Confidence, experimentation and belief updating

Pre-Analysis Plan
Rachel Frattarola, Travis Lybbert, Emilia Tjernström
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1. Introduction

1.1 Background

Agricultural technology adoption is slow among poor farmers in part because of pronounced variability and heterogeneity in the production conditions of these farmers. This project focuses on Kenyan maize farmers in a region that is characterized by significant heterogeneity in soil quality, which makes generic fertilizer recommendations inaccurate for large swaths of the population and makes learning from others challenging. Development researchers, practitioners and policy-makers are experimenting widely with input recommendations based on plot-level soil tests.

In theory, making soil tests available to smallholders and providing personalized soil fertility management advice to farmers has the potential to enable more efficient fertilizer application and could dramatically improve smallholder productivity. In practice, farmers must understand these recommendations in a way that is specific to their plots. They need to experiment and learn for themselves, and experimentation is both costly and risky. If a farmer tries a new input combination but her field is struck by a negative weather shock or attacked by pests, her ability to learn will be limited, and she will have to wait until the next season to try again.

1.2 Project Description

This project targets two constraints on farmers' ability to learn about new inputs: (i) temporal variability from stochastic weather shocks that make signal extraction harder, and (ii) heterogeneity in soil quality, which makes it harder for farmers to use the experiences of others as a proxy for their own. Together, these two constraints mean farmers have sub-optimally few observations for any given weather-soil-input combination. A carefully calibrated crop model designed in an approachable way could therefore give farmers proxy-observations for various input combinations and help them learn.

We use DSSAT, a crop modeling software that takes plot-level soil characteristics and historical weather in the area as inputs, to simulate yields under different fertilizer types and application rates. Each simulation is calibrated based on soil samples from that farmer's field, collected in November 2016 and analyzed by CropNuts, an ISO-certified soil testing lab in Nairobi, Kenya. Mahindi Master, an Android application created in Unity, animates the results from the simulations, allowing farmers to make in-game choices over fertilizer types, rates, and different rainfall levels. The application shows crop growth over fictional seasons with animations varying with the fertilizer and weather selections, and then displays expected yield ranges. At the end of each season, farmers can adjust the fertilizer -- and in later rounds, the rainfall levels -- and simulate a new season with these parameters.

In addition to interacting with the game, farmers will be given a fixed input budget, provided by the research team, and will be allowed to place orders for three different fertilizers at the prevailing market price. The farmers will be asked to place their "order" before playing the game and are allowed to update it after playing the game. A key outcome of interest is whether the participants update their orders and their beliefs after playing the game. The fact that the fertilizer will be provided according to the order that farmers place suggests that farmers have an incentive to report their preferences truthfully.

We will also investigate how underlying risk preferences and confidence affect how farmers use the crop simulation app (the number of rounds, the types of weather simulations that they choose) and how they update beliefs about optimal inputs levels on their fields.

1.3 Research Questions

Within the scope described above, our pilot study seeks to answer the following research questions:

1. **How do farmers' beliefs and input choices change in response to experimentation with inputs in the context of the game?** We elicit subjective expectations over fertilizer and optimal inputs both before and after farmers interact with the game. Farmers will "order" fertilizers, subject to a fixed budget, before and after the game. Changes to their order is a key outcome variable of interest, and updates to the order suggests some updating of beliefs about the absolute or relative returns to different inputs.

2. **How do individuals' risk preferences and confidence affect game play and belief updating?** We elicit participants' risk preferences after the farmers play the game and ask farmers a series of farming questions to measure confidence before the game is played. Outcome variables of interest include the number of rounds farmers choose to play, the types of weather simulations chosen, whether farmers choose to change their final order, and whether they update their beliefs about the returns to fertilizer.

3. **Does playing the game have any effect on farmers' self-reported self-efficacy and aspirations?** We will test this secondary question by comparing responses to aspiration and self-efficacy questions administered prior to the game (half of sample farmers are randomized into answering the questions before the game) to those administered after the game (other half of sample). This between-farmer design is meant to provide initial, exploratory evidence. One hypothesis to be tested is whether farmers whose fields were highly acidic, implying that regular nitrogen-based fertilizer has low returns, may improve self-efficacy and aspirations upon learning that lime can improve their yields.

2. Research Strategy

2.1 Sample

A sample of 200 Kenyan smallholders were chosen to participate in this study. This sample is a subsample of a larger panel of 1,800 households in Central and Western Kenya, whom we have surveyed a total number of three times in-person and four times by phone. Since the current project is a pilot and is funded by an early-stage grant, we are not conducting a randomized control trial but rather looking at variation across farmers in our sub-sample and within-person beliefs before and after playing the game.

The original panel originated with a team of researchers who conducted a randomized control trial of Western Seed Company hybrid maize seed, which was hypothesized to be better suited to the local environment. This sample consisted of 1200 households in Western Kenya and 600 households in Central Kenya; the main treatment (information about and samples of the seed) was randomized at the village level. A second intervention in Western Kenya, in which farmers received fertilizer tailored to their fields' needs, was randomized at the household level. From this project, we have three years of data on the agronomic practices and yields of farmers in the sample, including the subset of 200 farmers participating in the current pilot. Specifically, the data include detailed fertilizer and hybrid seed usage, household demographics, soil characteristics, and information on credit constraints. Soil data comes from soil samples collected in 2014 on individual maize fields and subsequently analyzed by CropNuts, an ISO-certified agricultural testing laboratory in Kenya. A full soil analysis was completed providing farmers with information on the levels of pH, cation exchange capacity (CEC), electrical conductivity, organic matter, and element levels (e.g. nitrogen, phosphorus), as well as micronutrients such as boron.

For the current study, a subsample from the RCT sample were chosen to participate in this study. A convenience sample of villages were chosen for inclusion in the pilot. We chose Western Kenya, south of Lake Victoria, as a geographic region that contained enough sample villages within a few hours of travel time of each other as the most manageable sample under the budget constraints. Households within these villages were randomly chosen, proportional to size. Given this sampling frame, some of the villages were in the RCT treatment villages; others were originally in control. Similarly, some households were randomly selected for the original fertilizer treatment arm, while others did not receive fertilizer in the original RCT. We collected a second round of soil samples on the main maize field of the 200 households in October 2016. These samples were also analyzed by CropNuts and provide the same soil information as the previous analysis.

In February and March, 2017, the 19 villages in the sample will be visited, and participating households will be invited to a central location in the village. At this location, farmers will be asked survey questions, and given the opportunity to play the app-based farming game. Enumerators will facilitate the initial learning of how to navigate the game, which will be played in semi-private once farmers feel comfortable with the game. Before playing the game, farmers will be asked survey questions, including a confidence elicitation. After the survey, risk preferences will be elicited, and several questions measure respondents' perceptions of the game.

These post-game questions will be used primarily as an input into the next version of the game, but since we might be concerned that some farmers may not find the game or the simulated yields convincing, we may use the knowledge questions as a sample restriction (i.e. re-estimate results, dropping those participants for whom the game did not perform well).

2.2 Data Collection

We will visit the 19 village in the pilot sample in February-March, 2017. The participating households (7-15 per village) will be invited to a central location in the village. At this location, farmers will

(i) answer a series of survey questions,
(ii) be given the opportunity to play the app-based farming game
(iii) answer a few additional exit questions (including their final order and aspirations/self-efficacy, if they were randomized into the post-game aspirations group)

Enumerators will facilitate the initial learning of how to navigate the game, which will be played in semi-private and remain available for questions while the farmer plays. The entry questionnaire will include, among other things, subjective yield expectations, confidence, and their initial fertilizer order; the post-survey will include questions related to risk and trust.

In August-September, near the time of the maize harvest, we will conduct a phone survey with the farmers to ask whether the fertilizers are performing up to expectations and a few qualitative questions about whether they feel they learned something useful from the game.

3. Hypotheses

The data collected from this project will be used to test hypotheses related to the efficacy of the game as a learning tool and how farmers' characteristics affect gameplay and belief updating.

Hypothesis Groups:
A. Impact on farmer's beliefs: *Farmers will update their beliefs about fertilizer as a result of playing the game. This effect will be strongest for those whose prior beliefs about fertilizer returns are diffuse and for those whose within-game "sanity check" is correct. Farmers who update their beliefs after playing the game are more likely to change their fertilizer order.*
B. Effect of farmer characteristics on game choices: *Farmer characteristics correlate with their in-game choices.*
C. Heterogeneity of farmer belief impacts: *Farmer characteristics, in particular confidence, will be predictive of the degree to which individuals update their beliefs and alter their input choices.*

3.1 Hypothesis Group A

Hypothesis A: *Farmers will update their beliefs about fertilizer as a result of playing the game.*

The game will allow farmers to "experiment" with three different fertilizers—DAP, CAN, and lime. Most farmers are expected to be familiar with DAP and will have used it at some point in the past. Some farmers are expected to be familiar with CAN, but many have not used it in the past. Almost all farmers are expected to be unfamiliar with lime, and we expect virtually nobody to have used it in the past. As such, Mahindi Master will enable farmers to learn about these three fertilizers with which they have differing familiarity. If farmers use Mahindi Master as a learning tool and trust in the game simulations, they should update their priors about the returns to different fertilizers. We would, as a consequence, expect to see a change in their reported subjective expectations. We also would expect farmers who update their beliefs to change their fertilizer orders following game play.

Since we do not have experimental variation in whether or not farmers get to play the game (i.e. no control group), most of the hypotheses are in terms of heterogeneity in the effect of playing the game.

A1: For DAP and CAN, we expect farmers who have less past experience with these two fertilizers (as observed in the RCT the panel data) to have more diffuse prior beliefs than farmers who have used these fertilizer extensively in the past. *We expect that farmers with less experience and/or more diffuse priors will update their beliefs more after playing the game.*

A2: *We expect that farmers who update their beliefs about the returns to fertilizer and/or lime after playing the game will be more likely to change their fertilizer "order" after playing the game.*

A3: We expect most farmers to have diffuse priors about the returns to lime (as measured by the difference between the subjective yield distributions with and without lime) prior to playing the game. *We expect farmers whose ex ante predicted returns to lime (low pH on their field) are high will allocate a greater share of their budget to lime after playing the game than those with low expected returns to lime.*

A4a: One of the first screens of the game asks farmers what maize yields they would normally get on this field if they applied no fertilizer at all. The game then simulates the DSSAT yields for this field without any fertilizer under three different rainfall scenarios. We refer to this as the "sanity check". *We expect farmers for whom the sanity check fails to update their beliefs (and orders) less than those whose sanity check is accurate.*

A4b: Another measure of farmer confidence in the game is their stated beliefs after the game. They will be asked questions related to how the game compares to real life farming and how the simulated yields compare to the yields they typically get on their field. *We expect farmers who do not feel that the game reflects their reality to be less likely to update their beliefs.* In particular:

- Farmers who answer “Much higher” or “Much lower” to the following question will be less likely to update their beliefs and orders than those who answer Higher/The Same/Lower: “Do you think overall the yields in the game are … than what you would get *with the same inputs* on your field?”

3.2 Hypothesis Group B

Hypothesis B: *Farmer characteristics correlate with their in-game choices.*

While all farmers will get to interact with a game that provides information on the returns to different fertilizers on their own plot of land, the actual information that farmers see will be different and is a choice variable in and of itself. Each farmer will make a series of choices in the game that affects the information that is displayed. We wish to test how farmer characteristics affect in-game choices and overall game play.

We will experimentally elicit two types of confidence measures from farmers-- overestimation and overplacement.

- To measure overestimation, we will construct a measure from the comparison of farmers’ responses of how many farming questions they answered correctly to the actual number of questions answered correctly.
- To measure overplacement, we will construct a measure from farmers’ responses to if they believe that they answered more questions correctly than other farmers in their village.

We also ask farmers a series of more subjective confidence questions. We get a subjective measure of overplacement by comparing farmers’ responses to a question about the degree to which their yields are higher or lower than the village average to their actual yield position in the village using yield data we have for previous agricultural seasons. We construct a measure farmers’ self-confidence in their own abilities and their abilities as compared to others by asking about how often they doubt their farming decisions.

B.1: If (over-)confidence causes farmers to search less, we would expect to see the number of rounds played by farmers in the game to be decreasing in confidence. If farmers’ believe that their ability or knowledge is higher than it actually is, they will demand less information and search less (overestimation). *The number of rounds that farmers play in the game (pre-final round) is expected to be decreasing in the participant’s measured confidence.*

B.2a: After playing the ‘regular’ game for as many rounds as desired, farmers can choose to go to the final round. In this final round, they get to choose their final fertilizer order and watch the game simulate yields for this combination of fertilizer under the three weather scenarios. Farmers will then be allowed to tweak their “final order” until they are happy with their choice. *We expect more confident farmers to be less likely to want to tweak their order (i.e. more likely to only play* *one final round).*

B.2b: *Conditional on tweaking their "final order" once, we expect the number final rounds played (i.e. the number of tweaks to the final order) to be decreasing in measured farmer confidence.*

B.3: *The number of rounds played by farmers in the game (pre-final round) is increasing in risk aversion.*

B.4: *The number of low-rainfall weather scenarios chosen is increasing in risk aversion.*

B.5: *The share of rounds played with unfamiliar inputs is increasing in risk aversion.*

B.6: *The number of times the final fertilizer order is changed is increasing in risk aversion.*

3.2 Hypothesis Group C

Hypothesis C: *Farmer characteristics, in particular confidence, will be predictive of the degree to which individuals update their beliefs and alter their input choices.*

One step further down the causal chain from game play, we might expect farmer characteristics to affect updating and beliefs. A more confident farmer who experiments less in the game, playing fewer rounds, would also be less likely to update his/her beliefs in response to interacting with the game.

C1: *We expect farmers who play fewer rounds of the game to be less likely to update their beliefs and fertilizer orders.*

C2: *We expect farmers with a higher stated farming ability to be less likely to update their beliefs and fertilizer orders because they will be less responsive to information.*

3.4 Questions with Unclear Hypotheses

There are a number of variables that we do not have concrete priors about the direction of impact on farmers' in-game choices and updating.

D.1: It is not clear how confidence affects the share of rounds played with unfamiliar inputs.

D.2: It is not clear how confidence affects the proportion of rounds spent in the regular game versus the final round.

D.3: It is unclear how risk aversion affect the probability of changing the final fertilizer order.

D.4: It is unclear how risk aversion affects the proportion of rounds spent in the regular game versus the final round.

D.5: We will also evaluate if farmers update beliefs differently along the following dimensions:

- Risk preferences
- Confidence (overestimation)
- Confidence (overplacement)
- Subjective confidence (overestimation)
- Subjective confidence (overplacement)