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Surveys

Impacts of natural resource management technologies on agricultural yield and household income: The system of rice intensification in Timor Leste

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ABSTRACT

Natural resource management (NRM) technologies, such as the system of rice intensification (SRI), have been proposed to tackle agricultural challenges such as decreasing productivity growth and environmental degradation. Yet, the benefits of NRM technologies for farmers are often debated. Impacts seem to be context-specific, which are especially relevant in the small farm sector with its large degree of agroecological and socioeconomic heterogeneity. This was not always considered in previous research. We analyze the impacts of SRI adoption on rice yield and household income among smallholder farmers in Timor Leste. Heterogeneity is accounted for in an endogenous switching regression framework. Comparing mean yield and income levels, we find no significant differences between SRI adopters and non-adopters. This is due to negative selection bias; SRI seems to be adopted more on plots and by farmers with less than average yields. Controlling for this bias reveals significant yield and income gains. Poor and non-poor households benefit from SRI adoption; small farms benefit more than larger farms. The results also suggest that in the context of Timor Leste SRI may not be beneficial when compared to conventional rice grown under favorable conditions. Some implications for future research are discussed.

1. Introduction

Input-intensive agricultural technologies have driven a revolution of global cereal production since the mid-1960s. Substantial yield gains were achieved through greater use of improved seeds, irrigation, chemical fertilizer, pesticides, and mechanization (Foresight, 2011). However, this technology model was not successful everywhere, and it has also contributed to environmental problems in some situations, such as loss of biodiversity and soil fertility, salinization, and water scarcity (Altieri, 2002; McIntyre et al., 2009). More recently, yield growth has been diminishing, which is especially true for rice in Asia (Pandey et al., 2010). Without a new and more sustainable boost to productivity, agricultural supply will hardly be able to keep pace with the rapidly rising demand caused by population and income growth and changing consumer preferences (Foresight, 2011).

Natural resource management (NRM) technologies have been proposed to improve the efficiency of cropping systems in a sustainable way (Altieri, 2002; Rammel et al., 2007). NRM technologies build on integrated agronomic principles, responding to a wide range of challenges in different environments. Prominent NRM technologies are conservation agriculture, agroforestry, and organic farming, which have raised considerable attention over the last few decades (Knowler and Bradshaw, 2007; Rigby and Cáceres, 2001). NRM approaches reduce the use of external inputs such as fertilizer by enhancing the potential of locally available resources through improved management practices (Altieri, 2002). Unlike standardized input-packages, NRM technologies involve adaptation of practices to location-specific conditions (Lee, 2005; Rammel et al., 2007). As a result, best practices in one place cannot simply be generalized (Giller et al., 2009; Lee, 2005; Rigby and Cáceres, 2001).

Especially in smallholder agriculture, resource endowments and farm management options are highly diverse, which complicates the rapid dissemination of NRM technologies (Marenya and Barrett, 2007). For example, location-specific biophysical factors were found to influence adoption of NRM practices in different environments (Aldy et al., 1998; Kassam et al., 2009; Ramirez and Schultz, 2000). Similarly, impacts of NRM technologies are likely to vary. Not considering context-specific factors may easily lead to biased estimates. A study may overestimate technological impacts if farmers with better resource endowment are more likely to adopt. In contrast, if certain NRM practices are primarily adopted by marginal farmers, effects may be underestimated. Controlling for sample heterogeneity and selection bias is therefore important in impact analysis. This was not always done in previous research on NRM technologies, which may be one reason for differing results (Alary et al., 2007; Giller et al., 2009; Glover, 2011a; Kassam et al., 2009; Knowler and Bradshaw, 2007; Lee, 2005).

In this article, we analyze the impacts of an NRM technology, using the system of rice intensification (SRI) in Timor Leste as a concrete example. Even though SRI has been widely promoted in some

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countries, technological impacts are still debated. Several studies found that SRI increases yields by 20–40% with water savings of up to 50% (Anthofer, 2004; Barah, 2009; Barrett et al., 2004; Ceesay et al., 2006; Gujja and Thiyagarajan, 2009; Kassam et al., 2011; Senthilkumar et al., 2008; Thakur et al., 2010; Uphoff et al., 2011). Other studies detected no significant gains or even decreasing yields (Dobermann, 2004; McDonald et al., 2006; Tsujimoto et al., 2009). Yield effects seem to depend crucially on the reference system. SRI is often adopted by smallholder farmers who cultivate rice under less-than-ideal conditions (Dobermann, 2004). Thus, yield gains may be underestimated when compared to conventional rice yields obtained under favorable conditions. On the other hand, when building on survey data, one needs to account for the fact that better or more motivated farmers may be those that adopt the technology first. A study by Barrett et al. (2004) in Madagascar found that half of the observed yield differences between SRI and conventional rice were actually due to farm and farmer characteristics rather than the technology itself.

Contradictory findings about SRI impacts may also be due to the fact that farmers adopt different SRI components and practices in different combinations. Partial adoption and discontinuance are sometimes observed (Moser and Barrett, 2006; Senthilkumar et al., 2008). Noltze et al. (2012) showed that not only farm and farmer characteristics, but also plot characteristics may influence adoption patterns and thus impacts. A few studies identified higher labor requirements of SRI as a constraint to adoption (Alagesan and Budhar, 2009; Moser and Barrett, 2002). Other studies showed that higher labor inputs occurred only in the early phase of adoption; labor requirements seem to decrease with growing SRI experience (Barrett et al., 2004; Uphoff, 2012).

Here, we analyze the impacts of SRI for the concrete example of Timor Leste. We extend the existing literature on SRI impacts in two particular ways. First, we analyze productivity effects by building on farm survey data. With few exceptions (Barrett et al., 2004; Sinha and Talati, 2007), most available studies on SRI impacts build on field trial data that may not be representative for real farmer conditions. We account for observed and unobserved heterogeneity by using endogenous switching regressions (e.g., Alene and Manyong, 2007; Di Falco et al., 2011; Rao and Qaim, 2011; Wollni and Brümmer, 2012). Second, we go beyond yield and also analyze SRI effects on household income. Such broader farm household economic impacts of SRI adoption have not, to the knowledge of the authors, previously been analyzed.

The rest of this article is organized as follows. The next section introduces the principles of SRI. Section 3 presents the analytical framework, survey design, and descriptive statistics. Estimation results will be shown and discussed in Section 4. The last section concludes.

2. The SRI Technology

SRI is often described as a high-yielding and environmentally friendly technology that relies on changing farmers' agronomic practices towards more efficient use of natural resources (Uphoff and Randriamiharisoa, 2002). The principles of SRI originate from experiments conducted by farmers in Madagascar to improve rice productivity for resource-poor producers. Today, SRI is usually understood as a package of possible practices, which have to be adapted to local conditions (Glover, 2011a; McDonald et al., 2006; Stoop, 2011). In accordance with the SRI International Network and Resources Center of the Cornell International Institute for Food, Agriculture and Development (SRI-Rice), the following four core components have been identified:

– *Intermittent irrigation*. Rice fields are recommended to be saturated instead of continuously flooded. This water-saving method minimizes anaerobic conditions, which hamper the growth of roots and soil organisms affecting plant architecture and canopy structure.
– *Early transplanting*. Planting seedlings younger than 15 days, which shall encourage tillering, reduce the transplanting shock, and extend the cropping cycle.
– *Single seedlings*. Planting only single seedlings per hill enhances tillering and root-system development, leading to increased drought tolerance and more efficient nutrient uptake.
– *Wide spacing*. Rice plants should be planted in a square pattern with a minimum distance of 20 × 20 cm. Together with *single seedlings* this practice increases the exposure of plants to sunlight, air, and nutrients.

This package of core components is reported to produce higher yields with less water and seeds (Barah, 2009; Zhao et al., 2009). Moreover, studies found rice under SRI to be more robust against extreme weather events, pests, and diseases due to improved plant vigor and root strength (Stoop et al., 2002). The effects of these components are described as multifold and complementary (Ceesay et al., 2006; Thakur et al., 2010). For example, intermittent irrigation aims to tackle various challenges such as the loss of soil quality and water scarcity, whereas early transplanting and wide spacing are both meant to boost tillering. However, not all studies found synergies between these core components (Anitha and Chellappan, 2011; Menete et al., 2008).

Additionally recommended practices for SRI farmers include improved nursery management, the use of organic fertilizer, and regular weeding. Use of organic fertilizer, such as compost or manure, can help to substitute for inorganic fertilizer, apart from stimulating growth-promoting soil bacteria (Mishra et al., 2007). Weeding is more important in SRI than in traditional rice, because weeds spread more rapidly under non-flooded conditions. In Timor Leste, neither organic fertilization nor weeding has yet been widely promoted in SRI programs (Noltze et al., 2012).

Today, SRI methods have been adopted in almost 50 countries, including major rice-producing nations such as India, China, Vietnam, and the Philippines (Glover, 2011b; Senthilkumar et al., 2008; Uphoff, 2012). SRI dissemination and adoption did not always happen spontaneously and unimpeded. In the beginning, development agencies and donor organizations were sometimes reluctant to promote this technology, because much of the evidence resulted from farmer and program reports rather than peer-reviewed scientific studies (Uphoff, 2012). This retarded the diffusion process, because successful adoption of SRI is training intensive and relies on effective extension services (Basu and Leeuwis, 2012). Farmers have to be convinced to break with well-known and widely applied practices of rice cultivation. Also in Timor Leste, there was some reluctance in the beginning. SRI proponents had to convince the extension agency and farmers that the innovation may be an interesting alternative to input-intensive rice cultivation systems that are sometimes too costly for Timorese smallholder producers (Deichert et al., 2009). Much of the initial skepticism has been overcome, but the ongoing debate suggests that more research is needed on SRI impacts under various conditions.

3. Material and Methods

3.1. Analytical Framework

We want to analyze impacts of SRI on rice yield and household income, using cross-section survey data from Timor Leste. In posttest-only designs, treatment and control groups (adopters and non-adopters) are usually not randomly formed. This could imply selection bias, one prominent source of endogeneity. The true impact may be underestimated or overestimated when observed or unobserved farm and household characteristics affect the probability of technology adoption and the outcome simultaneously. One solution to account for endogeneity is the use of instrumental variable (IV) models.