)	−0.001* (0.001)	−0.002 (0.001)
	PPI score	−0.002 (0.002)	0.000 (0.002)	0.002 (0.001)	−0.001 (0.001)
House characteristics	Dirt floor (0, 1)	−0.027 (0.031)	−0.012 (0.027)	0.018 (0.024)	−0.012 (0.027)
	Electric energy (0, 1)	0.026 (0.030)	−0.009 (0.035)	−0.032 (0.028)	−0.028 (0.034)
	House with freezer (0, 1)	−0.054 (0.036)	−0.045 (0.032)	−0.044 (0.029)	−0.022 (0.036)
Access to ferias	Time to paved road (logs)	0.011 (0.009)	0.005 (0.008)	0.005 (0.006)	−0.009 (0.008)
Land	Hectares worked (Has)	−0.012** (0.005)	−0.009 (0.006)	−0.005 (0.004)	−0.014*** (0.005)
	Household with 2 plots (1, 0)	−0.032 (0.048)	−0.118** (0.046)	−0.097** (0.047)	−0.060 (0.048)
	Household with 3 plots (1, 0)	−0.014 (0.048)	−0.100* (0.053)	−0.057 (0.052)	−0.041 (0.054)
	Household with 4 plots (1, 0)	0.014 (0.051)	−0.076 (0.053)	−0.068 (0.053)	−0.040 (0.055)
	Household with 5 plots (1, 0)	−0.004 (0.054)	−0.111** (0.053)	−0.056 (0.054)	−0.004 (0.059)
	Household with >5 plots (1, 0)	−0.037 (0.057)	−0.091 (0.058)	−0.056 (0.059)	−0.067 (0.058)
	Flat hectares worked (%)	−0.033 (0.032)	−0.005 (0.032)	−0.038 (0.027)	−0.029 (0.033)
	Constant	0.451** (0.207)	0.372* (0.216)	0.139 (0.151)	0.339* (0.190)
	Observations	860	860	860	860
	R-squared	0.083	0.123	0.090	0.086

Notes: The dependent variable is a dummy variable that takes the value of 1 if any children of the household: were unable to eat healthy and nutritious food (column (1)); ate only few types of food (column (2)); had to skip a meal (column (3)); ate less than he/she should have (column (4)). All models are estimated by 2SLS and include municipality fixed effects. Robust standard errors clustered at the community level are in parentheses.

	Variables (unit)	(5) You ever had to reduce the amount of food served to children (1 = yes)	(6) Any children were hungry but did not eat (1 = yes)	(7) Any children did not eat for a whole day (1 = yes)
Treatment	CRIAR (0, 1)	−0.092 (0.086)	−0.081 (0.054)	−0.070 (0.069)
Household	Size (# members)	0.001 (0.007)	0.006 (0.008)	−0.002 (0.007)
	Dep. ratio (%)	0.000 (0.013)	0.003 (0.011)	0.006 (0.011)
	Members in ag. Work (%)	−0.012 (0.022)	0.012 (0.020)	0.005 (0.017)
Head of household	Age (years)	0.006 (0.005)	0.003 (0.005)	−0.001 (0.005)
	Age squared	−0.000 (0.000)	−0.000 (0.000)	0.000 (0.000)
	Female (0, 1)	−0.053 (0.054)	−0.053 (0.044)	−0.024 (0.042)
	Single (0, 1)	0.067 (0.053)	0.074 (0.046)	0.043 (0.038)
	Indigenous or native (0, 1)	−0.017 (0.027)	−0.016 (0.025)	−0.032 (0.021)
Education of the head of household	Primary incomplete. (0, 1)	−0.020 (0.033)	−0.056 (0.036)	0.026 (0.032)
	Primary complete (0, 1)	−0.072** (0.036)	−0.061* (0.036)	−0.007 (0.035)

Table A2 (*continued*)

	Variables (unit)	(5) You ever had to reduce the amount of food served to children (1 = yes)	(6) Any children were hungry but did not eat (1 = yes)	(7) Any children did not eat for a whole day (1 = yes)
	Secondary incomplete (0, 1)	−0.010	0.012	0.000
		(0.039)	(0.048)	(0.039)
	Secondary complete (0, 1)	−0.025	−0.048	0.010
		(0.045)	(0.050)	(0.042)
	More than secondary (0, 1)	−0.112**	−0.132***	−0.036
		(0.046)	(0.046)	(0.040)
Technical assistance	Tech. assistance non CRIAR (0, 1)	0.050	0.020	0.037
		(0.054)	(0.054)	(0.052)
Associativity	HH belongs to an agric. coop. (0, 1)	−0.048**	−0.023	−0.021
		(0.023)	(0.023)	(0.025)
Economic status	Remittances (US$ year/HH)	0.000	0.000	0.000
		(0.000)	(0.000)	(0.000)
	Access to formal credit (0, 1)	−0.027	−0.015	−0.006
		(0.024)	(0.024)	(0.025)
	TLU	0.000	−0.002*	−0.001
		(0.002)	(0.001)	(0.001)
	PPI score	−0.003*	0.001	−0.002
		(0.001)	(0.001)	(0.001)
House characteristics	Dirt floor (0, 1)	−0.043*	−0.008	−0.021
		(0.022)	(0.021)	(0.020)
	Electric energy (0, 1)	0.025	−0.024	0.006
		(0.027)	(0.029)	(0.027)
	House with freezer (0, 1)	−0.004	−0.037	−0.023
		(0.033)	(0.025)	(0.022)
Access to ferias	Time to paved road (logs)	−0.006	0.008	0.003
		(0.008)	(0.007)	(0.006)
Land	Hectares worked (Has)	−0.007*	−0.008**	−0.008**
		(0.004)	(0.004)	(0.004)
	Household with 2 plots (1, 0)	−0.060	−0.036	−0.061
		(0.044)	(0.038)	(0.042)
	Household with 3 plots (1, 0)	−0.015	0.008	−0.025
		(0.047)	(0.047)	(0.050)
	Household with 4 plots (1, 0)	−0.073	0.004	−0.058
		(0.048)	(0.046)	(0.046)
	Household with 5 plots (1, 0)	−0.050	−0.001	−0.041
		(0.053)	(0.050)	(0.051)
	Household with >5 plots (1, 0)	−0.102*	0.058	−0.017
		(0.053)	(0.055)	(0.053)
	Flat hectares worked (%)	−0.012	−0.001	−0.027
		(0.026)	(0.022)	(0.023)
	Constant	0.374**	0.181	0.337**
		(0.165)	(0.143)	(0.138)
	Observations	860	860	860
	R-squared	0.103	0.080	0.067

Notes: The dependent variable is a dummy variable that takes the value of 1 if: the amount of food served to children had to be reduced (column (5)); any children of the household were hungry but did not eat (column (6);, any children did not eat for a whole day (column (7)); All models are estimated by 2SLS and include municipality fixed effects. Robust standard errors clustered at the community level are in parentheses.

* Significant at 10% level.
** Significant at 5% level.
*** Significant at 1% level.

Table A3
Impact of CRIAR on income and agricultural outcomes.

	Variables (unit)	(1) Household income (US$-logs)	(2) Household income per capita (US$-logs)	(3) Production sales (US$-logs)	(4) Household sells production (0, 1)
Treatment	CRIAR beneficiary (0, 1)	0.311***	0.179**	1.539*	0.172*
		(0.115)	(0.086)	(0.833)	(0.094)
Household	Household size (# members)	−0.012*	−0.026***	−0.015	0.006
		(0.007)	(0.005)	(0.039)	(0.010)
	Dependency ratio (%)	0.004	0.011	0.006	0.006
		(0.013)	(0.008)	(0.058)	(0.016)
	Members in ag. work (%)	−0.056***	−0.023	−0.255***	−0.188***
		(0.017)	(0.016)	(0.096)	(0.030)
Head of household	Age (years)	0.011***	0.004	0.039*	0.004

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Table A3 (*continued*)

	Variables (unit)	(1) Household income (US$-logs)	(2) Household income per capita (US$-logs)	(3) Production sales (US$-logs)	(4) Household sells production (0, 1)
		(0.004)	(0.003)	(0.020)	(0.005)
	Age squared	−0.000***	0.000	−0.000**	0.000
		(0.000)	(0.000)	(0.000)	(0.000)
	Woman (0, 1)	−0.060**	−0.064	−0.212	−0.124**
		(0.028)	(0.040)	(0.178)	(0.050)
	Single (0, 1)	0.083*	0.064	−0.094	0.010
		(0.046)	(0.050)	(0.153)	(0.038)
	Indigenous or native (0, 1)	0.041**	0.033	−0.121	−0.046
		(0.016)	(0.023)	(0.104)	(0.030)
Education of the head of household (HH)	Primary incomplete (0, 1)	0.061	0.002	0.348**	0.044
		(0.053)	(0.023)	(0.141)	(0.042)
	Primary complete (0, 1)	0.107*	0.042**	0.616***	0.030
		(0.060)	(0.018)	(0.166)	(0.046)
	Secondary incomplete (0, 1)	0.089	0.035	0.568***	0.029
		(0.058)	(0.022)	(0.182)	(0.051)
	Secondary complete (0, 1)	0.061	0.015	0.614***	0.014
		(0.057)	(0.024)	(0.200)	(0.062)
	More than secondary (0, 1)	−0.008	0.003	0.254	−0.003
		(0.057)	(0.054)	(0.326)	(0.095)
House chars.	Dirt floor (0, 1)	−0.033	−0.015	0.066	0.020
		(0.037)	(0.016)	(0.109)	(0.030)
	House with electricity (0, 1)	−0.036	−0.033	−0.228*	0.029
		(0.024)	(0.026)	(0.129)	(0.040)
	House with freezer (0, 1)	0.071	0.023	0.273*	0.017
		(0.044)	(0.028)	(0.145)	(0.039)
Associativity	Belongs to an ag. cooperative (0, 1)	0.014	−0.066	0.348*	−0.002
		(0.043)	(0.102)	(0.178)	(0.041)
Economic status	Remittances (US$ year/HH)	0.000 *	0.000	0.000	0.000
		(0.000)	(0.000)	(0.000)	(0.000)
	Access to formal credit (0, 1)	0.029	0.048	0.304**	0.065
		(0.029)	(0.036)	(0.154)	(0.040)
	TLU	0.001	0.001	0.000	−0.001
		(0.001)	(0.001)	(0.007)	(0.003)
	PPI Score	−0.003*	−0.001	0.005	0.002
		(0.002)	(0.002)	(0.006)	(0.002)
Modern irrigation	Prop. of land with modern irrigation (%)	−0.025	−0.070	N/A	N/A
		(0.033)	(0.054)		
	Modern irrigation (0, 1)	0.015	0.031	N/A	N/A
		(0.030)	(0.026)		
Tech. assist.	Tech. assistance non CRIAR (0, 1)	0.043	0.072	0.0608	0.0923**
		(0.033)	(0.070)	(0.200)	(0.045)
Land	Hectares worked (Has)	0.051***	0.038***	−0.114***	0.014**
		(0.006)	(0.005)	(0.023)	(0.006)
	Flat hectares worked (%)	0.003	−0.019	0.077	0.063*
		(0.016)	(0.026)	(0.096)	(0.034)
	Household with 2 plots (0, 1)	0.023	−0.085	0.220	0.120**
		(0.027)	(0.106)	(0.190)	(0.060)
	Household with 3 plots (0, 1)	−0.009	−0.051	−0.007	0.201***
		(0.027)	(0.075)	(0.193)	(0.059)
	Household with 4 plots (0, 1)	−0.044	−0.054	0.121	0.204***
		(0.060)	(0.080)	(0.205)	(0.065)
	Household with 5 plots (0, 1)	0.039	−0.019	0.172	0.300***
		(0.035)	(0.078)	(0.215)	(0.062)
	Household with > 5 plots (0, 1)	0.103***	0.037	0.480**	0.363***
		(0.038)	(0.082)	(0.217)	(0.063)
Access	Time to paved road (logs)	−0.002	0.002	0.018	−0.000
		(0.006)	(0.005)	(0.030)	(0.008)
	Constant	9.618***	9.090***	4.693***	0.175
		(0.149)	(0.133)	(0.746)	(0.201)
	Observations	1264	1264	936	1264
	R-squared	0.114	0.071	0.218	0.234

Notes: The dependent variables are: Household income (US$-logs) in column (1); Household income per capita (US$-logs) in column (2); Value of household sales (US$-logs) in column (3); and a dummy that takes the value of 1 if the household sells any production in column (4). All models are estimated by 2SLS and include municipality fixed effects. Robust standard errors clustered at the community level are in parentheses.

Table A3 (*continued*)

	Variables (unit)	(5) Home consumption (US$-logs)	(6) Value of production per HA (US$-logs)	(7) Value of production (US$-logs)	(8) V. of Prod. per HA – mean prices – (US-logs)
Treatment	CRIAR beneficiary (0, 1)	0.301	0.654*	0.762*	0.915**
		(0.500)	(0.347)	(0.019)	(0.363)
Household	Household size (# members)	−0.036	0.009	0.014	0.006
		(0.039)	(0.035)	(0.035)	(0.035)
	Dependency ratio	−0.043	−0.03	−0.028	−0.032
		(0.064)	(0.055)	(0.056)	(0.054)
	Members in ag. work (%)	−0.098	−0.293***	−0.312***	−0.257**
		(0.112)	(0.109)	(0.111)	(0.113)
Head of household	Age (years)	0.005	0.016	0.013	0.008
		(0.021)	(0.018)	(0.019)	(0.018)
	Age squared	−0.000	−0.000	−0.000	−0.000
		(0.000)	(0.000)	(0.000)	(0.000)
	Woman (0, 1)	−0.019	−0.095	−0.099	−0.106
		(0.223)	(0.179)	(0.185)	(0.186)
	Single (0, 1)	−0.028	0.009	0.012	−0.018
		(0.153)	(0.146)	(0.149)	(0.144)
	Indigenous or native (0, 1)	−0.015	0.008	0.012	−0.017
		(0.114)	(0.102)	(0.102)	(0.104)
Education of the head of household	Primary incomplete (0, 1)	0.0204	0.266**	0.277**	0.310**
		(0.130)	(0.130)	(0.132)	(0.132)
	Primary complete (0, 1)	0.100	0.279*	0.292*	0.330**
		(0.164)	(0.150)	(0.151)	(0.152)
	Secondary incomplete (0, 1)	−0.170	0.465**	0.463**	0.399**
		(0.216)	(0.182)	(0.185)	(0.198)
	Secondary complete (0, 1)	−0.279	0.276	0.294	0.318*
		(0.243)	(0.221)	(0.225)	(0.193)
	More than secondary (0, 1)	−0.081	0.303	0.261	0.279
		(0.318)	(0.267)	(0.268)	(0.225)
House chars.	Dirt floor (0, 1)	0.129	0.189**	0.190**	0.265**
		(0.103)	(0.094)	(0.096)	(0.104)
	House with electricity (0, 1)	−0.128	−0.220*	−0.242**	−0.260**
		(0.128)	(0.117)	(0.119)	(0.128)
	House with freezer (0, 1)	−0.056	−0.092	−0.114	−0.054
		(0.176)	(0.172)	(0.172)	(0.178)
Associativity	Belongs to an ag. cooperative (0, 1)	0.228	0.393***	0.373***	0.299**
		(0.191)	(0.129)	(0.130)	(0.126)
Economic status	Remittances (US$ year/HH)	0.000	0.000	0.000	0.000
		(0.000)	(0.000)	(0.000)	(0.000)
	Access to formal credit (0, 1)	0.058	0.219	0.231	0.098
		(0.221)	(0.156)	(0.164)	(0.182)
	TLU	0.006	0.006*	0.006*	0.006*
		(0.005)	(0.003)	(0.003)	(0.003)
	PPI Score	−0.007	0.005	0.006	0.005
		(0.007)	(0.006)	(0.006)	(0.006)
Modern irrigation	Land with modern irrigation (%)	0.054	0.057	0.081	0.001
		(0.210)	(0.161)	(0.162)	(0.157)
	Modern irrigation (0, 1)	0.337**	0.374***	0.383***	0.273**
		(0.168)	(0.128)	(0.130)	(0.125)
Input exp./value	Inputs – FIHF (US$/HA (logs))	0.098***	0.105***	0.107***	0.121***
		(0.034)	(0.031)	(0.031)	(0.033)
	Mach. and equip. (US$/HA (logs))	−0.040	−0.044	−0.046	−0.044
		(0.040)	(0.031)	(0.032)	(0.032)
	Unpaid labor (US$/HA (logs))	0.315***	0.252***	0.255***	0.258***
		(0.074)	(0.050)	(0.050)	(0.052)
	Paid labor (US$/HA (logs))	−0.016	0.030*	0.033**	0.020
		(0.020)	(0.016)	(0.016)	(0.017)
Tech. assist.	Technical assistance non CRIAR (0, 1)	0.317	0.233	0.232	0.152
		(0.201)	(0.158)	(0.159)	(0.166)
Land	Hectares worked (Has)	−0.027	−0.034	−0.029	−0.032
		(0.037)	(0.028)	(0.028)	(0.028)
	Flat hectares worked (%)	−0.194	−0.223**	−0.189	−0.198*
		(0.143)	(0.113)	(0.118)	(0.114)
	Household with 2 plots (0, 1)	0.607***	0.533***	0.512**	0.524**
		(0.216)	(0.202)	(0.205)	(0.205)
	Household with 3 plots (0, 1)	0.558**	0.549**	0.530**	0.536**
		(0.237)	(0.222)	(0.228)	(0.220)

(*continued on next page*)

Table A3 (*continued*)

	Variables (unit)	(5) Home consumption (US$-logs)	(6) Value of production per HA (US$-logs)	(7) Value of production (US$-logs)	(8) V. of Prod. per HA – mean prices – (US-logs)
	Household with 4 plots (0, 1)	0.619** (0.276)	0.704*** (0.229)	0.698*** (0.232)	0.703*** (0.227)
	Household with 5 plots (0, 1)	0.823*** (0.271)	0.884*** (0.239)	0.875*** (0.242)	0.865*** (0.226)
	Household with >5 plots (0, 1)	1.112*** (0.253)	1.210*** (0.220)	1.193*** (0.225)	1.136*** (0.219)
Access	Time to paved road (logs)	−0.015 (0.031)	−0.015 (0.030)	−0.014 (0.030)	−0.033 (0.032)
	Constant	3.421*** (0.973)	3.381*** (0.861)	3.387*** (0.897)	3.378*** (0.871)
	Observations	1264	1264	1264	1264
	R-squared	0.280	0.295	0.287	0.261

Notes: The dependent variables are: Home Consumption measured as value of production used for household consumption (US$-logs) in column (5); Value of production per hectare (US$-logs) in column (6); Value of production (US$-logs) in column (7); and Value of production per hectare valued at mean prices at the municipality (US$-logs) in column (8). All models are estimated by 2SLS and include municipality fixed effects. Robust standard errors clustered at the community level are in parentheses.

* Significant at 10% level.
** Significant at 5% level.
*** Significant at 1% level.

Table A4
Placebo tests.

	Variables (unit)	(1) TLU Cows	(2) TLU Bulls	(3) Head of HH Edu.	(4) Share of Flat Land
Treatment	CRIAR beneficiary (0, 1)	1.140 (0.809)	−0.193 (0.138)	−0.087 (0.189)	0.000 (0.104)
Household	Household size (# members)	−0.068 (0.078)	0.059*** (0.017)	0.167* (0.087)	−0.011 (0.009)
	Dependency ratio (%)	0.027 (0.091)	−0.038 (0.028)	0.017 (0.122)	0.008 (0.014)
	Members in agricultural work (%)	−0.073 (0.125)	−0.024 (0.044)	0.958*** (0.202)	−0.038 (0.026)
Head of household	Age (years)	0.002 (0.030)	−0.008 (0.007)	−0.122*** (0.037)	−0.009* (0.005)
	Age squared	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000* (0.000)
	Female (0, 1)	−0.502** (0.210)	−0.057 (0.082)	−1.540*** (0.295)	0.017 (0.046)
	Single (0, 1)	0.239 (0.234)	0.007 (0.078)	−0.564* (0.294)	0.007 (0.039)
	Indigenous or native (0, 1)	0.033 (0.251)	0.004 (0.056)	−0.036 (0.224)	−0.035 (0.034)
Education of the head of household	Primary incomplete (0, 1)	0.103 (0.171)	−0.031 (0.053)	N/A	0.041 (0.035)
	Primary complete (0, 1)	0.104 (0.227)	0.084 (0.066)	N/A	0.060* (0.038)
	Secondary incomplete (0, 1)	−0.114 (0.254)	−0.002 (0.088)	N/A	−0.020 (0.043)
	Secondary complete (0, 1)	−0.648** (0.306)	−0.007 (0.111)	N/A	0.015 (0.047)
	More than secondary (0, 1)	0.009 (0.417)	0.060 (0.127)	N/A	0.122 (0.076)
Technical assistance	Technical assistance non CRIAR (0, 1)	−0.060 (0.411)	−0.030 (0.090)	0.697* (0.419)	−0.021 (0.060)
Associativity	Household belongs to an agric. cooperative (0, 1)	0.046 (0.329)	−0.033 (0.075)	0.480 (0.468)	0.029 (0.042)
Economic status	Remittances (US$ year/HH)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
	Access to formal credit (0, 1)	−0.225 (0.236)	0.045 (0.058)	−0.131 (0.370)	−0.018 (0.054)
	TLU	0.105* (0.062)	0.019* (0.011)	0.029* (0.017)	0.001 (0.001)
	PPI score	−0.014 (0.012)	0.006** (0.003)	0.065*** (0.016)	−0.001 (0.001)

Table A4 (*continued*)

	Variables (unit)	(1) TLU Cows	(2) TLU Bulls	(3) Head of HH Edu.	(4) Share of Flat Land
House characteristics	Dirt floor (0, 1)	−0.420**	0.0403	0.122	−0.042
		(0.192)	(0.055)	(0.244)	(0.026)
	House with electric energy (0, 1)	−0.143	0.0461	0.336	0.078**
		(0.197)	(0.051)	(0.270)	(0.033)
	House with freezer (0, 1)	0.030	−0.111	0.308	0.108**
		(0.321)	(0.073)	(0.346)	(0.045)
Access to ferias	Time to paved road (logs)	0.019	0.011	−0.100	0.001
		(0.053)	(0.015)	(0.068)	(0.007)
Land	Hectares worked (Has)	0.030	0.028**	−0.053	−0.002
		(0.051)	(0.012)	(0.049)	(0.005)
	Household with 2 plots	0.487	0.110*	−0.668**	−0.020
	(0, 1)	(0.330)	(0.062)	(0.304)	(0.056)
	Household with 3 plots	0.295	0.147**	−0.230	0.007
	(0, 1)	(0.209)	(0.063)	(0.348)	(0.051)
	Household with 4 plots	0.377	0.205**	−0.769**	−0.024
	(0, 1)	(0.266)	(0.080)	(0.366)	(0.051)
	Household with 5 plots	0.793***	0.204**	−0.596*	−0.005
	(0, 1)	(0.297)	(0.080)	(0.351)	(0.059)
	Household with >5 plots	0.906**	0.525***	−0.434	−0.048
	(0, 1)	(0.355)	(0.106)	(0.385)	(0.053)
	Flat hectares worked (%)	−0.244	−0.008	0.006	N/A
		(0.156)	(0.047)	(0.219)	
	Constant	−0.395	−0.162	8.202***	0.599***
		(1.070)	(0.280)	(1.596)	(0.182)
	Observations	1264	1264	1264	1264
	R-squared	0.166	0.215	0.374	0.277

Notes: The dependent variable is the: TLU index for cows in column (1); TLU index for bulls in column (2); Head of the household education (years) in column (3); and Share of flat land in column (4). All models are estimated by 2SLS and include municipality fixed effects. Robust standard errors clustered at the community level are in parentheses.
* Significant at 10% level.
** Significant at 5% level.
*** Significant at 1% level.

Appendix B. FAO food security index

In order to obtain a measure of food security at the household level, we use 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 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: (i) eight questions related to food insecurity experienced by adults; and (ii) seven similar questions related to food insecurity affecting children under 18 years of age in the household. The questions are the following:

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

1. You were worried to run out of food in the household?
2. Your household ran out of food?
3. Your household was unable to eat healthy and nutritious food?
4. You or any adult in the household ate only few types of food?
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/they should have eaten?
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?
9. Any children in the household were unable to eat healthy and nutritious food?
10. Any children in the household ate only a few kinds of foods?
11. Any children in the household had to skip a meal?
12. Any children in the household ate less than you thought they should?
13. You had to reduce the amount of food served to the children in the household?
14. Any children in the household were hungry but did not eat?
15. Any children in the household went without eating for a whole day?

According to this index, the levels of food insecurity rise with positive responses. The classification of households within each category of food (in) security is done by 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 (answer the first 8 questions only)	0	1–3	4–6	7–8
Households with adults and children under 18 years of age (answer 15 questions)	0	1–5	6–10	11–15

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).

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