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Understanding the Process of Agricultural Technology Adoption: Mineral Fertilizer in Eastern DR Congo

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Summary. — We analyze the adoption of mineral fertilizer in South-Kivu. We model technology adoption as a three-step-process, including awareness, tryout, and adoption; and empirically analyze these steps using cross-sectional farm-household data, and bivariate and Heckman selection probit models. We find that awareness about fertilizer is high (57%) and mainly determined by education and social capital. Tryout is low (13% of aware farmers) but positively influenced by extension interventions. Continued adoption is high (70% of tryout farmers) but capital constraints are important and not all extension interventions are effective for continued adoption. Our results entail implications for extension policies in poor areas.

Key words — mineral fertilizer, Sub-Saharan Africa, Eastern DR Congo, technology adoption, soil fertility, agricultural research and extension

1. INTRODUCTION

For decades, researchers have tried to explain agricultural technology adoption (Doss, 2006; Feder, Just, & Zilberman, 1985; Feder & Umali, 1993; Lee, 2005). This has resulted in a broad literature, consisting of theoretical and empirical studies exploring varying but complementary strands of thought. Considerable attention was given to the role of risk (e.g., Just & Zilberman, 1983; Smale, Just, & Leathers, 1994), social learning and social capital (e.g., Conley & Udry, 2001), and cash or credit constraints (e.g., Zeller, Diagne, & Mataya, 1998) in agricultural technology adoption. Some studies focused on one specific technology, while others investigated joint, sequential or stepwise adoption of components of composite technology packages (Aldana, Foltz, Barham, & Useche, 2011; Byerlee & de Polanco, 1986; Feder, 1982; Khanna, 2001). A substantial part of the adoption literature has focused on technology adoption by smallholder farmers in developing countries.

A specific part of this literature has focused on the adoption of mineral fertilizer, and has been reviewed by Morris, Kelly, Kopicki, and Byerlee (2007). Various papers have focused on the role of markets and institutions in mineral fertilizer adoption, looking at the impact of input subsidies and fertilizer vouchers (e.g., Banful, 2011; Pan & Christiaensen, 2012). Others have explored the role of fertilizer profitability (e.g., Duflo, Kremer, & Robinson, 2011; Marenya & Barrett, 2009a, 2009b), input availability and credit access (e.g., Croppenstedt, Demeke, & Meschi, 2003), and risk (e.g., Dercon & Christiaensen, 2011).

In this paper, we analyze the adoption of mineral fertilizer among smallholder farmers in South-Kivu, a province in Eastern DRC (Democratic Republic of the Congo). With this case-study, we contribute to the literature on agricultural technology adoption in two ways. First, we use an innovative approach to model the farmers' decision-making process in agricultural technology adoption. We model technology adoption as a process consisting of three steps: 1/awareness about the technology, 2/tryout of the technology, and 3/continued adoption. Conceptually, these three steps are similar to the framework of Lindner, Pardey, and Jarrett (1982), who distinguish a discovery-stage, an evaluation stage and a trial stage. Empirically, however, Lindner *et al.* (1982) only analyze awareness (or discovery) and adoption. A handful of other studies (Asuming-Brempong *et al.*, 2011; Diagne & Demont, 2007; Edmeades, Phaneuf, Smale, & Renkow, 2008; Edmeades & Smale, 2006) also analyze awareness and adoption. Kabunga, Dubois, and Qaim (2012) further distinguish between awareness exposure (having heard of a technology) and knowledge exposure (understanding the attributes of a technology) to estimate adoption. Most empirical studies do not distinguish between a first trial of the technology (tryout) and continued or sustained adoption. Both are usually referred to as adop-

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tion, but the underlying decision parameters for tryout and continued adoption might be very different. Exceptions are the studies by Keil, Zeller, and Franzel (2005), Kijima, Otsuka, and Sserunkuuma (2011), Moser and Barrett (2006) and Neill and Lee (2001), who distinguish between tryout and continued adoption (or disadoption) and analyze the determinants of these decision steps. However, these studies do not take into account the awareness step. In this paper, we analyze three steps in the adoption decision of smallholder farmers—awareness, tryout, and continued adoption—and to the best of our knowledge, this study is the first to do so.

Second, we provide unique empirical evidence from South-Kivu, Eastern DRC, a region that has rarely been studied. We study the process of mineral fertilizer adoption in two territories in South-Kivu, 5 years after it was introduced in the region by the Consortium for Improving Agriculture-based Livelihoods in Central-Africa (CIALCA). Due to civil strife, this area has long been deprived from new research and development initiatives (Pypers, Sanginga, Bishikwabo, Walangululu, & Vanlauwe, 2011) and recent scientific output is extremely scarce. Until a few years ago, awareness of mineral fertilizer was completely absent in this area. Understanding mineral fertilizer adoption is very relevant in this context, and for Sub-Saharan Africa (SSA) in general. It is well-recognized that fertilizer use is essential for sustaining soil fertility in the long run, for improving yields, and for reducing food security among smallholder farmers (Crawford, Jayne, & Kelly, 2006; Dawson & Hilton, 2011; Liverpool & Winter-Nelson, 2010). However, current mineral fertilizer use is especially low in Africa. The entire African continent is using only 2–3% of total world mineral fertilizer consumption and SSA applies less than 1% (Kelly, 2006). Agricultural yields are lagging behind in Africa, especially in the poorest countries, and this is where the largest output and productivity gains are expected from the adoption of mineral fertilizer and other improved technologies (Pingali, 2012; The World Bank, 2007). In order to stimulate mineral fertilizer use, it is important to understand the drivers of the different stages toward sustained adoption and the impact of different types of program interventions.

To empirically estimate the different adoption steps and reveal the impact of different types of program interventions, we use cross-sectional data from 412 smallholder farmers in two territories in South-Kivu. We use different estimation techniques, including univariate probit models, Heckman selection probit models, and bivariate probit models, to understand and control for non-exposure bias, selection bias, and possible endogeneity bias. Our results indicate that the impact of program interventions varies over the different adoption steps, and entail important implications for the design of policies to stimulate technology adoption in areas where technology exposure and adoption is extremely low.

2. THE ADOPTION PROCESS

(a) *Three stages in the adoption process*

We distinguish three stages in the adoption process: awareness, tryout, and continued adoption. Theoretically, we follow the work of Lindner *et al.* (1982) who argue that the time to adoption is the sum of three stages: the discovery stage, the evaluation stage, and the trial stage. We further build on the concepts explained in the paper by Marra, Pannell, and Abadi Ghadim (2003), to clarify the importance of risk, uncertainty, and learning in these three adoption steps.

(i) *Awareness*

A first prerequisite for a farmer to apply a new technology is to be aware about the existence of the technology. The time from the availability of the innovation to the awareness of farmers is what Lindner *et al.* (1982) call the discovery stage. More recently introduced technologies are often less well known than technologies that have been spreading for a longer period of time. Awareness about a specific technology might be virtually complete in certain areas—like mineral fertilizer in Asian agro-industrialized countries—but very low or virtually zero in other areas—like in South Kivu. The rate of awareness about a technology likely varies with the type of technology, the specific context, and farm and farmer characteristics. The supply and diffusion of information—and hence the type and intensity of information campaigns and extension activities—are crucial for increasing awareness rates, but also the demand for information matters. Certain farmers might be more eager to learn than others and more actively engage in the search for information about farming. The cost of searching for information might be lower for better educated and more experienced farmers, and farmers with a larger network and more social capital.

It is especially for technologies and in contexts where awareness is limited and varies across the population, that awareness is an important first step in the analysis of technology adoption. Disregarding this step may result in non-exposure bias in estimates of adoption rates, program impact, and determinants of adoption (Diagne & Demont, 2007). Especially when farmers with a higher likelihood of adopting a new technology are more intensively targeted by extension programs or do more actively search for information themselves, adoption rates and effects may be overestimated and lead to misguided conclusions. In studies on the adoption of new rice varieties in Cote d'Ivoire and Ghana, Diagne and Demont (2007), and Asuming-Brempong *et al.* (2011) show that adoption rates would increase strongly if awareness would be complete and that estimated effects of adoption determinants differ strongly whether or not non-exposure bias is corrected for. In a study on banana tissue culture, which has been introduced already 10 years in Uganda, Kabunga *et al.* (2012) do not find significant differences between current and potential adoption rates and between determinants of awareness and adoption. In our case-study area, where mineral fertilizer was introduced only recently, we expect the awareness step to matter in the adoption decision process.

(ii) *Tryout*

Once farmers are aware about the existence of a new technology, they can acquire further information and decide if and when to first use the technology. Lindner *et al.* (1982) call this the evaluation stage. Tryout of a new technology requires farmers to be able to apply it, and to expect positive returns. Information again plays a very important role as more in-depth and practical knowledge about the technical specifications and the application modalities is needed for farmers to be able to apply the technology. To judge expected returns, farmers need information on technology attributes, such as yield effects, and labor and capital intensity, and on market prices and input costs. This is especially important for mineral fertilizer, which is a knowledge-intensive technology. Uncertainty and risk related to technology attributes and market prices may lower farmers' expected utility, especially for risk