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Agricultural extension and input subsidies to reduce food insecurity. Evidence from a field experiment in the Congo

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Abstract

Small holder farming in sub-Saharan Africa is plagued by low productivity levels and high malnutrition. Extension services aim to increase knowledge and uptake of new technologies to boost yields. However, despite the potential benefits adoption rates are still low. One explanation may be that providing training and demonstration trials alone is not enough to increase input demand needed to raise productivity. Lifting multiple barriers simultaneously could prove to be more effective. We use a field experiment in eastern DRC to test whether adding input subsidies to an extension programme provides synergistic benefits. Specifically, in a sample of 64 villages that received an agricultural extension programme, a random half was given the opportunity to buy subsidised input packages. We estimate the impact of the subsidy scheme on knowledge, input use, yields and food security indicators. We find robust evidence on input use at the extensive margin: providing subsidies increases fertiliser uptake by 5 percentage points, while uptake of inoculant increases by 3 percentage points, one year after the subsidy scheme was introduced. These effects are substantial given the extremely low baseline use (3% in both cases) of fertiliser and inoculant even after the extension intervention. In addition, villages further away from these markets have lower adoption rates as cost of access increase. Our results caution against overoptimistic views on the downstream effects of productivity enhancing technologies and that investments in structural changes in markets are likely needed to stimulate growth in the agricultural sector.

Keywords: agricultural extension, input subsidies, impact evaluation, food security, DRC
JEL codes: O13, O33, Q12

Highlights

- Productivity and technology levels in sub-Saharan Africa are low.
- We use a field experiment in eastern DRC to assess impact of adding input subsidies to an agricultural extension programme.
- We find providing subsidies increases uptake of technologies.
- This however does not translate in increased yields and food security.

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1. Introduction

Smallholder farmers in sub-Saharan Africa face acute constraints to productivity. Output prices are low, input costs high and credit markets function poorly. Extension programmes are a popular tool among donors for raising smallholder incomes and improving food security. Agricultural extension targets informational gaps through the transfer of knowledge on – and experimentation with – higher-yielding inputs. However, despite the potential benefits of new technologies, adoption rates are still low (see e.g. Foster and Rosenzweig, 2010; Conley and Udry, 2010; Giné and Yang, 2009; Bandiera and Rasul 2006; Doss, 2006) and the effectiveness of extension services has often been limited (Anderson and Federer 2007). A candidate explanation is that the provision of training and demonstration trials alone is not enough to boost demand for inputs needed to increase productivity. Lifting multiple barriers simultaneously could prove to be more effective. Input subsidisation programmes address constraints of high input prices, and hence lower cost of experimentation, ultimately opening input markets to farmers previously excluded.

Theoretically, both policy tools could have synergistic benefits. If farmers are poorly informed and face liquidity constraints with no or limited access to credit markets, then provision of one or the other intervention may not be sufficient for increasing technology adoption and food security. However, little systematic evidence on the joint provision of these interventions exists.[1] This holds more generally: there is a clear lack of understanding on how interventions that try to relax a single adoption constraint fare relative to interventions that try to overcome multiple barriers simultaneously (Jack, 2011). Despite the widespread popularity of both extension and input types of programmes, evidence on their joint effectiveness remains limited, and results are confounded by issues of endogeneity, selection bias, and measurement error (Birkhaeuser, Evenson, and Feder, 1991; Anderson and Feder, 2007; Morris et al., 2007).

The motivation for this paper is to understand the impact of lifting multiple constraints to the adoption new agricultural technologies. Specifically, we assess whether input subsidies increase smallholder inputs uptake, productivity, and food security in an environment where extension services are also provided to all villages in our sample. We collaborate with a large-scale agronomic programme implemented in rural eastern DRC that aims to improve welfare and food security through training and input provision within an agricultural extension framework. Our sample villages received training by an agricultural extension worker from local agronomic NGOs one season prior to the introduction of the subsidy scheme. Trainings comprised information sessions about input use and attending experimental demonstration trials. Agronomists showcased "best agronomic practices" in terms of plant density and planting in time; fertiliser application, inoculant or a combination of fertiliser and

[1] One reason for not having an abundance of joint programmes around may be due to potential conflicts of interest if information providers are also responsible for managing offers and distribution of subsidised inputs (Anderson and Feder, 2007).

inoculant (cf Woomer, Huising and Giller, 2014). A random half of the sampled extension villages were offered to buy subsidised input packages. Our design facilitates a causal analysis of offering subsidised inputs in a setting that also received agricultural extension services and hence is arguably primed to the potential benefits of using these new inputs. To measure impacts we measure outcomes along a causal chain of (i) improved knowledge that translates into (ii) higher adoption of new inputs and crop management techniques, which results in (iii) better yields that produce (iv) increased food security. Although the provision of subsidies per se does not necessarily lead to better knowledge about these inputs, the offering of such schemes is always accompanied by some introduction and explanation of its use and potential benefits and it allows for experimentation.

We find no robust result on better knowledge about these inputs, but report a positive impact of the subsidy scheme on the uptake of technology. Inoculant use increases by almost 3 percentage points, and fertiliser use by more than 5 percentage points in villages receiving the training with input subsidy, compared to villages receiving extension services only. These effects are substantial given the low proportion of users of inoculant and fertiliser prior to the subsidy scheme (3 percent in each case). Additional uptake however does not translate into higher yields or improved levels of food security, although this might be related to low statistical power for these models, especially where yields are used as a dependent variable. We assess impact heterogeneity with respect to variables that serve as obvious moderators for the subsidies scheme to be effective: distance to markets, land ownership, and the gender and education level of the household head (see e.g. Fenske, 2011; Jacoby, 2000; Ali, 2011; Magnan, 2015). We find that in villages further away from input markets there was no effect on input adoption rates, suggesting structural constraints in market development hinder further development in the agricultural sector.

The outline of the paper is as follows. Section 2 explores existing literature on constraints to agricultural technology adoption and reviews the evidence on the impact of targeted interventions related to agricultural extension services and input subsidies. In section 3 we describe the agricultural context of eastern DRC and the intervention design. In section 4 we discuss the data. In section 5 we discuss our empirical strategy to identify the impacts of the treatment on knowledge, adoption, yields and food security. Section 6 presents the results, including heterogeneous impacts related to market distance, property rights and gender of household head. Section 7 concludes.

2. Constraints to technology adoption

Despite abundant evidence of positive yield impacts at experimental trial stations, households in many Sub-Sahara African countries show (very) low adoption rates of new agricultural technologies. The literature on adoption decisions offers explanations ranging from barriers to information-, credit- and supply, to differences in agro-ecological suitability, (time-inconsistent) preferences and heterogeneous returns to adoption (Duflo et al., 2008; Suri, 2011). Extension services are expected to remove informational constraints about costs and benefits of the technologies, and provide knowledge on how to use them. Extension services take many forms and have included farmer field schools, training and visit systems (T&V), innovation platforms and fee-for-services programmes (Aker, 2011; Kondylis et al., 2014). Non-experimental studies (see e.g. Birkhaeuser, Evenson and Feder, 1991; Davis, 2008; Dercon et al., 2009; Maffioli et al., 2011; Krisnan and Patnam,2014); Rivera, Quamar and Crowder, 2001) present mixed results on its effectiveness and novel experimental designs show that extension services have only limited impact on technology adoption. Duflo, Keniston and Suri (2014) assess the impact of a coffee training programme in Rwanda on the adoption of 'best practices' for growing coffee. By randomly assigning farmers to a training programme and varying the proportion of applicants within treatment communities, they study adoption rates and speed of diffusion for the different types of recommended practices. They find increased levels of awareness across practices, but behavioural change was observed only for those practices that require minimal adoption effort. Agyei-Holmes et al. (2011) evaluate the effectiveness of the Millennium Challenge Account-Ghana programme using a randomised phase-in design. The intervention entails training farmer-based organisations in improving their business capacity through technical skills and helping them connect to value chains. They find no effect on crop yields or income. Pamuk et al. (2014, 2015) investigate whether innovation platforms[2] are able to boost adoption of improved agricultural practices. They find suggestive evidence that innovation platforms outperform traditional extension approaches in terms of poverty alleviation. Kondylis, Mueller and Zhu (2014) evaluate the impact of a randomised T&V system to increase adoption of sustainable land management (SLM) practices in central Mozambique. In the standard T&V system, extension agents are trained by technical staff from the Ministry of Agriculture, and subsequently train 'contact' farmers in their communities, under the expectation that contact farmers will transmit this information to those within their communities. In the modified version contact farmers receive the same training directly from the ministries technical officers. They find that a direct training of contact farmers leads to higher levels of demonstration, private adoption, and learning-by-doing among these contact farmers, yet has limited impact on adoption levels of SLM techniques among other farmers in the community.

Like extension services, subsidy programmes have witnessed a revival in recent years, with new programmes placing greater emphasis on better targeting, improved linkages with markets, and better facilitation of commercial fertiliser sales (e.g. World Bank, 2007; Morris, 2007). The new generation

[2] These are centralised initiatives at the village level where the various stakeholders, ranging from research experts to government representatives, producers, customers, and financial organisations come together to identify and propose solutions for local bottlenecks to agricultural development.

of input subsidy programmes therefore entails more than providing subsidy alone but often also addresses information-, credit-, and supply-side constraints. There is however little consensus or rigorous assessment of the success of these programmes (see Jayne and Rashildl, 2013; Druilhe and Barreiro-Hurlé, 2012; Morris, 2007 for recent syntheses on the evidence). Exceptions include a randomised control trial by Duflo et al. (2011), who find a positive impact of fertiliser vouchers on fertiliser use among rural farmers in Western Kenya, and a recent experimental study by Carter, Lajaaj and Yang (2016), who report positive impacts of vouchers for fertiliser and improved seeds that are consistent with a social learning model of adoption among rural households in Mozambique. They find an increased use of fertiliser for households with a higher proportion of social network members receiving the voucher. These studies suggest that liquidity constraints form an important barrier to adoption of modern farming technologies.

Our study is the first randomised design to estimate the causal impact of subsidised inputs offered in an environment where extension services have recently been delivered and made people arguably aware of the potential benefits of new inputs and techniques. This facilitates testing whether addressing information, financial- and supply constraints simultaneously, leads to greater improvement in outcomes compared to addressing information gaps alone.

3. Context and intervention design

Our study is set in eastern DRC, a region with severe infrastructural and market under-development. Farmers face numerous challenges in crop production including protracted violent conflict, extreme poverty and unfavourable climatic conditions (Ansoms and Marivoet, 2010; Vlassenroot and Raeymaekers, 2004). With more than 70 percent of the population primarily involved in the agricultural sector, the majority being rural smallholder producers, agriculture is an impactful sector to target for development and fight hunger and poverty. The area demonstrates high potential for sustainable agricultural growth, but as a result of recurring violence and high population displacement, agricultural development initiatives have been obstructed (Vlassenroot and Raeymaekers, 2004). [3] Currently, the region ranks amongst the highest in the world for food insecurity and malnutrition rates and is classified as a low-income food-deficit country (LIFDC) (Lambrecht et al. 2016; WFP 2014; UNDP, 2015). Recognising the need to strengthen agricultural sector performance, the DRC government has identified increased agricultural productivity and connecting farmers to markets as key priorities in their Poverty Reduction Strategy Paper (PRSP) and National Agricultural Investment Plan 2013-2020.

[3] Conflict-ridden environments like DRC are characterised by distorted in-and output markets, credit constraints, limited access to information, and changes in social networks, social cohesion, and risk preferences (e.g. Gonzalez and Lopez, 2007; Voors et al., 2012; Gilligan et al., 2014). These factors are in turn associated with people's propensity to invest in new(er) technologies, inputs or crops.

We collaborate with the N2Africa programme, which kicked off in 2009 in eight Sub-Sahara African countries. Its primary objectives are to improve agricultural yields, food security, and incomes by increasing soil fertility through the delivery and dissemination of technologies that advance biological nitrogen fixation (BNF) in legumes.[4] N2Africa specifically targets smallholder farmers in sub-Saharan Africa, as nitrogen depleted soils are ubiquitous across sub-Saharan Africa and are a key contributor to low agricultural yields among rural subsistence producers. N2Africa's focus is the use of Rhizobia, bacteria that attach themselves to the plant root and naturally convert nitrogen from an atmospheric gas-state (NH2) into ammonia (NH3), making it available for direct absorption for the host plant (Wagner, 2012). The result is a symbiotic relationship in which the Rhizobia obtain energy from the plant while the plant benefits from higher nitrogen levels in the surrounding soil (Mulongoy, 1992). BNF is considered to have great potential in increasing agricultural intensification by sustainably improving soil fertility thus increasing yields (Peoples et al., 1995).

Our study area lies in South-Kivu province in eastern DRC. The research area stretches along three axes within the South-Kivu province. The Northern Axis stretches north from the provincial capital of Bukavu following the shore of Lake Kivu, at an altitude of some 1500m. The Western Axis is located in the highlands to the west of Bukavu. The Southern axis comprises the Ruzizi plain to the south of Bukavu, at an altitude of 600m. Soil type, rainfall, temperatures, sunlight, and land use vary substantially across the three axes, necessitating careful tailoring of agricultural interventions to fit local agro-climatic needs.

An international consortium manages the N2Africa programme in eastern DRC.[5] For the dissemination of inputs N2Africa teams up with "outreach partners" that make use of local organisations to conduct the relevant N2Africa activities in communities of the target region (Woomer, Huising and Giller, 2014). In South-Kivu, N2Africa formed partnerships with six locally operating NGOs, each of which had prior experience with agricultural development initiatives undertaken within the designated project zone. To ensure that the NGOs' relationships of mutual trust with communities were effectively leveraged, implementing partners were assigned to the villages in which they implemented the N2Africa programme. The N2Africa intervention had a detailed protocol outlining specificities for the training sessions in order to ensure a standardised N2A intervention as much as possible. Key elements of the programme are described below.

[4] Legumes are interesting crops to produce for African smallholders, many of whom are seeking opportunities to diversify income sources and improve their diets that often contain insufficient protein (Woomer, Huising and Giller, 2014).
[5] Coordinated by the Plant Production Systems Group at Wageningen University in the Netherlands, the International Center for Tropical Agriculture (CIAT), the International Institute for Tropical Agriculture (IITA), the Consortium for Improving Agriculture-based Livelihoods in Central Africa (CIALCA), and the Catholic University of Bukavu (UCB)

N2Africa training intervention (extension services)

The N2Africa intervention commenced in January 2013 at the start of the secondary growing season (season B, see Figure 1 below) by having extension workers travel to interested villages, consult with the local authorities and begin "sensitising" interested households and farmers' groups on the use of new techniques and inputs.[6] Extension workers subsequently established experimental trials during which the production of legumes using traditional techniques was compared to production using new techniques and improved inputs. For the eastern DRC programme, the trials were conducted at the research station in Kalambo (close to Bukavu). These trials primarily consisted of the intercropping of soybean with either cassava or maize using best agronomic practices related to e.g. plant spacing and intercropping arrangements. Lead farmers were brought to visit these trials and to select the improved inputs and processes they expected to be most successful given local constraints and conditions.

During field visits extension workers engaged famers in a 'situation analysis' to identify local needs and constraints. Participating communities, in conjunction with extension workers, selected 'lead' farmers from eligible individuals who were able to read and write, owned land, and had extensive experience in farming. These lead farmers then worked in a group of 15-30 farmers within their community and received legume technology packages that included a small amount of inputs for a legume of choice (seed, fertiliser, inoculant, adhesive etc.) in addition to training on new management practices on plant spacing, intercrop management and educational information about the nutritional benefits of legume consumption, and training on value-added processing of legumes to generate income opportunities especially for women. Lead farmers were asked to set up local demonstration plots, where co-villagers could observe the application of new inputs and different management techniques (compared against a control plot where traditional methods were practiced). Newly gained knowledge about legume processing and nutritional information was also shared with the group members. Interested group members could ask to receive small input packages with which to experiment on their own fields. Extension workers regularly visited the communities during the growing season B in 2013 to assess results, listen to farmers' experiences and provide advice. Figure 1 below depicts the timeline of the interventions and research activities.

Figure 1: timeline

[6] This region has two growing seasons. The primary growing season (referred as growing season A) runs from July till November, while the secondary season B runs from January till the end of May.

Input subsidy programme

After the N2Africa training ended in May 2013, half of the villages in our sample were randomly selected to receive an offer to buy a package of subsidised inputs for use in the following primary growing season A. The same N2Africa training was purposefully provided to all villages in our sample – prior to the random assignment of the subsidy treatment to ensure that treatment effects can be attributed to the provision of the subsidy alone, removing information effects that are also provided (even if only implicitly) when the subsidy scheme is introduced. This means we cannot test the bundled effect of extension services and subsidies versus subsidies alone, nor whether extension services become (more) effective once subsidies are also provided.[7]

Local development committees (CLD) informed community members of the possibility to buy new inputs at a reduced price (75% of the market price) and provided a delayed payback scheme, in which a deposit of 500 FC ($0.54 USD) was required upfront and the remainder was owed after the next harvest. Participants were also offered the option the pay back in kind (seeds) instead of cash if preferred. Each implementing partner NGO customised six variations of input packages (each worth about 26 USD) that all contained a combination of improved seeds, fertiliser and (or) inoculant to best suit the preferences and needs of the local farmers.[8] CLDs were responsible for registering community farmers and ordering the necessary packages. Agro-dealers delivered the ordered inputs to the communities before the start of the new planting season A, a month later. Inputs were delivered to the CLDs, who were then responsible for coordinating the distribution of the inputs to the respective buyers within the community and collecting the remaining payment owed after the harvest.

4. Data

Our research comprises 64 villages. The sampling frame was developed in collaboration with the implementing partners and required villages selected satisfy (i) that at least one of the implementing partners had established contacts within the community, (ii) that the village was accessible by motorised transport; and (iii) that the village had not participated in any N2Africa intervention previously.

Villages were randomly assigned to receiving the subsidy scheme or not, stratified within each axis. Data collection involved several steps. First, the N2Africa consortium implemented the extension

[7] Even though it could have been interesting to estimate these impacts, the N2Africa programme is based on the premise of providing extension services combined with new inputs and improved technologies, hence providing subsidies alone would not naturally fit their approach. Also, South-Kivu provides an extremely challenging working environment due to high levels of insecurity. After long consultations with our local partners we therefore concluded that adding subtreatments was infeasible at this stage.

[8] Inoculant refers to a commercially available product. Grain legumes are coated (inoculated) with bacteria that fix nitrogen gas from the air into a form usable by plants. The nitrogen fixation thereby contributes to the production of high-protein legumes, increases yields and improves soil fertility (N2Africa, 2014).

programme between January and May 2013 in all villages. During June and July 2013, we administered a detailed household survey to 10 randomly selected households per village, comprising a sample of 521 households.[9] In addition to the household interviews, community meetings were organised to collect information on proximity to markets and demographics. A year and a half (two growing seasons) later, October 2014, we implemented a second round of surveys with the same households. The questionnaires included modules on demographics, housing, agriculture (including sources of agricultural knowledge), food security, and social and formal financial support systems. A team of 37 enumerators, recruited with the assistance of the Catholic University of Bukavu (UCB) conducted the surveys and community meetings.

Variable definitions and descriptive statistics of the first survey wave – shortly after the N2Africa training intervention – are provided in Table 1 and 2. Columns (1) and (2) of Table 2 present the mean and standard errors for the training only and training with input subsidy group, respectively. Column (3) presents the *p*-value from a regression with standard errors clustered at the village level. Knowledge of inoculum is low even after the N2Africa extension programme. Less than 7% of respondents had heard of inoculum. Knowledge of fertiliser was high, but use of both types of farm inputs (fertiliser, inoculum) is very low. Throughout the sample, only 3% of households report having used chemical fertiliser or inoculant in the previous season. Inputs provided in the programme hence comprise new technology for nearly all households in the sample. Yields for beans and cassava are log-transformed with a value of on average 72kg/ha and 2670kg/ha respectively and are comparable across both groups. Food security is measured using the Household Food Insecurity Access Scale (HFIAS) (Coates et al. 2007). This scale measures food insecurity over three domains that capture different aspects of food insecurity: Anxiety, Quality and Intake. Higher scores on these domains signify greater food insecurity. Reported insecurity is high throughout the sample, but with the input subsidy group being slightly worse off than the training-only group in all three domains.

Panel B reports a number of respondent characteristics. Household size averages to 6.5 people and the majority of households are male-headed (only 13% of households have a female household head). Education levels are low, as most household heads only have some primary education. About two-thirds of the household heads are born in the village and are heavily reliant on agriculture for their livelihoods. About 80 percent of households identify agriculture as the household head's primary occupation. Input markets on average are 3-7 km away from villages. Finally, some to most of the land that is farmed by households is privately owned.

[9] Interviews were conducted primarily in Swahili and data was recorded using ODK software on tablets.

Attrition

During data collection, measures were taken to minimise household and village attrition. Enumerators announced the arrival of the research team one day in advance to ensure that all targeted households were present during the scheduled enumerator visits. For those instances where households were not present on the scheduled visit, a second date was scheduled to interview any missing households. Despite these measures, 17% of the households that were part of the first round could not be reached during the second round of data collection. To some extent, this is to be expected given the post-conflict setting where migration is high. In Table A1 in the appendix, we analyse both whether attrition is random and whether any correlation to treatment is observed. We find no correlation of attrition to treatment, but younger household heads and smaller households are more likely to have dropped from the sample. We include these variables as controls in all of our regressions.

5. Empirical strategy

We assess the impacts of offering the subsidy intervention on knowledge, use of new inputs, yields, and food security indices relative to a condition where famers only receive the N2Africa extension programme. Specifically, we estimate:

$$Y_{ijt} = \alpha \quad + \beta Subsidy_j + \delta\, Y_{ijt-1} + \gamma X_{ij} + \Gamma A_k + \varepsilon_{ijt} \qquad (1)$$

where Y_{ijt} is the outcome measure for respondent *i*, in village *j*, in second round of data collection. $Subsidy_j$ is a dummy that takes value 1 if village j was randomly selected to receive access to subsidised inputs, X_{ijt-1} is a set of household characteristics (household size and age and education level of the household head), Y_{ijt-1} is the outcome during the first round of data collection included to increase precision, $A_k$is the stratum (axis) fixed effect, and ε_{ijt} is the error term. In all models, we cluster standard errors at the village level. β captures the intent to treat effect (ITT) of offering the subsidy scheme.[10]

In addition, we explore how the input subsidy intervention differentially affected households stratified across several dimensions. Understanding such heterogeneous impacts can provide key descriptive insights for future exploration to tailor policy towards particularly responsive households in order to improve project effectiveness. Second, heterogeneous treatment effects can elucidate key drivers and constraints to intervention effectiveness within the sample. Of particular interest in our sample are distance to input markets, land ownership (a binary indicator for whether the household owns any of

[10] We conducted a short follow-up study in September 2013 to assess take-up and check whether inputs had been (timely) delivered. Due to plausible reasons of increased insecurity this survey was not conducted well and take-up rates were only recorded in 20% of our sample. We therefore only report IIT impacts here.

their land), and the gender and education level of household heads (education is measured by a binary indicator for whether the household head has at least primary education). As our sample design does not randomise across these stratifications, we are unable to identify causal relationships and are limited to observing descriptive patterns within the data. We re-run model (1) and include a level and interaction term H_{ij} for a relevant subgroup dimension. Specifically, we estimate:

$$Y_{ijt} = \alpha \quad + \beta Subsidy_j + \delta\, Y_{ijt-1} + \gamma X_{it-1} + \pi\, H_{ij} * Subsidy_j + \theta H_{ij} + \Gamma A_k + \varepsilon_{ijt} \qquad (2)$$

All symbols are the same as above, and π captures differences in the intent to treat effect of the input subsidy intervention on outcomes between relevant subgroups.

6. Results

Below in Table 3 and Table 4, we show effects for outcomes along the full causal chain, going from knowledge about fertiliser and inoculant, to input use, to production (yields) of beans, and food security.

First, in Table 3 we assess the marginal effect of offering the subsidy scheme. We find no significant impacts on knowledge but a strong and positive impact on input use. The results are encouraging, compared to a very low baseline use level of 3% shortly after the training, the input subsidy programme more than doubles take-up: inoculant use increases by 3 percentage points (Column 3) and fertiliser use increases by more than 5 percentage points (Column 4). These results are obtained one year (that is, two agricultural seasons, A and B) after farmers received the subsidy, suggesting effects on input use are persistent. These findings are consistent with those by Carter, Lajaaj and Yang (2016) who find fertiliser use remains significantly higher two years after a subsidy was provided. Increased take-up however does not translate into better yields or outcomes on food security, contrasting work by Carter Lajaaj and Yang (2016) and Brune et al. (2015). The point estimates are small and not significant.[11] The absence of effects on yields and food security may be due to low statistical power and a low overall absolute increase in input use. Given that less than 10 percent in our sample uses fertiliser and (or) inoculant, any potential treatment effects on yield and food security would have to come from this (very) small group.

Next, we assess whether the input subsidy scheme had differential impacts among varying sub-groups of participants in order to reveal potential underlying mechanisms driving the ITT effects (Table 4).

[11] Note here that the number of observations for yields drops considerable, as households that do not grow beans or cassava are left out of the sample. Results are similar when setting crop yields for beans or cassava for these households to zero.

Overall, we find little evidence of treatment heterogeneity, except for distance to markets. The impact of the subsidy scheme on input use is smaller in households that are further away from input markets. The effect is significant only for inoculant use, but in terms of effect size the results suggest that both fertiliser use and inoculant use were not affected in households further away from the market. Hence the time and financial costs associated with accessing inputs is a barrier to a persistent impact of input subsidies on input use.

7. Discussion and conclusions

Smallholder agriculture in much of sub-Saharan Africa is severely constrained. Poorly functioning input, output and credit markets and low quality infrastructure inhibit growth in the agricultural sector. Extension programmes, often involving training and demonstration trials with lead farmers, are a common tool popular among policy makers interested in raising smallholder incomes and improving food security. However, despite the promise extension programmes offer their success has been limited (Anderson and Federer 2007) and therefore more is needed to raise smallholders' productivity. For example, access to input markets may hamper further uptake of introduced technologies. Lifting multiple barriers simultaneously could hence prove to be more effective. We study the causal effect of offering inputs subsidies within an extension training programme.

We estimate an intention-to-treat effect for outcomes capturing a larger theory of change of increased knowledge and adoption of inputs, which raises farmer productivity and thus reduces food insecurity. By incorporating the entire causal chain, we aim to identify the role that access to inputs plays in constraining household agricultural development.

Our results suggest that the intervention was successful in increasing use of two important yields enhancing inputs: a new technology called inoculant and chemical fertiliser. In our sample, reported input use nearly doubles, corresponding with findings elsewhere (Carter, Lajaaj and Yang 2016, Brune et al. 2015). In addition, we find that only villages relatively close to input markets are likely to benefit from the subsidy scheme: input use is not affected in villages further away from markets. This suggests that access to markets is a key constraint to raising adoption. Unfortunately, we do not find that increases in adoption translate into increases in yields and food security, but the lack of impact may be due to limited power in our sample and to a low absolute impact on input use. Taken together, our results caution against overoptimistic views on the downstream effects of productivity enhancing technologies. Perhaps, larger interventions that target fundamental changes in market structure and access are required in order to develop local supply chains and thus lower the longer-term costs of purchasing improved inputs. This would raise input use to a level where increases in yields and subsequent food intake may be realised.

There are three caveats to our study. First, and unfortunately, we do not have reliable data on actual adoption rates within villages what would allow for estimating local average effects among adopters. Programme implementation in DRC takes place under challenging conditions and keeping track of activities and key process indicators (such as who within each community ordered input packages) was not completed. Second, our design does not assess the impact of extension services or subsidies alone and hence cannot provide insight in to what binding constraint, i.e. information or input subsidies, would make the largest contribution to raising smallholder agricultural productivity. Finally, we have no information on whether the subsidy had any effect on the intensive margin. This is left for future work.

References

Agyei-Holmes, A., Ayerakwa, H. M., Osei, R. D., & Osei-Akoto, I. (2011). *Training and Farmer Productivity : An Evaluation using RCT for the MCA-Ghana Programme*.

Aker, B. J. C. (2010). Information from Markets Near and Far : Mobile Phones and Agricultural Markets in Niger. *American Economic Journal: Applied Economics*, *2*(3), 46–59.

Ali, R. (2011). Impact of Rural Road Improvement on High Yield Variety Technology Adoption : Evidence from Bangladesh. *Working Paper*

Anderson, J. R., & Feder, G. (2004). Agricultural extension: Good intentions and hard realities. *World Bank Research Observer*, *19*(1), 41–60.

Ansoms, A., & Marivoet, W. (2009). Profil socio-économique du Sud-Kivu et futures pistes de recherche. *L'Afrique Des Grands Lacs*, 259–271.

Bandiera, O., & Rasul, I. (2006). Social networks and technology adoption. *The Economic Journal*, *116*(514), 869–902.

Besley, T. (1995). Property Rights and Investment Incentives: Theory and Evidence from Ghana. *The Journal of Political Economy*, *103*(5), 903–937.

Besley, T. & Case, A. (1993) Modelling Technology Adoption in Developing Countries. *The American Economic Review, 83*(2), 396-402.

Birkhaeuser, D., Evenson, R. E., & Feder, G. (1991). The Economic Impact of Agricultural Extension: A Review. *Economic Development & Cultural Change*, *39*(3), 607–650.

Brune, L., Giné, X., Goldberg, J., & Yang, D. (2016). Facilitating savings for agriculture: Field experimental evidence from Malawi. *Economic Development and Cultural Change*, *64*(2), 187-220.

Carter, M. R., Laajaj, R., & Yang, D. (2014). Subsidies and the Persistence of Technology Adoption: Field Experimental Evidence from Mozambique. *NBER Working paper 20465*.

Conley, B. T. G., & Udry, C. R. (2010). Learning about a New Technology: Pineapple in Ghana. *The American Economic Review*, *100*(1), 35–69.

Davis, C. (2009). Extension in Sub-Saharan Africa. *Rural Development News*, *1*, 48–53.

Dercon, S., Gilligan, D. O., Hoddinott, J., & Woldehanna, T. (2009). The impact of agricultural extension and roads on poverty and consumption growth in fifteen Ethiopian Villages. *American Journal of Agricultural Economics*, *91*(4), 1007–1021.

Doss, C. R. (2006). Analyzing technology adoption using microstudies: limitations, challenges, and opportunities for improvement. *Agricultural Economics*, *34*(3), 207-219.

Druilhe, Z., & Barreiro-hurlé, J. (2012). Fertilizer subsidies in sub-Saharan Africa. *ESA Working Paper No. 12-04*.

Duflo, E., Kremer, M., & Robinson, J. (2011). How high are rates of return to fertilizer? Evidence from field experiments in Kenya. *The American Economic Review*, *101*(6), 2350–2390.

Duflo, E., Keniston, D., & Suri, T. (2014). Diffusion of Technologies within Social Networks: Evidence from a Coffee Training Programme in Rwanda. *IGC Working Paper*

Fenske, J. (2011). Land tenure and investment incentives: Evidence from West Africa. *Journal of Development Economics*, *95*(2), 137–156.

Foster, A. D., & Rosenzweig, M. R. (2010). Microeconomics of Technology Adoption. *Annual Review of Economics*, *2,* 395-424

Gilligan, M. J., Pasquale, B. J., & Samii, C. (2014). Civil war and social cohesion: Lab-in-the-field evidence from Nepal. *American Journal of Political Science*, *58*(3), 604-619.

Giné, X., & Yang, D. (2009). Insurance, credit, and technology adoption: Field experimental evidence from Malawi. *Journal of Development Economics*, *89*(1), 1–11.

Goldstein, M., & Udry, C. (2008). The Profits of Power : Land Rights and Agricultural Investment in Ghana. *Journal of Political Economy*, *116*(6), 981–1022.

Jack, B. K. (2011). Constraints on the adoption of agricultural technologies in developing countries. *White paper, Agricultural Technology Adoption Initiative, Boston: J-PAL (MIT) and Berkeley: CEGA (UC Berkeley)*.

Jacoby, H. G. (2000). Access to Markets and the Benefits of Rural Roads. *The Economic Journal*, *110*(465), 713–737.

Jayne, T. S., & Rashid, S. (2013). Input subsidy programs in sub-Saharan Africa: A synthesis of recent evidence. *Agricultural Economics*, *44*(6), 547–562.

Kondylis, F., Mueller, V., & Zhu, J. (2017). Seeing is believing? Evidence from an extension network experiment. *Journal of Development Economics*, *125*, 1-20.

Krishnan, P., & Patnam, M. (2013). Neighbors and extension agents in Ethiopia: Who matters more for technology adoption?. *American Journal of Agricultural Economics*, *96*(1), 308-327.

Lambrecht, I., Vanlauwe, B., & Maertens, M. (2016). Agricultural extension in Eastern Democratic Republic of Congo: does gender matter? *European Review of Agricultural Economics*, 1–33.

Magnan, N., Spielman, D., Gulati, K., & Lybbert, T. (2015). Information Networks among Women and Men and the Demand for an Agricultural Technology in India. *Discussion Paper No. 1411*.

Maffioli, A., Ubfal, D., Bar_e, G. V., and Cerd_an-Infantes, P. (2011). Extension services, product quality and yields: the case of grapes in Argentina. Agricultural Economics, 42(6).

Morris, M., Kelly, V. a, Kopicki, R. J., & Byerlee, D. (2007). *Fertilizer uses in African Agriculture: Lessons Learned and Good Practice Guidelines*. Washington D.C.: The World Bank.

Mulongoy, K. (1992). Technical Paper 2: Biological Nitrogen Fixation.

Pamuk, H., Bulte, E., & Adekunle, A. A. (2014). Do decentralized innovation systems promote agricultural technology adoption? Experimental evidence from Africa. *Food Policy*, *44*, 227–236.

Pamuk, H., Bulte, E., Adekunle, A. A., & Diagne, A. (2015). Decentralised innovation systems and poverty reduction: experimental evidence from Central Africa. *European Review of Agricultural Economics*, *42*(1), 99–127.

Peoples, M. B., Herridge, D. F., & Ladha, J. K. (1995). Biological Nitrogen-Fixation - an Efficient Source of Nitrogen for Sustainable Agricultural Production. *Plant and Soil*, *174*(1-2), 3–28.

Rivera, W. M., Quamar, M. K., & Crowder, L. V. (2001). *Agricultural and rural extension worldwide: options for institutional reform in the developing countries* (Sustainable Development Department). Rome.

Suri, T. (2011). Selection and comparative advantage in technology adoption. *Econometrica*, *79*(1), 159-209.

UNDP. (2015). *Human Development Report 2015: Work for Human Development*.

Vlassenroot, K., & Raeymaekers, T. (2004). *Conflict and social transformation in Eastern DR Congo*. Academia Press.

Voors, M. J., Nillesen, E. E., Verwimp, P., Bulte, E. H., Lensink, R., & Van Soest, D. P. (2012). Violent conflict and behavior: a field experiment in Burundi. *The American Economic Review*, *102*(2), 941-964.

Wagner, S. C. (2012). Biological nitrogen fixation. *Nature Education Knowledge*, *3*(10), 1–15.

Woomer, P., Huising, J., Giller, K. E., & Et, A. (2014). *N2Africa : Final Report of the First Phase 2009-2013*.

World Bank (2007). *Agricultural extension: The Kenya experience: An impact evaluation*. World Bank Publications.

Tables

Table 1: Variable Definitions

Outcome Indicators	
Knowledge	
Household Head knows inoculant	1= if the household knows something about input inoculant, 0=otherwise
Household Head knows fertiliser	1= if the household knows something about input fertiliser, 0=otherwise
Input Use	
Household Head uses inoculant	1= if the household uses fertiliser, 0=otherwise
Household Head uses fertiliser	1= if the household uses inoculant, 0=otherwise
Yield	
Yield bean (in Kg/ha)(log-transformed)	Bean yield, quantity harvested (in kg) divided by the surface (ha), log transformed
Yield cassava (in Kg/ha)(log-transformed)	Cassava yield, quantity harvested (in kg) divided by the surface (ha), log transformed
Food Insecurity	
HFIAS Anxiety	0=not worried on not having enough food during the past four weeks, 1= somewhat worried, 2= worried, 3= very worried
HFIAS Quality	Score food insecurity indicator from 0 (low level of food insecurity in terms of food quality) to 9 (more food insecure in terms of quality)
HFIAS Intake	Score food insecurity indicator from 0 (less food insecure in terms of calorie) to 12 (more food insecure in terms of calorie)
Controls	
Household size	Total number of people living in the household
Household Head is female	1=if the household head is a female, 0=otherwise
Household Head age	Age of the head of the household in years
Household Head level of education	0= No education, 1= Some primary, 2= Primary Complete, 3= Some secondary, 4= Secondary complete, 5= Higher education, 6= Professional education
Household Head was born in the village	1=if the household head was born in the village, 0=otherwise
Household Head primary occupation is farmer	1= if the household head primary occupation is a farmer, 0=otherwise
House roof material is thin	1= if the household roof construction material is thin , 0=otherwise
Dist. from Market	1= "Market dist. < 3km", 2= "Market dist. 3-7km", 3= "Market dist. >7km"
Property rights	0 ="No Land Owned", 1 = "Some Land Owned", 2 ="All Land Owned"

Table 2: Baseline descriptive statistics and balance

	(1)	(2)	(3)
	Training only	Training+ subsidy	t-test (p-value)
Panel A: Outcomes			
Inoculation knowledge	0.070	0.049	0.711
se	0.019	0.017	
Fertiliser knowledge	0.930	0.947	0.713
se	0.021	0.019	
Inoculant Use	0.013	0.026	0.183
se	0.007	0.012	
Fertiliser Use	0.039	0.026	0.725
se	0.012	0.010	
Beans Yield	4.111	3.570	0.293
se	0.251	0.383	
Cassava Yield	7.897	7.775	0.519
se	0.146	0.132	
HFIAS Anxiety	1.826	1.891	0.025
se	0.066	0.077	
HFIAS Quality	5.948	6.091	0.090
	(0.195)	(0.188)	
HFIAS Intake	5.183	4.740	0.066
	(0.362)	(0.248)	
Panel B: Household characteristics			
Female household head	0.121	0.141	0.588
se	0.02	0.031	
Age household head	44.898	46.862	0.206
se	1.152	1.034	
Level of education head	1.591	1.306	0.087
se	0.104	0.129	
Household size	6.785	6.59	0.425
se	0.146	0.196	
Household head born in village	0.645	0.59	0.423
se	0.05	0.048	
Primary occupation head is fa~e	0.792	0.785	0.856
se	0.026	0.031	
Household has a tin roof	0.517	0.531	0.826
se	0.046	0.046	
Dist. from Market	1.926	1.974	0.827
se	0.15	0.16	
N	265	256	

Notes: Column 3 p-value with robust standard errors, clustered at the village level; * 10%; ** 5%; *** 1%

Table 3: Knowledge, input use, yield, and food security

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Inoculant knowledge	Fertiliser knowledge	Inoculant Use	Fertiliser Use	Beans Yield	Cassava Yield	HFIAS Anxiety	HFIAS Quality	HFIAS Intake
Subsidy	0.0386	0.0112	0.0304**	0.0551**	0.0687	-0.211	0.160	0.258	0.455
	(0.0240)	(0.0239)	(0.0129)	(0.0225)	(0.427)	(0.312)	(0.111)	(0.313)	(0.448)
Lagged dependent variable	0.261***	-0.0408	0.214**	0.203*	0.0170	0.000270	0.203***	0.164**	0.121**
	(0.0978)	(0.0333)	(0.0930)	(0.119)	(0.0842)	(0.0532)	(0.0500)	(0.0643)	(0.0519)
Observations	509	509	509	509	166	266	509	509	509
Clusters	64	64	64	64	54	61	64	64	64

* p<0.10, ** p<0.05, *** p<0.01; Standard errors clustered at the village level in parentheses; controls include the level of education, household size and the age of the head of the household and stratum fixed effect. Column (5) and (6) exclude households that do not grow beans or cassava, reducing the sample considerably. We also estimated a model where yields were set to zero for those households. The results are not significant and coefficients are imprecisely estimated.

Table 4: Heterogeneous Effects

	(1) Inoculant knowledge	(2) Fertiliser knowledge	(3) Inoculant Use	(4) Fertiliser Use	(5) Beans Yield	(6) Cassava Yield	(7) HFIAS Anxiety	(8) HFIAS Quality	(9) HFIAS Intake
Subsidy	-0.00940	0.0247	0.0607	0.0507	0.678	-0.998	0.386	-0.0335	0.440
	(0.0525)	(0.0473)	(0.0369)	(0.0542)	(1.315)	(0.892)	(0.242)	(0.546)	(0.839)
Market dist. >5km	-0.0550	0.0677*	0.0181	-0.00510	-0.195	-0.308	0.281**	0.430	1.216**
	(0.0350)	(0.0351)	(0.0113)	(0.0194)	(0.509)	(0.572)	(0.138)	(0.545)	(0.556)
Female	0.00183	0.0562	-0.00793	-0.0229	-0.299	-0.259	0.157	0.280	1.422**
	(0.0517)	(0.0363)	(0.00767)	(0.0190)	(0.844)	(0.721)	(0.199)	(0.437)	(0.687)
Owns land	0.0210	-0.0600**	-0.00549	0.0308	0.587	-0.601	0.00746	0.00875	-0.218
	(0.0316)	(0.0298)	(0.00800)	(0.0199)	(0.920)	(0.491)	(0.178)	(0.480)	(0.585)
Market dist. >5km * Subsidy	-0.0327	-0.0227	-0.0811**	-0.0721	0.0579	0.250	-0.289	0.428	-0.512
	(0.0493)	(0.0444)	(0.0315)	(0.0511)	(1.093)	(0.801)	(0.230)	(0.747)	(0.934)
Female * Subsidy	-0.0497	-0.0299	-0.000509	0.0680	1.220	0.579	-0.167	-0.0344	-0.826
	(0.0764)	(0.0560)	(0.0379)	(0.0886)	(1.134)	(0.797)	(0.295)	(0.665)	(0.991)
Owns land * Subsidy	0.0978*	0.0105	0.0225	0.0684	-0.963	1.106	-0.200	0.105	-0.508
	(0.0530)	(0.0426)	(0.0360)	(0.0519)	(1.123)	(0.807)	(0.260)	(0.597)	(0.814)
At least primary education * Subsidy	0.0134	-0.0401	-0.0183	-0.0236	0.315	-0.0896	-0.117	-0.416	0.774
	(0.0591)	(0.0533)	(0.0334)	(0.0552)	(0.816)	(0.651)	(0.188)	(0.510)	(0.683)
Lagged dependent variable	0.247**	-0.0741***	0.220**	0.227*	0.0599	0.0212	0.216***	0.176**	0.167***
	(0.103)	(0.0208)	(0.0963)	(0.125)	(0.0789)	(0.061)	(0.0534)	(0.0691)	(0.0513)
Observations	404	404	404	404	160	229	404	404	404
Clusters	56	56	56	56	49	53	56	56	56

* p<0.10, ** p<0.05, *** p<0.01; Standard errors clustered at the village level in parentheses; controls include the level of education, household size and the age of the head of the household and stratum fixed effect. Column (5) and (6) exclude households that do not grow beans or cassava, reducing the sample considerably.

Table 5: Spillover analysis

	(1) Inoculant knowledge	(2) Fertiliser knowledge	(3) Inoculant Use	(4) Fertiliser Use	(5) Beans Yield	(6) Cassava Yield	(7) HFIAS Anxiety	(8) HFIAS Quality	(9) HFIAS Intake
Subsidy	0.0649**	0.0189	0.0318**	0.0543*	-0.0807	-0.316	0.172	0.299	0.458
	(0.0255)	(0.0319)	(0.0158)	(0.0285)	(0.430)	(0.312)	(0.131)	(0.392)	(0.532)
Subsidy village within 1km	0.0449	0.0179	0.00440	0.0102	0.0998	-0.261	0.0234	0.102	-0.00404
	(0.0409)	(0.0491)	(0.0123)	(0.0303)	(0.793)	(0.494)	(0.177)	(0.438)	(0.722)
Lagged dep var	0.269***	-0.0473	0.215**	0.147	0.00591	0.000547	0.217***	0.189***	0.125**
	(0.0944)	(0.0404)	(0.0934)	(0.115)	(0.0904)	(0.0540)	(0.0501)	(0.0624)	(0.0510)
N	479	479	479	479	156	252	479	479	479
No. clusters	61	61	61	61	51	58	61	61	61

* p<0.10, ** p<0.05, *** p<0.01; Standard errors clustered at the village level in parentheses; controls include the level of education, household size and the age of the head of the household and stratum fixed effect. Column (5) and (6) exclude households that do not grow beans or cassava, reducing the sample considerably

Appendix

Table A1: Correlates of Attrition

	(1) Attrition
Training	0.0643
	(1.36)
Subsidy	0.0409
	(1.02)
Implementing Partner 2	0.00394
	(0.03)
Implementing Partner 3	-0.104*
	(-1.90)
Implementing Partner 4	-0.0513
	(-0.43)
Implementing Partner 5	0.122
	(1.07)
ImplementingPartner 6	0.0192
	(0.35)
Household size	-0.0128***
	(-2.87)
Age household head	-0.00220***
	(-2.85)
Female household head	0.00368
	(0.10)
Education level hh head	0.00701
	(0.73)
Hh head born in village	-0.0353
	(-1.24)
Household took loan or credit in last 12 months	0.0173
	(0.70)
West Axis	-0.218***
	(-4.00)
South Axis	-0.130
	(-1.09)
Constant	0.469***
	(3.43)
N	898
No. clusters	93

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