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Is direct seeded rice a boon for economic performance? Empirical evidence from India

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ABSTRACT

The direct-seeded rice (DSR) establishment method can improve productivity and labor efficiency while taking into account the soil and hydrologic conditions of the field, the availability of appropriate land equipment, and irrigation-drainage systems. Using plot- and household-level data, we analyze the impacts of DSR adoption in two rice-growing states of India. We account for observed and unobserved heterogeneity using endogenous switching regression. We analyze the yield and costs effects of DSR adoption. Our study shows a small but significant effect of DSR adoption on yield and costs. We find increase in rice yields (by 3.74%) for DSR adopters; an increase in rice yields (by 6.79%) if the DSR method were adopted on puddled transplant rice (PTR) parcels. We find a 7.51% reduction in total costs for DSR adopters; a decrease in total costs (by 3.71%) if the DSR method was adopted on PTR parcels. DSR farmers can significantly reduce their fertilizer and land preparation costs. Hence, the decision to adopt DSR may help households with limited resources to reduce their cost of production without compromising the yield.

1. Introduction

Rice, a staple food for more than half of the world's population, is one of the most important food crops in terms of area, production, and consumer preference (Farooq et al., 2011; Kumar and Ladha, 2011).[1] More than 90 percent of the world's rice is produced and consumed in the Asia-Pacific region, including India. India is the second-largest producer and consumer of rice in the world[2]; in 2013–14 India was the largest exporter of rice followed by Thailand, Vietnam, and the United States of America. However, due to urbanization, industrialization, and crop diversification, the total area devoted to rice production is declining not only in India but also in the entire rice-producing region of the world. Similarly, the number of rice farmers is declining rapidly in most countries. The possibility of expanding the area under rice production, due to water shortage and land availability, to meet the domestic and global demand for rice[3] in the near future is limited. Additionally, erratic rainfall (drought in some regions and flooding in others), labor, and resource inputs[4] constraints (Global Rice Science Partnership (GRiSP), 2013) are pushing producers toward sustainable rice production methods.[5] Take the example of India, where the *Green Revolution* brought substantial gains in rice and wheat yields[6] with a significant use of improved seeds (high-yielding varieties), irrigation, chemical fertilizer and pesticides.

Five decades later, farmers in India face several problems (e.g., increased soil salinity, lower water-table, increased costs of fertilizer and irrigation, higher agricultural wages), and the need for resource

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[1] The term 'rice is life' is most appropriate for India as this crop plays a vital role in the country's food security; is the backbone of livelihood for millions of rural households.

[2] Rice production in India for 2013–14 was 107 million MT while world rice production was about 476 million MT. India exported about 10 million MT of rice in 2013–14 http://agricoop.nic.in/imagedefault/trade/Ricenew.pdf.

[3] 114 million tons of additional milled rice needs to be produced by 2035 (Khush, 2004).

[4] Includes pesticides, fertilizer, and herbicides.

[5] This involves enhancing productivity and efficiency of rice-based systems to safeguard the environment, food security and reduce rural poverty.

[6] Adequate water supply is one of the most important factors in rice production. In India, and perhaps in Asia, the rice crop suffers either from too little water (drought) or too much of it (flooding, submergence). Most studies on constraints to high rice yield indicate water as the main factor for yield gaps and yield variability from experiment stations to farms (Barker et al., 1998).

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conservation is paramount. With stagnant or declining yields and increasing energy prices, agriculture in India and South Asia in general (Ladha et al., 2007; Ray et al., 2012; Nguyen and Ferrero, 2006) is becoming a costly proposition. This would have an adverse impact on the income of smallholders and would pose a greater threat to the food security of smallholder and marginal farmers. Food security for a growing population in India and most South Asian countries—while sustaining agricultural systems under the current scenario calls for a paradigm shift in farming practices.[7] This requires eliminating unsustainable parts of conventional agriculture (plowing/tilling the soil, removing all organic material, monoculture) and adopting agricultural systems that conserve resources for productive agriculture. Additionally, the International Water Management Institute (IWMI) estimates that by 2020 one-third of the Asian population will face water shortages. In a recent study, Suryavanshi et al. (2013) argue that interest in maintaining the sustainability of rice farming is increasing with the scarcity of water and the competition for water resources.

Therefore, improved water usage at the systems level and plot level are important considerations. In Asia and Southeast Asia, rice is widely established by transplanting also known as the puddled transplanted rice (PTR) establishment method, it involves growing seedlings in a nursery bed and later transplanting them in the main field. An alternative way of growing rice is the direct-seeded rice (DSR) establishment method, a low-cost establishment technology that provides an opportunity to improve water and environmental sustainability methods (Joshi et al., 2013). In the DSR establishment method, seeds are broadcasted, drilled, or dribbled into dry or moist soils (Chauhan et al., 2015).[8] In this way, the DSR establishment method not only reduces the use of water but as Khush (1995) notes, that a new plant type of rice is amenable to direct seeding and dense planting and therefore would increase land productivity. Finally, Joshi et al. (2013) note that the DSR method could be considered a natural resource management technology because it reduces crop water requirements and emission of greenhouse gasses.[9]

The DSR establishment method was practiced by farmers only in areas with low population density and/or severe climatic constraints that prevented the intensification of rice systems (Pandey and Velasco, 2002; Kumar and Ladha, 2011; Singh et al., 2013). Rice farmers in Asia and other developing countries are trying to substitute the PTR establishment method with the low-cost DSR establishment method (Johnkutty et al., 2002). In early 2000s, Can and Xuan (2002) in their study note that DSR can improve land productivity and labor efficiency while taking into account a field's soil and hydrologic conditions, the availability of appropriate land preparation equipment, and irrigation-drainage systems. Finally, Marenya and Barrett (2007) argue that for smallholder agriculture, resource endowments and farm management options are highly diverse and tend to complicate the adoption and dissemination of resource management technologies like DSR establishment technology. Similarly, the impacts of rice establishment techniques (DSR versus PTR) may vary, and excluding context-specific factors may lead to biased estimates. Controlling for sample heterogeneity and selection bias is, therefore, important in impact analysis.

In this study, we analyze the impact of DSR's and PTR establishment methods in two rice-growing states of India. In particular, we use plot-level data from Eastern Uttar Pradesh (EUP) and Punjab. Our contribution to the literature is twofold. First, we analyze productivity and costs by using a farm-level survey data. Recall that most available studies (Johnkutty et al., 2002; Can and Xuan, 2002; Kumar and Ladha, 2011; Yadav et al., 2011) are based on field trial data that may not be representative of real smallholder conditions. Furthermore, we account for observed and unobserved heterogeneity by using endogenous switching regression method (see Wollni and Brummer, 2011). Second, we go beyond yield and also analyze the impact of the DSR establishment method on yield and total costs, and different cost components: fertilizer costs, irrigation costs, and land preparation costs. To our knowledge, such broader economic impact of the DSR establishment method using survey data from smallholders has not been previously analyzed. Our study provides a micro perspective on the impact of adoption of DSR on outcome variables (yield and costs). The ESR modelling approach allows us to better understand the exact benefits if the farmer chooses to switch from PTR to DSR establishment method in rice production.

2. Rice establishment methods

There are two principal methods of rice establishment: transplanting, known as the PTR method, and direct seeding, known as the DSR method. Direct seeding can be done under wet (wet-seeded rice) or dry (dry-seeded rice) conditions. Wet seeded rice or transplant is more suited for an irrigated environment, and dry seeded rice is equally suitable for irrigated and rain-fed environments. Historical evidence of rice cultivation in Asia indicates that dry seeding is the oldest method of crop establishment. In the case of the dry-seeded rice establishment method, dry seeds are either broadcasted, or line seeded, with a country plow or seed drill and is considered as one of resource conservation technologies.[10] In the case of wet-seeded rice sprouted rice seeds are broadcast or line-seeded on puddled soil just after drainage (Farooq et al., 2011).[11]

Though DSR is merely an alternative method of crop establishment but with optimum water management, it has potential to save irrigation water (primarily because of avoiding the water requirement for puddling) in irrigated environments (Yadav et al., 2011) and shortening the period of land preparation (Tabbal et al., 2002). In addition, high-yielding, short-duration rice varieties, and chemical weed control methods make it economically profitable to substitute the PTR method with DSR. The PTR method[12] is preferred in areas with lower wages and adequate water supply. Finally, short-duration rice varieties and cost-effective selective herbicides have encouraged Asian farmers to adopt the DSR method of establishing rice (Balasubramanian and Hill, 2002). DSR may not be feasible in lowlands where poor drainage conditions make transplanting the only viable method. However, Tabbal et al. (2002) in a study in the Philippines, conclude that direct wet-seeded rice (a method within DSR) resulted in higher yields than PTR rice by 3–17% and used 19% less water during the crop growth period; the direct dry-seeded DSR method resulted in the same yields as PTR and wet-seeded rice, but made more efficient use of rainfall early in the wet season and saved irrigation water for the subsequent dry period.

The DSR establishment method has other advantages: (1) DSR saves on variable production costs. Compared to the PTR method, DSR can reduce labor requirements by as much as 50%. DSR is fruitful in water-scarce areas, especially in uplands. DSR has a shorter crop duration and therefore has higher water-use efficiency than the PTR method (Ali et al., 2006); (2) DSR may help reduce production risks in possible drought situations and when rainfall at planting time is variably high (Kumar and Ladha, 2011); (3) DSR can facilitate crop intensification. For example, the spread of direct seeding has led to double rice cropping in Iloilo, Philippines (Pandey and Velasco, 2002); (4) total farm

[7] Integrating concerns of productivity, resource conservation and soil quality and the environment is now fundamental to sustained productivity growth.

[8] Rice establishment in the United States is largely done by direct seeded method (Kumar and Ladha, 2011).

[9] Reduced emissions of these gases help in climate change adaptation and mitigation, enhanced nutrient relations, organic matter turnovers and carbon sequestrations (Joshi et al., 2013).

[10] Direct seeding avoids three basic operations, namely, puddling (a process where soil is compacted to reduce water seepage), transplanting and maintaining standing water.

[11] A drawback of wet seeded rice is that too much standing water creates anaerobic conditions and inhibits germination of seeds because of reduction in oxygen.

[12] Puddled transplanting rice (PTR) method of cultivation became the dominant method of rice establishment in most of Asia in the 1950s.