Field Crops Research 111 (2009) 166–172

Contents lists available at ScienceDirect

Field Crops Research

journal homepage: www.elsevier.com/locate/fcr

Specification effects in zero tillage survey data in South Asia's rice–wheat systems

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ARTICLE INFO

Article history:
Received 2 October 2008
Received in revised form 4 December 2008
Accepted 4 December 2008

Keywords:
Impact survey
Specification effects
Zero tillage
Wheat
India
Pakistan
Indo-Gangetic Plains

ABSTRACT

Specification effects in terms of how technology options are contrasted can introduce bias in impact assessment. In a companion paper we evaluated the on-farm impacts of zero tillage (ZT) wheat as a resource-conserving technology in the rice–wheat systems of India's Haryana State and Pakistan's Punjab province [Erenstein, O., Farooq, U., Malik, R.K., Sharif, M., 2008. On-farm impacts of zero tillage wheat in South Asia's rice–wheat systems. Field Crop Res. 105, 240–252]. The underlying field work surveyed plots of full adopters (only ZT plots), partial adopters (ZT and conventional tillage [CT] plots on same farm) and non-adopters (only CT plots). The companion paper assumes that the comparison between the ZT plots of full plus partial adopters and CT plots of partial adopters is the least-biased assessment of ZT's on-farm impact. Here we revisit this underlying assumption and draw on complementary farm survey findings to illustrate the extent of specification effects in the assessment of on-farm impacts of ZT wheat in the same study areas. The study thereby distinguishes between three contrasts between ZT and CT within the same dataset: (1) plain contrast (all plots of adopters and non-adopters); (2) adopter-only contrast (full and partial adopters only, as used in Erenstein et al. [Erenstein, O., Farooq, U., Malik, R.K., Sharif, M., 2008. On-farm impacts of zero tillage wheat in South Asia's rice–wheat systems. Field Crop Res. 105, 240–252]); (3) pair-wise contrast (partial adopters only). Proceeding from type 1 to type 3 comparisons the number of observations decrease but this is compensated by an increasing ability to control for variation. The ability of type 3 comparisons to pick up relatively small but significant differences is an important consideration in farm survey impact assessment. However, there is also an increase in partial adoption bias and further follow-up studies are needed to understand the implications of this. The comparisons show that the ZT effects on savings for diesel, tractor time and cost for wheat cultivation are particularly robust. In Haryana ZT's positive implications for yield and the other financial indicators were also statistically robust, but in Punjab these were sensitive to specification effects. Particularly sensitive to specification effects were the ZT effects on the productivity of applied water in both sites.

1. Introduction

New agricultural technologies may show great promise in on-station and on-farm trials. Still, the proof of the pudding is in the eating, and the performance of new technologies in farmers' self-managed fields is of critical importance for farmer acceptance/adoption and technology uptake/diffusion. Understanding such performance thereby has great potential feedback value for agricultural research and development (R&D).

A number of factors complicate such performance or impact assessment of new technologies in farmers' fields (CIMMYT, 1993; Doss, 2006; Feder et al., 1985). For one, the adoption of new technologies is often associated with resource endowment differentials between adopters and non-adopters (CIMMYT, 1993; Feder et al., 1985). Such differences typically also imply underlying management and productivity differences between the two adopter categories. This can be offset by focusing on partial adopters of new technologies, i.e. those farmers that apply both the new and conventional technology on the same farm. Yet the extent of adoption is likely associated with inter alia the relative performance of the new technology on the adopters' farm. These differences introduce potential biases in empirical technology comparisons in farmers' fields. Specification effects in terms of how technology options are contrasted can thus introduce bias in impact assessment, with potentially misleading implications for R&D.

An empirical case in point is zero tillage (ZT) wheat in the rice–wheat systems of the Indo-Gangetic Plains. The prevailing practice uses a tractor-drawn ZT seed drill, which allows wheat seed to be planted directly into unplowed fields with a single pass of the

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doi:10.1016/j.fcr.2008.12.003

tractor. In contrast, conventional tillage (CT) practices for wheat in these systems involve multiple passes of the tractor to accomplish plowing, harrowing, planking and seeding operations. As outlined in separate papers, the technology has shown particular promise as a resource-conserving technology that reduces production costs and improves production (Erenstein et al., 2008; Erenstein and Laxmi, 2008). These favorable findings have been variously reported for on-station and on-farm trials, and to a lesser extent for farmers' self-managed fields. Confounding the assessment of ZT in farmers' fields are the structural differences between the ZT adopters and non-adopters in terms of resource base, crop management and performance (Erenstein et al., 2007a, 2008).

In a companion paper we evaluated the on-farm impacts of ZT wheat in the rice–wheat systems of India's Haryana State and Pakistan's Punjab province (Erenstein et al., 2008). The companion paper assumes that the comparison between the ZT plots of full plus partial adopters and conventional tillage plots of partial adopters is the least-biased assessment of ZT's on-farm impact. Here we revisit this underlying assumption and draw on complementary findings from the same farm surveys to illustrate the extent of specification effects in the assessment of on-farm impacts of ZT wheat. The subsequent section introduces the methodology and the three contrasts considered. The results section presents the three types of contrasts for wheat management, productivity and profitability indicators in each area. This is followed by a discussion and conclusion.

2. Materials and methods

The companion paper introduces and describes the two study areas in the irrigated northwest Indo-Gangetic Plains of South Asia (Erenstein et al., 2008): (i) the rice–wheat zone in Haryana State, northwest India (hereafter referred to as "Haryana"); and (ii) the rice–wheat zone in Punjab Province, northeast Pakistan (hereafter referred to as "Punjab"). The two study areas were purposively chosen for this study as they comprise the locations where zero tillage promotion was initiated and adoption was most significant (Khan et al., 2002; Malik et al., 2005b).

The main primary data source for this study and the companion paper was a formal adoption survey using a stratified sample of 400 rice–wheat farmers in Haryana and 458 farmers in Punjab. Within each country study, the districts (and sub-districts) with predominantly rice–wheat systems were purposively chosen, comprising at least four (sub)districts where ZT has been widely promoted and at least two where promotion of ZT has been less extensive (Erenstein et al., 2008). The two country studies varied somewhat in the exact sampling approach (for details see Erenstein et al., 2007b; Farooq et al., 2007), but within the selected (sub)districts a number of villages was randomly chosen, and within each selected village typically 8–10 randomly selected farmers were interviewed. For each selected household detailed plot level information was collected for wheat (rabi/winter [November to April] 2003–2004).

Surveyed wheat plots were classified as either ZT or conventional tillage based on the recorded wheat management during the 2003–2004 winter season, with ZT defined as the use of a tractor-drawn ZT seed drill in untilled fields. On adopters' farms where farmers had used both ZT and CT for their wheat crop, both plots were surveyed. On the other surveyed farms only one wheat plot was surveyed (i.e. either ZT or CT).

ZT adopters are defined here as farmers who had a ZT wheat plot during the 2003–2004 season, and thus comprise both partial ZT adopters (having both ZT and CT plots) and full ZT adopters (only ZT plots). Consequently, four plot types are distinguished:

- ZT plots of full adopters [ZT_{FA}];
- ZT plots of partial adopters [ZT_{PA}];
- CT plots of partial adopters [CT_{PA}];
- CT plots if non-adopters [CT_{NA}].

Three contrasts between ZT and CT are distinguished within the same dataset:

1. Plain contrast (all plots of adopters and non-adopters, i.e. ZT_{FA+PA} vs. CT_{PA+NA}).
2. Adopter-only contrast (only ZT adopters' plots, including full and partial adopters, i.e. ZT_{FA+PA} vs. CT_{PA}. This is the contrast used in Erenstein et al., 2008).
3. Pair-wise contrast (only partial adopters' plots, i.e. ZT_{PA} vs. CT_{PA}).

The type 1 contrast allows for all valid plot observations to be considered. However, it is subject to a potential *adoption bias*. A more favorable resource endowment that enables farmers to adopt ZT may also imply underlying management and productivity differentials not directly associated with ZT proper. The type 2 and type 3 contrasts are limited to adopter farms which thereby eliminates the effects of the underlying resource base and management differentials between adopters and non-adopters.

Type 2 and type 3 contrasts may however introduce new biases. There may be an *imperfect control bias*: partial adopters may have adapted their "conventional" crop management practices after having started to use ZT. ZT–CT comparisons on adopter farms may thus underestimate the impact of ZT in the event that partial adopters also reduced the intensity of their CT (i.e. $ZT_{FA+PA} < CT_{PA} < CT_{NA}$).

Partial ZT adoption may introduce a *plot selection bias* as partial adopters have purposively chosen to apply ZT to one field and CT to another in the survey year. Typically, such choice is influenced by a number of considerations and field characteristics. For instance, a partial adopter may be using ZT on relatively less-productive soils and CT on better ones because ZT is still under evaluation in the early adoption phase and/or CT performs poorly there.

Partial ZT adoption may also introduce a *technology under-performance bias*. Full adopters are likely to be more successful in terms of applying ZT than partial adopters who may still be in a learning/adaptation stage. The performance indicators for the ZT technology on full adopter farms are thereby likely to be superior to those on partial adopter farms.

These partial adoption biases potentially affect both contrasts of type 2 (comprising both partial and full adopters) and type 3 (partial adopters only), but are likely to be more pronounced in the latter.

Each contrast therefore has its shortcomings in terms of introducing new potential biases. The number of valid plot observations also clearly decreases from type 1 to type 3 contrasts. Based on the potential biases the magnitude of the observed differences is expected to decrease from type 1 to type 3 contrasts. Conversely, the ability to control for the underlying variation between households increases from type 1 to type 3 contrasts. This will imply trade-offs in terms of the likelihood of finding significant differences.

The specification effects of the three contrasts are assessed in terms of the magnitude and significance of the differences found with respect to selected indicators of wheat crop management, productivity and profitability indicators in each area. For the first two contrasts the independent samples *t*-test was used to establish statistical significance whereas the third contrast relied on the paired samples *t*-test.