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Adoption and adaptation in developing country agriculture

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Abstract – This paper reviews some of the challenges related to understanding constraints to agricultural productivity improvements in developing countries. It takes a micro-level approach to shed light on the complexity of farmers' adoption of new technologies and practices and of climate change adaptation decisions. The main arguments are illustrated using an example from the evaluation of a randomized pilot program in Nicaragua. The paper also highlights open questions for future research.

Keywords: agricultural technology adoption, climate change adaptation

L'adoption et l'adaptation dans l'agriculture des pays en développement

Résumé – Cet article précise les difficultés liées à la compréhension des freins à l'amélioration de la productivité agricole dans les pays en développement. À partir d'une approche micro-économique, ce travail met en lumière la complexité de la prise de décision des agriculteurs concernant, d'une part, l'adoption de nouvelles technologies et pratiques et, d'autre part, l'adaptation au changement climatique. Les principaux arguments sont illustrés par l'exemple de l'évaluation d'un programme pilote au Nicaragua caractérisé par une expérimentation aléatoire. L'article conclut en listant des questions ouvertes pour de futures recherches.

Mots-clés : adoption des technologies agricoles adaptation au changement climatique

JEL classification: O12, Q12

1. Introduction

Raising world food prices and fears for widespread food shortages with recurrent food price spikes have refocused attention of many policy makers on the challenge of increasing agricultural productivity in developing countries. Indeed increased agricultural productivity resulting from Green Revolution technologies has been credited with addressing prior global fears regarding food and resource scarcity. It is often also considered as having been fundamental for subsequent economic growth of the Asian countries that benefitted from these new agricultural technologies (World Bank, 2007). In recent years, hopes to replicate these positive historical examples in Sub Sahara Africa have led to increased donor investments targeted at improving agricultural technologies or at facilitating adoption of existing technologies with productivity enhancing potential. The renewed appeal of investing in developing country agriculture in part seems to come from a believe in a win-for-all. Increased agricultural productivity could increase worldwide food availability, addressing concerns regarding food security, while at the same time improving the living standards of poor smallholder producers and hence contributing to rural poverty reduction in developing countries (USAID, 2012; GAFSP, 2012; Gates Foundation, 2011).

Changes in climatic conditions worldwide possibly make increasing developing countries' agricultural productivity even more challenging. Changes in rainfall and temperature patterns and increased weather variability are often negatively affecting agricultural productivity (Burke *et al.*, 2011; Nelson and Olofinbiyi, 2011). To offset these trends, changes in agricultural practices, such as changes in planting dates, use of irrigation and adoption of drought or heat resistant varieties (Lobell *et al.*, 2008) might be necessary. Irrigation may be encouraged as it makes farmers less dependable on daily rainfall variability. And drought resistance varieties can help guarantee certain levels of yield even when rainfall falls short. Constraints to climate change adaptation might hence be closely related to those related to agricultural adoption decisions more general. Part of the climate change policy debates center on strategies that can facilitate such climate change adaptation (IPCC, 2007a; World Bank, 2009).

The policy concerns and the many open questions regarding agricultural productivity, food security and climate change, have revitalized academic research on agricultural adoption and adaptation. Questions of adoption and adaptation are arguably particularly complicated in developing countries, where farmers' decisions need to incorporate the existence of multiple market failures. For them, the *status quo* often reflects a second-best equilibrium. Deviating from this equilibrium to adopt new technologies will not necessarily make their situation better, even if the technology by itself might be profitable under perfect market conditions. Moreover, with imperfect markets consumption and production decisions are non-separable (Singh *et al.*, 1986). With imperfections in the food market, for instance, farmers will need to factor in their own consumption needs when making production decisions.

This has long been recognized in the literature as an important potential explanation for the lack of adoption of cash crops (de Janvry *et al.*, 1991). With the existence of multiple market failures in input, product and food markets, some of which might be more important than others, predicting the impact on adoption of interventions that address one of these constraints becomes theoretically challenging.

The challenge further comes from the dynamic nature of the adoption decision. Adopting a new technology often implies short-term investments for longer-term gains, because of learning or a possible need for initial high labor inputs (Feder *et al.*, 1985; Foster and Rosenzweig, 2010). Or new technologies such as organic fertilizer and those involving tree crops might for agronomical reasons only pay off after a number of seasons. *Vice versa* it is also possible that short-term gains are higher than longer-term ones, due to market saturation of new crops or soil exhaustion (Cochrane, 1979). Weather, pest or price shocks during any moment of these dynamic cycles can further affect the short and longer-term gains. None of these future developments are perfectly predictable, so that farmers need to account for the probabilities of these future events in making their decisions.

And the probabilities themselves might be changing due to climate change. Worldwide temperatures have been increasing and are predicted to continue to augment, affecting yields of crops worldwide (Lobell *et al.*, 2011). In addition, weather variability is increasing, and the probability of extreme events (droughts and floods) in particular has become higher (IPCC, 2007b). In many countries, the start of the rains and hence the planting periods are becoming less reliable. While scientific evidence can point to the general direction of those changes, and while farmers themselves are witnessing those changes on a season-to-season basis, it is hard to predict how they will affect a particular farmer in the foreseeable future. Hence even the probabilities regarding the likelihood of future events become unknown to the individual farmer, further complicating her decision process. Faced with such challenges, not changing agricultural practices might be a logical fall back. Empirical analysis indeed often suggest limited agricultural adaptation even in developed country context (Schlenker and Roberts, 2009). And evidence on the effectiveness of adaptation policies is limited.

A different type of adaptation could come from off-farm activities. Livelihood diversification might offer an alternative strategy by increasing revenue of income sources less affected by weather shocks (Howden *et al.*, 2007). Indeed, farmers in developing countries have long used income diversification as a mechanism to buffer weather variables. Yet income smoothing often comes at the cost of reducing average income in the presence of skill or capital constraints (Fafchamps, 2003; Dercon, 2004). Policies to address some of these constraints might hence be needed to help farmers help themselves.

The above arguments point to the complexity of understanding adoption and adaptation decisions in developing country agriculture. This makes it a

rich area for rigorous empirical research that can help test the importance of existing constraints and shed light on the underlying decision processes. The next sections illustrate some of these arguments using an example from the evaluation of a randomized productive safety net program in Nicaragua. The pilot program targeted poor rural households with a strong dependence on semi-subsistence agriculture and high vulnerability to weather shocks, in a context of recent climatic changes. One of its main objectives was to improve the nutritional intake of the targeted households on the short run, and another main objective was to increase households' resilience to climatic shocks on the longer run.

Section 2 presents the main features of the pilot and the experimental design. Section 3 discusses the impact of the intervention on agricultural decision making, focusing on the interaction between consumption and production decisions. Section 4 subsequently discusses the evidence on how these interventions helped farmers manage weather shocks. After discussing this example, section 5 returns to a more general discussion on questions for future research regarding adoption and adaptation.

2. A productive safety net pilot program¹

In 2005, the government of Nicaragua responded to a severe drought shock in six poor rural municipalities by implementing an innovative pilot program called *Atención a Crisis*. In the pilot region, there is a strong dependence on self-employment rain-fed agriculture and poverty levels are high. Before the program started, approximately 81% of households lived on less than a dollar a day, households spend 70% of total expenditures on food, and diets were heavily skewed towards corn, rice and beans, with very little consumption of fruit and vegetables or animal proteins. Corn and bean cultivation also dominated agricultural production, with 75% of the agricultural land dedicated to these two crops. In recent years, temperatures had increased, rainfall had become increasingly irregular, and the time window for the two annual crop cycles had shortened. Households in this area are conscious of the fact that farming is a risky occupation, with 77 percent reporting it to be riskier than non-agricultural activities.

To rigorously evaluate the impact of the different components of the pilot program, program assignment was based on a randomized design. Villages were placed into 44 stratification groups based on geographical proximity, microclimate and road access, and from each group half of the villages were randomly selected to receive treatment, while the other half were randomly selected to be in the comparison group. This resulted in 56 treatment villages

¹ Detailed information about the program and the experimental design is provided in the online appendix of Macours, Schady and Vakis (2012) and on: <http://go.worldbank.org/VUYJAQ3UN0>

and 50 control villages. In the treatment villages, households were randomly allocated to one of three treatments.

In the first treatment, all households were eligible for a basic conditional cash transfer (CCT). They received a transfer of US\$145 aimed to improve the quality and the quantity of the nutritional intake of all household members, and in particular of the children. Beneficiaries were reminded about the importance of a diverse diet during program sign up, during payment days and through weekly meetings with community program promoters.²

The second treatment was the CCT together with vocational training. In addition to the basic CCT, households in this treatment group received a scholarship that allowed one adult family member to attend a vocational training course offered in the municipal headquarters. These courses were aimed at building new skills for income diversification. They focused on practical skills such as tailoring, baking, mechanics or carpentry that could enable entry into wage employment or the development of service-focused self-employment.

The third treatment was the CCT together with a productive grant. In addition to the basic CCT, households in this treatment group received a US\$200 grant for productive investments, which was intended to encourage recipients to start a small non-agricultural business to diversify their income sources. Grants were typically used as start-up capital for starting a commercial self-employment activity (building an oven, buying supplies for a corner store, etc.) or for buying small livestock. Households also received technical assistance to help them start these businesses.

The main objectives of the pilot program were two-fold. On the one hand it provided a short-term safety net with the objective of increasing households' human capital investments by improving nutritional intake and preventing school drop out. On the other hand, it aimed at facilitating income diversification so that households could protect themselves against future weather shocks. Because of these objectives it provides a good case study to analyze constraints to both adoption and adaptation decisions. In the next section, we focus in particular on the adoption of the cultivation of fruit and vegetables. Section 4 then turns to adaptation through income diversification.

3. Social marketing, safety nets and agricultural decision-making

Given the likelihood of non-separability between consumption and production decisions in this context, the programs design and its strong focus on improving the quantity and the quality of the diet makes it of direct relevance

² Households with children between 7 and 15 who were enrolled and attending primary school received an additional US\$90 per household, and an additional US\$25 per child, conditional on school enrollment and attendance.

for understanding agricultural adoption decisions. Macours *et al.* (2012) show that the program was effective in shifting diets towards more fruit and vegetables and more animal proteins, to an extent greater than would have been expected from the increase in income alone. This shift persisted after the end of the program, indicating a sustained change in consumption behavior, possibly due to intense “social marketing”. Indeed, transfers were given with the explicit message that they were meant to improve nutrition, and while cash may be fungible, a possibly a “flypaper” effect (Thaler, 1999) could have contributed to increased consumption of more nutritious food groups. This clearly then raises the question on whether such changes in consumption patterns were reflected in agricultural production changes, and in particular whether the internal change in demand led to adoption of more fruit and vegetable cultivation by participating households.

To analyze this question, it is important to note that the program could also have affected agricultural production decisions through a variety of other mechanisms. First, the conditional cash transfer program, by providing regular bi-monthly cash transfers, effectively guaranteed a minimum level of household food availability for the entire year. By providing this safety net, it arguably relaxed the need for these rural households to make production decisions based on their consumption needs. Given that weather shocks were particularly harmful for corn and bean production during the first agricultural season, one could hypothesize in particular a shift out of those subsistence crops. Second, by providing regular cash, the program might have relaxed liquidity constraints allowing for longer-term investments in agriculture. Or alternatively, it might have reduced incentives for agricultural work by increasing the marginal utility of leisure. And finally, as women were the direct beneficiaries of the transfers the program might have had implications for the role of women in agricultural production decisions. At the same time, as women’s role in agricultural decisions is traditionally very limited in the study region, it is also possible that targeting of the main program messages to women limited the impact of the program on agriculture.

Lopez and Macours (2013) analyze these different hypotheses and find a number of striking patterns. Consumption shifts to fruit and vegetables were indeed translated in changes in fruit and vegetable production. These shifts were particularly noticeable on garden plots that are typically managed by women. During the program, treatment households were dedicating more of their land to fruits and vegetables than the control, and were also reporting higher fruit and vegetable consumption from own production. Overall, agricultural inputs - including labor - also increased, providing no support for a disincentive effect of the cash. Remarkably, two years after the end of the program, households continued to dedicate more land to fruit and vegetables. The sustainability of the change even long after the households stopped receiving the transfers hence suggests that it was not (only) the safety net or the liquidity part of the intervention that facilitated the adoption decisions.

There is also not much evidence of shifts away from subsistence crops. This may be surprising as households are clearly aware of the riskiness of agricultural production, and given the safety net features of the program. However if corn and bean are perceived to have high average returns (relative to other agricultural options) in addition to having high variance, households might have decided to continue to produce these crops, knowing that the CCT provided them with the necessary insurance in case of weather shocks. Additional explanations come from qualitative work conducted during and after the intervention. Semi-structured interviews and focus groups revealed the strong preference of people in the region for eating beans and corn that they had produced themselves. These patterns are consistent with the more general importance of the corn culture in Central America, dating back to pre-Columbian times. Qualitative fieldwork also revealed a possible role of gender identity, as it is traditionally the role of the men in the household to bring the basic food on the table. Hence while farmers recognize the risks involved with producing corn and beans, and are clearly aware of the fact that they might lose the entire harvest due to unreliable weather, they continued to invest in such crops without making adjustments for changing in weather patterns.

Hence while the sustained shift to fruit and vegetables is indicative of the potential of outside interventions to affect dynamic adoption decisions, the results on corn and beans arguably illustrate the complexity of farmers' production and adoption decisions in contexts where multiple constraints coexist.

4. Weather variability and constraints to income diversification

Turning now to the impact of the productive components of *Atención a Crisis* shows how adaptation to changes in the weather patterns occurred to changes in nonagricultural activities instead. Macours *et al.* (2012) tested the effect of the basic CCT program, as well as two complementary interventions, on households' vulnerability to irregular weather patterns. Addressing skill and capital constraints proved to be an effective strategy to increase income diversification. Families that received either vocational training or investment grants developed alternate income-generating activities, reducing their dependency on crops. Relative to households in the control group, households that were eligible for the productive grant were more likely to engage in non-agricultural self-employment, and were more likely to have higher profits from nonagricultural self-employment. And households that received training increase income from wage employment. Hence the grant and training interventions helped households to start new nonagricultural activities and adopt a more diversified income portfolio. In doing so, it increased farmers *ex ante* risk management, and made them less vulnerable to shocks even after the end of the program.

Two years after the program ended, households eligible for either productive intervention were better protected against droughts than households that qualified only for conditional cash transfers or were in the control group. The productive grant also increased household consumption. Very similar results are found for household income – household income was both higher and less variable for households that received productive grants than for control households. In contrast, the basic CCT package on its own does not appear to have significantly affected household consumption two years after the end of the intervention. This suggests that any visible impacts for the two other treatment groups were caused by the complementary interventions, not the basic CCT.

The evidence of this experiment hence showed that enhancing the safety net with productive interventions proved to be an effective strategy to help households successfully develop other income-generating activities to carry them through bad weather and smooth out the shocks to consumption that occur when crops fail. More broadly, the evidence is indicative of the potential of interventions targeting non-agricultural income sources to facilitate climate change adaptation.

5. From short-term constraints limiting adoption to longer-term productivity

The example of *Atención a Crisis* illustrates that understanding the binding constraints to agricultural adoption and adaptation can be complex in a context of multiple imperfections and changing environmental conditions. It also illustrates that analyzing farmers' decision making at the micro level by studying their reactions to exogenous variation introduced by randomized control trials (RCTs) can help understand some of these constraints. More generally, a new body of research is emerging with this specific focus. One clear illustration of this trend is the Agricultural Technology Adoption Initiative (ATAI) that systematically uses RCTs to shed light on the impact of interventions addressing different market imperfections and possible behavioral constraints on agricultural technology adoption (Jack, 2011). This research generally assumes that the appropriate technologies to increase average productivity exist, and that interventions targeted at lifting key constraints can be effective in increasing adoption on the short-term. Evidence to date typically focuses on short-term changes, but the approach also should lend itself over time to learning about dynamic adoption patterns.

Other constraints to adoption or adaptation might be harder to identify. This likely is particularly true for constraints that can only be affected on the long-term, such as farmers' cognitive skills. Cognitive skills are believed to be largely determined in early childhood, and to be important determinants of later success in life (Grantham-McGregor *et al.*, 2007; Heckman, 2007). Little is known about the importance of cognition for decision making in agriculture. Yet given the complicated decision processes discussed earlier,

it is not unlikely they can play a key role. Cognition also typically affects educational achievement. And skills learned in school may be important for agricultural productivity, in particular for making decisions regarding new technologies (Foster and Rosenzweig, 2010). Indeed, given farmers' need to evaluate probabilities of different events when choosing to adopt new technologies, basic math skills might be particularly helpful. Long-term follow-up studies of interventions that affected education in rural areas may help to further shed light on the role of education for agricultural decisions. Evidence from a different RCT in Nicaragua shows for instance that young men who benefited from higher education due to a CCT program, were able to find better agricultural jobs 10 years later (Barham *et al.*, 2013).

Non-cognitive skills might be equally or even more important. If farmers are fatalistic, have low aspirations, or make decisions thinking only about the near future, they could be less likely to adopt productive investments or new technologies with long-term payoffs. In developed country settings, non-cognitive abilities such as perseverance, motivation, time preference, risk aversion, self-esteem and self-control have been shown to be directly related to a large set of socio-economic outcomes such as wages, schooling, crime, performance on achievement tests (Bowles *et al.*, 2001; Heckman *et al.*, 2006; Cunha *et al.*, 2010). Such traits could be equally important for developing country farmers. "Impatient" decision makers, for instance, who put a large weight on current consumption, may be less likely to save and accumulate resources that can allow them to invest in capital-intensive inputs. This then raises the question on whether, when and how policy interventions can affect such non-cognitive skills.

Some emerging evidence suggests that well designed interventions indeed can do so and that this can lead to important multiplier effects. In the previously discussed pilot program in Nicaragua, for instance, interactions with local leaders led to a remarkable short-term increase on women's aspirations and attitudes towards the future (Macours and Vakis, 2014). This in turn facilitated the shift towards new activities, in particular for those households for whom a non-agricultural activity might have seemed outside of the realm of possibilities prior to the program. Similarly, in Mozambique, Laajaj (2012) finds that randomly selected recipients of either an agro-input subsidy or a matched savings intervention reacted to the intervention by increasing their planning horizon.

Finally, the discussion in this article—and indeed a large part of the related literature—has started from the assumption that there exists many profitable technologies waiting to be adopted, and many potential ways of changing existing practices to help households adapt to climate change. To conclude it is worth raising some questions regarding this underlying assumption, as it potentially suggests a wider area for future research. Knowing whether a new technology or practice is capable of increasing productivity in real life conditions and on a large scale is remarkably difficult. The example of the Green Revolution suggests that it is not

impossible. But evidence regarding a technology's potential all too often comes from small field trials, implemented by the agency that developed the technology. The trials are typically conducted in experiment stations or with a small group of farmers, often highly skilled and motivated, who might bias investments and efforts towards plots with the new technologies. Such an approach is likely to lead to an overestimate of the potential productivity gains of adoption of the same technology by average farmers and outside the controlled context of the experiment station (de Janvry *et al.*, 2010). Alternative and more rigorous empirical evidence on the productivity potential is therefore needed and research analyzing the agronomical research itself might help to further understand some of the potential concerns. This then could complement research on adoption and adaptation to fully understand the constraints to developing countries' agricultural productivity.

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