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Technology adoption under uncertainty

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Abstract

Many technology adoption decisions require investment at two or more points in time. The first investment is typically associated with take-up and subsequent investments with the use or implementation of the technology. After take-up, new information about the cost of subsequent investments is acquired, and adopters may decide to abandon the technology if they learn that following-through will not be worth it after all. We study this dynamic adoption problem in the case of agroforestry in Zambia. A field experiment that varies the payoffs from taking up seedlings and following through to keep the trees alive allows us to estimate the new information that arrives after take-up. We observe that, while farmers are responsive to the incentives offered in the experiment, a large share of the payoffs from adoption are not known to them at the time they make their take-up decision.

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• • • / • • • Importantly, this makes it difficult for farmers to self-select into the take-up decision, meaning that a higher initial cost for the technology does not make follow-through more likely. As a result, subsidies for take-up are less cost effective, but also less necessary since many farmers facing uncertainty about the costs of follow-through choose to take-up so that they have the option to follow-through should the new information that arrives after take-up contain good news about the profitability of the technology.

Policy Issue

Many technology adoption decisions require investment by adopters at two or more points in time. The first investment is typically associated with take-up and subsequent investments with the use or implementation of the technology (referred to here as "follow-through"). For example, agricultural technologies such as herbicides or crop varieties all require farmers to purchase inputs and follow-through with the recommended usage or cultivation instructions. This two-part adoption structure is not limited to agricultural technologies. For example, health treatments and many energy saving investments also require a follow-through step.

Subsidies are a common tool to increase the adoption of many of these technologies. However, many policy-makers worry that subsidizing the initial take-up decision may lower subsequent follow-through. In most cases, both the policy maker and the adopter are most interested in the follow-through step, which is required for the technology to generate private or social benefits. If follow-through is lower when take up is subsidized, subsidies are less cost effective, since everyone who takes up receives the subsidy even if they do not follow through. Research on the cost effectiveness of subsidizing take-up, when follow-through is also necessary, has shown mixed results.

There are a number of reasons why subsidizing take-up might result in lower follow-through among those who take-up. The most obvious one is that subsidies might simply attract users who value the technology less and are less likely to make the necessary follow-through investments. This is often referred to as a selection effect. Other possibilities include psychological channels, such as sunk cost effects, anchoring and time inconsistent preferences.

This paper focuses on the dynamic aspects of technology adoption. Specifically, even though potential adopters may have some information about their costs and benefits of adoption, there might be a component of these that is unknown at the time they decide whether or not to take-up. After take-up, new information about the cost of follow-through is acquired, and adopters may decide to abandon the technology if they learn that following-through will not be worth it after all. For example, some attribute of the technology or some external factor such as weather or pests could make follow-through more of a hassle than originally anticipated. This could occur even among adopters who take-up the technology at a positive price, leading to seemingly irrational behavior – some pay for the technology but never use it – if the dynamics of adoption are not taken into consideration.

This study proposes and tests a framework that allows for uncertainty in the costs of the follow-through stage at the time of the take-up decision, and assumes that adopters can "change their minds" about the technology even after they have taken it up. We investigate the implications of this type of dynamic adoption problem for the use of subsidies to increase adoption.

The technology

Faidherbia albida is an agroforestry species endemic to Zambia that fixes nitrogen, a limiting nutrient in agricultural production, in its roots and leaves. Optimal spacing of *Faidherbia* is around 100 trees per hectare, or at intervals of 10 meters. The relatively wide spacing, together with the fact that the tree sheds its leaves at the onset of the cropping season, means that planting *Faidherbia* does not displace other crop production.

Agronomic studies suggest significant yield gains from *Faidherbia*. However, these private benefits take 7-10 years to reach their full value, and may be insufficient to justify the front-loaded investment costs, particularly if farmers have high discount rates. In the first year after trees are planted on the field, the farmer has to invest time to weed, water and protect the trees from pests and other threats. Survey data indicate around 38 hours devoted to cultivation activities in the first year, though it may be hard for farmers to anticipate how costly this extra effort will be, since it will depend on available family labor, agricultural conditions, and other things that affect their opportunity cost of time. Once a seedling survives the first dry season, costs decrease substantially. In the baseline survey, less than 10 percent of the study households reported any *Faidherbia* on their land. This could be explained by low perceived private net-benefits, by high costs associated with accessing inputs – there is no existing market for *Faidherbia* seedlings – or cultivating the trees, or by a lack of information.

Subsidies may therefore be necessary to increase take-up rates, and are justified by positive environmental externalities and market failures that contribute to high private discount rates. Environmental benefits include erosion control, wind breaks, and carbon sequestration. Based on allometric equations adapted to the growth curves for *Faidherbia*, we estimate that a tree sequesters around 4 tons of carbon dioxide equivalent over 30 years. The combination of private and public benefits has led to renewed interest in agroforestry and afforestation in developing countries in recent years.

Context

The study was implemented in coordination with Dunavant Cotton Ltd., a large cotton growing company with over 60,000 outgrower farmers in Zambia, and with an NGO, Shared Value Africa. The project, based in Chipata, Zambia, targeted approximately 1,300 farmers growing cotton under contract with Dunavant, alongside other subsistence crops. The project is part of the NGO partner's portfolio of carbon market development projects in Zambia.

Dunavant organizes its farmers into groups of approximately 15 geographically clustered households, with 125 groups involved in the study. Each group has one lead farmer who, under the Dunavant system, is responsible for training his farmer group on cotton production and, in the case of this project, on *Faidherbia* planting and management.

Agriculture in Eastern Zambia relies on an annual monsoon and small scale farmers plant the main staple crop of maize, alongside cash crops including cotton, tobacco and soya. Most production is done by hand and small farming households make little or no profit.

Study design and implementation

Around 1,300 cotton farmers associated with the partner organization received training on *Faidherbia albida* and were given the opportunity to purchase a package of 50 tree seedlings (the take-up decision) at the training, which was held at the start of the planting season. Also at the training, farmers learned that they might be eligible to receive a reward for keeping trees alive for at least a year (the follow-through decision). One year later, households were re-visited to measure tree survival and administer rewards. The subsidies and rewards were varied as follows:

(1) Take-up subsidy – Farmer groups were randomly assigned to receive one of four input prices that range from fully subsidized (free) to the cost-recovery price for the implementing organization (approximately $2.50 US, which is still a subsidy relative to alternative ways of acquiring the seedlings). Farmers' response to the variation in the take-up price helps reveal the variation in expected costs and benefits of the technology across farmers.

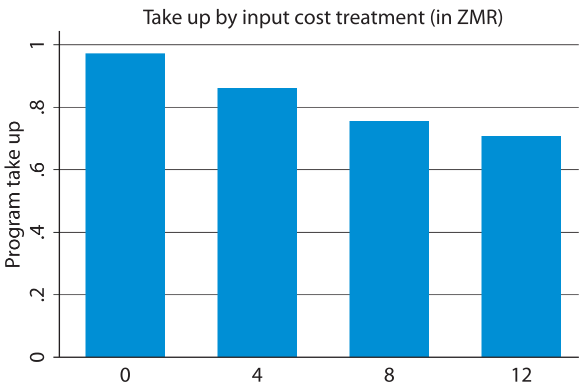
(2) Reward for follow-through – Individual farmers were randomly assigned to receive different levels a conditional reward, based on tree survival, which farmers are informed of either before or after making their take-up decision. The range of rewards ranged from $0 - $30 (0 - 150,000 ZMK), and pays out conditional on keeping 35 of the 50 trees alive through the first year. The tree survival outcomes in response to the rewards helps reveal the variation in costs and benefits of the technology across farmers one year after take-up.

In summary, the randomly varied take-up subsidy together with the randomly varied reward for follow-through are informative of the costs and benefits perceived by farmers at two different points in time. The difference between these reveals the new information that farmers received between their take-up and their follow-through decisions. In addition to recording the take-up and follow-through (tree survival) decisions, farmers participate in a baseline and endline survey.

Results

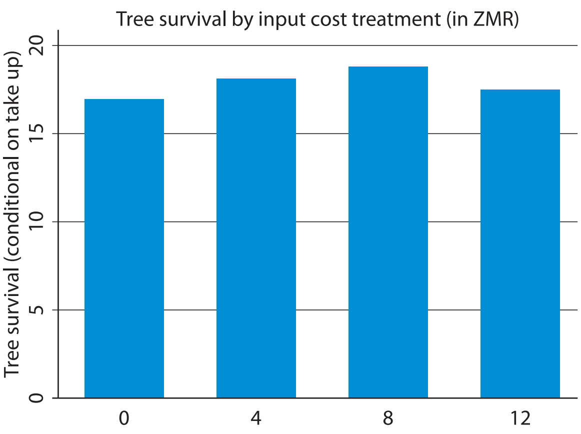
Our data analysis is guided by a theoretical model of the dynamic adoption process. The model highlights that, provided that the technology can be abandoned after take-up, a higher degree of uncertainty makes take-up more attractive, everything else held constant. This is because the adopter can keep options open – whether to follow-through or not – by taking-up in the first place. If instead, he or she chooses not to take-up, then there is no option to follow-through later. Thus, take-up provides option value when there is uncertainty in the costs or benefits of follow-through. The model also shows that subsidies are less likely to decrease follow-through in the presence of uncertainty. This is because subsidies cannot attract low valuation (and therefore low follow-through) types because adopters do not know whether they are low valuation types or not at the time of their take-up decision.

Figure 1. Take-up, by subsidy condition ('000 ZMK)



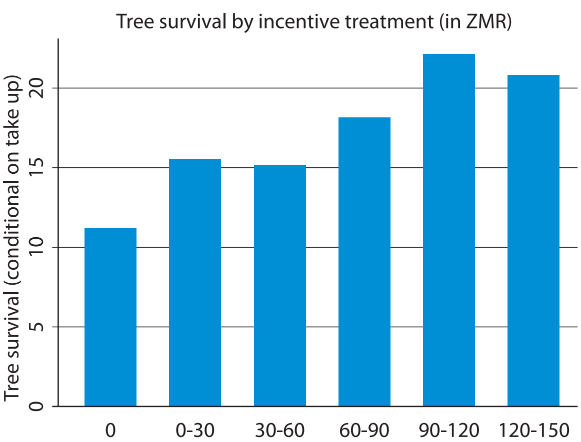
The raw data show patterns that are consistent with dynamic adoption framework that we propose. First, not surprisingly, farmers respond to economic incentives: they take-up at higher rates under higher subsidies and follow-through at higher rates under higher rewards (Figures 1 and 2). Second, the price at which each individual takes up is not predictive of the follow-through outcome (Figure 3). In other words, charging farmers more for the seedlings does not lead to more surviving trees per farmer after a year. In addition, a large share (37%) of farmers who paid a positive price end up abandoning the technology altogether.

Figure 2. Follow-through by reward condition ('000 ZMK)



Fitting the data to our model provides additional support for the interpretation that the results are driven by uncertainty rather than other explanations. We use these results to further investigate the relationship between subsidies by simulating what would happen to program outcomes at higher or lower levels of uncertainty. Relative to the study setting, eliminating uncertainty altogether (i.e. farmers know all of their costs and benefits of keeping trees alive for a year at the time they decide whether or not to take-up), would increase follow-through by 33%.

Figure 3. Follow-through, by take-up subsidy condition ('000 ZMK)
Conditional on take-up



Policy implications

The findings highlight insights into how policies designed to increase technology adoption should consider uncertainty in the follow-through stage:

1. When adopters have to pay to take-up a technology, uncertainty lowers the rates of follow-through conditional on take-up, and lowers the cost effectiveness of subsidies applied to take-up.

2. At low levels of uncertainty, charging a higher price may result in higher follow-through.

3. When uncertainty is high, rewarding follow-through is more effective than subsidizing take-up, providing the costs of monitoring follow-through are not too high.

Overall, uncertainty is neither good nor bad news for subsidies – it depends on the policy objective. On the one hand, subsidies become less cost-effective because take-up is driven up by the "option value" associated with take up, and everyone who takes up gets the subsidy. On the other hand, the selection problem – that adopters with lower valuations are attracted by the subsidy – is lower when the costs of follow-through are uncertain. Importantly, uncertainty has the effect of transferring benefits from the implementer, who would like follow-through, and the adopter, who would like to choose whether to follow-through depending on the new information that arrives after take-up. Thus, there are clear tradeoffs associated with the design of subsidies to increase follow-through.

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