Improving Jobs of Smallholder Women Farmers: Impact Evaluation Strategy

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Impact Evaluation Strategy

This project evaluates a novel policy intervention in rural Mozambique that supplements market-oriented agricultural extension services targeted to women farmers with a pilot training on non-cognitive skills. The randomized controlled trial comprises 3,000 women in 150 rural communities. The 150 communities will be randomly allocated into three groups with 50 communities each. The first group of 50 communities will receive training on agronomy and basic business techniques. The second group of 50 communities will receive the same agronomy training plus training on non-cognitive skills. The third group of 50 communities will not receive any training and will thus form a comparison group. This intervention seeks to deepen the impact of a feeder road rehabilitation program led by an active World Bank project in Mozambique (IGPP – P113971) on employment and earning opportunities in rural areas, while facilitating the creation of evidence on jobs challenges and solutions.

1. Motivation

Many women in sub-Saharan Africa appear to have restricted access to higher earning jobs and inputs that facilitate investments in their livelihoods. In particular, in rural areas women are thought to be disproportionally affected by market failures (e.g. limited access to information) and social norms (e.g. on the control of farm revenue), which limit their ability to participate in higher value agricultural chains.

These barriers can dampen women's personal motivation to exert themselves in the pursuit of economically independent lives, further exacerbating gender gaps in economic opportunities. An important question is whether investments in non-cognitive skills enhancing personal initiative, aspirations, and the will to persevere to overcome barriers can help women breakaway from such low-empowerment trap. This is the research question at the heart of this project, which to date has received little attention. This project evaluates a novel policy intervention that supplements agricultural extension services targeted to women farmers with a pilot training on non-cognitive skills. A key point of the analysis will be to examine whether investments in non-cognitive skills increase female participation in market-oriented agriculture.

A growing literature in psychology and economics documents the importance of non-cognitive skills in determining important economic outcomes [e.g. Bowles *et al.* 2001, Heckman *et al.* 2006, Borghans *et al.* 2008, Lindqvist and Vestman 2011]. Among these skills, perseverance ("grit") has been shown to predict educational and occupational achievement [Duckworth *et al.* 2007, Duckworth and Quinn 2009, Maddie *et al.* 2012, Eskreis-Winkler *et al.* 2014]. Optimism has been shown to affect occupational choices, portfolio choices, and marriage decisions [Puriw and Robinson 2007]. Personal initiative (defined as the combination of self-startedness, proactivity and perseverance) has also been shown to predict entrepreneurship and business success [Frese 2009, Koop *et al.* 2000, Frese *et al.* 2007]. While most of the existing evidence comes from rich country settings, an emerging literature documents a significant correlation between the non-cognitive skills of smallholder farmers and positive farm outcomes in the

developing world [Laajaj and Macours 2017, Montalvao *et al.* 2017, and Ali *et al.* 2017].

There are several reasons why non-cognitive skills can also matter in poor rural settings, in particular to engagement in commercial agriculture. In general, more perseverant farmers might be more patient, and thus more willing to cope with the long time lags between efforts and rewards associated with cash crops. And perseverance could manifest as the will to continue the pursuit of cash crops in the face of a new set of risks and challenges. More optimistic farmers tend to perceive the odds to be in their favor, and thus might be more willing to take the increased risk and uncertainty associated with cash crops. Farmers more passionate about their work might have direct utility benefits from spending the required time and effort farming cash crops. Farmers with a self-starting nature and proactive approach do not just wait to see what others in the community do, but they recognize and adopt agricultural technologies without being told or without an explicit role model.

Barriers to commercial agriculture can raise the importance of non-cognitive skills. An environment where adversity is absent makes it less necessary for farmers to have a high degree of grit and personal initiative. Women are thought to be disproportionally affected by market failures (e.g. limited access to information) and social norms (e.g. on the control of farm revenue). Non-cognitive skills could thus be particularly important for women farmers. Montalvao *et al.* [2017] document a positive, strong, and robust correlation between the non-cognitive skills of women farmers and the adoption of a cash crop in Malawi. To the extent that non-cognitive skills are malleable [e.g. Blattman *et al.* 2016, Allan *et al.* 2016], policy interventions aimed at fostering such skills in rural settings might thus be particularly effective if targeted to women.

Given that the evidence so far on the relationship between non-cognitive skills development in Africa and rural-level outcomes is based on non-experimental work, the project will pursue a randomized controlled trial (RCT) to learn rigorously about the causal relation.

2. Intervention

The experiment will take place in Mozambique, where agriculture contributes more than a quarter of its GDP and employs 80 percent of its labor force. As in most of sub-Saharan Africa however, market orientation is strikingly low – especially for women – with most of the farmers specializing in staple or subsistence crops. The agricultural extension intervention will have two training components, both using a training of trainers approach. The first component will provide training on agronomy and basic business techniques to build knowledge, enabling women farmers to produce and sell cash crops (hard-skills training). The second component will provide training on non-cognitive skills to help women stay motivated and overcome the psychological challenges associated with starting and running a cash crop business (soft-skills training).

2.1. Hard-Skills Training

The hard skills training will combine 36 hours of group training sessions with four 1-hour individual training sessions. It will take place over the course of twelve months in line with the agricultural cycle to ensure that women farmers have the necessary information and support to make the critical decisions at each

stage of the cycle. The process will begin with communication and involvement of community leaders in order to properly root the project locally and involve community interest and support.

The group training will consist of instruction reinforced by hands-on practice on a demonstration plot within the community to allow farmers to see the results of best farming practices. The curriculum will focus on locally relevant farming best practices related to land preparation and planting, weeding, fertilizing and other non-harvest activities, and harvesting.[1] The training will also include basic business skills and commercial practices needed to manage farm production more effectively and for better returns.[2] The individual training will take place at the woman's farm or home. These visits will reinforce the group training received, but will also allow the trainer to tailor the information and discuss technical matters specific to the situation of each woman.

The proposed schedule is to deliver the first six group training sessions on a monthly basis (i.e. one session per month) from August to February, excluding the month of December. The seventh and last group session will be in April and will serve as a recap session during which the acquired agricultural techniques and business skills will be reviewed. The individual training sessions will start in July and will gradually take place of over the space of twelve months, with 3 months apart between each of the four individual sessions.

2.2. Soft-Skills Training

The soft skills training will comprise twelve 3-hour group training sessions. The bulk of these sessions will take place over the course of four weeks, prior to the hard-skills training sessions, in order to enhance women farmers' personal motivation to adopt the selected cash crops before most farming decisions related to crop portfolio choices take place.

This training component will be developed by a team of entrepreneurial psychologists, and will be based on successful Personal Initiative training for small-business owners in urban African contexts [Campos *et al.* 2017]. It will focus on equipping women with the ability to take an active and self-starting approach necessary to start and run a cash crop business; persevere in the face of adversity; cope with the increased risk, uncertainty, and long time-lags between investments and returns associated with cash crops; and navigate through possible intra-household tensions that can ensue in response to increased income generation and participation in non-traditional activities by women farmers. All training materials will be suited to an illiterate and less educated audience.

The training sessions will be delivered in a group format through group discussions, activities, case studies, and shared experiences.[3] A few training sessions will take place five to six months later, in order to review and enhance the acquired skills.[4] Since it might be important to refresh specific soft skills throughout the farming season (e.g. during negotiation with input suppliers and produce buyers, or during spousal

[1] These activities will include, but will not be limited to: irrigation and water system; seeding; quality and care of the seeds; pest and disease control; spraying and how to use sprayer; post-harvest treatment; and understanding conservation agriculture.
[2] The beneficiaries will learn, among other subjects, to create a production plan; to establish and update production records (inputs, production, surplus, etc.); to learn the risks associated with production and the solutions to build resilience; to understand the value chain of crops in their area; and to build a marketing and commercialization strategy.
[3] The soft-skills training sessions will take place at an appropriate assembly point (e.g. under a tree or in a roofed meeting place). This point will be located within the community for easy and fast access by the trainees, and could be typically used for village meetings and community events.
[4] The final training schedule will be finalized jointly with the implementing partners.

negotiations over farm revenues), a few training sessions might be delivered in tandem with the hard-skills training.

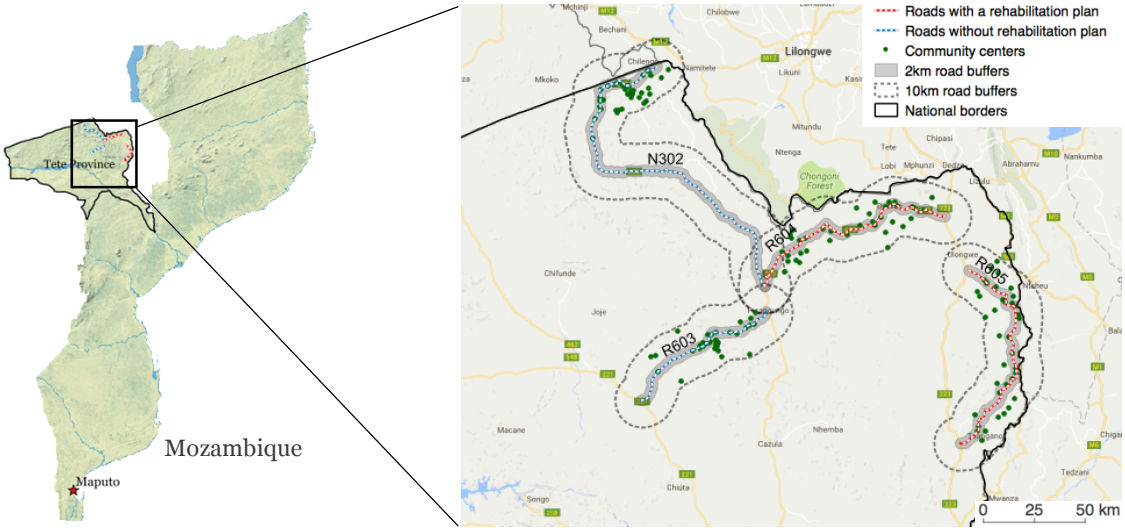
The training of trainers will start about two months before the intervention. The trainers will be local female community members, conversant in local languages. These women will be selected based on their non-cognitive skills, popularity/status in their communities, agricultural and livestock knowledge, and business skills. The trainers for the soft-skills training will not be the same for the hard-skills trainings in order to avoid contamination between the soft and hard skills training.[5] In order to improve the sustainability of the training, the project will also establish the necessary market linkages with input (seeds, fertilizer) suppliers, produce buyers (traders, processors, exporters), and finance.

3. Research Design

3.1. Sample Selection

This RCT is built on an ongoing impact evaluation of a feeder roads rehabilitation program under an active World Bank project (IGPP - P127303). The roads rehabilitation evaluation combines aspects of the (non-random) placement of the feeder roads rehabilitation program with baseline and follow-up survey data – in a difference-in-differences framework – to measure the effectiveness of better road infrastructure aimed at improving the ability of (male and female) farmers to sell their produce in the markets. We see this large-scale program as an ideal setting to test innovative market-oriented agricultural extension services targeted to women farmers – thus helping them take advantage of better road infrastructure connecting their communities with markets. Annex 1 explains in detail the design of the rural roads rehabilitation impact evaluation.

Figure 1. RCT Location

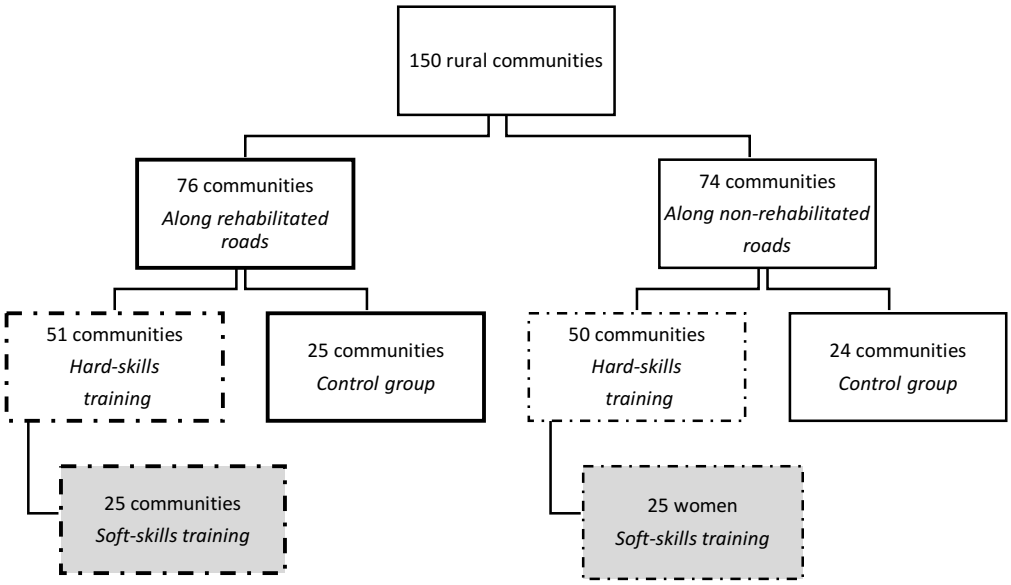


[5] For the hard-skills training, a total of 25 trainers will reach out to four communities each and serve a total of 80 woman farmers. There will be 10 additional trainers conducting the soft skills training to 50 identified communities.

A rigorous RCT approach will be used to measure the impacts of the agricultural extension interventions in Mozambique. The sample comprises 3,000 women in 150 communities (20 women per community) situated along four feeder roads (R604, R605, R603, and N302) in the northeastern part of Tete province, Mozambique (see Figure 1). The length of each of these roads is approximately 100kms. The communities are equally distributed along the four roads, with half of them located 0-2 km away from the roads and the other half located 2-10 km away from the roads.[6] Two of these roads (R604 and R605) will be rehabilitated under the Mozambique IGPP between May 2017 and December 2018. The other two roads (R603 N302) will not be rehabilitated.

The 150 communities will be randomly allocated into three groups with 50 communities each (Figure 2 outlines the design). The first group of 50 communities (Treatment 1) will receive the hard-skills training component only. The second group of 50 communities (Treatment 2) will receive the hard-skills training component and the soft-skills training component. The third group of 50 communities (Control group) will not receive any training and will thus form a comparison group. The random allocation of communities across the three experimental arms will be stratified by both road and distance to road.

Figure 2. RCT Design



3.2. Econometric Specification

As training participation is voluntary, not all eligible women will take-up the offer of receiving the training, and we therefore focus on intent-to-treat (ITT) impacts. Given the random assignment of communities to

[6] Road R604 is situated between N304 close to Mphulu all the way through Tsangano and up to Ulongwe (100 km). Road R605 is situated between Ulongwe, through Domue and up to Furancungo (99.6 km). Road R603 starts from Furancungo and is 74 km long toward the west. Road N302 is 160 km long, but all the communities that are part of the RCT study are spread out over a distance of 50 km along the Zambian borders.

treatment arms, it is straightforward to estimate the ITT impacts of the training interventions using the following OLS specification,

$$y_{\{i\}hv,t} = \gamma_0 + \gamma_1 T_v^1 + \gamma_2 T_v^2 + \gamma_3 y_{\{i\}hv,0} + \gamma_4 x_v + \varepsilon_{\{i\}hv,t} \quad (1)$$

where $y_{\{i\}hv,t}$ is an outcome of interest for household h in village v measure at midline or endline ($t = 1$ or 2). Index i denotes the individual (man or woman) for individual level outcomes. T_v^1 is a dummy variable equal to 1 for villages assigned to treatment 1 group (hard skills training), and 0 otherwise. T_v^2 is a dummy variable equal to 1 for villages assigned to treatment 2 group (hard skills training and soft skills training), and 0 otherwise. To improve the power of our dataset to detect meaningful treatment effects we control for the baseline level of each outcome $y_{\{i\}hv,0}$ [McKenzie 2012], as well as for the community-level randomization strata (road and distance to road) x_v [Duflo *et al.* 2007]. We allow the error term $\varepsilon_{\{i\}hv,t}$ to be clustered by community v. The parameters of interest are γ_1 and γ_2, which identify the standalone impact of the hard skills training and the combined impact of the hard skills training and the soft skills training. The difference, $\gamma_2 - \gamma_1$, identifies the marginal impact of incorporating soft skills training into an agricultural extension program.

3.3. Data

The main source of data for the impact evaluation will be annual surveys to collect community, household, and parcel level data. The community questionnaire focus on village-level crop prices and access to markets. Surveys are administered to the household head and his or her spouse.

Households and communities were first surveyed in April-June 2016 (baseline). The same households and communities will be interviewed again in June-July 2018 (midline), and in June-July 2019 (endline). Funds permitting, another round of data collection will take place post-2019 in order to detect longer-term effects.

The main outcomes of interest collected through these surveys are:

(i) cognitive and non-cognitive skills;
(ii) women empowerment and intra-household bargaining;
(iii) employment including off-farm;
(iv) feeder road usage and access to markets;
(v) agricultural production and sales, crop choices, input usage, and farming practices;
(vi) household and farm assets;
(vii) consumption.

The module on non-cognitive skills will be designed and validated by a dedicated team of psychologists. It will comprise multiple items tapping the construct of personal initiative specific to poor women in rural settings.

3.4. Power Calculations

Table 1 presents the results of power calculations using data from the baseline survey administered in April-June 2015.

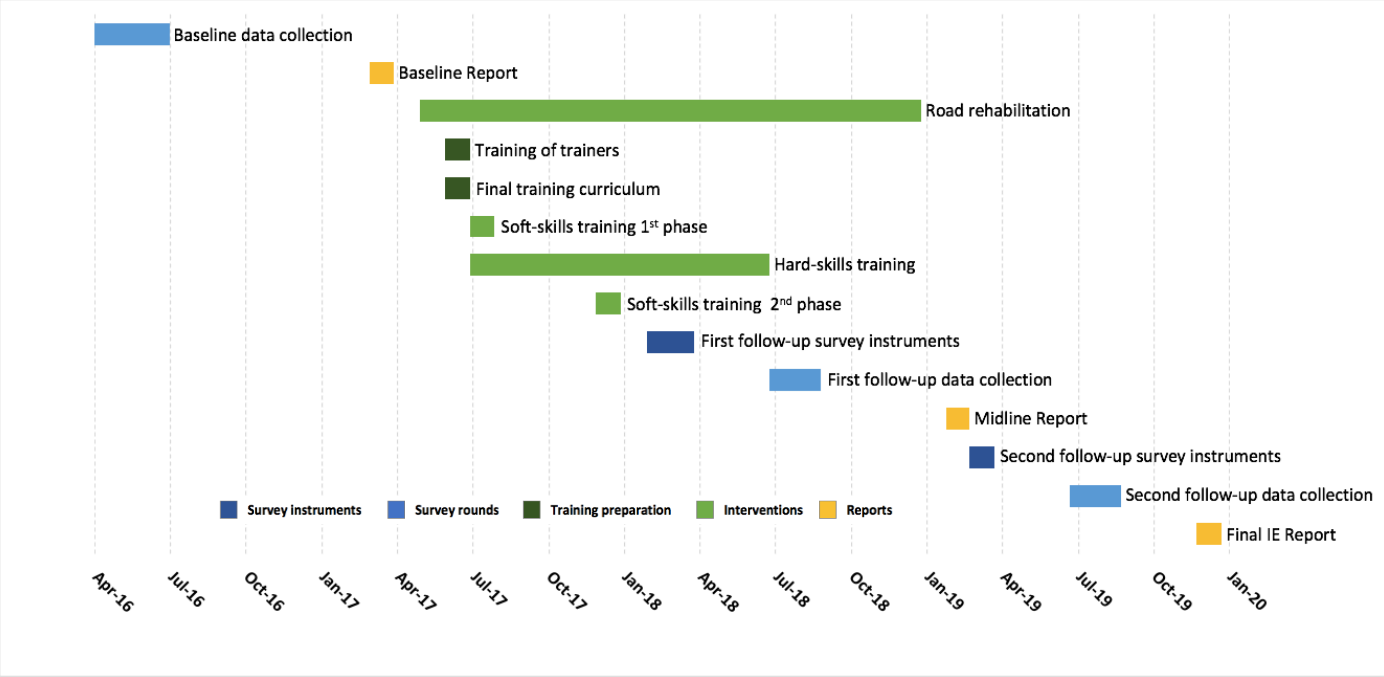
Table 1. Power Calculations

	(1) Share of produce sold in the market			(2) Farm yields			(3) Non-cognitive ability [score=0-10]			(4) Sample size [clusters]
Take-up rate:	**100%**	**75%**	**50%**	**100%**	**75%**	**50%**	**100%**	**75%**	**50%**	
Control										1,000 [50]
T1: Hard skills training	6.7pp	8.9pp	13.4pp	17.6%	23.4%	35.2%	3.3%	4.4%	6.6%	1,000 [50]
T2: Hard skills + Soft skills training	6.7pp	8.9pp	13.4pp	17.6%	23.4%	35.2%	3.3%	4.4%	6.6%	1,000 [50]
T1 + T2	5.8pp	7.7pp	11.6pp	15.3%	20.4%	30.6%	2.9%	3.9%	5.8%	2,000 [100]
Mean outcome at baseline		.406			11,552			6.3		
SD of outcome at baseline		.316			11,890			1.4		
Intra-cluster correlation		.211			.123			.08		

Notes: Data used for means, standard deviations, and intracluster correlations comes from the baseline survey for the impact evaluation. Calculations are based on the number of observations at baseline. All power calculations assume power=0.8 and significance level=0.05, two rounds of follow-up data, and ANCOVA estimation method. Autocorrelation is set at 0.3 and constant across survey waves. The non-cognitive ability is index is a continuous variable between 0 and 10 (with higher values corresponding to higher ability), constructed from the woman's level of agreement (1="strongly disagree" to 6="strongly agree") with 32 statements tapping the constructs of grit, locus of control, idea generation, personal initiative, general self-efficacy, entrepreneurial identity, need for autonomy, and goal orientation toward learning. Examples of statements for grit are: "I finish whatever I begin", "Setbacks don't discourage me", or "I am a hard worker".

We focus on share of produce sold in the market, farm yields, and non-cognitive ability of women farmers, which are key outcomes in the analysis. To deal with incomplete take-up of the trainings, we consider three alternative take-up scenarios: 100%, 75%, and 50% compliance. The results show that we are powered to detect a 6-12% increase in the share of produce sold in the market, a 15-31% increase in yields, and a 3-6% increase in non-cognitive ability. These results indicate that the increase in statistical power from high take-up of the trainings is substantial. The section on risks will discuss some strategies that will be in put in place in order to ensure high participation rates.

3.5. Timeline



4. Risk Assessment and Mitigation

This section outlines the main anticipated risks and the steps foreseen to avoid or mitigate these risks.

Take-Up. Low take-up of the trainings reduces the statistical power of the impact evaluation to detect meaningful impacts. To ensure high participation rates in the trainings, the following four strategies will be in put in place. First, the process will begin with communication and involvement of community leaders in order to properly root the project locally and involve community interest and support for the plot of land. Second, all women surveyed at baseline (the targeted women), as well as their husbands, will received door-to-door sensitization (prior and during the training) explaining the benefits of the training and highlighting its benefits to all members of the household. Third, the targeted women will receive farm inputs, as well individual technical assistance at their farms free-of-charge, only conditional on their participation in the training. This is typical to extension services' programs. Fourth, all targeted women will be notified in advance of the date and place of the (group and individual) training sessions, and attendance records will be maintained for every training session. Women not showing up will be called again to participate in the remaining sessions.

Sustainability. The intervention will have limited impact if the targeted women farmers are not effectively integrated into the selected cash crop value chains. To mitigate this risk the following three actions will take place. First, the implementing firm will lead field visits to the study area in order to gain a deeper understanding of the local agricultural value chains and identify one (or multiple) suitable high-value cash crop(s) to be promoted by the intervention. The choice of the cash crop(s) will be based on marketability, profitability, and ability to engage women farmers in its (their) production/marketing. Second, during the intervention period, the project will be responsible for procuring and distributing the required inputs (seeds, fertilizer) in order to allow targeted women to put the acquired knowledge into practice. Third, in order to ensure the long-term sustainability of the intervention, the necessary market linkages will be established with (i) input (seeds, fertilizer) suppliers, (ii) produce buyers (traders, processors, exporters), and (iii) finance.

Contamination. A common risk in randomized experiments is spillovers from treatment to control groups. In our setting, this could occur if for example women targeted by the intervention share knowledge acquired during the training sessions with other women in the community. To prevent contamination of the control group, the impact evaluation will randomize at the community level, rather than at the individual level. The average distance between any pair of communities along the same road is 11-25km. A dedicated field coordinator who will monitor the implementation to ensure that the implementation partner that will deliver the training adheres to the experimental design.

In order to better gauge the different risks involved and effectively prepare for them, the implementing firm will pilot the intervention in two nearby communities that are not part of the 150 communities surveyed at baseline as part of the RCT study. The pilot will test all the activities that will be implemented in the RCT communities, from mobilization, sensitization, and logistics, to the actual delivery of the training, and channeling of produce to the markets. In line with the RCT study design, one of the Pilot Communities will pilot the hard-skills training only, whereas the other Pilot Community will test both the

hard-skills and the soft-skills training. The piloting of all the different activities in each Pilot community will take place before their scale-up in the RCT communities, to provide the implementing partner with enough time to fine-tune and establish best practices.

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Appendix: Mozambique IGPP's Feeder Roads Rehabilitation Impact Evaluation

A. Conceptual Background

Few doubt that the lack of appropriate rural road infrastructure plays a key role in the development process. Rural road construction and rehabilitation, including the upgrade of feeder roads linking up small rural communities with each other or to larger roads, is an increasingly common policy tool used by governments in Sub-Saharan Africa. By reducing transportation costs, good feeder roads can improve the ability of poor farmers to sell their produce in the markets, thus raising the expected profitability of commercial agriculture. It is also possible that lower transportation costs can lead to increased nonfarm employment opportunities in local firms and nearby urban areas.

The effects of rural road rehabilitation might also differ with respect to gender. For example, traditional gender role norms might dictate that men specialize in the production and marketing of cash crops, and women should focus on the production of food crops for family consumption. This could diminish any increase in female participation in commercial agriculture. Attitudes against women working far away from home could also diminish any increase in female participation in nonfarm work. In such case however, an optimal response could be for men to take on more nonfarm jobs and for women to engage more in cash crop production at their farms. Given the additional constraints faced by female farmers, complementary human capital interventions targeted to women farmers – supplying them with the skills and aspirations needed to effectively crossover into these activities – could be particularly helpful in helping women take advantage of better road infrastructure.

To date the amount of rigorous evidence on the effectiveness of feeder road rehabilitation interventions is thin. One of the first studies on the impacts of rural road rehabilitation was conducted by Escobal and Ponce (2003) in Peru. The study compares the outcomes of households living near a rehabilitated road with those for households living further away using a propensity score matching approach. It finds that access to the rehabilitated road is associated with increased nonfarm income opportunities, especially wage-employment. Khandker *at al.* (2009) combine propensity score matching with difference-in-differences to evaluate the impact of a rural road program in Bangladesh. They find that rural road investments significantly reduce village level poverty. This effect was accompanied by increased agricultural production and output prices at local village markets, and reduce farm input and transportation costs.[7]

Casaburi *et al.* (2013) use a regression discontinuity design to examine the effect of a feeder roads rehabilitation program in Sierra Leone on agricultural markets. They find that improved feeder roads significantly lower market prices of the main staple crops (rice and cassava) produced in the country. Asher and Novosad (2016) also use a regression discontinuity design to study the impact of a national rural road construction program in India. This is one of the few studies looking at heterogeneity of the impact with respect to gender. They find that rural road construction leads to a reallocation of labor away

[7] Moreover, rural road development led to higher secondary schooling enrollment for boys and girls (but not higher primary school enrollment).

from agriculture towards nonfarm employment. This effect is concentrated among males, although due to lack of statistical power the gender difference is not statistically significant.

B. Empirical Methods

Sometimes the assignment of these projects is based on whether a road scores above or below a cutoff point on a continuously measure variable, such as population concentration or some composite multi-dimensional index. This feature eases the identification of a credible comparison group. To the extent that roads around the cutoff point are sufficiently similar to each other, a regression discontinuity design (RDD) can be used to compare roads or communities "just above" and roads "just below" the cutoff [Casaburi *et al*. 2014, Asher and Novosad 2015]. More often than not however the details of the prioritization used to decide which roads and communities to target do not follow a simple scoring procedure. The project we evaluate falls into this category. We will use the following four alternative quasi-experimental empirical frameworks, which differ in terms of their identification assumptions and data requirements. Together they will provide a rigorous, yet approximate, set of estimates of the causal impact of rehabilitating roads R604 and R605.

B.1. Double-Difference using Time and Comparison Roads

First, a popular strategy is to collect baseline and follow-up data and use a difference-in-difference (DD) methodology [e.g. Mu and Van de Walle 2007, Khandker *et al.* 2009, Ali 2011, and Aggarwal 2015]. This method compares the change over time in outcomes between communities in close proximity to rehabilitated roads and communities in close proximity to non-rehabilitated roads. In discussions with the project team and counterparts at the ANE (Associacao Nacional de Estradas) and FE (Fundo de Estradas), roads R302 (between Farracungo and Mualadze (≈100 km)) and N603 (between Farracungo and N9 (≈100 km)) were selected for the comparison group. These roads are in the vicinity of roads R604 and R605, share the same agro-ecological characteristics, and are in an equally bad state.

This method identifies the causal impact of road rehabilitation under the assumption that unobservable factors driving a wedge in underlying time-trends between communities along roads R604/R605 and communities along roads N302/R603 are constant across time. In practice this method is estimated with the following specification using pre- and post-intervention data on households in communities along roads R604/R604 and roads N302/R603:

$$\Delta y_{hcr} = \alpha_0 + \alpha_1 R_{cr} + \alpha_2 X_{ct=0} + \Delta\varepsilon_{hcr} \qquad \text{(B.1)}$$

where $\Delta y_{hcr} = (y_{hcrt=1} - y_{hcrt=0})$ is the change in the outcome of interest between baseline and follow-up for household h, in community c close to road r. R_{cr} is a rehabilitation dummy that equals 1 if road r is either R604 or R605, or 0 if either N302 or R603. $X_{ct=0}$ is vector of community level controls measured at baseline. The parameter of interest is α_3 which measures the differential change in mean outcomes between communities along rehabilitated roads and communities along non-rehabilitated roads. The inclusion of vector $X_{ct=0}$ controls for observable factors driving a wedge between these two types of communities in their underlying time trends. Throughout all specifications standard errors will be clustered at the community level.

B.2. Double-Difference using Time and Distance to Roads

Second, an alternative DD approach exploits proximity to the rehabilitated roads. This method only uses data from households in communities along rehabilitated roads, and avoids the common time-trend assumption between rehabilitated and non-rehabilitated roads used in the DD approach described above. It compares changes in outcomes between communities that are in close proximity to the rehabilitated roads and communities that are further away [Ghani *et al*. 2015]. The identification assumption here is that had the rehabilitation intervention not occurred these two types of communities would have been on a similar pattern of evolution.

In practice this method is estimated with the following specification using pre- and post-intervention data on household in communities along roads R604/R605:

$$\Delta y_{hcr} = \beta_0 + \beta_1 D_{cr} + \beta_2 X_{ct=0} + \Delta\varepsilon_{hcr} \quad \text{(B.2)}$$

where D_{cr} is a distance dummy that equals 1 if community c is 0-2 km from the road, and 0 if 2-10 km away. The parameter interest is β_1 which measures the differential change in mean outcomes between communities in close proximity to roads R604/R605 and communities at some distance from roads R604/605. As before, the inclusion of vector $X_{ct=0}$ controls for observable factors driving a wedge between these two types of communities in their underlying time trends.

B.3. Triple-Difference using Time, Comparison Roads and Distance to Roads

Third, a more robust method is to use a triple-difference (DDD) approach that combines variation across time, across rehabilitated and non-rehabilitated roads, and across distance to roads. This method compares changes in outcomes between communities that are in close proximity to roads and communities that are further away, both along rehabilitated and non-rehabilitated roads. It relaxes the common time-trend identification assumptions of the two DD models described above. Under this approach the identification assumption is instead that in the absence of the project, the effect of proximity to roads on changes in outcomes over time is constant across rehabilitated and non-rehabilitated roads.

This method is estimated with the following specification using pre- and post-intervention data on household in communities that are close and not so close to both roads R604/R605 and roads N302/R603:

$$\Delta y_{hcr} = \gamma_0 + \gamma_1 R_{cr} + \gamma_2 D_{cr} + \gamma_3 [R_{cr} \times D_{cr}] + \gamma_4 X_{ct=0} + \gamma_5 [X_{ct=0} \times R_{cr}] + \gamma_6 [X_{ct=0} \times D_{cr}] + \Delta\varepsilon_{hcr}. \quad \text{(B.3)}$$

The coefficient of interest is γ_3 which can be shown to equal the change across time in mean outcomes for households in communities located 0-2 km from roads R604/R605, net of changes in mean outcomes for households in communities located 0-2 km from roads N302/R603 and of changes in mean outcomes for households in communities located 3-10 km from roads N604/R605.

B.4. Straight-Lines Instrumental Variables

Finally, as a robustness check we will follow an approach similar to Banerjee *et al.* [2012] and Ghani *et al*. [2015] and use an instrumental variable (IV) approach based on straight-line distances between termini communities. Specifically we will instrument for being 0-2 km from roads R604/R605 with being 0-2 km

from a straight line between the termini communities of these roads. The identification assumption of this method is that proximity to the straight line only affects communities in the post-intervention period due to the likelihood of the community being in close proximity to the roads experiencing the rehabilitation upgrade.

In practice this method is estimated with the following system of equations:

$$D_{cr} = \pi_0 + \pi_1 L_{cr} + \pi_2 X_{ct=0} + \varepsilon_{cr} \quad \text{(B.4)}$$

$$y_{hcrt=1} = \delta_0 + \delta_1 D_{cr} + \delta_2 X_{ct=0} + \varepsilon_{hcrt=0} \quad \text{(B.5)}$$

where L_{cr} in equation (C.4) is a dummy that equals 1 if community c is 0-2 km from the straight line, and 0 if 2-10 km away. This method only uses data from communities along roads R604/R605. Equation (B.4) only uses community level pre-intervention data, and equation (B.5) only uses household and community level post-intervention data. We use equation (B.4) as a first-stage to predict how distance to the straight-line predicts distance to the roads. Our parameter of interest is δ_1 in equation (B.5) in which D_{cr} has been instrumented with L_{cr} using equation (B.4) as our first-stage.

C. IGPP's Feeder Roads Rehabilitation (Technical Details)

In total, 207 kilometers of roads are going to be rehabilitated by the Associacao Nacional de Estradas (ANE) under the IGPP, between May 2017 and December 2018. Currently, the existing surface of R604 and R605 is predominantly made of gravel. The width of the gravel surface varies from 6.2 to 6.7 meters. Small stretches of R605 have a cape sealed surface, mainly in places where the longitudinal gradient is extreme. In total, about 20 kilometers of R605 is covered by a cape sealed surface. On the contrary, only 0.2 kilometers of R604 has a cape sealed surface. The area around the roads is mountainous. Therefore, the terrain along roads R604 and R605 is very uneven. Especially R605 becomes mountainous over 18 kilometers. Along the R605, the altitude varies between 989 meters and 1,717 meters with a median altitude of 1,382 meters. The altitude of R604 is more constant and ranges between 1,094 and 1,357 meters, with a median altitude of 1,250 meters. The insufficient routine maintenance and the poor water drainage created high irregularities on the roads (holes, grooves, ravines etc.). Water flows from rainfalls or natural sources constantly damage the surface. Coated drains are observed irregularly along the roads with steep longitudinal gradients especially around bridges. Overall, the horizontal geometry of the roads is good but a significant improvement of the vertical geometry is needed. In addition, the drainage system is in a bad state, worsening the quality of the road.

The rehabilitation works plan to seal with a cape sealed surface 25 kilometers and 32 kilometers of R604 and R605 respectively. The remaining of the roads will be entirely upgraded and re-graveled with a new gravel material. Table C1 summarizes the modifications of the roads' pavement before and after the works as set out in the construction plan. Aside from the surface of the roads, the works also include the rehabilitation of the drainage system along the roads: rehabilitation, reconstruction and when necessary construction of new drains and culverts. An inventory of the works on the roads, culvert and drains, as well as bridges and intersections is reported in Table C2.

Table C3 details the different activities that will be undertaken along the roads rehabilitation process. The activities start with the bush clearing of the roads' areas and the preparation of the surface (stabilizing the embankment, harmonizing the width of roads, smoothing and priming the surface). Then, the new material of the road pavement will be applied and culverts and drains will be installed. Finally, the works include activities such as marking, painting and installing traffic sign boards. The 18-month rehabilitation works will be followed by another 18-month of routine maintenance works and quality control checks so that all road performance standards are achieved.

Table C1. Planned road surface type before and after rehabilitation works (Km)

	Total length of rehabilitated roads	Before works		After works	
		Gravel surface	Cape sealed surface	Gravel surface	Cape sealed surface
R605	104	84.7	19.3	52.6	51.4
R604	103.6	103.4	0.2	78.4	25.2
Total	**207.6**	**188.1**	**19.5**	**131**	**76.6**

Sources: Administraçao Nacional de Estradas (2016), "Estudo Ambiental Simplificado para o projeto de Rehabilitaçao das Estradas R605 e R604" and "Biding Document for Procurement of Works and Services under Output- and Performance-based Road Contracts of R605 and R604".

Table C2. Other road rehabilitation works

	Unit	R605	R604
Road Surface Works			
Sealing of existing gravel surface	Km	32.2	25
Re-gravelling of existing gravel road	Km	52.6	78.4
Road Side Drains			
Construction of open lined drain	Km	9	15.2
Construction of open unlined drain	Km	114	79.6
Rehabilitation of existing drain	Km	5.95	2.9
Intersections			
Re-gravelling of major junctions	No	1	3
Re-gravelling of minor junctions	No	10	11
Rehabilitation of Existing Bridges	No	11	9
Construction of Retaining Wall	Meters	250	0
Culverts			
Rehabilitation of Existing Culverts	No	150	112
Reconstruction of Existing Culverts	No	17	19
Construction of New Pipe Culverts	No	5	0

Sources: Administraçao Nacional de Estradas (2016), "Estudo Ambiental Simplificado para o projeto de Rehabilitaçao das Estradas R605 e R604" and "Biding Document for Procurement of Works and Services under Output- and Performance-based Road Contracts of R605 and R604".

Table C3. Scope of the Activities in the Road Rehabilitation Works

A) Bush clearance along the road
Clearing, grubbing, removing and disposing of vegetation, including sand, dirt, mud and earth inside the construction area.
B) Strengthening and widening embankment/cut formations
Constructing and compacting embankment/cut formations so as to provide stable side slopes and adequate bearing capacity.
C) Road carriage way
Rehabilitating the road width.
D) Road surface smoothing
Smoothing and priming the surface.
E) Road pavement
Applying cape seal layer bitumen surface OR placing and compacting of natural gravel layer.
F) Road lane marking and traffic sign boards
Road marking and designing, producing and installing sign panels.
G) Desilting
Desilting on existing culverts, masonry and concrete drains.
H) Earth Drain
Constructing an earthen drain to discharge of water run off to the valley or natural stream.
I) Slope Protection
Providing protection by grounted to the side slopes of embankments susceptible for erosion/slip.
J) Painting and Numbering
Applying two coats of best quality synthetic enamel paint on non-metallic guardrails, bridge marker post and other marker posts.
K) Reinforced Concrete Pipe Culvert
Constructing reinforced concrete pipe culverts on 100mm of blinding concrete. Any unsuitable material below the proposed bedding level shall be replaced with good quality soil to ensure bearing and drainage.

Sources: Administraçao Nacional de Estradas (2016), "Estudo Ambiental Simplificado para o projeto de Rehabilitaçao das Estradas R605 e R604" and "Biding Document for Procurement of Works and Services under Output- and Performance-based Road Contracts of R605 and R604".