Complementarities of Training, Technology, and Credit in Smallholder Agriculture: Impact, Sustainability, and Policy for Scaling-up in Senegal and Uganda

I. Overview and Intellectual Context.

I.A. Overview

Many proven technologies and improved farming practices hold great promise for boosting agricultural production and reducing poverty in developing countries, but the adoption of such technologies by smallholder farmers, in particular in Sub Saharan Africa, has been slow, at best. Among the various barriers to technology adoption, up-front costs, absence of effective and reliable supply chains, and information gaps are prominent; and they often work in tandem: a farmer may be reluctant to make what she would consider risky and large investments (inputs and capital) needed to apply an unfamiliar technology. Combining an initial subsidization and easy supply of inputs and/or capital with training and demonstrations can, in theory, help address this obstacle: once farmers have been convinced of the technology's benefits, and had a successful (and affordable) initial experience in applying it, it may be hoped that they re-invest (some of) the profits in the inputs and maintenance required for continuing to apply the technology effectively, making its usage financially self sustaining.

How effective are such programs in actually achieving a sustained usage of new technologies, especially after the initial intervention terminates? Can they be designed to be more sustainable, and in particular, does the manner in which they are withdrawn have an effect? Can they be designed to be more effective in focusing on the central role of women farmers, who are often marginalized in access to information and opportunities to participate in extension, in countries such as Uganda (Opio 2003)? Despite its importance, empirical evidence on this issue is very sparse, even though outside agriculture, sustainability has been shown to be elusive (Kremer and Miguel, 2007); and even in agriculture, there are concerning reports of dis-adoption (see below), while recent research has shown behavioral factors can lead farmers to fail to under-invest in profitable inputs (Duflo, Kremer, and Robinson, 2011).

We propose to address this research gap by studying two agricultural development programs that target some of the poorest smallholder farmers, particularly women, in *Feed the Future* countries Uganda and Senegal. The two programs differ fundamentally in the technologies they promote and in their financial and extension models: The Uganda program promotes use of improved seeds and fertilizer by individual farmers through demonstrations by 'model farmers' and a proactive supply of inputs through a network of village promoters. The Senegal program will promote the use of drip irrigation systems and a complementary package of improved inputs, and to achieve the economies of scale required by this technology (often considered to prevent their adoption by smallholders) will work directly with groups of farmers, and provide them with collective drip systems, intensive extension, supply chains (of inputs at full cost) and marketing services. Despite these differences, the programs are also similar in that both attempt to ease constraints to adoption for a limited period by combining time-limited investments in human capital (through extension and training) and physical capital (through subsidization or grants); and for achieving sustainable impacts, rely on farmers to make complementary investments (purchase and proper application of improved inputs, investment in maintenance) both during and *after* the programs' duration.

Our research will evaluate the programs' impacts on income and nutrition, and will especially focus on the degree to which participating farmers make the required investments sustainably; the financial, behavioral or other obstacles they face in doing so; and whether additional policies help farmers overcome these obstacles: In Uganda, access to microcredit, and in Senegal, cooperative usage of inputs. Unlike most studies, we will extend the evaluation beyond the limited duration of the intervention and examine these questions both before **and after** the programs cease in order to assess their long-term impacts and sustainability, a question of critical importance to policy that has nonetheless received little empirical attention to date.

Our research will be based on rigorous identification methods. In Uganda, we will exploit a partial spatial overlap of the agricultural program with a microcredit program administered by the same large NGO (a retrospective study using a regression discontinuity plus difference-in-difference design), and apply a novel randomized "scale-back" design to evaluate the sustainability of the program. In Senegal, we plan to use a randomized control trial (RCT) to evaluate the program's impact under two models of collective management.

In addition to examining post-intervention impacts, the proposed research is very unusual in its contributions in three other dimensions. First, implementers of both programs may be scaling them up substantially in the future through two rather different mechanisms; one is a government-implemented program (Senegal); the other is implemented by BRAC-Uganda, an affiliate of one of the largest NGOs, which is noted for its success in scaling-up (Smillie 2009). This helps avoid some recent concerns about the applicability of lessons learned from small NGOs' field pilots (Deaton 2010) to a scaled up application by governments or bigger organizations (Bold et al 2013).

Second, we will work closely with the leading indigenous policy think tanks in the two countries to link field research directly to national policy analysis: the Economic Policy Research Center (EPRC) in Kampala, Uganda; and the Consortium pour la Recherche Economique et Sociale (CRES) in Dakar, Senegal. Our affiliation with EPRC and CRES is based on our partnership with the Africa Growth Initiative of the Brookings Institution, which works closely with them to build their capacity and work on key policy challenges.

Also of unique interest, the program in Senegal is co-implemented by the Senegalese, Italian and Israeli governments and is centered on an irrigation technology originally developed in Israel and being adapted to local conditions in sub Saharan Africa (Woltering, Pasternak, and Ndjeunga, 2011). The early successes of Israeli agriculture to flourish in an environmentally and economically constrained setting have long made Israeli expertise highly sought after in the developing world; but despite the long tradition of Israeli agricultural assistance in developing countries, to our knowledge our project is the first rigorous impact evaluation to date of a program implemented by Israel's international development agency (MASHAV). MASHAV is seeking to introduce such evaluations into its programs in order to improve their design, and is working closely with the co-PI (Fishman) on this matter.

The proposed research will be carried out over a four-year period, commencing on 1 May 2013.

I.B. Intellectual context

The recent development economics literature has focused on the need to address fundamental constraints in moving out of poverty in general and low-productivity smallholder agriculture in particular. Important identified

culprits include lack of knowledge, lack of access to markets, credit constraints, uninsured risks, and problems of coordination with neighbors (World Bank, 2007). These problems may lead to chronic and severe poverty, and may, though need not be, associated with poverty trap conditions (Carter and Barrett, 2006, 2012).

These constraints sometimes act in a complementary manner (Anderson and Feder 2007). For example, improved knowledge is of limited usefulness when farmers are credit constrained, if putting training to work requires the purchase of inputs and capital goods. And relaxation of credit constraints is of limited benefit if farmers do not know about the most productive uses of loans. Similarly, there might be strong complementarities between several inputs, farming practices and technologies. Thus, poverty alleviation activities and programs have designed and implemented one of these activities separately may achieve greater effectiveness and efficiency through recognition of this interdependence and through greater programmatic integration; or new activities may need to be initiated as additional constraints are identified.

The development economics literature has given increasing attention to the potential complementarities among poverty alleviation programs generally between microfinance on the one hand, and infrastructure, health or education/training programs on the other hand (Armendáriz and Morduch, 2010; Anderson and Feder, 2007; Lapenu, 2000; Chowdhury, 2009; Smith, 2002; Karlan and Valdivia, 2011). However, there has been a dearth of systematic attention to the complementarity between microfinance and agricultural extension programs. Some research, particularly the policy literature, has noted the likely complementarity between microfinance and agricultural programs; in particular, that many developing country governments recognize that farmers face credit constraints in the adoption of improved technologies (Lapenu, 2000). To address this problem, policies have typically entailed direct state intervention, through establishing public agricultural development banks, rather than building an efficient rural financial market. Most of these institutions have experienced problems such as low repayment rates, and insufficient availability of funds during financial crises (World Bank, 2007).

Our proposed field studies will help fill this critical knowledge gap by examining the complementarities of availability of physical inputs and knowledge, credit access, and effective methods of cooperation in achieving adoption and sustained use of improved agricultural technologies by smallholder farmers.

II. Description of Proposed Research

II.A. Description of proposed research: Senegal

II.A.1 Program Description

Drip irrigation is widely considered to be a promising technology for sustainable agricultural intensification, as it can achieve a simultaneous increase of yields and a decrease in input use (water, fertilizer and pesticide), and has a high rate of return on investment and potential for poverty alleviation (Foley, 2011; Postel, 2001; Sivanappan and Padmakumari, 1980). However, while highly effective in controlled conditions or in demonstration farms, its adoption by smallholder farmers in developing countries, especially in Sub-Saharan Africa, is still limited. In fact, efforts to introduce drip irrigation to individual smallholders in the region have often resulted in failure to realize the technology's potential and eventual dis-adoption and abandonment. The failure was attributed to factors such as mismanagement, disregard for agronomic recommendations, lack of maintenance, small plot size, and lack of access to technical support, complementary inputs, spare parts, and markets (Kabutah et al, 2000; Kulecho and Weatherhead, 2005; Moyo, 2006). But even when these conditions are better addressed, sustainability is not guaranteed. For example, half of the AMG systems that were installed in Burkina Faso in 2004 with farmers who had larger plot sizes and proper access to marketing, inputs and extension are operational today (Woltering, Pasternak, and Ndjeunga, 2011).

The proposed research will analyze the impacts and sustainability of PAPSEN,[1] a project undertaken jointly by the Israeli, Italian and Senegalese governments to overcome these obstacles and promote irrigated vegetable

[1] For more information, see http://www.agriculture.gouv.sn/category/projets/papsen

cultivation by several thousand[2] farming households in some 60-80 villages in the Thies, Djourbek and Fatik regions of Senegal. At the heart of the program is the *TIPA* (Techno-Agricultural Irrigation for Poverty Alleviation) model, based on the AMG (African Market Garden), which combines drip irrigation with a locally optimized package of improved inputs, and has been proven in several field trials to deliver high rates of returns to farmers. The AMG was gradually developed by one of the co-investigators (Pasternak) and others while he was serving as principal scientist (Systems and Crops Diversification) at the ICRISAT Sahelian Center from 2001-2011. By relaxing severe labor constraints associated with the traditional manual delivery and distribution of irrigation water, the donors estimate the model will allow farmers in this region to increase the area they cultivate and the revenue they generate during the dry seasons fourfold or more (Woltering, Pasternak, and Ndjeunga, 2011; Burney et al. 2010). PAPSEN will provide low-pressure drip systems to farmers at no cost, to be installed on public land provided by participating villages.

To address lessons of past initiatives related to missing complements, the TIPA model combines the AMG with intensive extension, supply of inputs and marketing services for rapid realization of the profits. During the three year project implementation[3], a service center in Bambey will provide centralized training, demonstration, a reliable supply of optimized complementary inputs (fertilizer, improved seeds and pesticides) and marketing support (all to be provided by the program – no funds for input resources are required or will be used from BASIS funding). In addition, extension agents will visit each village weekly and carefully monitor each plot – an approach inspired by the intensive extension effort applied in Israel during the 1960s when drip irrigation was originally introduced there.

Like other modernized agricultural technologies that involve high upfront costs and substantial economics of scale [4], drip irrigation is relatively inefficient and unattractive for smallholders with limited access to credit, and

[2] The exact number of participating farmers is yet to be determined. A hydrological survey conducted in the area by MASHAV identifies a potential to irrigate about 200 Ha, which, at a planned plot size of 500 m^2 per farmer, would serve 3000 farmers (households).

[3] PAPSEN is planned to last for three years. Our study will continue for four years in order to examine impacts up to a year after the program terminates.

[4] Sharing an AMG system by ten farmers, each cultivating a 500 m^2 , can cut investment costs by half (Woltering, Pasternak and Ndjeunga, 2011).

small plot size has been identified as a key factor leading to past dis-adoption of the AMG in Africa.[5] A natural approach to overcoming this obstacle, which will be followed by PAPSEN, is to install collective AMG systems with new or existing farmers' associations, which are common in Senegal, especially with women farmers. Each of these groups will enter a formal agreement with PAPSEN, and nominate a *Village animator*, who will be carefully trained to manage the operation of the water supply and irrigation system.

Cooperative or group models of production have a long tradition in agriculture. Despite their advantage in achieving economies of scale; however, these models can also introduce other challenges, particularly coordination and collective action challenges related to collective system maintenance, which is crucial to the model's sustainability, especially once external intervention withdraws (see below). Evaluating the success of this approach and the factors influencing it is an important research question with implications extending beyond irrigation, and it forms a central theme of our proposed research. To date, only limited anecdotal evidence on the performance of the model is available from a few pilots, painting a mixed picture. [6]

A customized package of complementary inputs like improved seeds, fertilizer and pesticides are key to realizing the AMG's proven potential, but under-investment in these inputs has also been identified as a pervasive problem plaguing earlier dissemination attempts of the AMG and agricultural development efforts more generally. A low rate of input use can be the result of liquidity constraints, knowledge gaps, and behavioral factors (e.g. Duflo, Kremer and Robinson, 2009). PAPSEN will follow a novel approach to address this challenge. To deal with an initial lack of funds, PAPSEN will provide these inputs to farmers at no cost during the first harvest cycle, but later, costs will be recovered and farmers will be required to purchase the recommended package of inputs at full cost, or be excluded from further participation in the project. By linking decisions on input use with overall participation in the project, and thus raising the costs of under-investment, project leaders expect that farmers will choose to follow

[5] In 2002, for example, 600 AMG systems were installed on small plots (80 m^2) in Niger and all were abandoned after one year, but not systems installed on larger (500 m^2) were not (Woltering, Pasternak and Ndjeunga, 2011; Kulecho and Weatherhead,2006).

[6] For example, communal AMG solar powered models installed in Benin in 2007 are still operational (Burney et al, 2010) as are 2-3 TIPA systems installed in Senegal by MASHAV in cooperation with other donors (internal MASHAV report, personal communication), whereas 1-2 others have dis-integrated.

expert advise instead of applying sub-optimal amount of water and fertilizer.

In addition, the project will also experiment with using a cooperative model of cultivation as a means to ensure proper input usage. Two variants of the TIPA model will be applied in randomly assigned villages, the cluster and the communal models (Woltering, Pasternak and Ndjeunga, 2011): In the cluster model, water delivery infrastructure is cooperatively managed, but each farmer makes independent crop choices and controls the application of inputs and water to her field. In the communal model, all farmers plant the same crops, as chosen by the group, and inputs and water are applied to all fields through centralized operation. The communal model is relatively rigid, and by tying farmers together more closely, places greater stress on farmer associations' capacity for coordination and collective action, and over time, may increase the chances of their disintegration. From that perspective, the sustainability of the model will depend on the ability of farmers' group to develop institutions for collective action (Ostrom 1990) and to deal with free-riding behavior that will be able replace the authority of the PAPSEN coordinators, after the project ceases (for a review of these issues and evidence from Ugandan farmer cooperatives, see Baldassarri and Grossman, 2011). At the same time, by shifting input decisions from farmers with no experience in horticulture to an intensively trained field manager, the project leaders believe it may help uniform compliance with the suggestion of the project's extension agents, and result in effective learning and habit formation. A central theme of our research will be to evaluate the tradeoffs between these two approaches – collective action vs. learning by doing - in terms of short term and long-term (especially post program cessation) impacts. This will be facilitated by an RCT of the alternative designs across villages.

The MASHAV evaluation team is supportive of this RCT approach (cluster vs. communal), under the enthusiastic backing of Dov Pasternak, the project's "intellectual father" and implementation team guide and our participating investigator. Since MASHAV will take the lead on this part of the project we cannot foresee any problem with allocating the two models of collective management as needed across the selected villages and ensure effective implementation of our RCT design.

We have not yet received official approval from the Senegalese government to randomly choose the set of (overall) treatment villages from among a broader list of comparable villages in the three regions. However, an

Israeli irrigation expert was already sent by MASHAV to identify a list of feasible villages with suitable hydrologic conditions and this list will serve as our candidate pool. We expect to receive timely approvals for randomized selection, but if randomization is not ultimately possible, we will use matching techniques to select the pure control villages. In the eventuality that pure randomization is not possible, first we will garner as much information as possible about the underlying process of treatment villages selection (in addition to our other villages data). We anticipate having sufficient candidate villages (and village level data) to utilize MB-IPW estimates for control village selection (according to our preliminary estimate), and if so we will select our treatment and control selections accordingly; but we would scrutinize the results before proceeding.[7] Specifically, we plan to compare results with the Mahalnobis distance matching estimator with calipers, which may perform better with a small sample size (and is a viable alternative in any case). Thus, we can safely conclude that randomized or at least rigorously matched treatment and control villages will be available for the program analysis.

II.A.2 Research Questions

1. What are the short and long term impacts of TIPA on farmers' incomes, household food consumption and nutritional status? Do farmers make the recommended investments in complementary inputs?
2. After external intervention ceases, do farmers' groups continue to operate their systems and continue to invest in improved inputs and system maintenance?
3. How do the communal and cluster model compare in achieving short and long-term impacts?
4. What other factors of farmers associations, such as the group's history, institutional arrangements or gender composition correlate with the program's success and sustainability?

II.A.3 Proposed Research Methodology

Experimental Design. The project is planned to cover 60-80 villages. Contingent on the agreement of the

[7] In Emran, Robano and Smith (forthcoming EDCC), we used Klein - Vella heteroskedasticity-based identification for continuous household outcomes, and the Millimet - Tchernis MB-IPW estimator for binary household outcomes.

Senegalese government, these villages will be randomly selected from an initial pool of candidate villages identified to have a water supply of sufficient quantity and quality, and within treated villages, farmers will be randomly selected for participation (demand within villages is expected to exceed availability). Another group of about 30 villages will be randomly selected as a control group. In the eventuality that pure randomization turns out to be infeasible, we will utilize rigorous matching methods as described above. Treatment villages will be further randomly assigned to follow either the communal or the cluster model.

Data Collection: The irrigation implementation project is planned to last three years. We will conduct three field surveys of farmers' associations and individual households belonging to both treatment and control groups: a baseline survey, a midline survey two years into the project, and an end-line survey at the fourth year of the project, about a year after the intervention has ceased. In addition, we will also utilize detailed records of farmer specific input use and seasonal yields that will be collected by the project staff.

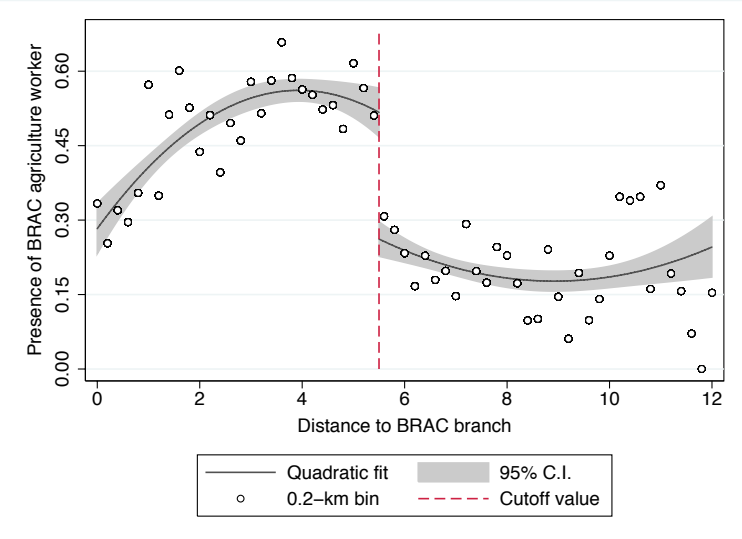
II.B. Description of proposed research: Uganda

II.B.1 Program Description

Launched in August 2008, BRAC's agriculture program seeks to increase the usage of improved inputs (fertilizer and improved seeds) and the productivity of low income, smallholder women farmers, by providing extension and supporting a network of *model farmers* and *community agriculture promoters* (CAP). The program operates in 41 districts in Uganda (Poghosyan, 2011), engages 800 model farmers, who were selected among poor, marginalized women, and reaches 40,000 general farmers. Model farmers received six days of training in crop production techniques, adoption of new crop varieties and pest control, as well as follow-up refresher courses. Then, they were made responsible for providing a three-day training activity for other ("general") farmers in their villages. Community agriculture promoters (CAPs) were also selected from the same populations, and their role is to make available and sell advanced agricultural inputs in the villages, such as improved seeds and fertilizers (Barua, 2011).

Not all areas participating in the program are served by both CAP and model farmers: some areas have only CAP, some have only model farmers, and some have both. In addition, BRAC Uganda also runs a microcredit

program, and even though BRAC's financial services are formally separate, there is some geographical overlap between the two programs. One part of our research will attempt to exploit this spatial heterogeneity in coverage of the various program components to study and evaluate their complementarities (using a regression discontinuity design based on unique features of BRAC's program design, see below for details). BRAC's own estimates (using difference in differences and propensity score matching methods) indicate that the program has had substantial impacts on the usage of improved seeds and other farming practices (Barua, 2011). One line of investigation of the proposed research will extend this investigation by using a substantially more extensive household dataset (Poghosyan, 2011) and apply a regression discontinuity design to exploit geographical features of the BRAC program design. BRAC agricultural workers extend their activities up to a specified limit from designated program offices; the resulting discontinuity is illustrated in Figure 1 below.[8]



Preliminary results (village level intent-to-treat) of this RD analysis confirm some of BRAC's preliminary findings at the village level, but also suggest that results depend on strong complementarity with the presence of micro-finance services. BRAC is now planning to withdraw CAP and model farmer support from certain randomly

[8] The treatment discontinuity restricts the sample to households within 12km of each branch. In the figure, we plot the mean treatment status for 0.2km bins, and the quadratic fit of the data and 95% confidence interval. The non-parametric RD estimator using rectangular kernel and a bandwidth of 0.5km shows a significant (at 5% level) decrease in treatment probability of 15.7%.

selected villages; this provides a unique research opportunity to both study the complementarities between the program's components (demonstration, training, and a subsidized, accessible supply chain) as well as the impacts of various forms of program withdrawal. Support will be phased out, with half the villages randomly selected to receive continued services for an additional two years. Accordingly, our second line of investigation will employ randomized control trial (RCT) methods to examine the impacts of scaling back support for either model farmers, who provide training to general farmers, community agriculture promoters, who provide advanced agricultural inputs, or both, as well the impact on long-term outcomes of prolonging the intervention by another two years.

When support for model farmers and/or CAP is withdrawn, these farmers may or may not continue to engage in these operations in less formal ways. For example, CAP may continue to operate the supply of seed in the village as private enterprises. Even if they do not, seeds will still be available to farmers (at least they can purchase them in other villages), but procuring them might become more costly, for example because of travel time. Accordingly, we will test sustainability across three dimensions: 1) *activities*, such as maintaining demonstration farms, maintenance of supply chains by independent farmers as private enterprises, savings, and utilization of credit facilities; 2) *practices*, such as technology adoption and improved seed and fertilizer use; and 3) *impacts* such as yields, incomes, and nutritional status

II.B.2 Research Questions

1. To what extent is there complementarity between demonstration (model farmers and extension agents), supply chains (CAP) and microfinance in achieving usage of improved inputs? What is the impact of active and passive integration of smallholder agricultural extension with credit access?
2. Are the effects of an agricultural extension program sustainable after a necessary program scale-back? Is sustainability impacted by whether supply chain or extension are scaled back first? How does it depend on the duration of the program?
3. Does relative proximity to other villages that still receive extension and supply chain services impact the sustainability of the program's impacts?

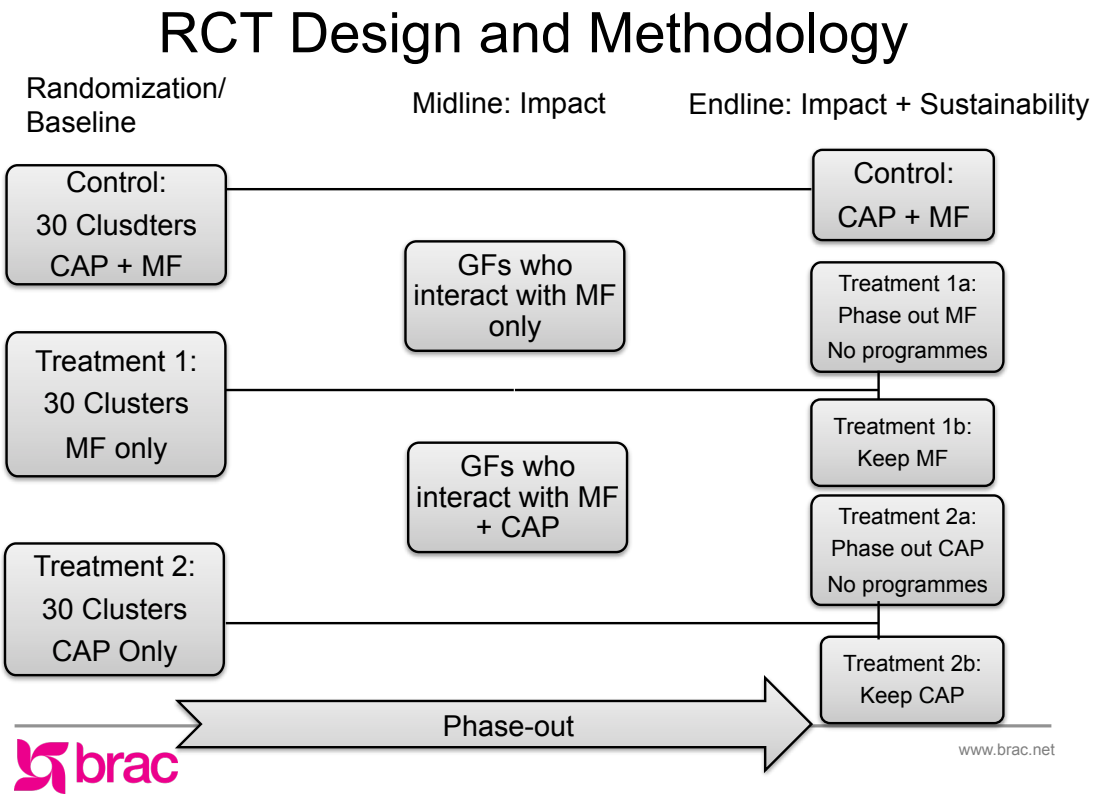
II.B.3 Proposed Research Methodology

Experimental Design and Empirical Strategy. As mentioned above, the BRAC program design is such that some villages have community agriculture promoters (CAPs), who provide advanced inputs; some have model farmers, who provide training; and some have both model famers and CAPs. Moreover, according to the BRAC program design, in some areas access to its microfinance programs, and to its extension programs, is determined by households' distance to the nearest BRAC branch. Because the cutoff distances for the two programs are different, we will be able to compare the separate impacts of the agricultural program (subsidies and extension) with or without access to credit, using a regression discontinuity framework, to address our first research question.

Our second research question will be addressed through a novel "reverse RCT" design, that will exploit the randomized design of the planned scale-back of the program. This procedure for determining which villages will receive temporarily continued period of subsidy is more equitable than a bureaucratic decision, which may be based upon political connections or similar asymmetries; moreover, randomization provides for a clean identification of the causal effect of reduced program inputs. Often, an RCT may be carried out as a program is phased in, comparing new impacts on villages that receive a program earlier with those who receive it later. But in our analysis, the experimental design provides for a novel "scale-back-RCT" methodology, in which the extent of sustained effects in villages where support is withdrawn earlier is compared with effects in villages that will continue to receive the support for some time. Thus, the project contributes more generally to methods for experimental research design in rural areas of developing countries where many programs are transitory in nature and where sustainability is an important program objective.

90 clusters of villages serviced by both CAPs and model farmers will be studied here. They are randomly assigned into three groups, each consisting 30 clusters. The plan for the first stage is to phase out just the CAP program in group A, phase out the model farmer program in group B, and keep both in the last group (C). In the second stage, each of the former two groups is further divided into 15-cluster subgroups randomly. Within each group, we phase out the remaining program in one subgroup and keep it in the other. In principle, this RCT design

can identify the "sustainable" effects of CAP and model farmer programs separately and evaluate potential complementarity effects between the CAP and the model farmer programs. Additional insights will be possible through phasing out the offices to be closed more gradually, if this can be financially feasible for the NGO (discussions are underway). BRAC is open to further methodological refinements. The Uganda RCT design regarding the existing program villages (excluding the pure control) is summarized in Figure 2 below.



Data Collection. We will also seek to identify any spillover effect between the RCT clusters and nearby villages. Potentially, farmers could purchase agricultural inputs from nearby villages (which may or may not be included in the RCT). Clearly, withdrawing extension programs does not strictly prevent farmers from accessing agricultural services; but it does increase their transaction costs.

The analysis will use existing and new BRAC program evaluation panel surveys at household and village levels. We are working with BRAC to identify and survey two types of relevant control groups for the extension scale back research. First, we will add two additional waves of observations on control group households in the baseline survey that did not receive either extension or microfinance. Second, we will supplement these data with observations on new control group households who reside in villages statistically matched with the extension RCT scale-back study villages. Taken together, we will be able to identify the effect of program scale-back benchmarked to villages that have never received (previous or ongoing) interventions. Moreover, we will work more broadly to connect the households surveyed in previous research on BRAC-Uganda's microfinance and extensional programs to households to be surveyed for the scale-back RCT research; this will improve the precision of the identification of the sustainable effects of BRAC's programs. The initial project gives the overall impact of BRAC's services on households' outcomes. The second project provides a unique way to calculate the effect of phasing out these services. With this design, the difference can be interpreted as the sustainable effects of BRAC's programs.

Aside from more general closure effects, we plan to investigate whether farmer networks that were generated or reinforced through the program operations affect outcomes. Most data will be newly collected to examine the impacts of extension program scale-back and selective village service withdrawal.

III. Policy analysis scope of work, and policy relevance

We propose to develop an innovative model of linking field research with national policy making through close cooperation with local leading policy think tanks in Uganda and Senegal, EPRC and CRES, both of which have a long standing relationship with our partner, the Brookings Africa Growth Initiative (AGI). Brookings AGI works closely with EPRC and CRES, and is actively seeking opportunities to further assist with building their policy research capacities.

EPRC and CRES will both participate in the field research, and place it in the broader context of national agricultural policy thorough the preparation of policy papers to be conducted through interaction with and guidance by the Brookings Africa Growth Initiative, along with the GW Economics Department.

A first written product (one for each country) will include an analytical overview of some past, existing and planned government and public/private partnership based policies aiming at agricultural development. This component will be completed during the first year of the project. Among other things, preliminary findings of this paper will be used to direct and fine-tune the design of field research and interventions carried out in the second year of fieldwork, to ensure that they can contribute usefully to pertinent questions for national policy formation. The product will cover lessons learned from successes and failures of past policies for agricultural development, including extension and microfinance programs aimed at smallholder farmers; review existing government policies for smallholder farmer training and other extension programs, including access to farming technologies and inputs and potential areas for improvement; analyze the sustainability of government smallholder farmer programs and potential scope for improved sustainability; review the degree to which proven and field evaluated interventions have been considered for national scale up, and if so, the degree to which these were successfully scaled-up in practice; analyze government policy for scaling-up of programs and potential scope for improved scaling-up capacity and strategies; and analyze local market constraints to sustainability, including marketing, storage facilities, and other forward linkages through the whole value chain.

The second major component (one for each country) will draw on lessons from the findings of the fieldwork to address the formation of national policy, and analyze the potential for scaling up the successful outcomes. The resulting paper will be competed in the fourth year of the project.

The work for each of these papers builds on previous EPRC and CRES capabilities, including previous work with Brookings. For example, EPRC has previously conducted studies on agricultural extension and on determinants of membership in farmer groups. In addition, the learning process of the first paper will help to shape the development of the second paper.

In addition, during this process, EPRC and CRES will communicate with each other in their development of an analytical description of relevant similarities and differences between the two country cases. A meeting of researchers from EPRC and CRES at the midpoint of this process will provide further training, review of draft materials, and a work plan to move this part of the project to completion. EPRC and CRES will carry out other specific policy research questions as requested by Brookings AGI, working together with GW researchers.

After the policy studies have been completed and approved by Brookings AGI and GW researchers (and relevant drafts of the fieldwork studies have become available), EPRC and CRES will organize and carry out the Uganda and Senegal policy outreach components, respectively. These will be carried out independently but with active communication with each other and with George Washington University and Brookings AGI. As part of this process, the parties will:

1. Engage government in Uganda/Senegal through organizing and conducting policy forums based on the results of the policy analysis and the fieldwork; and
2. Engage with other African governments, and with aid agency representatives including USAID, on findings and policy outgrowths of the work

IV. Contributions to Host Countries' Research Capacity

Our local think tank partners will make substantial contributions to the overall product and will take an active part in all aspects of the research. As a result, they will gain in capacity in three main ways: First, they will learn about rigorous and effective policy analysis in a hands-on way: EPRC and CRES will write the first drafts of the policy pieces based on our general guidance; then, Brookings and GW researchers will provide feedback, and advise them through additional analysis and revisions of the paper. Second, as an aspect of its ongoing work with EPRC and CRES, Brookings will support their thinking on best practices on how to "translate" academic field research into policy impact (in Dakar and Kampala), which will be applied to this project. Previous analysis of local think tanks in other countries has found its way to Washington government and international agency policy circles via Brookings connections. We note that the Brookings Institution is regarded as the globally leading think tank,

both in overall ranking, and also for the specific category of international development (TTCSP, 2013). Thus, GWU's partnership with Brookings greatly expands our ability to help build capacity in Uganda and Senegal, as well as to underpin the quality of the policy analysis component of the overall study. Third, EPRC and CRES researchers will be engaged in the field evaluations and gain experience in design and execution of impact evaluations. These capacities can supplement their research capabilities in crucial ways. This experience will be complemented by formal training workshops in experimental design and econometrics, conducted by Yao Pan at EPRC in Kampala; and Ram Fishman will present talks on research methods at CRES in Dakar.

BRAC Uganda, which already has one of the best research and evaluation capabilities in East Africa, will gain enhanced capacity in research methods and field studies. BRAC Uganda has already become predominantly a Ugandan organization, and they are actively indigenizing all activities. In particular, a growing number of BRAC Uganda's Research and Evaluation staff members are Ugandan nationals. GWU and BRAC-Uganda researchers will jointly author publications. In fact, GWU researchers have longstanding close working relationships with researchers at BRAC-Uganda. Stephen Smith and Yao Pan are already conducting joint research with Munshi Sulaiman using existing data to study impacts of BRAC-Uganda extension and microcredit interventions at the village (intent-to-treat) level. Smith serves on the Advisory Council of BRAC USA. Team fieldwork visits to BRAC-Uganda include Smith in 2007 and Pan in 2013; Sulaiman visited GWU in 2012, when planning for potential joint research was initiated. In summary, this is a close partnership; and BRAC Uganda has the solid foundations needed to benefit most from working with US researchers.

In Senegal, field research will be conducted in close cooperation with local implementers ANIDA (l'Agence Nationale d'Insertion et de Développement Agricole) and MASHAV (Israel's Agency for International Development Cooperation) with whom one of the investigators has a long-standing relationship (Pasternak). Researchers from ANIDA will take an active part in the experimental design, data collection and analysis, and will be invited to receive formal training in impact evaluation and statistical analysis from the co-investigator (Fishman).

V. Contributions to USAID Objectives and Initiatives

Overall. This study contributes to the Feed the Future (FtF) goal of sustainably reducing global poverty and hunger by supporting inclusive agricultural sector growth. The study contributes to *inclusive* and *sustainable* growth by focusing on marginal, smallholder farmers, especially women, and on factors achieving sustainable post-intervention impacts. The study's outcomes will have direct bearing on ways to achieve a number of FtF objectives, including *Improved agricultural productivity*; *Increased resilience of vulnerable communities and households* (by allowing efficient usage of scarce water); and *Improved access to diverse and quality foods* (by enabling vegetable cultivation in the dry seasons).

The study will also contribute to three FtF Whole of Government Common Indicators on Improved Agricultural Productivity: The number of farmers and others who have applied new technologies or management practices, the number of additional hectares under improved technologies or management practices, and the number of private enterprises, producers organizations, water users associations and community-based organizations (CBOs) that applied new technologies or management practices (by increasing usage of improved inputs and of drip irrigation, specifically working with, creating and supporting farmers' groups, and increasing extent of irrigated land).

Our study is consistent with FtF emphasis on country-led processes, for example by working with the Senegal government program. It contributes to strengthening the continuum from research to improved M&E to improved practice. The project's approach emphasizes local capacity building with strong involvement of local policy, research, and implementation partners. Capacity building opportunities are threaded throughout the project process. By identifying interventions, intervention complementarities, and factors and conditions that lead to adoption of new technologies and practices among smallholder famers, the study will inform FtF and its partners in improving the design, targeting and implementation of programs to increase adoption of new technologies and improved practices, including improved seeds and inputs in Uganda, and drip irrigation in Senegal.

Uganda. The proposed study will contribute to one of USAID's major missions in Uganda, "Agriculture and Food Security" (USAID, accessed 1 April, 2013). It will contribute to all core components of Agriculture objectives (p. 5): "Enabling Environment: improved statistics, data and M&E capacity", "Research: improved soil and water management", "Production: reduced farmer vulnerability to environmental shocks", "Market Linkages: effective farmer organizations leverage finance". Maize and beans are grown by farmers targeted by the interventions..The study will also directly contribute to achieving FtF Uganda indicators and targets (pp. 32, 34), including "400,000 farmers using improved technology" (especially due to its focus on smallholders) and "Expenditures of rural households" (through large predicted increases in income).

Senegal: Increased human resource capacity to ensure access to modern agricultural technologies is one of the USAID FTF strategy core areas in Senegal, and environmental sustainability, natural resource management and gender (in particular the inclusion of women in technology dissemination) are three of its cross-cutting guiding principles" (USAID, accessed 2 April, 2013). The study will directly contribute to these goals, by studying models for the dissemination of Drip irrigation, a promising modern technology for environmentally sustainable and water and fertilizer-saving intensification, primarily to women smallholder farmers.

The proposed study will help address three core challenges identified in the Senegal FY 2011-2015 Multi-Year Strategy and support the corresponding core investment areas:

1. Agriculture driven economic growth - productivity increases through a value chain approach and promotion of sound land management: through more efficient usage of improved fertilizer and water achieved by drip irrigation through a dedicated supply chain.

2. Household behaviors that promote optimal nutrition: by increasing the cultivation of vegetables. The FtF multi-year strategy states that vegetables are under represented in local diets (p. 6) stresses a "promotion of a more diverse food basket at the community level" (p. 7), identifies investments in vegetable production in home gardens (p. 23) as an key strategy. Previous small-scale studies of TIPA have already identified positive impacts on household food consumption (Burney et al, 2010).

3. Increased human resource capacity, including associated institutions: by studying intensive extension models for the usage of modern technologies and by cultivating cooperative cultivation and water management by new and existing farmers' associations.

Conclusion

Our proposed project provides innovations in research methods, both for field studies and for policy analysis, and studies programs that offer high promise for achieving substantial improvements in food security in two Feed the Future countries, Uganda and Senegal. Drip irrigation is a heralded solution for sustainable intensification and food security, but there has been a dearth of rigorous impact evaluation; our study contributes with a unique RCT study of an Israeli-assisted drip irrigation program in Senegal. Agriculture programs often have to be scaled back; in Uganda, we have a unique opportunity to study a randomized scale back of an extension program- a novel revers-RCT analysis. Another unique innovation is our engagement of domestic think tanks (CRES and EPRC) in development of policy analysis and policy outreach in two African countries, through engagement of a leading international think tank (Brookings). This will lead to the highest standards in public policy analysis as well as best-practice outreach strategy.

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