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Are matching funds for smallholder irrigation money well spent?

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ABSTRACT

Groundwater irrigation can dramatically affect agricultural production and productivity. Despite its potential as an agricultural development tool, little credible evidence exists for the impacts of groundwater development on smallholder agriculture. We add to the evidence on the benefits of irrigation investments for small producers by evaluating the Rural Business Development (RBD) program of the Millennium Challenge Corporation in Nicaragua for small plantain producers. The RBD program offered matching funds covering up to 30% of the cost of two years of inputs, extension services, and diesel-powered micro-sprinkler irrigation for individual farms. In order to estimate the average impact of the RBD program on its beneficiaries, we combine model selection via the LASSO with doubly robust treatment effect estimation as applied to two years of panel data for 146 producers. We find that the program had substantial impacts on plantain revenue and production, while achieving nearly complete irrigation coverage of plantain land among beneficiaries. We find no discernible impact on household expenditure.

1. Introduction

While many interventions can positively affect agricultural production, the history of agricultural development shows that irrigation can be transformative. For example, Edwards and Smith (2017) estimate that expansion of irrigation accounted for 90% of the growth in the value of crop production in the Western United States after 1940. Fan, Gulati, and Thorat (2008) find that each rupee invested in irrigation returned an average of eight rupees in agricultural GDP in India throughout the 1960s and 1970s. Irrigation may be particularly beneficial for smallholder producers of perennial crops, as access to water can be constrain participation in modern agricultural value chains. Supermarkets and exporters require a constant and reliable supply of product (Barrett et al., 2012), and smallholder producers of perennial crops relying on rainfall may fail to meet this criterion. If small producers underinvest in irrigation because of difficulty accessing credit or other constraints, then promoting irrigation among small producers may improve welfare.

In this paper, we add to the evidence on the effectiveness of smallholder irrigation investments by measuring the impacts of the Rural Business Development Program (RBD) for small plantain producers in Nicaragua. The RBD program paid up to 30% of the cost of executing producer "business plans". Business plans consisted of installing micro-sprinkler irrigation systems, purchasing inputs such as fertilizer, planting material, and pesticide, and obtaining extension advice on fertilizer use, integrated pest management, irrigation, as well as harvest and post-harvest management. In addition, the RBD program expanded capacity at a local collection center in order to address post-harvest bottlenecks.

Using a two-year panel data set of 95 RBD beneficiaries and 51 non-beneficiaries, we estimate the Average Treatment Effect on the Treated (ATT) for a series of outcome variables, where the ATT is identified by the Conditional Independence Assumption (CIA). In estimating the ATT, we follow a procedure detailed by Farrell (2015) that combines "doubly robust" treatment effect estimation with model selection using the LASSO algorithm. We use the LASSO to select from a set of variables that are potentially correlated with our outcomes of interest as well as RBD participation under a unitary agricultural household model. Doubly robust estimation combines regression with inverse probability weighting, and identifies the ATT if either the propensity score model or the model for the conditional mean of the untreated potential outcome is correctly specified. By relying on the LASSO for variable selection, we minimize ad hoc modeling assumptions and select variables in a way that results in valid inference under standard conditions, in contrast to many other model selection procedures.

In year one, we find that the RBD program increased irrigated plantain area by 42%, reduced exposure to drought by 16%, and reduced fertilizer expenditure per unit of land by 33%. We find no clear evidence for or against program impacts on other outcomes. In year two, we find large and statistically significant impacts on sales and

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production indicators, as well as irrigated area. Larger and more precisely estimated impacts in year two were most likely a result of program design, as beneficiaries received irrigation late in the first year of participation. Year one impacts would have been caused by input subsidies and extension. As a result of RBD participation, plantain revenue, production, revenue per unit of land, and yield grew by 249%, 130%, 110%, and 46% in year two, respectively. The value of credit received by beneficiaries in year two fell by 60% as a result of RBD participation. The RBD program increased irrigated plantain area and area producing plantain among beneficiaries by 72% and 24%, respectively, in year two. As a result of the RBD program, nearly 93% of area producing plantain on beneficiary farms was irrigated, as compared to an estimated 66% in the absence of the program. Our results are robust to a large number of changes in model specification.

While agricultural indicators grew sharply as a result of RBD participation, we find no discernible impact on household expenditure. We consider several potential reasons for this finding, and cautiously conclude that the most likely explanation is a sharp increase in production costs. Administrative cost data provided by RBD program administrators show that variable costs of production increased from around $800 per beneficiary to over $4000. Beneficiaries also contributed an additional $2500 in year one for irrigation equipment and land preparation. Whether beneficiaries will enjoy higher expenditures in future years is unclear. On one hand, the high cost of land preparation and irrigation equipment may indicate that beneficiaries traded short-term expenditure gains for long-term benefits. On the other hand, the sharp growth in variable costs may reflect modest increases in profits in future years.

In general, the available empirical evidence demonstrates that access to irrigation has positive effects on yield, production, and revenue, as well as household expenditure or income. Examples of studies finding positive effects of irrigation access include Huang et al. (2006), Del Carpio, Loayza, and Datar (2011), Dillon (2011a, 2011b), Kuwornu and Owusu (2012), Van den Berg and Ruben (2006), Hagos et al. (2012), and Adeoti et al. (2009). Most existing studies measure impacts of surface water projects serving large numbers of farmers or the effects of on-farm irrigation technologies designed for larger farmers. Studies of the impact of treadle pump technology are exceptions (e.g. Adeoti et al., 2009). We address a gap in the agricultural development literature by evaluating a program that promoted smallholder adoption of motorized groundwater irrigation, a technology with far greater potential for production impacts than human-powered pumps.

In addition, our paper is one of the few to use a credible identification strategy in evaluating a matching funds program designed to promote agricultural development. Matching funds are a common development policy tool, both inside and outside of agriculture (Crespi and Maffioli, 2014). As shown by recent reviews of the literature on matching funds programs in agriculture, the quality of the available evidence for their effectiveness is generally poor (Ton et al., 2013; Ton et al., 2015; Nankhuni and Paniagua, 2013). In particular, evidence for the effectiveness of matching funds for investment in irrigation is virtually non-existent.

In what follows, we first present background on the development of plantain production on Nicaragua's Pacific Coast and the RBD program. We then describe the data set and present summary statistics for program beneficiaries and non-beneficiaries in our sample. Next, we discuss our identification strategy and model selection process before presenting our results and summarizing several robustness checks. We conclude with a discussion of our findings and possible directions for future research.

2. Background

Producers on the Pacific Coast of Nicaragua began farming 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 intermediaries at the farm gate. Beginning in 2003 farmers began to organize themselves into cooperatives with the help of development projects from the EU and USAID. Greater organization is a step towards deeper involvement in modern agricultural value chains, as it can lower the transaction costs associated with dealing with large numbers of small producers (Barrett et al., 2012). However, to participate fully in modern agricultural value chains, small producers must meet the quantity and quality standards demanded by grocery stores, exporters, and processors.

The RBD program for plantain producers was introduced in 2007 in order to continue the agricultural development process described above. The plantain program was part of a larger development package for the Nicaraguan Pacific Coast co-financed by the Millennium Challenge Corporation (MCC), which is a development agency of the US government, and the Government of Nicaragua (GON). The Pacific Coast was selected by MCC and the GON for its economic potential, particularly in agriculture. Other components of the compact between MCC and GON included extensive road rehabilitation, investment in several agricultural value chains, and a land titling program that was canceled following the 2007 Nicaraguan presidential election.[2,3]

The RBD plantain program was administered by MCC's office in Nicaragua, known as the Millennium Challenge Account in Nicaragua (MCA-N), and Chemonics, a private firm specializing in the management of development projects. MCA-N and Chemonics promoted the RBD program in its initial stages through meetings with producers groups and cooperatives. Cooperative membership was not a prerequisite for RBD participation. Three cohorts entered the RBD plantain program from 2007 through 2009. The results presented in this paper include impacts of the RBD plantain program in 2010 and 2011 for the cohort entering in 2009, which consisted of 239 producers. RBD program services were co-financed by beneficiaries and the program itself. For each individual producer, the RBD program financed up to 30% of participation costs. For the program as a whole, the program paid 24% of all costs while facilitating access to the inputs, irrigation equipment, and other materials provided to beneficiaries.

Any farmer meeting a set of eligibility criteria could submit a "business plan" to the MCA-N office. The full set of criteria is provided in the supplementary appendix. Each business plan detailed how the producer would benefit from participation, how he or she would finance participation, evidence that he or she had no access to services similar to those provided by MCA-N, and a detailed budget. MCA-N provided farmers with technical support in designing their business plans. While detailed data on applicant rejections are not available, conversations with MCA-N and Chemonics indicate that lack of financing and insecure property rights over land producing plantain were the most common reasons for rejection.

If a business plan was approved, the beneficiary received inputs (planting material, fertilizer, and agrochemicals) as well as extension services in each year of participation. Beneficiaries also received micro-sprinkler irrigation systems late in the first year of participation. Inputs and irrigation were meant to be sufficient for a single manzana[4] of land. For the cohort studied in this paper, extension agents emphasized fertilization, integrated pest management, and management of the irrigation system.

3. Data

The data set used in our analysis consists of a two-year panel of 146 plantain producers, including 95 RBD participants and 51 non-participants serving as a control group.[5] RBD participants included in the

[2] The background information presented here draws from RBD program documents.

[3] See Carter et al. (2016) for an evaluation of other components of the MCC-Nicaragua compact.

[4] 1 manzana = 1.72 acres = 0.70 hectares.

[5] While 150 producers were interviewed for the initial round of data collection, three