Report to the Millennium Challenge Corporation: An Impact Evaluation of the Rural Business Development Program for Rice and Plantain Producers in Nicaragua

Conner Mullally

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Executive Summary

This report is an impact evaluation of two components of the Rural Business Development Program (RBD) in Nicaragua, specifically the components benefitting rice and plantain farmers on Nicaragua's Pacific coast. The RBD program helped finance irrigation equipment, inputs, and extension services for plantain producers, as well as extension, inputs, and drying patios for rice producers in 2009 and 2010; the price of rice is a function of its moisture content, and by increasing access to drying patios the RBD program sought to increase the value of sales by producers. Using a unique data set collected for the evaluation, average impacts of the RBD program on participating plantain farmers were estimated using difference-in-differences, while average impacts of the rice component on beneficiaries were estimated using fixed effects regressions. Estimated program impacts were combined with administrative cost data to calculate an internal rate of return for the plantain program and for one aspect of the rice program (construction of drying patios). Key results of the evaluation are:

- Estimated impacts suggest that the RBD rice program raised yields and revenues by 11% in the 2009 – 2010 growing season and 18% in 2010 - 2011 on average relative to the yields and revenues beneficiaries would have obtained without the program.
- The estimated IRR of the drying patio component of the RBD rice program ranges from 7% under the assumption of a five year lifespan for drying patios to 27% when assuming a 20 year lifespan.
- No IRR was estimated for the input/extension component of the rice program; part of the value of the extension/input bundles received by beneficiaries was to be paid back by each beneficiary farmer to his or her cooperative, and the sum total of payments was to serve as seed money for credit funds managed by cooperatives in future years. The

reliance of future benefits of this program component on farmer repayment performance makes its long-term value uncertain; therefore I chose to focus my IRR calculation on the drying patios.

- While average impacts and the drying patio IRR are both positive, RBD rice program impacts are estimated imprecisely, and we cannot reject the null hypothesis that average impacts of the program on yields and revenues were zero.
- Estimated impacts of the RBD plantain program were large and significant for revenues and yields of first quality plantains (harvested plantains come in three different quality grades).
- The average impact of the RBD program on sales suggests that the program raised the value of plantain sales by 72% relative to what beneficiaries would have obtained without the RBD program.
- I use the estimated impact on revenues as well as administrative data on production costs and program costs to estimate the IRR of the plantain program.
- The plantain IRR ranges from -23% when assuming a lifespan of 5 years for irrigation equipment and 13% when assuming a lifespan of 20 years.
- The apparent discrepancy between large impacts on sales and the modest IRR is a reflection of the high cost per beneficiary of the program, which was around $15,062 per farmer for the cohort studied here (around $3.6 million divided by 239 beneficiaries).

In sum, the RBD program appears to have had success in the short term in the case of the plantain component, while conclusions regarding positive effects of the rice component are tempered by the lack of precision in estimated impacts. Long-term benefits will hinge on the ability of individual farmers and farmer cooperatives to properly manage their new productive capital.

Introduction

Identifying interventions that can help small farmers adapt to an evolving agricultural sector is a key goal of development policy. In the case of Nicaragua, one major change to the economic landscape in agriculture is the signing of CAFTA-DR, a regional trade agreement between the US, the Dominican Republic, and the nations of Central America. Although agriculture has not historically been a protected sector in Nicaragua, rice has benefited from trade protection (Berthelon, Kruger and Saavedra 2007). Nicaragua will phase out rice tariffs over the coming years as part of CAFTA-DR, raising the question of whether or not policy intervention could help small producers adjust to heightened competition, and if so, how. One possible policy response to changing rice markets would be to monetarily compensate farmers for bearing the costs of opening up to trade, as in the case of the PROCAMPO program in Mexico (Sadoulet and de Janvry 2001). But it may be less costly and more effective to address market failures through short-term policies, allowing the best rice producers to compete at liberalized prices. In addition, long-term policies such as PROCAMPO are generally not an option for international development institutions, key players in small countries like Nicaragua, while interventions with a limited lifespan are. Evidence on the effectiveness of short-term interventions could therefore be quite valuable to policymakers.

Another aspect of the agricultural economy in Nicaragua is the prominence supermarkets (Reardon, Michelson and Perez 2012). For smallholder producers of highly perishable crops such as plantain, the question is how small producers can best position themselves to take advantage of new marketing opportunities presented by the rise of supermarkets. Supermarkets demand a constant stream of high-quality produce and adherence to strict phytosanitary standards. Failures in the market for information that prevent farmers from learning how to adopt standards and an inability to finance productive capital can potentially shut small farmers out of supermarket value chains. Identifying interventions that can address these market failures and allow farmers to increase the volume and quality of production is therefore highly relevant to agricultural development policy.

This report is an evaluation of the Rural Business Development (RBD) program for smallholder rice and plantain producers in León and Chinandega, located on the Pacific Coast of Nicaragua. The program was funded and administered by the Millennium Challenge Corporation (MCC) through the Nicaragua Millennium Challenge Account (MCA-N). The program helped fund the creation and execution of producer "business plans" meant to build up the commercial viability of smallholder agricultural production on the Pacific Coast.

In the case of rice, business plans detailed how producers would improve agricultural practices on two manzanas[1] of rice by using high-quality inputs and applying agricultural extension advice. The emphasis of extension advice was placed on the proper use of chemical fertilizers and efficient use of agrochemicals, including the adoption of integrated pest management, as well as better management of the post-harvest stages of production. A total of 309 individual rice business plans were approved, and MCC paid up to 30% of the cost of each individual plan and 12% of program costs overall. Extension and inputs were received by beneficiaries as in-kind loans to be paid back to their cooperatives net of the discount from MCC. Cooperatives would use the loan repayments to establish rotating credit funds after the close of the RBD program, expanding access to liquidity among their members. MCC also helped fund drying patios for eight participating cooperatives; all 480 cooperative members would have access to the drying patios, whether or not they had approved business plans and received subsidized inputs and extension (MCA-N 2011).

[1] 1 manzana = 1.72 acres = 0.70 hectares

Beneficiaries of the plantain component also received up to 30% funding of business plans, and MCC paid for 25% of total program costs. Plantain beneficiaries received micro-aspersion irrigation equipment and inputs for up to two manzanas of plantain; unlike the case of rice farmers, inputs did not pass through cooperatives before being received (MCA-N 2011). The program also expanded capacity at local collection centers where plantains are peeled and prepared for sale to processors. While the rice component had a single cohort of beneficiaries, three cohorts of plantain producers joined the RBD program, totaling 414 farm households. This evaluation focuses on the last cohort of plantain producers, which included 239 producers that entered the program in the 2009-2010 agricultural year.

Estimates indicate that the rice component of the RBD program had a positive average impact on rice yields and revenues among beneficiaries; estimated impacts suggest that both yields and revenues were 11% higher in 2009 and 18% higher in 2010 than they would have been if beneficiaries had not participated in RBD. However, we cannot reject the null hypothesis that rice program impacts were zero. For the plantain component, results show large, positive, and significant impacts on plantain revenue in 2010-2011, as well as large and significant impacts on yields and substantial impacts on irrigated area.

This report provides further evidence on the effectiveness of agricultural development interventions based on the transfer of productive assets, extension advice, and loosening of liquidity constraints. As shown by Del Carpio and Maredia (2011), there are a relatively small number of rigorous impact evaluations of agricultural extension, rural credit market, and irrigation projects in the literature, and none that measure the impact of small-scale processing facilities such as the drying patios built through the RBD program; most evaluations of infrastructure additions in the context of agriculture measure the effects of larger projects, such as roads (e.g., Dercon, et al. 2009). Del Carpio and Maredia (2011) survey the literature from 2000 through 2009 and identify 26 studies of agricultural extension projects, 9 addressing rural credit interventions, and 11 irrigation studies that satisfied a few basic criteria for categorization as a rigorous impact evaluation.[2] Of the projects identified, 13 extension projects, 6 credit interventions, and 7 irrigation projects showed positive impacts, while the effects of the majority of other projects were not statistically significant. Outcomes used in the surveyed evaluations included yields, income, production, and profits. The literature has grown since 2009,[3] but the point remains that there is much room for improvement and deepening of the evidence for the effectiveness of interventions such as the RBD program.

Selection into the RBD program was not random, and as a result I must make assumptions beyond those of an experiment in order to identify RBD program impacts. I employ different methods in evaluating the impact of each program component to account for the fact that rice beneficiaries were affected by the program in both years while plantain beneficiaries should only have been affected in year two when newly installed irrigation equipment should have begun to take effect on production. In the case of rice, I use a first-differenced regression model, relying on temporal variation in the per-hectare value of inputs and extension received by beneficiaries, variation across cooperatives in the timing of the completion of the drying patios, and a sub-sample of rice producers who did not receive any RBD program benefits to identify the Average Treatment Effect on the Treated (ATT), i.e., the average impact of the program on beneficiaries of the RBD program. In the case of plantain, I exploit the fact that beneficiaries should not have felt any program effects until year two of participation, and estimate the ATT of the RBD program using

[2] Basic criteria for inclusion were 1) A focus on agriculture, 2) A defined agricultural intervention, 3) A clearly stated counterfactual (e.g., cannot measure impact simply by using a before and after comparison on a single group).
[3] For example, see the special issue of the Journal of Agricultural Economics dedicated to impact evaluations in agriculture (Winters, Maffioli and Salazar 2011).

difference-in-differences, where the comparison group is mostly comprised of rejected RBD program applicants.

Background

According to the 2005 Nicaragua Census, the departments of León and Chinandega are home to around 830,000 persons, 39% of which live in rural areas. Access to basic services is second only to the capital of Managua, but poverty rates are still quite high, with 50% of residents in poverty and 12% in extreme poverty. Nearly all smallholder agriculture is rain-fed, with the vast majority of irrigated land under the control of large agribusinesses, usually sugarcane or plantain. Primary crops include sesame, maize, and sorghum, and rice. Smallholder rice production is rainfed, with the few irrigated acres available dominated by a small number of agroprocessors. Rice is the primary staple crop in Nicaragua and a portion of the crop is typically grown for household consumption. By comparison, plantain is largely a cash crop on the Pacific Coast and is relative newcomer to the area. Farmers on the Pacific Coast of Nicaragua began planting plantain as a main crop beginning in the 1990s on land received through earlier agrarian reforms. Production was limited to small-scale operations where farmers sold output individually to middlemen at the farm gate. Beginning in 2003 production began to commercialize in earnest as farmers started to organize themselves into cooperatives with the help of development projects from the EU and USAID (MCA-N 2011).

RBD program eligibility and costs

In the case of the rice component, the emphasis of the RBD program was to address shortcomings in management practices by small scale producers, particularly with respect to the use of inputs and post-harvest management. The proper use of fertilizer was a key aspect of extension services received, as extension experts used chemical soil analysis and leaf color charts to teach farmers about nutritional needs of the rice plant at different points of the year. Extension experts also identified the wasteful use of agrochemicals as a management deficiency, and sought to improve farmer knowledge about their proper use. Lastly, bottlenecks in access to processing equipment such as drying patios and dominance of the demand side of the market by a small number of large processors were determined to be the cause of low output prices for rice farmers; this issue was addressed by the construction of drying patios for participating cooperatives, which would relieve processing bottlenecks and increase the value added of post-harvest activities for beneficiaries (MCA-N 2008).

Rice farmers interested in submitting individual business plans for the RBD program first had to meet eligibility criteria. These included:

- The producer has planted or currently has at least 2 manzanas of rice.
- Area of farm must be between 2 and 50 manzanas, non-irrigated.
- The main rice parcel must be property of the beneficiary.
- The main rice parcel must be outside environmentally sensitive areas.
- The beneficiary must be at least 20 years of age.

While these criteria were meant to be strictly enforced, experience during the process of data collection indicates that this was not the case, particularly with respect to land tenure; many farmers rent their rice plots, and eligibility had to be adjusted once the program had begun.

Farmers submitted requests for assistance to their cooperatives. The cooperatives then organized these requests into a single business plan that was submitted to the MCA-N for approval. The business plans themselves are at the cooperative level but are collections of requests made by individual farms to participate in the RBD program, along with proposals for the construction of drying patios. Whether or not an individual farmer participates in the program depends upon the decision by producers to apply, the decision by their cooperatives to include them in the collection of business plans sent to MCA-N, and the decision by MCA-N to approve or reject the collection of plans.

Drying patios were ready for three cooperatives in December 2009, about half of the way through the harvest period, while all participating cooperatives had access to them in 2011; no cooperative had a drying patios prior to the start of the program, although a small number of farmers in the data collected for the evaluation own their own drying patios. Access to the drying patios is at the discretion of each cooperative, but discussions with program officers and agricultural extension workers indicate that cooperative members would get priority of use. Costs of the rice component of the RDB program and the number of beneficiary households are summarized in Table 1 below:

Table 1: RBD rice program costs and number of beneficiaries					
Year	Number of beneficiaries*	Costs paid by participants	Costs paid by MCC	Total	Cost per beneficiary
2009	480	$1,092,760	$240,358	$1,333,119	$2,777
2010	-	$1,048,955	$79,044	$1,128,000	$2,350
Total	**480**	**$2,141,716**	**$580,602****	**$2,722,317**	**$5,672**
* All 480 beneficiaries entered in 2009 and remained in program for two years. 309 beneficiaries received in-kind loans of extension services and inputs ** Includes $261,199 payment made to Chemonics					

Drying patio construction accounted for 6% of the total budget, while the remainder went to inputs and extension. In other words, the vast majority of RBD resources went to the 309 producers with approved individual business plans, but a larger group of cooperative members could potentially benefit from those resources after the close of the program if cooperatives succeeded in establishing rotating credit funds.

As in the case of the rice program, management deficiencies were a key point of emphasis in the plantain component of the RBD program. In addition, MCA-N recognized that plantain producers would need to sharply improve output and quality in order to participate fully in modern agricultural value chains. This was the impetus behind the installation of irrigation equipment. Plantain producers wanting to participate in the RBD program had to meet the following criteria:

- Must have at least 2 manzanas with access to a water source for year round irrigation
- Area of farm must be between 2 and 20 manzanas
- Must have planted at least 2 manzanas of plantain prior to installation of irrigation system (later reduced to 1 manzana)
- The depth of the well for irrigation water cannot exceed 15 meters
- The main land parcel for plantain must be property of the beneficiary

- The main land parcel for plantain must be outside environmentally sensitive areas
- The beneficiary must be at least 20 years of age

Plantain producers had to submit a business plan to the MCA-N office in order to participate. Costs of the RBD plantain component are given below in Table 2.

Table 2: RBD plantain program costs and number of beneficiaries, by cohort

Cohort	Number of beneficiaries	Costs paid by participants	Costs paid by MCC	Total	Cost per beneficiary
2007	60	$1,097,069	$450,654	$1,547,723	$25,795
2008	115	$2,281,517	$607,921	$2,889,438	$25,125
2009	239	$2,708,234	$910,638	$3,618,872	$15,141
2010*	-	$27,800	$13,552	$41,352	
Total	**414**	**$6,114,621**	**$1,982,766****	**$8,764,895**	**$21,171**

* All amounts in 2010 US$. 2010 costs were for construction of a collection center
** Includes $667,508 paid to Chemonics

Around 34% of the total cost of the program went to purchase and installation of irrigation equipment. The cost per beneficiary of the plantain component was far higher than that of the rice component, and MCC paid a larger share of the total cost for the plantain component (23%) than for rice (21%). However, it should be noted that these costs do not include the value of time provided by MCA-N, their efforts to promote the RBD program, or their ability to cut transaction costs relative to those faced by individual farmers and cooperatives. These may be the factors that allow a development agency to overcome market failures that constrain agricultural development, rather than the simple provision of services. The market for agricultural extension can fail if transaction costs associated with working with individual farmers are too high, or if uncertainty over the value of information drives a wedge between willingness to pay for extension among farmers and price for private extension. Transaction costs can also hamper investment in productive capital and financing of inputs by limiting supply of credit to small farmers. MCA-N addressed the problem of different values of information by meeting with farmer cooperatives and individuals in order to promote the program, and cut transaction costs by contracting extension agents and purchasing inputs in bulk. The added time of these services and the reductions in transaction costs would have offsetting effects on the total bottom line of the program, but they would likely raise the share paid by MCC.

Data collection

A sample of 450 farm households, including 300 rice producers and 150 plantain producers, was drawn from lists provided by MCA-N. This unbalanced split was chosen because the original evaluation design was to collect a single round of information from rice households while collecting two years of data from plantain producers, and irrigation was expected to have a large impact on sales and production, implying that a smaller sample would be needed in the case of plantain to precisely estimate program impacts.

In order to maximize statistical power with respect to estimated RBD impacts, the subsample of rice producers was originally selected to yield an equal split between RBD beneficiaries and non-beneficiaries, under the assumption that the only benefit received from the RBD program in its initial year was extension and inputs. However, this optimal split was undermined by several factors. Firstly, it was revealed prior to the second round of data collection that some cooperatives had operating drying patios by the time the 2009-2010 harvest arrived. Secondly, the purpose of the evaluation was expanded in order to measure impacts in year two of the program, when all cooperatives participating in RBD would have operating drying patios. On one hand this is unfortunate because estimating impacts of three separate interventions (inputs/extension, inputs/extension plus access to drying patio, and access to a drying patio only) asks considerably more of the data than estimating the impact of a single intervention. The result is estimated impacts that are likely to be less precise than what would be obtained if focusing solely on the effect of inputs and extension. On the other hand, the variation in access to drying patios across the two years of the evaluation makes is possible to isolate the effects of input and extension from that of the drying patios; in 2009-2010, there were some farmers who only had access to credit and extension, some who only had access to the drying patios, some who received both benefits, and some farmers who received neither benefit. In 2010-2011, farmers either received no benefit or had access to drying patios as well as credit and extension. This variation in access to drying patios is exploited below in the econometric analysis.

The data were collected in two household visits shortly after the post-harvest stage of the agricultural calendar for rice farmers in 2010 and 2011. The timing of data collection means that RBD beneficiaries had already been affected by the program when the survey was conducted. The danger of using data collected after the intervention is that we may “partial out” part of the impact of program; i.e., we may hold fixed one of the channels through which the impact of the RBD program is realized, biasing estimated program effects (Rosenbaum 1984).

Monitoring data from the plantain component of the program indicated that beneficiaries began receiving irrigation equipment in August of 2009 and that irrigation would begin to result in higher production in April of 2010, or approximately when data collection for the baseline survey was concluded. As a result, the potential for holding variables constant that may have been affected by participation in RBD is of greater concern in the case of rice. To guard against this possibility, recall data were collected on purchases and sales of consumer durables, agricultural implements, and land in order to construct a measure of the wealth of each household prior to implementation of the RBD program, in addition to data on the current household situation. These assets are major elements of wealth and it seems reasonable to expect households to remember substantial changes in asset holdings over a one year period. These data were used along with information on construction materials used in housing and access to basic services to construct indices of agricultural and non-agricultural wealth using Principal Components Analysis (PCA).[4] Each index serves as a ranking of a household with respect to a particular kind of wealth, and these indices were used to control for household wealth in the case of the rice component. For plantain producers, wealth was recorded as the sum of the self-reported values of land, durables, and agricultural implements, net of the value of irrigation equipment purchased in 2009 or later. This aggregate measure was used along with an indicator for having a dirt floor to control for wealth among plantain households.

For data on the agricultural year immediately prior to the RBD program, rice and plantain households were asked about loans taken out for agricultural activities, changes in household membership and demographics, and sown area of marketed crops. Data on crops in the previous year included planted area and output of rice, allowing us to control for a key pre-RBD agricultural outcome for rice beneficiaries and non-beneficiaries. Other information collected included non-agricultural and unearned income, geographic location, sown area suffering production shocks (drought, flooding, and excessive rain) in 2009-2010 and 2010-2011, and expectations regarding rice or plantain production.[5]

[4] PCA maps variables into a series of orthogonal components explaining successively smaller shares of the total variation of whatever is being indexed. Härdle (2007) offers a more detailed explanation of PCA with examples of applications.

[5] Farmers were asked what they typically produced in years characterized by good, bad, or normal conditions for growing rice. The questions were framed to capture expectations based on experience, but if the RBD program had permanent impacts on productivity, including these variables in the model might bias estimated impacts. For the rice and plantain models considered here, excluding our measures of subjective productivity had no effect on conclusions drawn from the analysis.

Rice summary statistics

Summary statistics for the subsample of households that planted rice in both years are presented below in Table 3:[6]

[6] A logit regression with selection into both years of the data as the dependent variable was run to look for impacts of panel attrition on the characteristics of the sample. No variables were found to be significant, and weighting our models of RBD rice impacts to correct for panel attrition had no substantive effect on our results.

Table 3: Summary statistics by treatment status, rice

	Means				Normalized Differences in Means			T-statistics		
	All Beneficiaries	Inputs/extension and patios	Patios only	Non-beneficiaries	All Beneficiaries	Inputs/extension and patios	Patios only	All Beneficiaries	Inputs/extension and patios	Patios only
Variables	(1)	(2)	(3)	(4)	Column (1) - Column (4)	Column (2) - Column (4)	Column (3) - Column (4)	Column (1) - Column (4)	Column (2) - Column (4)	Column (3) - Column (4)
Years of Education (most educated member), 2008	10.27	10.71	9.24	9.49	0.142	0.218	-0.047	1.10	1.65 *	-0.30
Female Head of Household, 2008[a]	0.10	0.10	0.08	0.11	-0.039	-0.022	-0.081	-0.29	-0.16	-0.51
How Many of Last 10 yrs. With Rice	6.72	6.87	6.36	7.2	-0.108	-0.075	-0.178	-0.88	-0.58	-1.17
Expected Yield in a Good Year (100 lb/Ha)	121	123.3	115.5	119	0.055	0.131	-0.099	0.44	0.98	-0.65
Expected Yield in a Bad Year (100 lb/Ha)	53.11	55.13	48.45	59.36	-0.185	-0.126	-0.314	-1.41	-0.92	-2.03 **
Expected Yield in an Average Year (100 lb/Ha)	90.79	92.92	85.88	91.29	-0.018	0.063	-0.173	-0.15	0.48	-1.15
Altitude of Farm, Meters above Sea Level	117.7	110	135.3	168.8	-0.375	-0.462	-0.214	-3.05 ***	-3.45 ***	-1.42
Total Planted Area (Ha), 2008	7.13	6.50	8.57	7.17	0.005	-0.062	0.064	0.05	-0.44	0.44
Secure Land Tenure[a]	0.93	0.96	0.86	0.97	-0.003	-0.056	-0.275	-0.02	-0.43	-1.88 *
Simpson Index of Crop Diversity[c], 2008	0.60	0.60	0.58	0.59	-0.141	0.028	-0.029	-1.25	0.21	-0.19
Index of agricultural wealth, PCA component 1	0.12	0.12	0.13	0.08	0.011	0.013	0.013	0.08	0.09	0.09
Value of Land and Ag. Implements ($), 2009	55,317	58,036	49,063	36,517	0.013	0.198	0.121	0.10	1.74 *	0.81
Index of Non-agricultural wealth, PCA component	0.20	0.38	-0.22	-0.30	0.176	0.246	0.028	1.68 *	2.11 **	0.19
Value of Consumer Durables ($), 2009	969.5	1,063	754	1,053	0.180	0.005	-0.138	1.67 *	0.03	-0.86
Owns Non-agricultural Business, 2008[a]	0.39	0.42	0.32	0.31	-0.038	0.149	0.009	-0.27	1.11	0.06
Loan from Farmer's Cooperative, 2008[a]	0.20	0.24	0.10	0.06	0.108	0.355	0.111	2.76 ***	3.15 ***	0.73 *
Observations	165	115	50	35	200	150	85	200	150	85

[a]Dummy, 1=Yes 0=No, [b]Farmers who planted in 2008, 2009, 2010 (141 beneficiaries, 32 non-beneficiaries), [c]Simpson Index = $\sum_{i=1}^{n} p_i^2$, where p_i is the proportion of a farm's total sown area taken up by crop *i*, *Significant at 10%, ** 5%, ***1%.

Table 3 shows summary statistics and differences means for key variables among all RBD rice beneficiaries, beneficiaries who had approved business plans (direct beneficiaries), beneficiaries that did not have business plans but were members of cooperatives receiving drying patios (indirect beneficiaries), and non-beneficiary households. Non-beneficiary households consist of 20 members of a cooperative that was eliminated from the RBD program for not maintaining its legal status, and 16 farmers who do not belong to any cooperative. The latter group consists of the farmers located by enumerators in the field to complete the sample when the list of replacements was exhausted because of failure to meet RBD program criteria.[7]

Table 3 shows means, normalized differences (i.e., differences in means divided by the sample standard deviation) and t-statistics for direct and indirect beneficiaries versus households ineligible for the RBD program. Unlike t-statistics, normalized differences do not change with sample size; given the small number of observations in each of the three treatment groups, the normalized differences may be a better guide to how well I can expect linear regression to result in covariate balance than t-statistics. Rosenbaum and Rubin (1985) suggest that that normalized differences of less than 0.25 standard deviations for continuous variables are acceptable for regression analysis. By this measure, regression ought to do a good job of improving covariate balance across the two beneficiary groups and non-beneficiaries, except possibly with respect to altitude and expected yield in a bad year. Taken together, the normalized differences and t-statistics indicate that RBD beneficiaries are more educated, less productive under poor conditions for rice farming, wealthier in terms of land and agricultural implements (according to both the index constructed using PCA and the value of land and implements reported in the first round of the

[7] MCA-N only wanted to include producers meeting RBD criteria in the sample, as producers who were participating in the program but did not meet criteria would be removed following an audit in year 1. In reality, tenure requirements were loosened so as to allow producers who rented all land planted with rice to continue to participate.

survey), are more likely to have received a loan from farmer cooperative in 2008, and have farms at lower altitudes than their non-beneficiary counterparts.

Table 4 summarizes agricultural outcomes for RBD rice beneficiaries and non-beneficiaries for the 2008-2009, 2009-2010, and 2010-2011 rice growing years:

Table 4: Agricultural outcomes by year and treatment status, rice										
	Mean				Normalized Differences in Means			T-statistics		
	All Beneficiaries	Inputs/ extension and patios	Patios only	Non-beneficiaries	All Beneficiaries	Inputs/ extension and patios	Patios only	All Beneficiaries	Inputs/ extension and patios	Patios only
Variable	(1)	(2)	(3)	(4)	Column (1) - Column (4)	Column (2) - Column (4)	Column (3) - Column (4)	Column (1) - Column (4)	Column (2) - Column (4)	Column (3) - Column (4)
Yield (100 lb/Ha.), 2008-2009[b]	62.34	65.01	55.06	56.92	0.165	0.245	-0.064	1.26	1.81 **	-0.38
Yield (100 lb/Ha.), 2009-2010	68.45	68.15	68.86	78.66	-0.185	-0.192	-0.168	-1.44	-1.42	-1.09
Yield (100 lb/Ha.), 2010-2011	85.92	86.05	85.86	81.84	0.107	0.112	0.094	0.81	0.81	0.61
Price/100 lb Rice, 2009-2010	18.63	18.03	20.08	17.67	0.157	0.064	0.331	1.33	0.50	2.22 **
Price/100 lb Rice, 2010-2011	15.94	15.88	16.42	16.34	-0.084	-0.102	-0.048	-0.65	-0.74	-0.32
Rice Planted Area (Ha), 2008-2009	5.49	5.609	3.93	5.58	-0.007	0.003	-0.022	-0.06	0.02	-0.15
Rice Planted Area (Ha), 2009-2010	4.76	5.259	2.84	6.02	-0.116	-0.068	-0.235	-0.84	-0.49	-1.47
Rice Planted Area (Ha), 2010-2011	5.58	5.609	4.52	7.72	-0.117	-0.177	-0.041	-0.88	-1.14	-0.27
Loans for Agriculture ($), 2008-2009	3,651	1,799	6,450	1,969	0.063	-0.026	0.106	0.76	-0.17	0.83
Loans for Agriculture ($), 2009-2010	4,495	3,106	6,459	2,973	0.063	-0.019	0.092	0.77	-0.15	0.72
Loans for Agriculture ($), 2010-2011	5,058	2,843	8,354	3,861	0.036	-0.114	0.086	0.43	-0.78	0.67
Proportion of Rice Area with Shocks, 2009-2010	0.82	0.8031	0.75	0.72	0.178	0.035	-0.037	1.30	1.81 *	0.41
Proportion of Rice Area with Shocks, 2010-2011	0.79	65.01	0.76	0.78	0.012	0.245	-0.064	0.09	0.25	-0.24
Observations	165	115	50	35	200	150	85	200	150	85

[b]Farmers who planted in 2008, 2009, 2010 (141 beneficiaries, 32 non-beneficiaries)

*Significant at 10%, ** 5%, ***1%

RBD rice beneficiaries had substantially higher yields in 2008-2009, much lower yields in 2009-2010 (although the difference is not significant), and slightly higher yields in 2010-2011. Lower yields among direct beneficiaries in 2009-2010 were accompanied by a higher proportion of area planted with rice experiencing production shocks (mostly drought). Average prices received her hundredweight of rice are similar across all three groups in 2009-2010 and 2010-2011, with indirect beneficiaries receiving higher prices on average in 2009-2010 than non-beneficiaries. Indirect beneficiaries have greater loan volumes in all three years than direct beneficiaries and non-beneficiaries. Whether any of the differences or changes over time in productivity, prices received, or access to credit can be attributed to the RBD program will be addressed in the analysis that follows.

Estimation of rice impacts

Let the outcome (yields or revenue per hectare) for rice farm *i* at time *t* be Y_{it}, where $t \in [0,1]$. Let S_{it} represent the payment received per planted hectare of rice by farm household *i* at time *t* from the RBD program. Let d_{it} be a dummy variable taking a value of 1 if farm *i* is a member of a cooperative with a functioning drying patio at harvest time in year *t*. There will be overlap between the two groups of beneficiaries in each year, with all members of RBD-eligible cooperatives having access to new drying patios when $t = 1$. Farm characteristics at baseline (i.e., $t = -1$) and farm characteristics assumed to not be affected by S_{it} or d_{it} are contained in X_{it}, a vector of covariates with dimension *k*. The vector X_{it} includes baseline characteristics which do not vary over time, such as gender of the household head, as well as time-varying covariates, such as the proportion of area planted with rice affected by production shocks (primarily drought in 2009 and flooding in 2010).

Let u_i represent time-invariant, unobserved characteristics of farm *i* that may be correlated with S_{it} and d_{it} even after conditioning on X_{it}, while ε_{it} is an error term that is uncorrelated with X_{is}, d_{is}, and S_{is} for all *s*, $t \in [0,1]$. The model for the outcome is:

$$\begin{aligned} Y_{it} &= u_i + \delta t + \beta_1 X_{it} + \beta_2 \left(X_{it} \times t \right) + \\ &\gamma_1 d_{it} + \gamma_2 \left(d_{it} \times X_{it} \right) + \\ &\alpha_1 S_{it} + \alpha_2 \left(S_{it} \times t \right) + \alpha_3 \left(S_{it} \times S_{it} \right) + \alpha_4 \left(S_{it} \times S_{it} \times t \right) + \\ &\alpha_5 \left(S_{it} \times X_{it} \right) + \alpha_6 \left(S_{it} \times X_{it} \times t \right) + \varepsilon_{it} \end{aligned} \quad (1)$$

The change in the outcome between *t* = 0 and *t* = 1 for a given rice farm in the absence of the RBD program is given by $\delta + \beta_1 \Delta X_i + \beta_2 X_i + \Delta \varepsilon_i$. In other words, RBD rice beneficiaries and non-beneficiaries with identical observed characteristics would have experienced the same average change in the outcome in the absence of the program.

The impact of payments per hectare from the RBD program is allowed to vary with observed characteristics as well as over time. Production conditions were radically different in the 2009-2010 and 2010-2011 agricultural years, with the former characterized by drought and the latter by an excess of rain. Therefore it makes sense to allow for the effects of agricultural extension and inputs/extension to vary by year. There is not sufficient variation over time in d_{it} to allow the effect of the drying patios to vary with *t*, but it is interacted with observed characteristics.

Using the model given in equation (1), the average impact of the RBD program on farmers with characteristics *X* when *t* = 0 is given by:

$$\begin{aligned} \left[\text{ATT} \mid X, t=0 \right] &= \gamma_1 E\left[d_{i0} \mid X \right] + \gamma_2 E\left[d_{i0} \mid X \right] \times X + \\ &\alpha_1 E\left[S_{i0} \mid X \right] + \alpha_3 E\left[S_{i0} \times S_{i0} \mid X \right] + \alpha_5 E\left[S_{i0} \mid X \right] \times X \end{aligned} \quad (2)$$

Where ATT stands for "Average Treatment Effect on the Treated." In year *t* = 1, the ATT among farmers with characteristics *X* is:

$$\begin{aligned}&[\text{ATT} \mid X, t=1] = \gamma_1 E[d_{i1} \mid X] + \gamma_2 E[d_{i1} \mid X] * X + \\ &(\alpha_1 + \alpha_2) E[S_{i1} \mid X] + (\alpha_1 + \alpha_2) E[S_{i1} \times S_{i1} \mid X] + (\alpha_4 + \alpha_5) E[S_{i1} \mid X] \times X\end{aligned} \tag{3}$$

The average impact of the program over both years of operation is found by taking a weighted average of (1) and (2). The ATT for the entire population of beneficiaries when $t = 0$ is found by taking the expectation of equation (2) over the support of the distribution of covariates (X) within the group of RBD beneficiaries at time $t = 0$, with the ATT at year $t = 1$ defined similarly; these beneficiary populations differ in each time period because not all beneficiary cooperatives had drying patios constructed at time $t = 0$. For beneficiary cooperatives without drying patios in the initial periods, only the impacts of the RBD program on members who received RBD payments are included in the ATT at time $t = 0$.

Correlation between u_i and the different treatment variables means that estimation of (1) by OLS will result in biased coefficients. Instead, I take the first difference of equation (1), which results in:

$$\begin{aligned}&\Delta Y(i) = \delta + \beta_1 \Delta X_i + \beta_2 X_{i1} + \\ &\gamma_1 \Delta d_i + \gamma_2 \Delta(d_{it} \times X_{it}) + \\ &\alpha_1 \Delta S_i + \alpha_2 S_{i1} + \alpha_3 \Delta S_i^2 + \alpha_4 (S_{i1} \times S_{i1}) + \\ &\alpha_5 (\Delta S \times X_i) + \alpha_6 (S_{i1} \times X_{i1}) + \Delta \varepsilon_i\end{aligned} \tag{4}$$

All parameters needed to estimate the ATT of the RBD rice program in each year are identified by the first-difference formulation of the model.

Among the covariates included in the model are controls for geography (municipality in which the main rice plot is located, altitude of the plot), production expectations and conditions (shocks, what producers expect to produce under different conditions), demographics (age of household head, years of education of most educated household member), wealth (PCA indices of agricultural and non-agricultural wealth), and sources of liquidity (unearned income and transfers, ownership of another business), and owning a drying patio before the start of the program. I also include an indicator for having received a loan in 2008 from one's farmer cooperative. RBD program administrators worked with cooperatives to identify farmers who could succeed in the program, and as stated earlier, part of the motivation behind the subsidized in-kind loans of inputs and extension was to establish rotating credit funds for the cooperatives. Thus an indicator for having previously received a loan from your cooperative should control for a variety of otherwise unobservable producer characteristics correlated with RBD participation as well as yields and rice revenue. Selected variables were interacted with the RBD inputs/extension, while a smaller set of interactions was used for the indicator for having access to a drying patio. The results of estimating of equation (4) are given below in Table 5; the parameters displayed in the table are used to compute the estimated impacts of the RBD program following presentation of the regression results:

Table 5: Rice model results		
	Yields	Revenue
t (δ in equation (4))	73.52*** [20.14]	210.005 [0.45]
Cooperative had drying patio (γ_1 in equation (4))	18.53 [23.41]	279.4 [510.8]
RBD payment per planted hectare (α_1 in equation (4))	0.129 [0.0964]	0.881 [2.103]
RBD payment per planted hectare^2 (α_3 in equation (4))	-0.00003 [0.00004]	-0.000271 [0.000882]
RBD payment per hectare*t (α_2 in equation (4))	0.0518 [0.161]	6.206* [3.512]
RBD payment per hectare^2*t (α_4 in equation (4))	-0.000135* [0.00008]	-0.00342** [0.00167]
(Years of Education, most educated household member, 2008)*t	-0.863 [0.913]	12.50 [19.92]
(Municipality dummy 1)*t	6.972 [12.46]	498.3* [271.9]
(Municipality dummy 2)*t	10.27 [12.64]	244.9 [275.8]
(Municipality dummy 3)*t	-5.491 [11.17]	-9.394 [243.6]
(Age of household head, 2008)*t	-0.379 [0.239]	-4.427 [5.219]
(Altitude of Farm, Meters above Sea Level)*t	-0.0198 [0.0363]	0.104 [0.792]
(Expected Yield in a Bad Year (100 lb/Ha))*t	-0.623*** [0.139]	-5.624* [3.025]
(Loan from Farmer's Cooperative, 2008)*t	-10.38* [6.150]	-198.9 [134.2]
(Index of non-agricultural wealth, PCA component 1)*t	3.952** [1.879]	45.93 [40.99]
(Index of non-agricultural wealth, PCA component 2)*t	5.893*** [2.242]	74.28 [48.92]
Proportion of Rice Area with Shocks	-37.82*** [4.770]	-825.7*** [104.1]
Unearned income (transfers, pensions, etc)	-0.00461* [0.00255]	-0.109* [0.0557]

Interactions		
RBD payment*Education	0.00008 [0.00409]	0.0502 [0.0892]
RBD payment*Municipality 1	-0.0591 [0.0622]	-1.186 [1.357]
RBD payment*Municipality 2	-0.0189 [0.0588]	-0.335 [1.284]
RBD payment*Municipality 3	-0.0428 [0.0621]	-1.091 [1.355]
RBD payment*Age	-0.00226** [0.00108]	-0.0346 [0.0236]
RBD payment*Altitude	0.000170 [0.000227]	0.000147 [0.00496]
RBD payment*(Expected yields, bad year)	-0.000173 [0.000650]	0.0106 [0.0142]
RBD payment*(Non-ag wealth, comp. 1)	-0.000604 [0.00713]	0.0778 [0.156]
RBD payment*(Non-ag wealth, comp. 2)	-0.00301 [0.0116]	-0.250 [0.252]
RBD payment*Transfers	0.00004 [0.00004]	0.000651 [0.000921]
RBD payment*Shocks	0.0375 [0.0287]	0.832 [0.625]
RBD payment*Education**t*	0.0282*** [0.00910]	0.448** [0.198]
RBD payment*Municipality 1**t*	-0.0616 [0.109]	-4.469* [2.386]
RBD payment*Municipality 2**t*	-0.104 [0.0962]	-3.548* [2.099]
RBD payment*Municipality 3**t*	0.0531 [0.138]	-4.124 [3.001]
RBD payment*Age**t*	-0.00289 [0.00210]	-0.0320 [0.0459]
RBD payment*Altitude**t*	-7.51e-06 [0.000390]	-0.00722 [0.00851]
RBD payment*(Expected yields, bad year)**t*	-0.00248** [0.00109]	-0.0833*** [0.0238]
RBD payment*(Non-ag. wealth, comp. 1)**t*	-0.0394* [0.0202]	-0.409 [0.440]
RBD payment*(Non-ag. wealth, comp. 2)**t*	0.00966 [0.0148]	-0.174 [0.323]

Interactions continued		
RBD payment*Transfers**t*	.00004 [.00005]	0.00116 [0.000991]
RBD payment*Shocks**t*	0.0206 [0.0819]	-0.326 [1.787]
Cooperative had drying patio*Age	0.191 [0.427]	4.879 [9.309]
Cooperative had drying patio*Altitude	-0.164* [0.0865]	-3.151* [1.886]
Cooperative had drying patio*(Non-ag wealth, comp. 1)	-1.549 [2.264]	35.73 [49.39]
Cooperative had drying patio*(Non-ag wealth, comp. 2)	-4.832 [3.446]	-68.24 [75.18]
Observations R-squared	200 0.654	200 0.619
OLS standard errors in brackets		
* significant at 10%; ** significant at 5%; *** significant at 1%		

The standard errors presented in Table 5 were calculated under the assumption that the error term in (4) is homoscedastic. Standard errors under the assumption of homoscedasticity were in general larger than those generated using a heteroscedasticity-robust covariance matrix, and the former are presented in Table 5 in order to ensure conservative conclusions with regard to statistical inference. However, this mode of inference is potentially problematic given that rice farmers in the data set are organized into eight groups: seven farmer cooperatives and a group of farmers not belonging to a cooperative. In addition, the main explanatory variables of interest, i.e. inputs/extension from the RBD program and access to drying patios, are highly correlated within these groups, or "clusters". If the error term in equation (4) is correlated within the clusters described above then the standard errors presented in Table 5 may be too small. However, for clustering to be an issue in statistical inference, it must be that both the regression error term and the explanatory variables of interest exhibit intracluster correlation. The regression residuals from both models exhibited no intracluster correlation, suggesting that clustering is not an issue I need be concerned with when calculating standard errors in the present case.[8]

Table 6 presents the estimated ATTs of the RBD rice program, the average impact of the inputs/extension, and average impacts of access to drying patios for both outcomes of interest over the two years of the program.

Table 6: Average impacts of the RBD rice program				
	Yields (hundreds of pounds per hectare)		Revenues per Hectare (2010 US$)	
	Two-year average		Two-year average	
Average Effect of the Program on Beneficiaries	9.89 [7.51]		136.6 [163.8]	
	Year one	Year two	Year one	Year two
	6.93 [7.09]	13.18 [8.43]	93.98 [154.5]	183.89 [183.93]
Average Impact of Drying Patios	4.63 [7.68]	7.87 [6.79]	80.08 [167.5]	142.17 [148.1]
Average Impact of Input/Extension	4.21 [4.51]	7.44 [7.82]	70.44 [98.49]	11.67 [170.56]
Standard errors in brackets. Standard errors calculated using the delta method.				

Table 6 shows the average impact of the program on beneficiaries for each outcome over both years of the program's operation, as well by year and by program component (patios and inputs/extension). We can use the estimated impacts presented in Table 6 and the summary statistics in Table 4 to translate estimated impacts into percentages. Average yields among RBD beneficiaries in 2009-2010 were 68.45 hundredweight per hectare; subtracting off the estimated program impact of 6.93 gives us an estimate of 61.52 for average yields that would have been

[8] Specifically, I used the "Moulton" package written by Jorn-Steffen Pischke and available from http://economics.mit.edu/faculty/angrist/data1/mhe/brl to adjust the OLS covariance matrix for intracluster correlation, using the Moulton parametric correction factor (Moulton 1986). The calculations needed to compute the Moulton factor revealed that the OLS residual exhibited no intracluster correlation, i.e., no adjustment was needed for the estimated standard errors to be consistent, provided the assumption of homoscedasticity is correct. While it may be the case that the estimate of the intracluster correlation will be imprecise given the small number of groups in the data, the results of applying the Moulton correction suggest that clustering is not an important problem in these data.

obtained by RBD beneficiaries had they not participated in the program. Dividing the program impact of 6.93 by 61.52 suggest that RBD participation raised yields by 11% on average relative to what would have been obtained had beneficiaries not participated in the program. Repeating this calculation for 2010-2011 gives an estimated percent impact of 18%. Using this same method, estimated revenues per hectare among beneficiaries in 2009 in the absence of RBD participation are estimated to be $1,164; thus the estimated impact on revenues per hectare in 2009 of $93.98 translates into an 8% increase. In 2010, revenues per hectare without RBD participation for RBD beneficiaries are estimated to be $1,173, and the percent increase in revenues per hectare was 16%. The larger magnitudes of impacts in year 2 are unsurprising given the severity of the drought in 2009, as described in the introduction to this report. However, none of the estimated average impacts can be statistically distinguished from zero; the smallest p-value among the estimated ATT parameters in Table 6 is that for the average impact on yields in year two ($p = 0.12$). These ATTs were also estimated after correcting for panel attrition using inverse probability weighting; this change in the regression specification had no effect on the signs, magnitude, or significance of the ATTs.

Calculating the net economic benefits of the RBD rice program is complicated by the fact that the long-term benefit of the extension and inputs delivered by the program will come from the ability of the cooperatives to establish rotating credit funds. I opt to not speculate with respect to the viability of this component of the program and instead estimating the internal rate of return for the rice patios. I do this using the estimated average impacts for the rice patio component in year two of the program, despite the fact that the impact is not significant at conventional levels. The lack of precision in the estimated impact of the patios should clearly be taken into consideration when deciding how much weight to place on the estimated rate of return; this decision is left to the reader. Table 7 below calculates the internal rate of return of the drying patios for the six cooperatives in the sample using four different lifespans.

Table 7: Internal Rate of Return, Drying Patios				
Lifespan of drying patios beyond the RBD project:	5 years	10 years	15 years	20 years
Internal rate of return:	7%	21%	25%	27%
Linear depreciation and zero salvage value assumed.				

Taking the estimated impact on revenues in year two from Table 6 as representative of impacts of the patios going forward, deducting out construction costs, and assuming linear depreciation with no salvage value leads us to conclude that the patios show a positive economic return even with a brief lifespan.

Potential spillover effects

It should be noted that we cannot rule out the possibility that non-beneficiary households were affected by the RBD program, i.e., that there were spillover effects. Non-beneficiary farmers could make use of the information learned from extension agents by beneficiary farmers and raise their own yields or revenues, leading to a downward bias of the estimated impact of inputs and extension on yields and revenues. An argument against this is that farmers are likely to mimic the actions of their neighbors and peers when they are successful, such as in the study by Conley and Udry of input use among pineapple growers in Ghana (2010). Given that there is one rice harvest per year in Leon and Chinandega, farmers not participating in the RBD program would have had very little information to act upon when deciding to change their production practices to mimic those of RBD program participants. As a result, strong impacts on production practices of non-beneficiaries and indirect beneficiaries seem unlikely.

Another potential channel for spillovers is impacts on input and output prices brought about by changes in input demand and output levels among beneficiaries. Given the small number of growers represented by the program, this seems doubtful. Lastly, the construction of drying patios could have raised revenues for non-beneficiaries through greater access to the patios, and raised yields through increased incentives. This would mean a downward bias in the estimated impacts of the drying patios. Cooperatives stated that they would give preferential access to their members in the use of drying patios, which is exactly what we would expect, but this does not rule out the possibility of benefits for non-beneficiary farmers. A back of the envelope calculation suggests that it would take 16 to 30 days on average for all of a cooperative's members to dry their output.[9] Any delay in drying of harvested rice leads to a rapid delay in quality, and presumably a lower sales price.[10] Therefore non-beneficiaries of the RBD program would not likely wait around to use drying patios built in part with MCC funds. However, if cooperative members are no longer using drying patios that were in place before the RBD program, then non-beneficiaries might gain by not having to wait as long to dry their harvests. In light of this possibility, we must conclude that the estimated impacts of the drying patios, and the program overall, are conservative.

Estimation of plantain impacts

A richer set of outcome variables was selected for the analysis of the plantain component,[11] including food consumption per capita, plantain production (in units), area planted with plantain (in manzanas), and application of a precision harvesting technique taught as part of the RBD program. The harvesting technique involves tying colored ribbons to the plantain heads and

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[9] According to RBD program documentation, each drying patio can dry 500 hundredweight of rice every four hours. Planted area averages around 5.6 hectares, and yields average around 68 hundredweight in 2009-2010 and 85 in 2010-2011; this suggests that each producer could dry his or her output in three to four hours. Assuming that two or three growers can dry their output per day would mean that a single cooperative of 65 members (the average number of rice grower per cooperative according to cooperative leaders) would need 16-30 days to dry everything for a single cooperative.

[10] For example, see http://www.knowledgebank.irri.org/factsheets/post-harvest-management/how-to-use-dryer.html.

[11] Since the original plan for the rice evaluation was to collect a single round of data, emphasis was put on measuring impacts of the rice component on outcomes for which pre-program recall data could be collected and expected to be reasonably accurate, such as rice yields and revenues as opposed to household consumption. Not having to rely on recall data made it possible to collect information on additional outcomes in the case of plantain.

changing the ribbon color at specified times. Farmers know it is time to harvest when arriving at the appropriately colored ribbon.

The outcomes were chosen in an attempt to present a comprehensive picture of RBD plantain program impacts. Food consumption per capita ought to give us an idea of overall welfare impacts of the RBD program on participating households. Impacts on yields for first and second quality plantain will capture program impacts on quantity produced and production quality.[12] Program impacts on area planted with plantain and irrigated area in production can show effects on crop composition among beneficiaries and the impacts of the RBD program on land productivity potential. Application of the precision harvesting technique taught by RBD extension agents are an indicator of the success of the knowledge transfer component of the program.

Explanatory variables are dominated by data from the first round of interviews so as to avoid biasing estimated impacts by holding variables constant that were affected by program participation, although time-varying covariates were also included, such as the proportion of plantain area hit by production shocks (not including drought, since this would likely be affected by access to irrigiation) and the week in which the household was interviewed (since the productivity of newly planted trees may be quite sensitive to time since planting).

I estimate the impacts of the plantain RBD component using difference-in-differences. The difference-in-differences method estimates program impacts by comparing the change in the outcome among participants to that of non-participants from the baseline period to a period after the close of the program. If in the absence of the program the group of participants (i.e., the “treatment” group) would have experienced the same average change in the outcome as the non-

[12] Plantains may be first, second, or third quality, with first quality receiving the highest price.

participants (i.e., the "control" group), then the difference in the average change in the outcome across the two groups is an unbiased estimate of the impact of the program on participants. In other words, the treatment and the control group can differ in the levels of the outcome that they would experience in the absence of the program, but the average change in the outcome experienced by the two groups in the absence of the program must be the same.

Let u_i be an observed, fixed household characteristic which may be correlated with participation in the RBD program. Let *POST* be a dummy variable taking a value of 1 in the period after participation in the RBD program and zero in the period prior to the start of the program. Let y_{i0} be the value of the outcome in the initial period. Let X_i be a set of time constant household characteristics or covariates measured at baseline which might affect growth in the outcome *y*. Let *RBD* be a dummy variable taking a value of 1 for RBD beneficiaries, i.e., the treatment group. Let Z_{i1} be the value of a time-varying household characteristic in the period after participation in the RBD program. Let ε_{it} be an error term that is uncorrelated with *RBD* in all time periods. We have the following expression for *y* in the initial period:

$$y_{i0} = u_i + \beta_0 RBD + \beta_2 X_i + \beta_3 Z_{i0} + \varepsilon_{i0} \tag{5}$$

and for *y* in the period after participation in the RBD program:

$$y_{i1} = u_i + \delta POST + \beta_0 RBD + \beta_1 RBD \times POST + \beta_{2'} X_i + \beta_3 Z_{i1} + \varepsilon_{i1} \tag{6}$$

Setting *RBD* = 1 in (5) and (6) and taking the difference between them gives us the change in the outcome for household *i* conditional on participation in the RBD program, or:

$$\begin{aligned} &\left(y_{i1} - y_{i0} \mid RBD = 1\right) = \\ &\beta_1 + \left(\beta_{2'} - \beta_2\right) X_i + \beta_3\left(Z_{i1} - Z_{i0}\right) + \left(\varepsilon_{i1} - \varepsilon_{i0}\right) \end{aligned} \tag{7}$$

Setting *RBD* = 0 in (5) and (6) and taking the difference gives us the change in the outcome for household *i* conditional on not participating in the RBD plantain program, or:

$$\begin{aligned}&\left(y_{i1}-y_{i0} \mid RBD=0\right)= \\ &\left(\beta_{2'}-\beta_{2}\right) X_{i}+\beta_{3}\left(Z_{i1}-Z_{i0}\right)+\left(\varepsilon_{i1}-\varepsilon_{i0}\right)\end{aligned} \tag{8}$$

Substracting the mean of (8) from the mean of (7):

$$E\left(y(i,1)-y(i,0) \mid RBD=1\right)-E\left(y(i,1)-y(i,0) \mid RBD=0\right)=\beta_{1} \tag{9}$$

If the assumption that ε_{it} uncorrelated with *RBD* in all time periods is correct, then β_1, is the average impact of the RBD plantain program on the outcome *y*.

Monitoring data and discussions with technicians from Chemonics (the firm contracted to implement much of the RBD rice and plantain programs) indicated that the newly installed irrigation systems should not have had any effect on production until April of 2010 at the earliest, and only for a minority of beneficiaires. Thus any effects of the RBD program in year 1 should be very limited and not include any of the effects of new irrigation. However, this is impossible to verify in the data. Data from the first round of interviews show that RBD program participants had a total of 254 irrigated manzanas planted with plantain, 195 of which had irrigation installed in 2009 or later; 95 of these newly irrigated manzanas were already in production at the time of the first interview, or around 48% of the total. This does not necessarily imply that irrigation systems received through RBD participation had already begun to affect output in earnest. It is equally possible that RBD beneficiaries installed irrigation on land from which plantain was already being harvested pre-program but that the bulk of program impacts would not occur until after a delay, e.g. once newly planted trees had begun to produce. Nevertheless, any effects of the RBD program that had already been realized prior to collection of the first round of data will bias impacts.

However, it is likely that these biases will push estimated impacts down and make any conclusions drawn about the magnitude of program impacts more conservative. The key assumption of difference-in-differences is that of "common trends," i.e., in the absence of the program the treatment and control groups would have experienced the same average change in the outcome variable. Suppose that the assumption of common trends holds in the present case, and that had data collection occurred prior to the realization of any program impacts, estimated impacts would represent an unbiased measure of the average impact of RBD-plantain on its beneficiaries. Now suppose that beneficiaries had already been positively affected by the RBD program prior to the arrival of enumerators collecting data for the evaluation. In this case, the difference in the average change in production-related outcomes (yields and sales) for beneficiaries and non-beneficiaries will be smaller than what would be observed had data been collected prior to the realization of any program impacts. Given that extra agricultural inputs and irrigation are unlikely to have had a negative effect on the outcomes used in this analysis, it seems reasonable to assume that the timing of data collection may have biased estimates of program impacts downwards but not upwards.

The common trends assumption may be more likely to hold if it is made conditional on observed characteristics. That is, farmers with similar characteristics pre-program would have the same average change in outcomes of interest in the absence of the RBD plantain program. This suggests that the group of beneficiaries (the treatment group) and the control group used to estimate the impacts of the RBD program ought to have similar observed characteristics. One way of ensuring that the treatment and control groups have similar distributions of observable characteristics is to restrict the sample to the common support of the propensity score. Unlike in the case of rice, where there are three different classes of rice producers (inputs/extension plus patios, patios, and no benefits), some of which are quite small, the plantain component lends itself to restricting the sample to beneficiaries and non-beneficiaries that are observationally similar. In the current context, the propensity score is the probability that a household will enroll in the RBD program conditional on observable characteristics. It is estimated here using a logit regression:

$$e_i = \frac{\exp\left(\pi_0 + \pi_1 X_i + \pi_2 Z_{i0} + \pi_3 Z_{i1}\right)}{1 + \exp\left(\pi_0 + \pi_1 X_i + \pi_2 Z_{i0} + \pi_3 Z_{i1}\right)} \quad (10)$$

where e_i is the propensity score and the π are coefficients to be estimated. The common support of the propensity score refers to the overlap of the support of the propensity score in the treatment and control groups. Restricting the sample to this region will change the interpretation of the estimated program impact if members of the treatment group are dropped from the sample; the estimated impact would then capture average program effects on treatment group households within the common support region of the distribution of the propensity score. But not restricting the sample would mean that for some treatment households the change in the outcome that would have occurred in the absence of the program would be estimated using control households that are observationally quite dissimilar. This is not a problem if the regression model used to estimate program impacts is the correct one, but the more likely scenario is that the regression is an approximation to the true process generating the outcome which becomes less accurate as the treatment and control groups become more dissimilar (Imbens and Wooldridge 2008). The main regression results presented below restrict the sample to the common support; these results were later tested for robustness to estimation using a broader sample of households, and our conclusions regarding program impacts were unaffected.

Plantain summary statistics

Table 8 below gives summary statistics for the indicators and covariates used in the analysis of the plantain program, as well as for the propensity score. The first four columns summarize the sample after removing a small number of observations with extreme values of at least some of the outcome variables, with means presented by treatment status, the differences in means normalized by the standard deviation in the treated group, and t-statistics for the difference in means. The second four columns present the same statistics for the portion of the sample on the common support of the propensity score.

Table 8: Plantain summary statistics								
	Full sample minus outliers				Common support			
	Mean: RBD==0	Mean: RBD==1	Difference: Normalized	Difference: T-stat	Mean: RBD==0	Mean: RBD==1	Difference: Normalized	Difference: T-stat
Linearized propensity score[a]	-0.132	1.350	0.654	5.693***	-0.132	0.803	0F.544	4.101***
Log of food consumption per capita, 2009	8.586	8.818	0.261	2.126**	8.586	8.758	0.193	1.449
Yield, 1st quality (units/mz.), 2009	15,113.88	13,333.77	-0.078	-0.616	15,113.88	12,656.87	-0.108	-0.797
Yield, 2nd quality (units/mz.), 2009	6,463.91	6,438.14	-0.002	-0.017	6,463.91	5,230.28	-0.104	-0.773
Plantain revenue ($US), 2009	3,304	2,997	-0.053	-0.417	3,304	2,606	-0.120	-0.889
Plantain area (mz.), 2008	1.167	1.110	-0.028	-0.232	1.167	1.206	0.018	0.138
Irrigated manzanas of plantain in production, 2009	1.020	1.349	0.150	1.235	1.020	1.230	0.095	0.712
Precision harvesting, 2009 and earlier	0.020	0.022	0.012	0.095	0.020	0.016	-0.018	-0.137
=1 if house has dirt floor	0.412	0.429	0.024	0.193	0.412	0.435	0.034	0.252
Altitude of farm, meters above sea level	30.725	32.543	0.082	0.695	30.725	30.781	0.003	0.021
=1 if municipality 1	0.078	0.121	0.099	0.825	0.078	0.065	-0.038	-0.282
Experience (num. of last 10 years with plantain)	4.137	4.077	-0.014	-0.109	4.137	3.919	-0.049	-0.366
=1 if member of cooperative pre-program	0.216	0.242	0.044	0.354	0.216	0.258	0.070	0.524
Production in a good year (units/mz.)	70,549.02	66,898.63	-0.097	-0.741	70,549.02	67,798.79	-0.072	-0.531
Production in a bad year (units/mz.)	39,176.47	37,377.53	-0.072	-0.567	39,176.47	37,069.44	-0.085	-0.629
Production in a bad year (units/mz.)	56,357.84	52,844.51	-0.109	-0.831	56,357.84	53,259.68	-0.096	-0.706
=1 if had other business pre-program	0.647	0.813	0.258	2.051**	0.647	0.774	0.195	1.449
Total unearned income ($US)	102	151	0.055	0.483	102	200	0.094	0.730
Total loans for agriculture ($US), 2008	89	107	0.035	0.278	89	123	0.059	0.444
Years of education, most educated member	9.275	9.692	0.074	0.599	9.275	9.484	0.037	0.275
Gender of household head	0.157	0.198	0.075	0.615	0.157	0.145	-0.023	-0.171
Household size, adult equivalents	4.218	4.006	-0.091	-0.729	4.218	4.142	-0.033	-0.243
Total wealth, pre-program ($US)	26,457	35,601	0.200	1.716*	26,457	35,755	0.185	1.422
Simpson index of crop diversity, 2008	0.675	0.664	-0.019	-0.151	0.675	0.682	0.013	0.096
Total planted mz., 2008	1.843	2.262	0.119	1.010	1.843	1.972	0.043	0.324
Share of mz. in production suffering shocks, 2009	0.525	0.490	-0.050	-0.406	0.525	0.558	0.047	0.351
Share of mz. in production suffering shocks, 2010	0.824	0.773	-0.092	-0.760	0.824	0.790	-0.061	-0.455
Week of interview, 2009	8.471	6.451	-0.481	-3.912***	8.471	6.887	-0.391	-2.921***
Week of interview, 2010	11.784	11.637	-0.085	-0.696	11.784	11.726	-0.032	-0.241
Observations	51	91			51	62		

[a] ln[*e*/(1- *e*)] where *e* is the propensity score

* significant at 10%; ** significant at 5%; *** significant at 1%

Using the same rule of thumb employed above in the case of rice with respect to standardized differences in covariates, none of our continuous explanatory variables chosen by theory are so different across the two groups that we might expect regression to struggle to eliminate biases due to imbalance. However, there are differences in pre-program wealth, ownership of other businesses, total wealth, and the week of the survey interview that might give us reason for concern.

When the sample is restricted to the common support, balance in per capita food consumption, business ownership, and the week of the 2010 interview is improved. The standardized differences increase for some of the covariates and 2009 outcomes, but for the covariates all differences remain within the range that can be dealt with using linear regression, with the exception of the week of the 2010 interview.

For the propensity score itself arule of thumb is that the normalized difference in means should be less than 0.50 standard deviations and the ratio of the variances in the treatment and control samples should be close to 1 when covariates are normally distributed (Rubin 2001). Although not shown here, the ratios of the variance of the propensity score are around 1 for both the larger sample and the sample restricted to the common support. The standardized difference in means remains large after restricting the sample to the common support, and further trimming of the sample only improved the situation when a large proportion of the remaining sample was removed. Given the already small sample, this was viewed as too large a sacrifice to improve balance. Overall, I am left with the impression that any method for estimating the counterfactual of no RBD program participation for the treatment group will require some degree of extrapolation and that biases in estimated impacts may remain. A larger sample of controls might be needed to remove all biases due to observed characteristics.

Plantain estimation results

The main estimating equation used for the econometric analysis of the plantain component is:

$$\Delta y_i = \delta + \beta_1 RBD + \gamma X_i + \beta_3 \Delta Z_i + \Delta \varepsilon_i \qquad (11)$$

That is, the first difference in the outcome is regressed on an intercept, and indicator for being an RBD beneficiary (*RBD*), baseline household characteristics (*X*), and the change in time-varying characteristics (*Z*, which includes shocks to plantain area and the week of the household's interview). The average impact of the RBD plantain program is given by the estimated coefficient on *RBD*. For each indicator this coefficient and its standard error are given in the second row of figures.

Table 9: Regression results and average impacts of the RBD plantain program

	(1) Log of food consumption per capita	(2) Yield, 1st quality (1,000 units/mz.)	(3) Yield, 2nd quality (1,000 units/mz.)	(4) Total plantain revenue ($US)	(5) Plantain planted area (mz,)	(6) Irrigated manzanas in production	(7) Use of precision harvesting system
***RBD* (Average impact of RBD program, β_1)**	**-0.0531** **[0.121]**	**25.59**** **[10.06]**	**9.662** **[6.916]**	**2,879***** **[1,053]**	**0.116** **[0.253]**	**0.494*** **[0.268]**	**0.0492** **[0.0721]**
=1 if house has dirt floor	-0.123 [0.155]	-10.03 [16.42]	-1.083 [8.382]	358.6 [1,014]	0.418* [0.244]	0.0918 [0.237]	-0.194** [0.0907]
Altitude, meters above sea level	-0.0117*** [0.00401]	0.281 [0.364]	0.104 [0.223]	5.049 [40.47]	-0.0283*** [0.00999]	-0.0163* [0.00978]	0.00259 [0.00285]
=1 if municipality 1	0.236 [0.198]	-4.918 [17.20]	-5.582 [8.623]	2,903 [2,641]	0.189 [0.427]	0.623 [0.414]	-0.156 [0.0955]
Experience	-0.00683 [0.0163]	-5.506*** [1.890]	-2.565* [1.358]	-171.8 [164.8]	-0.0103 [0.0424]	-0.0144 [0.0490]	0.0173 [0.0136]
=1 if member of cooperative pre-program	0.275** [0.129]	21.86 [18.01]	9.703 [8.596]	-1,154 [1,149]	-0.0946 [0.303]	-0.503 [0.372]	-0.0188 [0.106]
Production in a good year (Units/mz.)	-0.00355 [0.00627]	-1.176* [0.682]	-0.527 [0.464]	-38.21 [43.91]	-0.0176 [0.0121]	-0.0115 [0.0128]	-0.00164 [0.00494]
Production in a bad year (units/mz.)	0.00366 [0.00511]	0.0553 [0.594]	0.138 [0.468]	-42.93 [53.76]	-0.0509* [0.0291]	-0.00572 [0.0169]	0.00635* [0.00356]
Production in an avg. year (units/mz.)	0.00283 [0.00820]	0.844 [0.945]	0.177 [0.667]	63.99 [66.42]	0.0554** [0.0260]	0.0187 [0.0201]	2.31e-05 [0.00592]
=1 if had other business pre-program	-0.413*** [0.122]	-7.698 [12.08]	5.126 [6.785]	-628.7 [1,092]	-0.565 [0.399]	-0.282 [0.297]	-0.116 [0.0953]
Total unearned income (Córdobas)	-2.24e-05 [0.000100]	-0.00151 [0.00760]	0.00477 [0.00340]	-0.393 [0.603]	-0.000128 [0.000222]	-0.000255 [0.000192]	-4.83e-05 [4.42e-05]
Total loans for agriculture (Córdobas), 2008	2.28e-05 [0.000113]	-0.0124 [0.0118]	-0.0111* [0.00563]	-0.423 [1.147]	-0.000189 [0.000330]	-0.000246 [0.000432]	0.000153** [7.40e-05]
Years of education, most educated member	-0.0345* [0.0204]	-1.403 [1.964]	0.139 [0.890]	201.0 [139.1]	-3.33e-05 [0.0309]	-0.0153 [0.0317]	0.000240 [0.0102]
Gender of household head	0.0681 [0.198]	-5.236 [21.19]	-13.65* [7.709]	-1,289 [1,126]	0.292 [0.303]	0.191 [0.247]	-0.0507 [0.0994]
Household size, adult equivalents	0.00823 [0.0414]	-5.947** [2.930]	-2.755 [1.878]	-373.8 [299.9]	-0.0351 [0.0780]	0.0186 [0.0745]	0.00934 [0.0249]
Total wealth, pre-program (Córdobas)	-1.44e-07* [8.00e-08]	-4.24e-06 [9.58e-06]	7.54e-06 [6.72e-06]	-0.00124 [0.00115]	1.03e-06*** [3.45e-07]	3.06e-07 [4.22e-07]	-2.11e-07*** [6.67e-08]

Table 9 continued: Plantain regression results, observations on common support							
Simpson index of crop diversity, 2008	-0.0582 [0.187]	3.674 [16.17]	4.516 [10.69]	711.3 [1,248]	-0.822* [0.430]	-0.190 [0.312]	0.00868 [0.105]
Total planted mz., 2008	-0.0126 [0.0399]	3.562 [3.078]	1.265 [1.823]	817.4** [325.8]	-0.300* [0.174]	-0.127* [0.0761]	0.0541* [0.0297]
Planted area in plantain pre-RBD, mz.	0.135** [0.0600]	-12.80** [4.876]	-7.218** [2.782]	-2,024*** [724.5]			-0.0902*** [0.0325]
Share of mz. in production suffering shocks, non-drought	0.0924 [0.121]	-7.572 [14.97]	4.629 [5.985]	159.7 [871.0]	-0.280 [0.248]	0.525** [0.260]	-0.0242 [0.0719]
Week of interview	0.00655 [0.0241]	3.931* [2.208]	-0.496 [1.498]	277.8* [156.0]	0.0791* [0.0453]	0.0970* [0.0496]	0.0456*** [0.0123]
Intercept	1.677*** [0.480]	113.0** [48.32]	42.58 [27.26]	2,150 [2,803]	3.188*** [1.142]	0.814 [0.815]	0.0536 [0.281]
Observations	113	113	113	113	113	113	113
R-squared	0.514	0.441	0.404	0.399	0.598	0.329	0.393
Robust standard errors in brackets; sample is restricted to observations on the common support of the propensity score							
* significant at 10%; ** significant at 5%; *** significant at 1%							

Estimated impacts on yields of first quality plantains as well as total sales are quite large in magnitude as well as statistically significant. For the beneficiary group, sales grew by $2,918 on average from round one of data collection to round two; this suggests that the RBD program led to a 73% increase in sales for beneficiaries, which is a very large effect. The average impact on irrigated area is also significant and equal to half a manzana. Note that the difference-in-difference model for irrigated area used irrigated manzanas pre-RBD as imputed using questions about when irrigation systems were installed on each plot, rather than taking irrigated area in 2009 as our baseline period. This avoids contaminating the baseline measure of the outcome variable with irrigated land that was installed as a result of the RBD program. That the estimated impact on irrigated area is less than one manzana (the minimum area needed with access to irrigation water for program eligibility, following adjustments to eligibility requirements) suggests that irrigated area would have grown somewhat in the absence of the RBD program, but that the program still had a substantial effect.

All of the regression results reported in Table 9 were estimated using OLS. Equations with non-negative or binary dependent variables were re-estimated using Poisson models or, in the case of adoption of the precision harvesting system, a logit model with no notable changes in the estimated impacts of the program. As noted earlier, the difference-in-differences model was also re-estimated using the full sample with no substantive difference in estimated impacts.

While the regression results presented above can give us an idea of what the gross short-term impacts of the RBD were, making additional assumptions will enable us to calculate the net long-term benefits of the program. Table 10 presents estimated internal rates of return for the RBD plantain program under different assumptions about the lifespan of irrigation equipment installed as part of participating in the program. In calculating the internal rate of return, benefits from the program in the initial period (year 0) and in years on were net of all RBD program costs for the 2009 cohort. In subsequent years, the gross benefit was set equal to the estimated program impact on revenue, minus the change in variable costs (land rental costs, inputs, labor). The survey data do not contain the information necessary to estimate program impacts on variable costs. Instead, the change in variable costs was calculated as follows:

$$\begin{aligned}&\text{(Increase in planted area)*(New per manzana production cost)} + \\ &\text{(Baseline planted area)*(New per mz. prod. cost - Old per mz. prod. cost)}\end{aligned} \tag{12}$$

The increase in planted area and the baseline planted area were taken from the survey, with the former coming from our estimated impacts. The production cost figures were taken from administrative data provided by MCA-N. The change in production costs does not include a comparison to a control group, and therefore may not be very accurate; the IRR calculations below should be considered a rough estimate that is the best that can be done with available information.

Program costs in year 2 as used to calculate the IRR also included the cost of payments made to Chemonics for administering the plantain program. The total payment to Chemonics for the plantain program was $667,508. This was incorporated into the impacts below by multiplying the total Chemonics payment by share of all beneficiaries that were in the 2009 cohort.

Table 10: Internal rate of return, plantain				
Lifespan of irrigation equipment:	5 years	10 years	15 years	20 years
Internal rate of return, results from Table 9:	-26%	-2%	7%	11%
Linear depreciation and zero salvage value of irrigation equipment assumed.				

The estimated internal rate of return is modest compared to the large estimated impact on revenue. This is unsurprising if we consider the high cost per farmer of the program; as shown in

Table 2, the cost of inputs, extension, and irrigation equipment was around $3.6 million for a group of 239 farmers. The IRR is also quite sensitive to assumptions about the lifespan of irrigation equipment. Depreciation figures in documentation from the RBD program suggest that diesel irrigation pumps will depreciate at 3% of the original value per year, which would imply a useful lifespan of 31 years. Other sources, such as FAO documentation on irrigation management, suggest diesel pumps of the size installed through the RBD program have a useful lifespan of 10 years (FAO 1992). While trying to pin down how long pumps and other equipment can be expected to last would be speculation, MCA-N and Chemonics trained mechanics on how to take care of irrigation equipment as part of their investment in the program. Since program administrators have taken the long view with respect to maintaining their investment in plantain production on the Pacific Coast of Nicaragua, there is reason to be optimistic that the long-term net benefits of the RBD plantain program will be positive.

Conclusion

This paper uses two rounds of survey data to estimate the impacts of the RBD program for smallholder rice and plantain producers in Nicaragua. The rice component of RBD supported input purchases and agricultural extension use for a subset of beneficiaries, while allowing all beneficiaries to enjoy greater access to drying patios. Plantain beneficiaries also received funding for inputs and agricultural extension, and benefited from partial funding of micro-aspersion irrigation on newly planted land. I estimate significant impacts of the program on plantain revenue, plantain yields, and irrigated area for plantain producers in the 2010-2011 agricultural year; impacts on rice producers were positive but not statistically significant.

I can estimate the rate of return to the drying patio component using our estimated program impacts; a ten year lifespan of the patios would mean a 15% internal rate of return, and longer lifespans raise the return above that figure. But projecting out the long-term benefits of the rice component is difficult given the information available. The vast majority of costs for the rice component came from the subsidized inputs and extension. While these were designed to have impacts on program beneficiaries with approved business plans in the short-term, they were also meant to help cooperatives establish rotating credit funds, thereby expanding access to liquidity among their members. It is difficult to predict how viable this strategy will be long-term, given the sensitivity of rice production in the Pacific Coast to shocks from El Niño and the absence of any risk management tools in the RBD program. In any case, an area for future research would be how short-term interventions can be designed to include risk management components so as to ensure their long-term success.

The internal rate of return of the plantain component of RBD proved to very sensitive to changes in parameter values, and irrigation equipment must last beyond a decade for the program to break even. But given the fact that the RBD program expanded the supply of agricultural extension and trained mechanics to care for irrigation equipment, there is reason to be optimistic about the potential of small plantain producers to build on the developments introduced by MCC.

The relative success of the plantain component raises the questions of how the differences between the two program components may have affected their relative impacts. The rice component demonstrated that working with groups that would be expected to have an information advantage in identifying the most capable farmers does not guarantee success, particularly when agriculture is subject to systemic shocks. The larger short-term impacts and greater hope for continued success in the plantain component may demonstrate the benefit of investing the preponderance of program resources in fixed productive capital that is less susceptible to risk.

Given that much of the benefits of the programs studied in this report will depend on long-term changes in variables that are impossible to capture using two rounds of data, a natural question to ask is whether more could be learned through additional data collection and analyses. If this evaluation were constructed using a stronger design and if the samples were large enough to ensure sufficient power for rejecting the null hypothesis of no effect when the true program effect is at least somewhat large, I would suggest further survey data collection and econometric analysis. However, this is not the case here; the samples used here are relatively small, and the use of fixed-effects methods and differences-in-differences, which can under some circumstances yield quite credible evaluations, was complicated by the timing of data collection relative to the realization of program impacts and the absence of the rich background information usually needed to make these methods convincing (e.g., a long time series of pre-program data on outcomes such as yields and revenues, possible drawn from administrative sources, or a census which would be used to identify a large pool of farmers with a strong resemblance to beneficiaries). What the evaluation of the rice and plantain program could benefit from is simple follow-up with beneficiaries to verify that the productive assets put in place by the program are being managed well. Particularly in the case of plantain, despite the imperfections of the evaluation design it seems quite clear the short-term impacts of the program were large and positive. Confirming that irrigation equipment is being used and managed properly would do more to confirm the positive long-term benefits of the RBD program than additional collection of detailed survey data and econometric analysis.

Appendix: Data collection issues

The original sample was drawn from a list of rice producers provided by farmer cooperatives, and was designed for an evaluation of the first year of the RBD program and based on the assumption that the drying patios would not be completed during the 2009-2010 agricultural year, as was stated by MCA-N. Only later was the decision made to expand the data collection and evaluation effort to two years.

During the process of data collection in year one, a large number of farmers were replaced in the sample at the request of MCA-N because they did not satisfy program eligibility criteria; the program was to last for two years, but farmers found to violate program criteria would be disqualified in their first year of participation. In the case of rice, nearly 50% of the original sample had to be replaced and the complete list of replacements was exhausted. The most common cause for being dropped from the sample was failure to satisfy program criteria with respect to land tenure status, followed by households being listed more than once on the roster provided by MCA-N. A summary of the reasons for dropping producers from the sample is given below:

	Rice	Plantain
Member of other interviewed household	51	4
Violates some program criterion	35	23
Does not own land	73	12
Could not be located	9	1
Outside country	9	3
Refused interview	2	0
Name repeated in the sample	17	4
Total	145	47

Source: FIDEG

To round out the sample, a small number of farmers were located in the field by enumerators: 18 in the case of plantain, and 29 in the case of rice. Note that in the case of rice, producers located in the field were not members of cooperatives, unlike other farmers included in the sample.

References

Berthelon, Matias, Diana Kruger, and Diana Saavedra. 2007. *Distortions to Agricultural Incentives in Nicaragua.* Agricultural Distortions Working Paper 18, Washington, DC: The World Bank.

Deaton, A., and S. Zaidi. 2002. *Guidelines for Constructing Consumption Aggregates for Welfare Analysis.* Living Standards Measurement Study Working Paper, Washington, DC: World Bank.

Del Carpio, X., and M. Maredia. 2011. *Impact Evaluations in Agriculture: An Assessment of the Evidence.* Independent Evaluation Group, Washington, D.C.: The World Bank.

Dercon, S., D. Gilligan, J. Hoddinott, and T. Woldehanna. 2009. "The Impact of Agricultural Extension and Roads on Poverty and Consumption Growth in Fifteen Ethiopian Villages." *American Journal of Agricultural Economics* 91 (4): 1007-1021.

Härdle, Wolfgang. 2007. *Applied Multivariate Statistical Analysis.* New York: Springer.

Imbens, Guido, and Jeffrey Wooldridge. 2008. *Recent Developments in the Econometrics of Program Evaluation.* Working Paper, Cambridge, MA: National Bureau of Economic Research.

IRI. 2009. *ENSO Quick Look.* January-December. Accessed April 18, 2011. http://portal.iri.columbia.edu/portal/server.pt?open=512&objID=945&mode=2.

MCA-N. 2011. *Conglomerado Agrícola Arroz.* Cuenta Reto del Milenio.

MCA-N. 2011. "Conglomerado Plátano."

MCA-N. 2008. "Plan de Acción de la Estrategia de Salida."

Moulton, B. 1986. "Random Group Effects and the Precision of Regression Estimates." *Journal of Econometrics* 32 (3): 385-397.

Reardon, T., H. Michelson, and F. Perez. 2012. "Small Farmers and Big Retail: Trade-offs of Supplying Supermarkets in Nicaragua." *World Development* 40 (2): 342-354.

Rosenbaum, P.l, and D. Rubin. 1985. "Constructing a Control Group Using Multivariate Matched Sampling Methods That Incorporate the Propensity Score." *The American Statistician* 33-38.

Rubin, Donald B. 2001. "Using Propensity Scores to Help Design Observational Studies: Application to the Tobacco Litigation." *Health Services & Outcomes Research Methodology* 2 (1): 169-188.

Sadoulet, E., and A. de Janvry. 2001. "Cash Transfer Programs with Income Multipliers: PROCAMPO in Mexico." *World Development* 29 (6): 1043-1056.

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