A protocol for the role of incentives for adoption of climate-smart agricultural innovations: An experimental evaluation in Uganda

Emmanuel Bizimungu, Robert Sparrow, Ruerd Ruben
Development Economics Group, School of Sciences, Wageningen University & Research

Introduction

The impacts of climate change on agriculture have risen globally but developing regions, such as Sub-Sahara Africa, have been affected the most. Climatic shocks, such as droughts, and floods are increasingly causing losses among many African farming communities, as farmers depend on rain-fed agriculture and are thus highly vulnerable to climatic shocks. According to climate projections, these countries will be hit the hardest by climate change. As climate change brings about more risks for farmers, improving technology adoption to bolster agricultural production remains a key challenge.

Technology adoption in agriculture has remained strikingly low in Africa, compared to other developing countries (Carter et al., 2013). Consequently, agricultural productivity has generally remained low. For soybean, yields have even declined over the years despite its growing demand, nationally and internationally. Recent research shows that although agricultural production in Africa has increased over the past decades, such progress is mainly attributed to land area expansion and labor force mobilization rather than yield-enhancing technologies (Blein et al., 2013; William et al., 2015). As food demand continues to grow due to high population growth, the use of sustainable modern techniques for raising productivity becomes indispensable since farmland expansion is no longer feasible. Achieving productivity growth requires addressing technology access and its adoption constraints (Bold et al., 2017; Dercon & Christiaensen, 2011; Duflo et al., 2011; Feder et al., 1985; Foster & Rosenzweig, 2010).

Climate-smart agriculture (CSA) has been suggested as a key strategy that could potentially enhance agricultural productivity and build resilient farming systems, while mitigating the impacts of climate change. However, since its inception (Food and Agriculture Organization of the United Nations, 2013), CSA has not been fully embraced by many developing countries including Uganda, Kenya, and Tanzania. Low commitment by the governments to implement adaptation and mitigation plans, such as CSA coupled with poor agricultural extension systems, means that smallholder producers, the majority of whom are women, have limited options for managing risks in agriculture.

To invest in CSA innovations, farmers will need incentives that address production and market risks as well as informational constraints. The SNV-led ‘Climate Resilient Agribusiness for Tomorrow (CRAFT)’ program[1] offers financial and technical support for SMAEs and other service-providers to deliver a wide range of incentives for smallholder adoption of CSA innovations. These include both “push” incentives (farm-level training in CSA practices and technologies, and agricultural extension services) and “pull” incentives (value-chain (VC) linkages through production and marketing contract, and index-insurance). We study these incentives under the soybean value-chain because soybean has a huge potential to raise household income and nutrition.

The push (supply-driven) incentives are offered at no cost to the farmer to address informational constraints regrading CSA innovations. The pull (demand-driven) incentives address risks and technology access constraints and the uptake of these pull incentives depends on smallholders’ resource endowments, gender, education, gender, risk attitudes, among others.

[1] https://snv.org/project/climate-resilient-agribusiness-tomorrow-craft

Many studies have analyzed the role of production/marketing contracts and index-insurance incentives separately (Benyishay & Mobarak, 2019; Marr et al., 2016; Oya, 2012; Ragasa et al., 2018; Shikuku et al., 2019) while many other studies have utilized principal-agent theory to analyze the role of a single (incentive) contract (Azumah et al., 2017; Barrett et al., 2012; Mishra et al., 2018; Saenger et al., 2013). We build on these studies to examine the role of mixed contracts such as production and marketing contract and index-insurance on the adoption of CSA innovations. Our research thus contributes to the body of knowledge regarding the role of mixed incentive contracts on technology adoption, in general, and CSA innovations, in particular.

The main objective of this study is to assess the **effectiveness of the incentives** for the adoption of CSA innovations, and ensuing impacts on farming systems resilience and household welfare. Specifically, this research will:

1. Assess the effects of different bundles of 'push' and 'pull' incentives on adoption intensity of climate-smart agricultural practices and technologies;
2. Assess the impacts of CSA practices and technologies on farming systems' resilience, factor productivity, revenues, income and, nutrition.

Methods and Analysis

Three small and medium agribusiness enterprises (SMAEs) namely: ACILA enterprises, ALITO Joint, and OKEBA operating in the eastern, northern, and western and central regions, respectively are implementing an intervention involving three key incentives. First, farmers organized in groups are trained through training workshops to create awareness and their understanding of different CSA practices and technologies. Thereafter, trained farmers begin to access agricultural extension services through demonstration sites or farmer field schools (FFSs) established within their communities. At the demo sites, the extension agents also residing within the same communities practically teach farmers how to apply different CSA practices and technologies. Second, the SMAEs facilitate smallholders' access to quality inputs either directly through direct sales on cash/credit, or indirectly through brokered linkages with agro-input dealers. Upon harvest, farmers sell their output to the SMAEs at a higher than average market price. This SMAE-farmer relationship is established through either a written or verbal contract. Through this relationship, input and output market risks are addressed. Finally, the SMAEs with support from SNV identify key insurance service providers to sell index-based insurance to farmers. Farmers pay half of the premium while the other half is subsidized by the government of Uganda. Index-based insurance insulates smallholder farmers against risks associated with weather changes including excessive rains or seasonal drought.

Famers do not pay for the *supply-driven* training and extension services. However, farmers may incur other costs associated with travels to and from the training venues and demo sites. We combine training and extension and label these *push* incentives since both incentives address informational constraints and any uncertainties associated with the technologies. On the other hand, *demand-driven* technologies/inputs such as improved seed, and insurance services are accessed through production/marketing contract, and index-based insurance incentive instruments, respectively. In other words, farmers have to decide whether or not to participate (buy) in contract farming arrangements (index-based insurance). Therefore, production/marketing contract is labelled *pull-1* while index-based insurance is labelled *pull-2* incentive.

We form different combinations (bundles) of *push* and *pull* incentives and assess their effectiveness on adoption intensity of CSA practices and technology before assessing impacts of CSA innovations on factor productivity, incomes and household welfare. The bundles include: (i) *push*; (ii) *Push + Pull-2*; (iii) *Push + Pull-1*; and (iii) *Push + Pull-1 + Pull-2*. Incentive bundles/combinations of *push* and *pull* incentives can potentially effectively address the multiplicity of risks and other constraints faced by smallholders thereby improving adoption of seemingly profitable innovations such as improved seed and rhizobia inoculants. In other words, raising adoption might require incentive bundles that address various risks and constraints, contemporaneously. This is particularly important because standalone incentives are normally offered to address specific risks or constraints but not a continuum of risks/constraints.

The SMAEs roll-out the intervention to the participants in phases by targeting new farmer groups every season for two years (Table 2). Also important to note is that, index-based insurance becomes available to farmers in the second year due to the delays in the identification and selection of insurance service providers. Therefore, we implement a concurrent stepped-wedge Cluster Randomized Controlled Trial (CRCT) with SMAEs to assess among their farmer groups the effectiveness of the four incentive bundles. Randomization is done in three steps. First, we randomly assign farmer groups across seasons due to phased roll-out of the intervention where new farmer groups are enrolled at the beginning of a new season. Using block-cluster randomization approach, we randomized farmer groups (clusters) into three instead of four cropping seasons because the SMAEs (blocks) had already selected beneficiaries for the first season of 2020 by the time of randomization. Random assignment of farmer groups to the seasons helps us to randomly determine the sequencing of enrolment of farmer groups into the CRAFT program. Second, farmer groups were randomly assigned to *push* or *push + pull-1* incentive bundles. Finally, we randomize access to index-based insurance among farmer groups that begin to receive *push* or *push + pull-1* in either year 2020 or year 2021. This results in the four treatments (Table 1).

Table 1. Treatment and control conditions across years

Treatments	Baseline done in 2020 (0)	Mid-line done in 2021 (1)		Endline done in 2022 (2)		No. of farmer groups
	Seasons 1 & 2	Season 1	Season 2	Season 1	Season 2	
T1-1	■ ■ ■	A ■ ■	A ■ ■	A ■ ■	A ■ ■	39
T2-1	■ ■ ■	A ■ ■	A ■ ■	A ■ C	A ■ C	34
T3-1	■ ■ ■	A B ■	A B ■	A B ■	A B ■	39
T4-1	■ ■ ■	A B ■	A B ■	A B C	A B C	37
T1-2	■ ■ ■	■ ■ ■	■ ■ ■	A ■ ■	A ■ ■	48
T2-2	■ ■ ■	■ ■ ■	■ ■ ■	A ■ C	A ■ C	44
T3-2	■ ■ ■	■ ■ ■	■ ■ ■	A B ■	A B ■	38
T4-2	■ ■ ■	■ ■ ■	■ ■ ■	A B C	A B C	50
Total # groups	329	69	80	89	91	329

Key
A= Training & extension services (Push)
B= Value-chain linkages through production & marketing contract (Pull-1)
C= Value-chain linkages through index-based insurance (Pull-2)
■= Non-exposure to an intervention

Each farmer group starts with (1) the business as usual condition or the baseline phase in which usual farming without incentives is assessed, followed by (2) a second (mid-line) phase in the year 2020 in which 73 farmer groups receiving *push* (T1-1 and T2-1) and/or 76 farmer groups receiving *push+pull-1* (T3-1 and T4-1) incentive bundles are compared with 92 and 88 control farmer groups that begin to access *push* (T1-2 and T2-2) and *push+pull-1* (T3-2 and T4-2) incentives in the year 2021, respectively (Table 1).[2] In the final (end line) phase, five more comparisons can be made. That is, 89 farmer groups receiving *Push+Pull-1+Pull-2* (T4-1 and T4-2) are compared with: (i) 87

[2] The number of farmer groups determined through power calculations were found to be sufficient to aid comparisons across treatment conditions. See sample size section for more details about power calculations.

farmer group receiving *push* (T1-1 and T1-2) incentives; (ii) 77 farmer groups receiving *push+pull-1* (T3-1 and T3-2); and (iii) 78 farmer groups receiving *push+pull-2* (T2-1 and T2-2) incentives. Similarly, recipients of *Push+pull-2* incentives are also compared with recipients of (i) *push*, and (ii) *push+pull-1* incentives. Noteworthy, 180 farmer groups that wait to receive interventions in the year 2021 serve as the control groups for assessment at the mid-line period. Farmer groups that began to receive *push* and *push+pull-1* incentives in the first year (2020) continue to receive the same incentives in the second year (2021) except that part of these are randomly assigned to receive index-based insurance as an additional incentive (the last two bars in seasons 1 and 2 of year 2021 in Figure 1). We collect data from 2,533 households on several variables of interest at the baseline period in the year 2019 before implementing the CRAFT program to facilitate measurement and estimation of outcomes of interest such as adoption intensity.

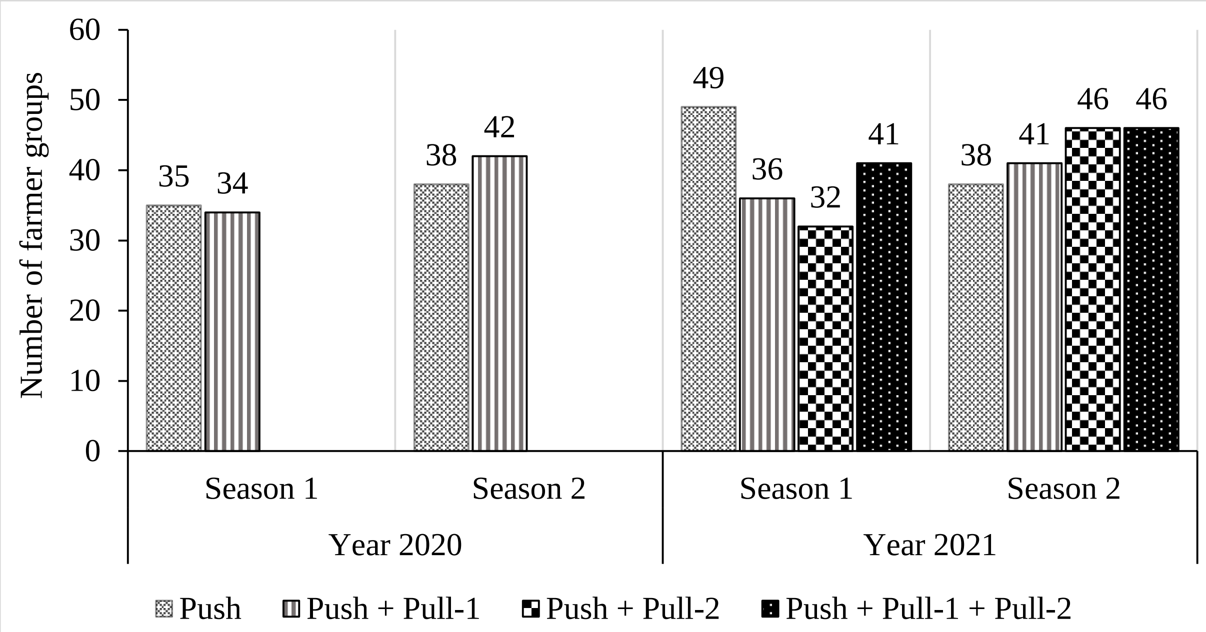

Figure 1. Treatments per season per year.

It is possible to have cases of non-compliance or partial compliance within treatments. Due to different number of incentives in each incentive bundle, each treatment can have different degrees or levels of compliance. We can define two types of non-compliers: never-takers that will always reject a new intervention if they are offered it, and always-takers that will always receive a new intervention even if they are not offered it (Ye et al., 2014). For instance, a member of a farmer group in the *push* treatment is regarded as a complier if he or she takes both the training and extension services, but would not have done so if it was not offered. A member is regarded as a partial complier if he or she takes only extension services or only training but not both. There is a possibility for farmers to access inputs and technologies and other services under a (verbal or written) contract and, for some reasons, still sell soybean output outside the contract. In this study, a farmer takes up *pull-1* incentive if he or she sells the largest share or all of marketed soybean output to the SMAE, regardless of receipt of inputs and other services. A farmer takes up *pull-2* incentive if he or she uses it, irrespective of whether or not it was bought. By design, receipt of *pull-1* and *pull-2* incentives depends on receipt of push incentives. Therefore, it is not possible that a farmer can access only *pull-1* or *pull-2* incentives. However, a farmer can choose not to take *push* incentives although such cases are expected to be very rare. Instead, there might be cases where some farmers take only extension services or training. Similarly, a farmer can take both or part of *push* incentives but chooses not to take *pull-1* or *pull-2* depending on assigned treatment.

We assess the effects of the four incentive bundles in two ways. First, we estimate the average intention-to-treat (ITT) effect among those assigned to treatment (incentive bundles). The ITT effect reflects how farmers respond to te randomized offer regardless of their actual take-up of the treatment. Second, we can account for non-random compliance by using the random offer as instrumental variable for non-random take up of the treatment, yielding a local average treatment effect (LATE).

Participants

Study sites and eligibility

A preliminary qualitative survey was conducted in March 2020 to understand underlying differences among the SMEs, interventions and implementation arrangements. This helped to adapt a stepped wedge cluster randomization trial design and identification of variables for the development of a household questionnaire. As mentioned earlier, the interventions being assessed by this research are implemented by three SMEs, namely ACILA Enterprises found in the eastern region (with farmer groups in six districts); ALITO Joint Farmers' Cooperative Limited in northern region (with farmer groups in six districts), and OKEBA in the central (farmer groups in one district) and western regions (with farmer groups in three districts). The SMEs will cover 806 farmer groups in two years and each group has 27 members, on average. This population is 54% males; aged 38 years (50.6% of the population is typical youths aged 28.2 years, on average) (Appendix I) producing soybean on 2.62 acres (or 1.1 hectares), on average (Tables 3 & 4). Of 806, this research covers 336 eligible groups distributed across regions and districts. A farmer group is eligible if: (1) it is the only farmer group targeted by the SME agribusiness in a village. In other words, there is only one farmer group in a village; (2) has members from different villages but those villages have no other farmer groups targeted by the business champion; (3) has 8 members or more. Each farmer group must meet all the three eligibility criteria to be included in the study. Therefore 336 farmer groups (clusters) is our sample frame.

Intervention and control

SNV extends technical and financial support to small and medium agribusiness enterprises (SMAEs) to deliver an intervention involving varied incentives based on their business plans. The intervention being assessed by this research involves three key incentives as described below.

Training in CSA practices and technologies & agricultural extension services (Push). The CRAFT programme engages Master Trainer of Trainers (MToTs) with substantial experience in climate-smart agriculture and farmer field school (FFS) methodology to train employees of SMAEs working as extension agents. The extension agents train trainer of trainees (ToTs) and the ToTs in turn train organized farmer group members in climate-smart agricultural practices and technologies, and offer agricultural extension services through farmer field schools (FFSs). The FFSs are established within the communities with technical support from extension agents. The trainer of trainees (ToTs) are experienced individual farmers identified from the communities within which farmer group members reside. A farmer field school (FFS) benefits one farmer group. The extension agents continue to offer oversight and technical backstopping to the ToTs as implementation progresses. Although the CRAFT programme considers training and extension as two distinct incentives, this research views them as one considering that they both address one thing – informational constraints regarding CSA practices and technologies.

Value-chain (VC) linkages through contract (Pull-1). In addition to the training and extension services, the SMAEs contract part of their farmer groups to produce seed and the majority of others to produce grain, which the SMAEs buy back through collective bulking and marketing arrangement. However, some soybean seed producers are also engaged in grain production. The key functions of the contract are assured supplies of quality inputs including seed, rhizobia inoculants, among others as well as market assurance for seed and grain supplies. Upon harvest, soybean seed and grain is delivered by farmers to the designated satellite (collective bulking) centres managed by the village-agents. The village-agents are paid a commission by the SMAEs.

Value-chain (VC) linkages through index-based insurance (Pull-2). The SMAEs with support from SNV identify key insurance service providers to sell index-based insurance to farmers. Farmers pay half of the premium while the other half is subsidized by the government of Uganda. Index-based insurance services are marketed through village-agents using digital platforms availed by the insurance service-providers.

Farmer groups are covered by the intervention in four phases (cropping seasons) where each SMAE targets a fraction of its farmer groups per season. Importantly, the SMAEs are willing to randomly assign these incentives over different farmer groups. We take this opportunity to form different bundles of push and pull incentives and assess their effects on adoption intensity of CSA innovations such as improved seed. Hence, we form four incentive bundles namely; (i) Training & extension; (ii) Training & extension + Contract; (iii) Training & extension + Index-insurance; and (iii) Training & extension + Contract + Index-insurance. Project participants that get access to push and push + pull-1 incentive bundles in the first year will begin to have access to index-insurance in the second year. Farmer groups that never had access to any incentives in the first year (control) will begin to have access to push and push + pull-1 incentives in the second year. The experimental design and allocation of these incentive bundles to treatment and control conditions are portrayed in Figure 2.

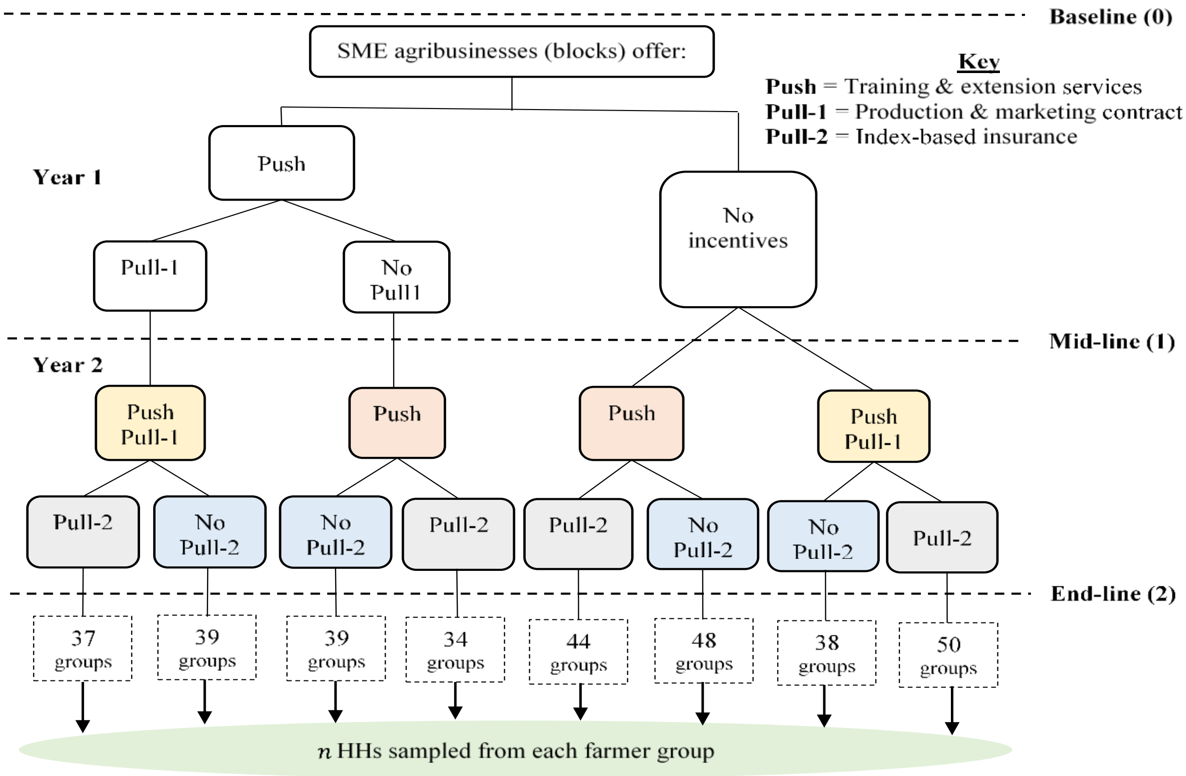

Figure 2. Illustration of treatment design

Hypotheses

The magnitude or size of impacts in terms of adoption intensity of CSA innovations due to the treatments: (i) push; (ii) push + pull-2; (iii) push + pull-1; and (iv) push + pull-1 + pull-2 incentives will largely depend on the level of participation in the trainings; visits and intensity of visits to FFS or demonstration sites for agricultural advisory services; extent of participation in contract farming arrangements; and level of uptake of index-based insurance.

The level of participation in trainings, visits and intensity of visits to FFSs or demonstration sites will depend on the distances farmers have to travel to the training venues and FFS or demo sites; availability of resources to cater for transportation to the training venues and FFSs or demo sites; perceived benefits from participation, among others. Participation in trainings and visits to FFSs or demo sites is expected to be higher due to relatively closer proximity of farmer group members to the farmer field schools (FFSs) or demo sites. If increased participation in trainings and visits to farmer field schools raise awareness and knowledge, and farm households have capital or access to credit to facilitate investments in CSA practices and technologies, adoption intensity will be higher. Due to the differences in households' wealth, gender, education, etc., adoption intensity due to exposure to push incentives is expected to be different across farm-households. Therefore, our predictions are as follows:

Prediction 1. Exposure to push incentives raises awareness and knowledge regarding application of CSA practices and technologies thereby enhancing intensity of adoption among recipients of combined training and extension than recipients of only training or only extension services.

Prediction 2. Adoption intensity of CSA practices and technologies will be significantly higher among recipient households of push incentives that are wealthy or have access to credit than less wealthy or credit constrained households.

Prediction 3. Adoption intensity of CSA practices and technologies will be significantly higher among recipient households of push incentives that are headed by males or households where both man and woman participate in trainings and visits to FFSs than in households headed by females or households where only man or woman participates in trainings and visits to FFSs.

The second treatment concerns value-chain linkages through production/marketing contract delivered in combination with *push* incentives. The production/marketing contract is intended to facilitate smallholder's access to: (i) inputs/technologies; (ii) output markets; and (iii) others such as credit access through use of a contract as collateral. We call these contract incentives labelled *pull-1* incentives. While contracting is done at the farmer group level for all the SMAEs, participation in either verbal or written contract farming arrangements is random. For instance, farmers have to decide whether or not to sell to SMAEs irrespective of whether or not the contract facilitates smallholders' access to inputs and other services. As defined earlier, a farmer participates in either verbal or written contract farming arrangement if he or she sells the largest share or all of marketed soybean output to the SAME regardless of status of access to inputs and other services under the same contract.

Participation in contract farming arrangements can be attenuated by innate risks, contract-induced risks and time preferences especially when households anticipate that contract prices will be lower than market prices at the time of harvest or when households anticipate late payments upon supplies to the SMAEs. We also expect that farmers will mostly accept verbal contracts instead of written contracts to safeguard themselves against uncertainties regarding future prices and timing of payments. Under a verbal contract, farm-households can easily violate contractual obligations and sell outside the contract if the contract price falls short of a general market price or when the SMAEs cannot buy and pay farmers immediately upon supplies. On the other hand, the SMAEs may also be reluctant to award written contracts if they anticipate that future market prices will be poor or when they anticipate insufficient capital that hinders their ability to absorb quantities specified in written contracts.

While this study assesses the effectiveness of a contract as an instrument through which these incentives are delivered, the study does not assess the effects of separate contract incentives. We also note that, there might be inherent differences in terms of implementation of these contract incentives by the three SMAEs. Under this framework, it can be difficult to understand the extent to which contract incentives influence adoption intensity. We address these gaps in three ways. First, we use block-cluster randomization to identify any differences in outcomes across SMAEs. Second, we examine impact pathways/mechanisms through which a contract incentive instrument (*pull-1*) together with push influence adoption intensity. We achieve this by assessing the effects of *push+pull-1* and *push+pull-1+pull-2* on a) access to input (or financial) credit; b) perceived quality of accessed inputs; c) perceived quality of output sold through SMAEs relative to that sold elsewhere; and d) perceived price for output sold through SMAEs relative that sold elsewhere. Third, we conduct focus group discussions (FGDs) to collect data that helps us to understand smallholders' perceptions about (verbal and written) contracts, aspects regarded important by farmers about these contracts, as well as an understanding of weather and why there might be differences in access to contract incentives among farmer group members even when contracting is done at farmer group level. We shall use FGD data to understand input quality issues.

Therefore, *push* + *pull-1* incentive bundle has a huge potential to drive adoption of CSA innovations than push treatment if the SMAEs can adopt strategies that mitigate highlighted issues. In other words, the *push* + *pull-1* treatment can address input and output market risks while at the same time addressing informational and knowledge constraints regrading CSA innovations. We also expect that smallholders can make more investments in complementary inputs and technologies due to reduced risks as well as improved access to credit services. Therefore, we make the following predictions:

Prediction 4. Access to input (or financial) credit is significantly higher among farmers exposed to bundles involving *pull-1* incentive than farmers in the control condition or farmers exposed to bundles without *pull-1* incentive.

Prediction 5. There is perceived better quality of inputs among farmers exposed to bundles involving *pull-1* incentive than farmers in the control condition or farmers exposed to incentive bundles without *pull-1* incentive.

Prediction 6. There is perceived higher quality of soybean outputs among farmers exposed to bundles involving *pull-1* incentive than farmers in the control condition or farmers exposed to incentive bundles without *pull-1* incentive.

Prediction 7. Farmers exposed to bundles involving *pull-1* incentive sell their soybean output at relatively higher prices than farmers in the control condition or farmers exposed to bundles without *pull-1* incentive.

Prediction 8. Adoption intensity is significantly higher among farmers exposed to bundles involving pull-1 incentive than farmers in the control condition or farmers exposed to bundles without pull-1 incentive.

Prediction 9. Uptake of incentive bundles is significantly higher among households headed by males, are wealthy, better educated, or whose head and spouse jointly make production decisions.

Prediction 10. Adoption intensity is significantly higher among households headed by males, are wealthy, better educated, or whose head and spouse jointly make production decisions.

Finally, as index-based insurance becomes available in the second year, farmer groups that were originally randomly assigned to *push* or *push + pull-1* are further randomly assigned to either receive or not receive index-based insurance. This leads to two more treatments namely *push + pull-2* and *push + pull-1 + pull-2* in the second year. As noted earlier, uptake of index-insurance will depend on farmers' confidence that insurance service providers will make pay-outs upon manifestation of bad weather as triggered by the index, as well as wealth, risk and time preferences of decision makers. This is particularly important because low uptake of agricultural insurance in Africa, in general and Uganda in particular, has been hampered by lack of regulatory policies and information asymmetries in the insurance markets. Consequently, insurance service providers take advantage of the situation by exploiting unsuspecting smallholder farmers who qualify for pay-outs upon manifestation of bad weather as triggered by the index but end up not being paid. The CRAFT project, through a workshop held in March 2021 together with a series of earlier engagements with insurance regulatory authority has played an important role of engaging and linking different players in the agricultural insurance market with the SMAEs to address some of the challenges. The players include Uganda Insurer's Association (UIA) and insurance brokers (service providers). These efforts could build confidence among smallholder farmers, thereby improving uptake of index-based insurance. If these efforts are not adequate enough to address risks and uncertainties that underlie low uptake, the impacts of index-insurance will be negligible; otherwise, we should expect significant impacts if issues associated with agricultural insurance are addressed. Thus, we make two additional predictions:

Prediction 7. Exposure to push + pull-2 incentives has the same effect on adoption intensity as exposure to only push incentives.

Prediction 8. Exposure to push + pull-1 + pull-2 incentives has the same effect on adoption intensity as exposure to push + pull-1 incentives.

Finally, despite the variation in the intensity of exposure to the incentives, we expect that households adopting CSA practices will realize significantly higher land and labour productivity than non-adopting households. Farm-households adopting CSA practices and technologies are also expected to realize significantly higher revenues and incomes than non-adopters.

Wealthy farm households with bigger farmers will likely adopt more CSA practices and technologies than less wealthy households. Moreover, wealthy farm households will likely have more diversified enterprises in terms of number of crops grown as well as type of livestock and number of animals kept. Therefore, adopting households are likely to have better nutrition due to consumption of different varieties of both crop and animal-based products. Adopters are also likely to purchase nutritious foods than non-adopters. The exception is when adopters are households with smaller pieces of land who adopt practices and technologies to raise yields or when households mainly engaged in the production of cash crops realize higher incomes but do not necessarily buy foods for better nutrition. This could be true for soybean grown as a cash crop but is less consumed in Uganda. We hypothesize that, farm-households adopting CSA innovations have better women dietary diversity scores (WDDS) than non-adopter households. We also hypothesize that, farm-households will have high WDDS if they have larger farms, have lactating mothers, are headed by men, participate in off-farm employment, and their main source of food is own production.

Outcomes

For the first objective, the primary outcomes include the proportion of households participating agricultural-related trainings; proportion of households visiting (visited by) demo sites (extension agents) and number of visits; proportion of households that report having applied acquired knowledge about CSA innovations; proportion of farm-households participating in collective bulking and marketing; proportion of households reporting participation in contract farming;

proportion of households using agricultural insurance; and gender empowerment. The secondary outcomes include: (i) proportion of households accessing input (or financial) credit; (ii) proportion of households reporting access to better quality inputs such as improved seed; (iii) proportion of households reporting having sold high quality output; (iv) proportion of households reporting having sold output at a relatively higher than average market price; (v) proportion of households adopting CSA practices and technologies; and (vi) the intensity of adoption of CSA practices and technologies. We define adoption intensity in two ways. First, as the number of CSA practices and/or technologies used by the farm-household in a given cropping year (Mahama et al., 2020; Nkegbe & Shankar, 2014). Second, as the number of hectares or the proportion of total cultivated land that is under the CSA practice such as zero/minimum tillage and soybean-cereal intercrop or CSA technology such as drought-resilient seed and rhizobia inoculants. For CSA innovations, a third definition applies as the amount (or value) of improved seed and rhizobia inoculants applied per hectare.

The main variables of interest with regard to the first objective include *trainings*, defined as participation and intensity of participation, by farm-household's main decision-maker and/or their spouse, in organized training workshops concerning climate-smart agricultural (CSA) practices and technologies in a given cropping year. Intensity of participation is defined as the number of times the decision-maker and/or their spouse participated in organized training workshops. *Farm-household visits*, defined as the number of times the farm-household's main decision-maker and/or their spouse visited farmer field schools (FFSs) or demo sites in a given cropping year. *Extension visits*, defined as the number of times any agricultural extension agent or officer visited the household or farm in a given cropping year.

Collective bulking and marketing, defined as farm-household's participation in collective bulking and marketing of soybean and any other crop and livestock products in a given cropping year. *Contract farming*, defined as participation by the farm-household in contract farming arrangement for soybean and other crop or livestock products in a given cropping year. *Agricultural insurance*, defined as the use of agricultural insurance including index-based insurance for soybean and any other crop or livestock in a given cropping year.

Gender, defined as Women's Empowerment in Agriculture Index (WEAI). This index will be developed using twelve indicators namely, autonomy in income; attitudes about intimate partner violence against women; respect among household members; input in productive decisions, ownership of land and other assets; access to and decisions on credit and financial accounts; control over use of income; work balance; visiting important locations; group membership; and membership in influential groups (Malapit et al., 2019).

Practices. Defined as climate-smart agricultural (CSA) practices such as minimum/zero tillage or intercropping used by the farm-household in the production of soybean and other crop and livestock enterprises in a given cropping year. *Technologies.* Defined as climate-smart agricultural (CSA) technologies such as drought-resilient seed or rhizobia inoculants used by the farm-household in the production of soybean and other crop and livestock enterprises in a given cropping year (two cropping seasons).

For the second objective, the main variables of interest include quantity harvested (kilograms) per crop, quantity sold (kilograms) per crop, quantity of livestock (cattle, goats, sheep, pigs, etc.) and poultry sold; market price (UGX) for crops and livestock sold; land area (hectares) under each crop; family and hired labour (man-days); value of production (total quantity produced multiplied by the farm gate price); production costs (UGX) for crops and livestock; household size; and types of food consumed. These variables will be used to construct both the primary and outcome indicators.

The primary outcomes include: land productivity; as well as labour productivity. *Land productivity* is measured as the volume of output (Kg or value of production (UGX)) produced per hectare, while *labour productivity* is the volume of output (Kg or value of production (UGX)) produced per man-day in a given cropping year.

The secondary outcomes include revenues, total household income, share of soybean income in total household income; and nutrition. *Revenue*, defined as market price multiplied by quantity sold will be computed for all crop and livestock/poultry products sold by farm-households in a given cropping year. *Total revenue* will be the summation of revenues from crop and livestock/poultry enterprises. We shall also compute the share of soybean revenue in both the total revenue and revenue from all the crops.

Household income will entail total income earned by all members of the farm-household from all the crops grown (per hectare); livestock and poultry kept as well as other incomes from other farm and off-farm sources and activities in a given cropping year. We shall deduct all costs involved to secure each type of income. *Income per adult equivalent* (OECD, 2011) will also be computed for well-being comparisons across households with different number of members. We shall then compute the share of soybean income in total household income.

Nutrition, we use a proxy indicator namely *women's dietary diversity score* (WDDS) will be developed from different food groups consumed by women in a household over the 24-hour recall period. The different food groups are formed from different food categories including cereals, roots/ tubers/plantains, legumes, oil seeds, vegetables, fruits (including juices), meats, dairy products, fats/oils, among others (Gina et al., 2013).

Sample size

We perform two sample size calculations since we assess the effects of different incentive bundles on adoption intensity of different innovations such as improved seed as well as various CSA practices and CSA technologies. As described earlier, the interventions depend on each other, particularly, the pull incentives depend on the push incentives. Therefore, the largest sample size among the two sample size calculations is considered appropriate for the entire study. We perform power calculations to determine the number of farmer groups (clusters) needed to test research hypotheses stated earlier.

The baseline survey which was delayed by the COVID 19 pandemic was conducted in 2020 after lifting the lockdown measures by the government of Uganda. Before the baseline survey, we performed power calculations based on statistics obtained from other studies such as (Arslan et al., 2013; Azumah et al., 2017; Karlan et al., 2014; Mahama et al., 2020; Mishra et al., 2018; Nkegbe & Shankar, 2014) and determined that we would need an overall sample of 2,978 households (372 clusters and 8 households per cluster) to detect minimum effects of different treatments. Although 372 eligible farmer groups were randomized to the four treatments, we found during the baseline survey that some of the farmer groups never existed while a few others were either not eligible or refused to participate in the survey. Farmer groups that refused to participate in the survey had unresolved issues with respective SMAEs. We ended up covering a total of 2,533 households from 329 clusters. For reasons mentioned earlier, we could not re-randomize the remaining 329 farmer groups to the four treatments. Hence, we use the baseline survey data to: (i) recalculate power to obtain minimum detectable effects to assess effectiveness of the different incentive combinations; (ii) conduct balancing tests to check if the issues mentioned above lead to any systematic differences in different characteristics across different treatments (Tables 3 & 4).

Prior to performing power and sample size calculations, we first determine: average values for the outcome variables and intra-cluster correlation coefficients for each treatment through large oneway analysis of variance, using ‘loneway’ stata command. We use standard significance level of 0.05 (double sided). We use these values to simulate minimum detectable effects (MDEs) associated with the sample that we collected at the baseline. MDEs are estimated using a simple analysis of variance (ANCOVA) that controls for the outcome at the baseline. We use a ‘steppedwedge’ stata command to perform power calculations. In our calculations, we put into consideration of the fact that two parallel treatments are implemented at the same time as well as the fact that farmer groups (clusters) are covered in four phases (seasons). Therefore, we first perform power and sample size calculations for one of the two treatments such as push + pull-1 against its control and include four steps (seasons) in the stata command (see appendix I). The resultant maximum sample size is then doubled to cater for an additional treatment.

Figure 3 plots MDEs against power for the number of CSA practices and technologies (adoption intensity) in the push and push + pull-1 treatments. On average, farm-households used 2.94 CSA practices and technologies between February 2019 and February 2020. The black solid curve shows MDE against power for adoption intensity among 535 households that begin to receive push + pull-1 incentives in the first year compared to 703 households in the control condition that wait to start receiving the same incentives in second year. At the baseline, push + pull-1 recipient households use 3.04 relative to 2.81 CSA practices and technologies used by their control counterparts. This represents a difference of 0.24 (or 8.49%) CSA practices and technologies which is significant at 5% significance level.

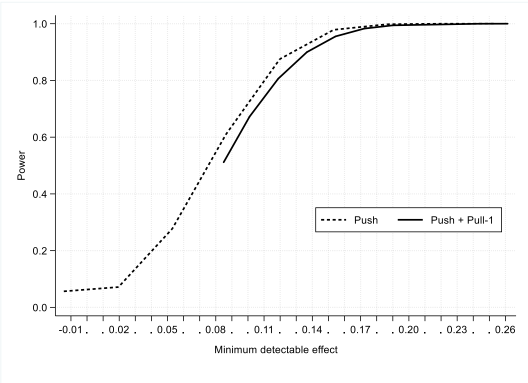

Figure 3. Power curves for adoption intensity of CSA technologies.

At a power of 80%, this difference would increase to about 11.9% representing an increase to 3.14 CSA practices and technologies. This is effect is low compared to an increase by 2.23 in the number of practices and technologies adopted due to participation in contract farming alone (Azumah et al., 2017). The black dash curve shows MDE for adoption intensity among 582 households in the push treatment compared to 713 households in the control condition that wait to begin receiving push incentives in the second year. At the baseline, recipients of push incentives use 2.95 compared to 2.99 CSA practices and technologies used by their control counterparts. The difference in intensity of adoption of -0.04 (or -1.44%) is not statistically significant. At 80% power threshold, this difference would increase to 11% representing an increase to 3.27 CSA practices and technologies. Again, this effect is very low compared to an increase in adoption intensity by 1.63 due to improved access to agricultural extension services (Azumah et al., 2017).

Figure 3 shows the effects detectable in the adoption of crop rotation under push and push + pull-1 treatments. On average, 75.8% of the households practiced crop rotation between February 2019 and February 2020. As shown by the black sold line, we can detect, at 80% power threshold, an increase in adoption by about 10.4 percentage points among 582 households that begin to receive push + pull-1 incentives in the first year, compared to 713 control households that would begin to receive the same incentives in the second year. For the push treatment indicated by the dash curve, we can detect an increase in adoption by about 9.5 percentage points among 535 households relative to 703 households in the control condition.

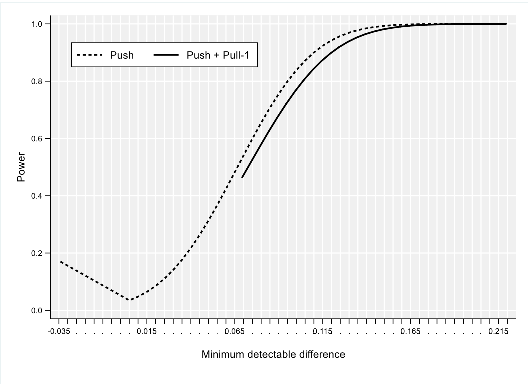

Figure 4. Power curves for adoption of crop rotation

Figure 5 shows MDEs in the adoption of improved soybean seed under push and push + pull-1 treatments. About 31.5% of the households grew soybean between February 2019 and February 2020 and of these, 14.9% used improved seed. Among soybean growers, we compare 221 households that begin to receive push + pull-1 incentives in the first year, compared to 276 households that begin to receive the same incentives in the second year. We also compare 225 households whose exposure to push incentives begins in the first year against 228 households that begin to receive the same incentives in the second year. For push + pull-1 treatment, the power curve hits the 80% power threshold at about 9.2% implying an increase in adoption to 13.3% from 12.2%. On the other hand, the power curve for push treatments hits the 80% power threshold at about 7.4% indicating an increase in adoption to 23% from 15.6%.

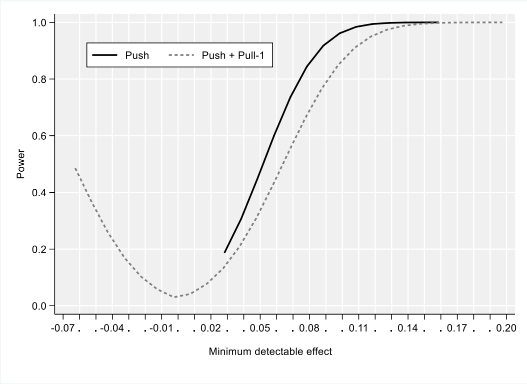

Figure 5. Power curves for adoption of improved seed

In terms of investment in soybean seed, we find through a two-sided t-test, that the seed rate (53.6 Kg/Ha) for households that bought seed is significantly higher (at less than 5% significance level) than the seed rate (46.0 Kg/Ha) for households that never bought seed. The seed rate for households participating in the seed market falls within the recommended range of 50-60 Kg/Ha (Tukamuhabwa & Obua, 2015). About 59.9% of the households growing soybean report having bought seed and of these, 22% report having bought improved seed. However, farmers may not differentiate improved seed from traditional seed sold on markets. For this reason, we consider expenditure on seed per Ha as a proxy for intensity of adoption of improved seed and simulate MDE that we shall use to judge effectiveness of different incentive combinations (treatments). Households participating in seed markets spend an average of UGX.113,489 per hectare translating into UGX.2,246 per Kg. This price is far less than the price of genuine improved seed. Thus, figure 6 plots MDEs against power for adoption intensity of improved seed. The black solid line shows the power curve associated with push treatment, comparing 582 households that begin to receive incentives in the first year, to 713 control households that wait to receive push incentives in the second year. The black dash line shows the power curve associated with push + pull-1 treatment comparing 535 households to 703 control households that start to receive push incentives in the second year. At a power of 0.8, we expect to detect an increase in investment by about 17.5% due to exposure to push treatment and an increase by 28% due to exposure to push + pull-1 treatment.

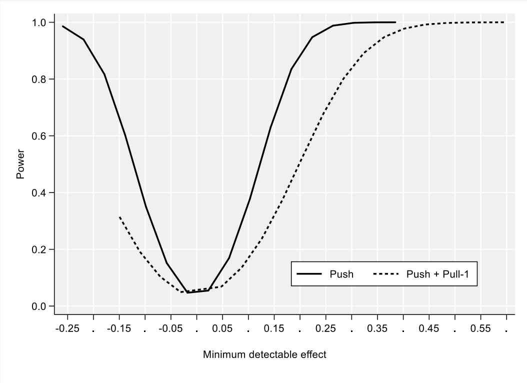

Figure 6. Power curves for investment in soybean seed

Figure 7 plots MDEs against power for the number of CSA practices and technologies adopted (adoption intensity) due to exposure to the four different treatments in the second year. Treatments, T1, T2, T3 and T4 represent *push*, *push+pull-2, push+pull-1*, and *push+pull-1+pull-2*, respectively. The green solid line shows the power curve associated with 649 recipient households of *push+pull-1+pull-2* incentives (T4) relative to 676 recipient households of *push* incentives (T1). The black dash line shows the power curve associated with 649 recipient households of *push+pull-1+pull-2* incentives (T4) relative to 619 recipient households of *push+pull-2* incentives (T2). The blue solid line shows the power curve associated with 649 recipient households of *push+pull-1+pull-2* incentives (T4) relative to 589 recipient households of *push+pull-1* incentives (T3). Similarly, the pink dash line shows the power curve for *push+pull-2* (T2) comparing 619 households to 676 recipients of *push* incentives (T1). Finally, the black solid line shows the power curve for *push+pull-2* bundle (T2) comparing 619 households to 589 recipients of *push+pull-1* incentives (T3). The power curves for T4-T3 and T2-T1 virtually mirror each other while T4-T1 appears to powered than the rest of compared treatments. At the baseline, farmers in T1, T2, T3, and T4 treatment adopt 2.94, 3.01, 2.85 and 2.96 CSA practices and technologies, respectively. None of the differences T4-T1, T4-T2, T4-T3, T2-T1, and T2-T3 is statistically significant.

At a power of 0.8, we would detect an increase in adoption intensity by about 15.4 percent due to exposure to *push+push-1+pull-2* treatment relative to a case where push recipients remain in a counterfactual scenario. Relative to counterfactual scenarios for push+pull-2 and push+pull-1, a power of 80 percent would, respectively, detect an increase in adoption intensity by 23.2 percent and 23.5 percent due to exposure to *push+pull-1+pull-2* incentive bundle. Similarly, at a power of 80% we would detect an increase in the number of CSA practices and technologies by 23.5 percent and 24.4 percent due to exposure to push+pull-2, compared to push and push+pull-1 in the counterfactual situation.

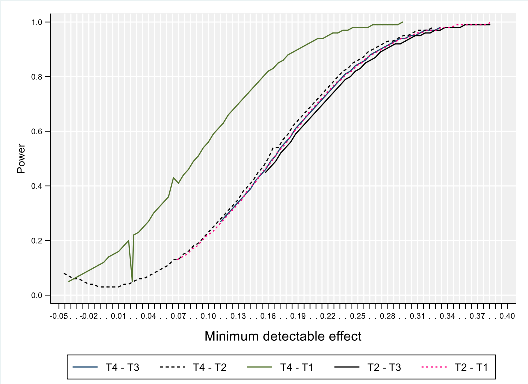

Figure 7. Power curves for adoption intensity of CSA practices and technologies at end line.

Figure 8 plots MDEs against power for adoption intensity of (investment in) soybean seed, due to exposure to the four different treatments in the second year. Treatments, T1, T2, T3 and T4 remain as defined before. The purple dash line shows the power curve associated with 141 recipient households of *push+pull-1+pull-2* incentives relative to 115 recipient households of *push* incentives. The purple sold line shows the power curve associated with 141 recipient households of *push+pull-1+pull-2* incentives relative to 148 recipient households of *push+pull-2* incentives. The black solid line shows the power curve associated with 141 recipient households of *push+pull-1+pull-2* incentives relative to 165 recipient households of *push+pull-1* incentives. The green solid line shows the power curve for *push+pull-2* comparing 148 households to 115 recipients of *push* incentives. Finally, the pink solid line shows the power curve for *push+pull-2* bundle comparing 148 households to 165 recipients of *push+pull-1* incentive bundle. These treatments could be less powered due to relative smaller sample sizes. However, we expect an increase in sample sizes as more farmers begin to grow soybean especially in the central and western regions where soybean production is just being promoted. At the baseline, farmers investment in seed is UGX.119,350 for T1; UGX.111,226 for T2; UGX.117,703 for T3 and UGX.103,167 for T4. None of the differences T4-T1, T4-T2, T4-T3, T2-T1, and T2-T3 is statistically significant.

At a power of 0.8, we can detect an increase in investment in soybean seed by about UGX.37,500 due to exposure to *push+push-1+pull-2* treatment relative to *push* recipients in the counterfactual situation. A power of 80 percent can detect an increase in investment in soybean seed by UGX.40,000 and UGX.60,000 due to smallholders' access to *push+pull-1+pull-2* incentives relative to exposure to *push+pull-2* and *push+pull-1* at the counterfactual scenarios. Similarly, at a power of 80% we would detect an increase in investment in soybean seed by UGX.30,000 and UGX.55,000 due to exposure to *push+pull-2*, compared to push and push+pull-1 in the counterfactual situation.

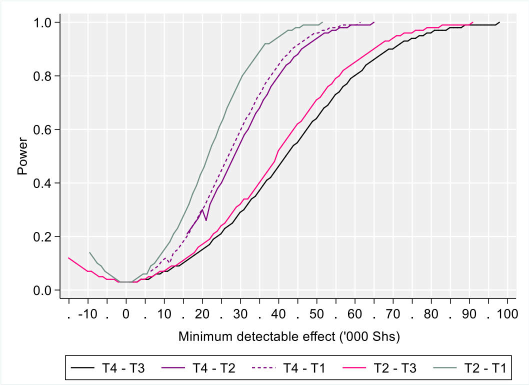

Figure 8. Power curves for adoption intensity of improved seed at end line.

Randomization and blinding

We have used block-cluster randomization to allocate farmer groups (clusters) to the treatment and control conditions across SMAEs (blocks). We randomly assigned clusters to the treatment and control conditions using a cluster as a unit of randomization. Prior to randomizing clusters to the treatment and control conditions, we first randomly determined clusters to enroll into the CRAFT program at the beginning of each of the three seasons (second season in 2020 and both seasons in 2021). Randomization of the farmer groups across seasons follows the phased implementation of the CRAFT programme. Random assignment of clusters to the first season of 2020 was not possible since SMAEs had already started implementing push incentives in the first season of the year 2020 by the time of time randomization. For this reason, randomization was done before the baseline survey. We also needed to avail randomized groups (clusters) to enable SMAEs to plan for the second and subsequent season. All eligible farmer groups that had been targeted by the SMAEs in the first season of the year 2020 were considered for randomization into treatment and control conditions. Excluding these groups would leave us with fewer eligible groups and this would affect power of the experiment.

The outbreak of COVID 19 pandemic further made it difficult to have all the groups ready for randomization at the beginning or slightly after beginning of the first season. SMAEs were asked to delay awarding of contracts for 84 farmer groups receiving training and extension services to form part of the sampling frame. For these reasons and the reasons specified in the previous section (sample size), we ended up with 329 clusters randomly assigned four incentive bundles (treatments) namely: (i) push; (ii) push + pull-2; (iii) push + pull-1; and push + pull-1 + pull-2.

Considering the nature of the treatments, blinding of the village-agents about a contract and index-insurance may not be feasible because contracts and index-insurance services are promoted to smallholder farmers through village-agents. Also as mentioned earlier, it is the trainer of trainees

(ToTs) that train and deliver agricultural extension services to organized smallholder farmers through farmer field schools established in the communities. Consequently, blinding of ToTs about push incentives may not be feasible but these can be blinded of recipients and non-recipients of contracts and index-insurance. However, blinding of the farmer groups and their members can be feasible if the village-agents don't disclose different treatments to farmer groups in different treatments. This research has made efforts to explain to SMAEs the advantages of blinding village agents, ToTs, farmer groups and individual farmers. However, farmer groups will be informed about the incentives of respective treatments from which they benefit.

In table 2, we show the description of all the variables used for balancing tests. Tables 3, 4 and 5 show balancing tests conducted using the baseline survey data. The differences in the characteristics between farmers assigned to the push and push + pull-1 treatments and those assigned to the control condition are not statistically significant except for off-farm employment in the case of push + pull-1 treatment (Table 3). In Table 4, we also show balancing tests across treatments to be compared at the end line period. All the characteristics include outcomes are generally balanced.

Table 2. Description of explanatory variables and outcomes of the CRAFT program.

Variable name	Variable description
Panel A. *Household head's characteristics*	
Gender of head	Whether female-headed household (1 if yes, 0 otherwise)
Age of head	Age of the household head (complete years)
Education	Household head's number of years of education
Panel B. *Household characteristics*	
Household size	Number of members in a household
Radio ownership	Whether a household owns a radio (1 if yes, 0 otherwise)
Mobile phone ownership	Whether a household owns a mobile phone (1 if yes, 0 otherwise)
Total landholding	Amount of land (hectares) owned by the household
Grew soybean in 2019	Whether a household grew soybean in the year 2019 (1 if yes, 0 otherwise)
Enterprise employment	Whether any of the household members owned and earned income from an enterprise between February 2019 and February 2020 (1 if yes, 0 otherwise)
Farm employment	Whether any of the household members had temporary or full time employment on other people's farms between February 2019 and February 2020 (1 if yes, 0 otherwise)
Off-farm employment	Whether any of the household members had temporary or full time employment on outside the farm between February 2019 and February 2020 (1 if yes, 0 otherwise)
Panel C. *Push incentives*	
Attended training workshops	Whether any of the household members participated in training workshops between February 2019 and February 2020 (1 if yes, 0 otherwise)
Visited Farmer field school	Whether any of the household members visited farmer field school between February 2019 and February 2020 (1 if yes, 0 otherwise)
Visited by agricultural expert	Whether the households was visited by an agricultural agent (expert) between February 2019 and February 2020 (1 if yes, 0 otherwise)
Panel D. *Pull incentives*	
VSLA/SACCO credit	Whether household acquired credit/loan from a VSLA/SACCO between February 2019 and February 2020 (1 if yes, 0 otherwise)
Formal lender credit	Whether a household acquired credit/loan from a formal lender (e.g. banks or microfinance institutions) between February 2019 and February 2020 (1 if yes, 0 otherwise)
Insurance awareness	Whether a household has ever heard of agricultural insurance (1 if yes, 0 otherwise)
Collective action	Whether a household participated in collective bulking and marketing of any product (e.g. crop, milk, etc.) between February 2019 and February 2020 (1 if yes, 0 otherwise)
Panel E. *Farm environment and conditions*	
Drought/long dry spell	Whether a household experienced drought/long dry spell between February 2019 and February 2020 (1 if yes, 0 otherwise)

Floods/excessive rains	Whether a household experienced floods/excessive rains between February 2019 and February 2020 (1 if yes, 0 otherwise)
Subcounty distance	Distance (km) from the household to the sub county headquarters
All-weather road distance	Distance (km) from the household to the nearest all-weather road
Input market distance	Distance (km) from the household to the nearest input market
Output market distance	Distance (km) from the household to the nearest output market
Land parcel distance	Average distance (km) from the household to the household's land parcels.
Panel F.*Outcomes*	
Minimum tillage	Whether a household adopted or practiced minimum tillage between February 2019 and February 2020 (1 if yes, 0 otherwise)
Crop residue recycling	Whether a household adopted or practiced crop residue recycling between February 2019 and February 2020 (1 if yes, 0 otherwise)
Planting in rows	Whether a household adopted or practiced row planting between February 2019 and February 2020 (1 if yes, 0 otherwise)
Intercropping	Whether a household adopted or practiced intercropping between February 2019 and February 2020 (1 if yes, 0 otherwise)
Crop rotation	Whether a household adopted or practiced crop rotation between February 2019 and February 2020 (1 if yes, 0 otherwise)
Number of practices	Number of CSA practices and technologies adopted or used by the households between February 2019 and February 2020
Improved soybean seed	Whether a household adopted or used improved soybean seed between February 2019 and February 2020 (1 if yes, 0 otherwise)
Investment in seed	Amount of money (UGX.) soybean growers invest in soybean seed per hectare

Table 3. Orthogonality tests – treatment condition versus control condition

Variables	Push				Push + Pull-1		
	Pooled	Year 1 beneficiary	Year 2 beneficiary	diff.	Year 1 beneficiary	Year 2 beneficiary	diff.
Panel A. *Household head's characteristics*							
Gender of head	0.221	0.210	0.226	-0.016	0.237	0.212	0.025
	(0.010)	(0.021)	(0.019)	(0.029)	(0.022)	(0.017)	(0.028)
Age of head	45.049	45.151	45.403	-0.252	45.299	44.417	0.882
	(0.356)	(0.793)	(0.646)	(1.020)	(0.734)	(0.693)	(1.007)
Education of head	6.771	6.775	6.923	-0.148	6.727	6.646	0.081
	(0.103)	(0.238)	(0.197)	(0.309)	(0.236)	(0.167)	(0.288)
Panel B. *Household characteristics*							
Household size	6.858	6.921	6.895	0.026	6.813	6.802	0.011
	(0.067)	(0.149)	(0.137)	(0.202)	(0.125)	(0.126)	(0.177)
Radio ownership	0.636	0.646	0.628	0.018	0.643	0.632	0.011
	(0.012)	(0.023)	(0.022)	(0.032)	(0.027)	(0.023)	(0.035)
Mobile phone ownership	0.833	0.840	0.826	0.014	0.856	0.818	0.038
	(0.009)	(0.017)	(0.017)	(0.024)	(0.016)	(0.019)	(0.025)
Total landholding	5.321	5.593	5.361	0.232	5.06	5.256	-0.196
	(0.194)	(0.488)	(0.303)	(0.573)	(0.424)	(0.354)	(0.551)
Grew soybean in 2019	0.315	0.325	0.268	0.057	0.353	0.326	0.028
	(0.020)	(0.051)	(0.030)	(0.059)	(0.042)	(0.040)	(0.058)
Enterprise employment	0.235	0.227	0.259	-0.032	0.226	0.222	0.004
	(0.010)	(0.022)	(0.018)	(0.029)	(0.023)	(0.018)	(0.029)
Farm employment	0.135	0.148	0.137	0.011	0.108	0.144	-0.035
	(0.009)	(0.019)	(0.018)	(0.026)	(0.016)	(0.019)	(0.024)
Off-farm employment	0.186	0.199	0.168	0.031	0.234	0.158	0.076**
	(0.009)	(0.018)	(0.019)	(0.026)	(0.020)	(0.014)	(0.025)
Panel C. *Push incentives*							
Attended training workshops	0.216	0.237	0.217	0.020	0.215	0.196	0.019
	(0.012)	(0.030)	(0.020)	(0.035)	(0.022)	(0.022)	(0.031)
Visited farmer field school	0.102	0.103	0.094	0.009	0.093	0.115	-0.022
	(0.009)	(0.020)	(0.015)	(0.025)	(0.015)	(0.019)	(0.024)
Visited by agricultural expert	0.054	0.065	0.042	0.023	0.050	0.061	-0.011
	(0.005)	(0.012)	(0.009)	(0.015)	(0.011)	(0.011)	(0.016)
Panel D. *Pull incentives*							
VSLA/SACCO credit	0.455	0.433	0.453	-0.020	0.452	0.477	-0.024
	(0.015)	(0.030)	(0.027)	(0.040)	(0.030)	(0.031)	(0.043)
Formal lender credit	0.063	0.064	0.059	0.005	0.075	0.057	0.018
	(0.006)	(0.011)	(0.012)	(0.016)	(0.014)	(0.010)	(0.017)
Insurance awareness	0.158	0.168	0.149	0.019	0.176	0.144	0.032
	(0.009)	(0.022)	(0.016)	(0.027)	(0.020)	(0.017)	(0.026)
Collective action	0.043	0.036	0.056	-0.020	0.045	0.034	0.011
	(0.006)	(0.009)	(0.016)	(0.018)	(0.012)	(0.009)	(0.015)
Panel E. *Farm environment and conditions*							
Drought/long dry spell	0.656	0.648	0.631	0.017	0.652	0.691	-0.039
	(0.015)	(0.024)	(0.031)	(0.040)	(0.033)	(0.027)	(0.042)
Floods/excessive rains	0.319	0.304	0.332	-0.028	0.320	0.319	0.001
	(0.014)	(0.027)	(0.028)	(0.039)	(0.030)	(0.026)	(0.040)
Subcounty distance	5.693	5.848	5.546	0.302	5.849	5.593	0.256
	(0.172)	(0.383)	(0.309)	(0.490)	(0.417)	(0.294)	(0.509)
All-weather road distance	1.131	1.192	1.075	0.117	1.108	1.156	-0.049
	(0.076)	(0.123)	(0.152)	(0.195)	(0.142)	(0.175)	(0.225)
Input market distance	4.460	4.656	4.266	0.390	4.677	4.328	0.348
	(0.138)	(0.332)	(0.224)	(0.399)	(0.327)	(0.251)	(0.411)
Output market distance	4.352	4.192	4.311	-0.119	4.267	4.590	-0.323
	(0.164)	(0.326)	(0.26)	(0.416)	(0.369)	(0.361)	(0.515)
Land parcel distance	3.437	2.579	4.968	-2.389	3.101	3.296	-0.195
	(0.454)	(0.258)	(1.799)	(1.811)	(0.531)	(0.499)	(0.727)

Table 3. Continued

	Pooled	Push			Push + Pull-1		
		Year 1 beneficiary	Year 2 beneficiary	diff.	Year 1 beneficiary	Year 2 beneficiary	diff.
Panel F. *Outcomes*							
Minimum tillage	0.165	0.139	0.184	-0.045	0.140	0.186	-0.046
	(0.012)	(0.023)	(0.023)	(0.032)	(0.025)	(0.025)	(0.035)
Crop residue recycling	0.182	0.191	0.18	0.011	0.178	0.182	-0.005
	(0.011)	(0.022)	(0.021)	(0.030)	(0.023)	(0.021)	(0.031)
Planting in rows	0.508	0.483	0.529	-0.046	0.527	0.495	0.032
	(0.016)	(0.032)	(0.029)	(0.043)	(0.035)	(0.029)	(0.045)
Intercropping	0.459	0.488	0.467	0.021	0.454	0.431	0.023
	(0.015)	(0.029)	(0.028)	(0.040)	(0.030)	(0.030)	(0.042)
Crop rotation	0.758	0.730	0.764	-0.034	0.807	0.738	0.069
	(0.014)	(0.031)	(0.028)	(0.041)	(0.027)	(0.026)	(0.037)
Number of practices	2.942	2.948	2.992	-0.044	3.045	2.807	0.238
	(0.043)	(0.098)	(0.077)	(0.124)	(0.088)	(0.082)	0.1120
No. of observations	**2,533**	**582**	**713**		**535**	**703**	

Robust standard errors in parentheses. Reported standard errors are clustered at the level of randomization.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 4. Orthogonality tests – all the four incentive combinations in the second year.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Variables	T4	T3	T2	T1	T4–T3	T4–T2	T4–T1	T2–T3	T2–T1
Panel A. *Household head's characteristics*									
Gender of head	0.208	0.239	0.221	0.216	-0.031	-0.013	-0.008	-0.018	0.005
	(0.017)	(0.022)	(0.023)	(0.018)	(0.028)	(0.028)	(0.025)	(0.031)	(0.029)
Age of head	44.871	44.718	46.137	44.513	0.153	-1.266	0.358	1.419	1.624
	(0.694)	(0.743)	(0.756)	(0.672)	(1.014)	(1.023)	(0.963)	(1.057)	(1.009)
Education of head	6.801	6.548	6.785	6.922	0.253	0.016	-0.121	0.237	-0.137
	(0.191)	(0.203)	(0.188)	(0.238)	(0.277)	(0.267)	(0.304)	(0.276)	(0.303)
Panel B. *Household characteristics*									
Household size	6.786	6.830	7.113	6.717	-0.044	-0.327	0.069	0.283	0.396**
	(0.124)	(0.131)	(0.160)	(0.121)	(0.180)	(0.202)	(0.173)	(0.206)	(0.200)
Radio ownership	0.632	0.642	0.638	0.635	-0.010	-0.006	-0.003	-0.004	0.003
	(0.023)	(0.026)	(0.024)	(0.022)	(0.035)	(0.033)	(0.032)	(0.035)	(0.032)
Mobile phone ownership	0.838	0.830	0.830	0.834	0.008	0.008	0.004	-0.000	-0.004
	(0.017)	(0.020)	(0.018)	(0.016)	(0.026)	(0.024)	(0.024)	(0.027)	(0.024)
Total landholding	5.076	5.275	5.552	5.386	-0.199	-0.476	-0.310	0.277	0.166
	(0.285)	(0.478)	(0.289)	(0.457)	(0.555)	(0.405)	(0.537)	(0.557)	(0.539)
Grew soybean in 2019	0.345	0.329	0.289	0.297	0.016	0.056	0.048	-0.040	-0.008
	(0.039)	(0.044)	(0.035)	(0.044)	(0.058)	(0.052)	(0.058)	(0.056)	(0.056)
Enterprise employment	0.214	0.234	0.242	0.247	-0.020	-0.028	-0.033	0.008	-0.005
	(0.018)	(0.023)	(0.020)	(0.020)	(0.029)	(0.027)	(0.027)	(0.030)	(0.029)
Farm employment	0.140	0.115	0.134	0.149	0.025	0.006	-0.009	0.019	-0.015
	(0.018)	(0.018)	(0.017)	(0.020)	(0.025)	(0.025)	(0.027)	(0.024)	(0.026)
Off-farm employment	0.180	0.202	0.173	0.191	-0.022	0.007	-0.011	-0.029	-0.018
	(0.016)	(0.019)	(0.017)	(0.020)	(0.025)	(0.023)	(0.025)	(0.025)	(0.026)
Panel C. *Push incentives*									
Attended training workshops	0.217	0.190	0.247	0.207	0.027	-0.030	0.010	0.057	0.040
	(0.020)	(0.024)	(0.022)	(0.025)	(0.031)	(0.030)	(0.032)	(0.033)	(0.034)
Visited farmer field school	0.102	0.110	0.120	0.078	-0.008	-0.018	0.024	0.010	0.042†
	(0.015)	(0.020)	(0.020)	(0.014)	(0.026)	(0.025)	(0.021)	(0.029)	(0.024)
Visited by agric. expert	0.060	0.053	0.055	0.050	0.007	0.005	0.010	0.002	0.005
	(0.012)	(0.011)	(0.010)	(0.011)	(0.016)	(0.015)	(0.016)	(0.015)	(0.015)
Panel D. *Pull incentives*									
VSLA/SACCO credit	0.484	0.447	0.426	0.460	0.037	0.058	0.024	-0.021	-0.034
	(0.028)	(0.033)	(0.030)	(0.026)	(0.044)	(0.041)	(0.039)	(0.045)	(0.040)
Formal lender credit	0.063	0.066	0.053	0.068	-0.003	0.010	-0.005	-0.013	-0.015
	(0.011)	(0.013)	(0.010)	(0.013)	(0.017)	(0.015)	(0.017)	(0.016)	(0.016)
Insurance awareness	0.163	0.151	0.166	0.149	0.012	-0.003	0.014	0.015	0.017
	(0.018)	(0.019)	(0.021)	(0.017)	(0.026)	(0.028)	(0.025)	(0.028)	(0.027)
Collective action	0.052	0.024	0.044	0.050	0.028**	0.008	0.002	0.020	-0.006
	(0.011)	(0.008)	(0.012)	(0.014)	(0.014)	(0.017)	(0.018)	(0.015)	(0.019)
Panel E. *Farm environment and conditions*									
Drought/long dry spell	0.692	0.655	0.646	0.632	0.037	0.046	0.060	-0.009	0.014
	(0.030)	(0.028)	(0.030)	(0.028)	(0.041)	(0.042)	(0.041)	(0.041)	(0.041)
Floods/excessive rains	0.324	0.314	0.347	0.294	0.010	-0.023	0.030	0.033	0.053
	(0.026)	(0.030)	(0.030)	(0.025)	(0.040)	(0.040)	(0.036)	(0.042)	(0.039)
Subcounty distance	5.612	5.805	5.613	5.745	-0.193	-0.001	-0.133	-0.192	-0.132
	(0.342)	(0.353)	(0.303)	(0.372)	(0.490)	(0.455)	(0.504)	(0.464)	(0.479)
All-weather road distance	1.177	1.089	1.073	1.177	0.088	0.104	0.000	-0.016	-0.104
	(0.161)	(0.170)	(0.117)	(0.160)	(0.233)	(0.198)	(0.226)	(0.206)	(0.197)
Input market distance	4.592	4.354	4.583	4.311	0.238	0.009	0.281	0.229	0.272
	(0.297)	(0.268)	(0.246)	(0.292)	(0.400)	(0.385)	(0.415)	(0.363)	(0.381)
Output market distance	4.446	4.455	4.192	4.317	-0.009	0.254	0.129	-0.263	-0.125
	(0.298)	(0.438)	(0.267)	(0.309)	(0.529)	(0.399)	(0.428)	(0.512)	(0.407)
Land parcel distance	3.203	3.221	3.112	4.148	-0.018	0.091	-0.945	-0.109	-1.036
	(0.489)	(0.545)	(0.509)	(1.502)	(0.730)	(0.704)	(1.576)	(0.744)	(1.582)

Table 4. Continued

Variables	(1) T4	(2) T3	(3) T2	(4) T1	(5) T4–T3	(6) T4–T2	(7) T4–T1	(8) T2–T3	(9) T2–T1
Panel F. *Outcomes*									
Minimum tillage	0.169	0.163	0.194	0.136	0.006	-0.025	0.033	0.031	0.058ǂ
	(0.025)	(0.026)	(0.026)	(0.020)	(0.036)	(0.036)	(0.032)	(0.037)	(0.033)
Crop residue recycling	0.183	0.177	0.179	0.189	0.006	0.004	-0.006	0.002	-0.010
	(0.023)	(0.021)	(0.022)	(0.021)	(0.031)	(0.032)	(0.031)	(0.031)	(0.030)
Planting in rows	0.505	0.513	0.525	0.493	-0.008	-0.020	0.012	0.012	0.032
	(0.027)	(0.036)	(0.028)	(0.033)	(0.045)	(0.039)	(0.042)	(0.046)	(0.043)
Intercropping	0.453s	0.428	0.478	0.475	0.025	-0.025	-0.022	0.050	0.003
	(0.029)	(0.031)	(0.029)	(0.028)	(0.043)	(0.041)	(0.040)	(0.042)	(0.040)
Crop rotation	0.766	0.771	0.740	0.757	-0.005	0.026	0.009	-0.031	-0.017
	(0.024)	(0.030)	(0.030)	(0.028)	(0.038)	(0.038)	(0.037)	(0.042)	(0.041)
Number of practices	2.963	2.851	3.008	2.939	0.112	-0.045	0.024	0.157	0.069
	(0.071)	(0.100)	(0.086)	(0.086)	(0.123)	(0.112)	(0.112)	(0.132)	(0.122)
No. of observations	**649**	**589**	**619**	**676**	**1,238**	**1,268**	**1,325**	**1,208**	**1,295**

Robust standard errors in parentheses. Reported standard errors are clustered at the level of randomization.
ǂ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
T1 = Push; T2 = Push + Pull-2; T3 = Push + Pull-1; T4 = Push + Pull-1 + Pull-2.

Table 5. Orthogonality tests – first season versus second season of both the first and second year

Variable	Year 1 Season 1 beneficiary	Year 1 Season 2 beneficiary	diff.	Year 2 Season 1 beneficiary	Year 2 Season 1 beneficiary	diff.
Household head's characteristics						
Gender of head	0.249	0.195	0.054*	0.211	0.227	-0.016
	(0.022)	(0.021)	(0.030)	(0.018)	(0.019)	(0.026)
Age of head	46.044	44.354	1.690	44.832	44.992	-0.160
	(0.696)	(0.815)	(1.069)	(0.700)	(0.644)	(0.949)
Education of head	6.599	6.913	-0.314	6.938	6.636	0.302
	(0.239)	(0.230)	(0.330)	(0.195)	(0.171)	(0.258)
Household characteristics						
Household size	6.953	6.781	0.172	6.762	6.933	-0.171
	(0.132)	(0.146)	(0.197)	(0.136)	(0.127)	(0.186)
Radio ownership	0.643	0.646	-0.003	0.643	0.617	0.026
	(0.025)	(0.026)	(0.036)	(0.024)	(0.020)	(0.032)
Mobile phone ownership	0.855	0.840	0.015	0.852	0.792	0.060**
	(0.016)	(0.018)	(0.023)	(0.016)	(0.019)	(0.025)
Total landholding	5.279	5.399	-0.120	4.991	5.618	-0.627
	(0.504)	(0.408)	(0.647)	(0.341)	(0.314)	(0.463)
Grew soybean in 2019	0.310	0.368	-0.058	0.272	0.320	-0.048
	(0.048)	(0.046)	(0.066)	(0.037)	(0.034)	(0.050)
Enterprise employment	0.235	0.217	0.018	0.229	0.252	-0.023
	(0.023)	(0.022)	(0.032)	(0.016)	(0.019)	(0.025)
Farm employment	0.108	0.151	-0.043*	0.113	0.167	-0.054**
	(0.016)	(0.020)	(0.025)	(0.014)	(0.021)	(0.025)
Off-farm employment	0.221	0.210	0.011	0.160	0.166	-0.006
	(0.018)	(0.020)	(0.027)	(0.018)	(0.016)	(0.024)
Push incentives						
Attended training workshops	0.267	0.184	0.083**	0.199	0.214	-0.015
	(0.028)	(0.024)	(0.036)	(0.020)	(0.022)	(0.029)
Visited farmer field school	0.106	0.090	0.016	0.066	0.142	-0.076***
	(0.018)	(0.018)	(0.026)	(0.012)	(0.020)	(0.023)
Visited by agricultural expert	0.063	0.053	0.010	0.054	0.049	0.005
	(0.012)	(0.011)	(0.016)	(0.011)	(0.010)	(0.015)
Pull incentives						
VSLA/SACCO credit	0.432	0.453	-0.021	0.456	0.474	-0.018
	(0.030)	(0.030)	(0.042)	(0.029)	(0.029)	(0.041)
Formal lender credit	0.085	0.052	0.033*	0.056	0.060	-0.004
	(0.014)	(0.010)	(0.017)	(0.011)	(0.010)	(0.015)
Insurance awareness	0.172	0.171	0.001	0.149	0.143	0.006
	(0.020)	(0.022)	(0.030)	(0.016)	(0.017)	(0.023)
Collective action	0.037	0.044	-0.007	0.043	0.047	-0.004
	(0.011)	(0.010)	(0.015)	(0.011)	(0.015)	(0.018)
Farm environment and conditions						
Drought/long dry spell	0.618	0.683	-0.065	0.655	0.667	-0.012
	(0.029)	(0.027)	(0.040)	(0.029)	(0.030)	(0.041)
Floods/excessive rains	0.308	0.315	-0.007	0.298	0.352	-0.054
	(0.028)	(0.030)	(0.040)	(0.024)	(0.029)	(0.038)
Subcounty distance	5.552	6.162	-0.610	5.823	5.323	0.500
	(0.411)	(0.384)	(0.560)	(0.295)	(0.305)	(0.423)
All-weather road distance	1.055	1.253	-0.198	1.171	1.061	0.110
	(0.120)	(0.143)	(0.186)	(0.164)	(0.163)	(0.231)
Input market distance	4.571	4.766	-0.195	4.516	4.084	0.432
	(0.347)	(0.309)	(0.464)	(0.246)	(0.227)	(0.334)
Output market distance	4.091	4.373	-0.282	4.483	4.416	0.067
	(0.332)	(0.361)	(0.489)	(0.281)	(0.343)	(0.442)
Land parcel distance	3.521	4.658	-1.137	2.914	2.955	-0.041
	(0.545)	(1.913)	(3.984)	(0.388)	(0.407)	(0.561)

Table 5. Continued

	Year 1			Year 2		
	Season 1 beneficiary	Season 2 beneficiary	diff.	Season 1 beneficiary	Season 2 beneficiary	diff.
		Outcomes				
Minimum tillage	0.125	0.155	-0.030	0.203	0.167	0.036
	(0.023)	(0.025)	(0.034)	(0.026)	(0.022)	(0.034)
Crop residue recycling	0.192	0.177	0.015	0.183	0.178	0.005
	(0.024)	(0.021)	(0.031)	(0.020)	(0.023)	(0.030)
Planting in rows	0.531	0.475	0.056	0.526	0.499	0.027
	(0.036)	(0.031)	(0.047)	(0.028)	(0.030)	(0.041)
Intercropping	0.493	0.449	0.044	0.496	0.404	0.092**
	(0.028)	(0.030)	(0.041)	(0.032)	(0.025)	(0.040)
Crop rotation	0.775	0.759	0.016	0.765	0.738	0.027
	(0.028)	(0.030)	(0.041)	(0.028)	(0.026)	(0.038)
Number of practiced	3.078	2.906	0.172	2.979	2.823	0.156
	(0.094)	(0.094)	(0.133)	(0.081)	(0.078)	(0.112)
Number of observations	**574**	**543**		**698**	**718**	

Robust standard errors in parentheses. Reported standard errors are clustered at the level of randomization.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Study procedures

Before data collection, we trained enumerators and supervisors covering all aspects contained in the household questionnaire. We ensured that enumerators understood all the terms used in the household questionnaire including the meaning of a household, land parcel, plots, etc. We facilitated several rounds of role players where one enumerator acted as an interviewer and the other as a respondent and recorded all emerging issues for corrections. Through role plays, enumerators had a better understanding and experience in asking all the questions which ultimately reduced the amount of time spent on each interview. The household questionnaire was pre-tested among soybean producers in one of the communities outside villages covered by this study. The pre-test helped us to: (1) test enumerators understanding of the questions; (2) test whether the questions on the questionnaire were well phrased; (4) check for persistent errors in collected data (3) determine the amount of time an interview would take, on average; among others. The issues identified from this pilot helped us to modify questions and we extended the training for two extra days which helped addressed remaining gaps. All the questions were programmed onto computer tablet using a computer program called Open Data Kit (ODK). This helped us to minimize errors during data collection.

As indicated earlier, we randomly selected 8 members from each of the 329 farmer group using stata software. We utilised the databases of farmer group members availed by SMAEs for random selection of members (respondents) before deployment of teams to the field. The ToTs of the three SMEs helped us in the mobilization of randomly selected households. Due to good mobilization, we achieved high participation in the study and household replacements were very minimal. For a few cases where replacements were inevitable, we had reserved 4 more randomly selected members per group that replaced any household whose household head or spouse was not available on the day of data collection and a day that followed.

Before starting any interview, enumerators would first introduce themselves and thoroughly explain to the respondents the objectives of the study and ask the respondent if they have any questions. Enumerators would then seek consent from respondents before starting any interview. These details were included on the household questionnaire in the introductory statements (consent form). Farmers that declined to be interviewed were thanked and then enumerators proceeded to the next household assigned to them by the supervisor. We shall use the same procedures during the midline and end line surveys.

Data collection

The baseline survey data was collected from randomly selected farmer group members (household representatives) by well-trained enumerators through face-to-face interviews using computer-assisted personal interviews (CAPI). The collected data was cleaned and verified before being transmitted to the servers. Supervisors conducted random spot checks to not only ensure that enumerators covered selected households but also to ensure that enumerators asked all the questions and recorded the responses accurately. The respondents were asked questions related with their personal, household, farm-level, and farm environment characteristics as well as questions concerning training and extension services they accessed in the past two cropping seasons (cropping year), participation in contract farming; participation in collective bulking and marketing and use of index-based insurance, among others.

Safety

This research is conducted a mid COVID 19 crisis. Therefore, while undertaking field data collection, we observed all the standard operating procedures (SOPs) and measures put in place by the Uganda's Ministry of Health and SNV Netherlands Development Organization office in Uganda to safeguard the research team and farmers (from whom data was collected) against risks. In particular, the following preventive measures were implemented and we shall continue to implement them during the midline and endline surveys:

a) Procurement of facial masks for the research team and the respondents.
b) Procurement of hand sanitizers used in cars as well as before and after interface with respondents by the research team.
c) Strictly observing social distancing of 2 metres; therefore, avoiding handshakes and greetings through hugs at all times.
d) The cars used in the field can only accommodate half of its capacity as directed by the government of Uganda.
e) All the enumerators and supervisors will reside in only one hotel to avoid multiple interactions that could pose risks. The research team will be accommodated in a hotel that takes temperatures of research team on a daily basis.
f) All interviews will always be conducted in open spaces (not inside the buildings).

Estimation strategy

The overarching aim of this study is to assess the effectiveness of the four incentive bundles on adoption intensity of CSA practices and technologies before examining the impacts of CSA practices and technologies on factor productivity, income and household welfare. The incentive bundles include: (i) push; (ii) push+pull-2; (iii) push+pull-1; and push+pull-1+pull-2. To assess the impacts of the incentive bundles, we first estimate the ITT effects using the following OLS regression specification:

$$Y_{ti} = \alpha + \sum_{m=1}^{4} \beta_m T_{mti} + \varphi X_t + \omega Y_{1i} + \varepsilon_{ti} \qquad (1)$$

where, Y_{ti} is the outcome for farm-household, i measured using the mid-line and end line survey data if $t = 1$ and $t = 2$, respectively. T is a farmer-group (cluster) level dummy variable which is equal to one if a farmer group member from household i was assigned to a particular treatment condition, while $m = 1$ to 4 represents the four types of incentive bundles under the CRAFT programme. β is the (ITT) treatment effect of interest. As noted earlier, we used block-cluster randomization approach. Therefore, we need to cater for any inherent differences regarding implementation of the incentive bundles across the SMAEs (blocks). Also, farmers are enrolled to begin accessing incentive bundles in phases at the beginning of a new season. Therefore, we will account for block and season dummy variables represented by the vector X. Y_{1i} represents the baseline value of the outcome of interest, while ε_i is the cluster-level error term. We shall code missing control variables as zero and include dummy variables to indicate missing values.

Our results will be presented in two parts. First, we shall present the effects on adoption and intensity of adoption. Then we shall examine the channels through which intensity of adoption could be affected by estimating the impact of incentive bundles on access to input (or financial) credit, perceived quality of accessed inputs, quality and quantity of output marketed through SMAEs, as well as price at which soybean output is sold at SMAEs relative to prices offered elsewhere. We shall also test multiple hypotheses simultaneously to make adjustments that cater for multiple inference (Anderson, 2008).

Next, we then employ an instrumental variable approach to estimate the LATE, instrumenting take up of the incentive bundle with random assignment to treatment. We use two-stage least squares estimator. In the first stage, we estimate the reduced form equation as follows:

$$Z_{mti} = \delta + \sum_{m=1}^{4} \gamma_m T_{mti} + \varphi X_t + \mu_{ti} \quad (2)$$

In the second stage, we then estimate the structural equation as follows:

$$Y_{ti} = \alpha + \sum_{m=1}^{4} \beta_m Z_{mti} + \varphi X_t + \omega Y_{1i} + \varepsilon_{ti} \quad (3)$$

where $Z_{mti} = 1$ if a farm household, i complied in incentive bundle m at the mid-line period ($t = 1$) or end line period ($t = 2$) and $Z_{mti} = 0$ if a farm household, i never complied. The rest of the variables and coefficients remain as defined earlier.

In the second objective, we examine the impacts of CSA practices and technologies on (a) factor (land and labour) productivity; (c) household income; and (d) nutrition (women's dietary diversity score (WDDS)). These outcomes remain as defined before. The analysis will rely on variation of CSA adoption following the CRAFT interventions. We shall also employ an instrumental variable approach to estimate the LATE.

Ethics and dissemination

Before the baseline survey, we sought and got research ethical approvals from the Research Ethics Committee (REC) at the School of Social Sciences, Wageningen University in the Netherlands. We also applied for research clearance from Uganda National Council for Science and Technology (UNCST) and we are yet to receive clearance certificate. As the baseline survey had been delayed by the lockdown measures due to COVID 19 pandemic, we could not wait for research clearance from UNCST before we could conduct the baseline survey. However, we sought permission from the district local authorities to conduct the baseline survey.

Collected data will be coded and stored safely to limited access by authorized individuals. Only investigators will have access to the identification lists. Most importantly, all the data collected at the baseline, mid-line and end line periods will be managed according to the research data policy of Wageningen University & Research[3]. Results of this study will be disseminated to local project partners and beneficiaries in the form of reports and organized workshops. Thereafter, the results including the statistical code will be published in peer-reviewed scientific journals and be presented

[3] https://www.wur.nl/en/Value-Creation-Cooperation/WDCC/Data-Management-WDCC.htm.

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