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Heterogeneous Demand for Drought-Tolerant Rice: Evidence from Bihar, India

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Summary. — Efforts to develop rice cultivars with drought tolerance (DT) traits have resulted in several varieties that demonstrate significant resilience to drought stresses. We employ discrete choice experiments to examine farmers' preferences for DT traits and explore heterogeneity in these preferences using primary data from Bihar, India. Results suggest that farmers value reductions in yield variability offered by DT paddy, but are willing to pay even more for seeds that offer yield advantages under normal conditions. We demonstrate that risk aversion and loss aversion not only significantly influence choice probabilities but also affect the way farmers value different seed attributes.

Key words — choice experiments, drought tolerance, risk, rice, farmers, India

1. INTRODUCTION

Droughts represent a significant constraint to rice production in much of India. Roughly 20% of India's total land area is drought-prone, including 16 million ha. of rainfed lowland rice and 6.3 million ha. of upland rice. When droughts occur, there are significant negative impacts on rice production, both in terms of reductions in area cultivated as well as lower yields, resulting in lower rice production and lower farm incomes. In addition to these immediate, farm-level consequences, there are often significant secondary household impacts such as indebtedness, asset depletion and health consequences that perpetuate already high levels of poverty and deprivation in India (World Bank, 2008). Even broader and economy-wide impacts include rapid increases in rice prices that can increase vulnerability among food-insecure households, and strains of fiscal expenditures required to offset price increases and operate social protection schemes. This situation is disconcerting, since evidence suggests that droughts are occurring with greater frequency in India since the beginning of the 20th century (World Bank, 2008).

Recent efforts to develop rice cultivars with drought-tolerance (DT) traits have resulted in the release of several varieties that demonstrate significant resiliency to drought stresses with no yield penalty under normal conditions. [1] Simulation exercises aimed at assessing the impacts of DT rice suggest that the successful development and delivery of these varieties will produce significant benefits across South Asia, well in excess of the investments necessary to develop the technology (Mottaleb *et al.*, 2012). While this holds potential promise for both public or private sector research efforts, Lybbert and Bell (2010) argue that development of DT cultivars does not necessarily imply that DT varieties will be widely adopted with the same speed as other recent improvements (e.g., crops genetically engineered to contain the *Bacillus thuringiensis* toxin, thereby making crops virtually impervious to insect infestation) due primarily to the non-monotonic nature of the benefits associated with drought tolerance and their effect on social learning and technology diffusion.

In this article, we use a discrete choice experiment to examine farmers' preferences for DT traits embodied in different rice backgrounds (hybrid and varietal), and explore heterogeneity in these preferences. This distinction is motivated by differences in the potential avenues or scenarios through which such traits could be embodied in seed technologies.

In the scenario that characterizes most of India's innovation in rice to date, public research institutions (e.g., Indian State Agricultural Universities or Institutes of the Indian Council of Agricultural Research, ICAR) develop inbred cultivars with desirable traits such as higher yield, shorter duration, or drought tolerance. These cultivars are then distributed through various channels as low-cost seeds that small-scale, resource-poor farmers can save and replant each season. In an alternative scenario that is much less common in rice, it is the private, profit-maximizing firms (e.g., crop science companies or seed companies) that develop these desirable traits, typically by introducing them in a hybrid, rather than inbred, background that allows the firm to maintain control over the gains afforded by its innovation. We examine this in greater detail below, and simply highlight here the idea that multiple scenarios may play out in the development of DT rice, each with implications for the potential impacts on poverty and productivity in emerging countries such as India.

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The remainder of this article is organized as follows. In Section 2, we provide a background on rice production in India, paying specific attention to the challenges wrought by frequent droughts in key rice-growing regions. In Section 3, we describe the empirical methodology used in analyzing farmer preferences and demand heterogeneity. In Section 4, we describe the data used in this study, including a discussion of the geographic and socioeconomic context of our sample area. In Section 5, we present the results of our empirical analysis. Finally, we offer some concluding remarks in Section 6.

2. BACKGROUND

During the Green Revolution, the introduction of modern agricultural inputs such as improved seeds, fertilizers, and pesticides—along with supportive policies and investments in credit, pricing, research, and infrastructure—greatly increased agricultural production in India (see, e.g., Hazell, 2010). However, Green Revolution's impacts in India were largely confined to the country's main irrigated areas and favorable agro-ecologies, most notably the western Indo-Gangetic plains (Punjab, Haryana, and western Uttar Pradesh) where irrigation infrastructure was most developed and where the provision of credit and fertilizers was particularly concentrated (Evenson & Gollin, 2003; Kumar, Bernier, Verulkar, Lafitte, & Atlin, 2008). In other parts of India, including the eastern reaches of the Indo-Gangetic plains (including eastern Uttar Pradesh, Bihar, and West Bengal) where irrigation was slow to develop, the innovations associated with the Green Revolution are still being introduced today. Even despite such investments, the rate of yield growth for rice across India has decelerated in recent decades alongside a similar deceleration in wheat yields. While some estimates of food supply do not suggest an impending Malthusian crisis (e.g., Ganesh-Kumar *et al.*, 2012), there is still a need for increased investment in new and innovative technologies that improve yield, conserve scarce natural resources used in production, and resist both biotic and abiotic stresses associated with changing climate patterns.

Droughts represent one of the most pressing constraints to rice yields in unfavorable and rainfed ecosystems (Pandey, Bhandari, & Hardy, 2007; Serraj *et al.*, 2009). Since the early 1960s, there have been 15 instances in which total rice production in India failed to exceed the production level from the previous year. Not coincidentally, the majority of these have coincided with significant droughts in key rice-growing regions. The dynamics of drought impacts involve a complex interaction between climate, weather, infrastructure, and human behavior. The ultimate agricultural and societal impacts of droughts are dependent upon factors such as the timing and severity of the drought. For example, the 2002 drought was particularly destructive to rice production, affecting some 300 million people across India, some in the most important rice producing states in India such as Uttar Pradesh, Andhra Pradesh, Punjab, Orissa (now Odisha), and Tamil Nadu. For the country as a whole the monsoon season rainfall was roughly 20% below the historical average, mainly due to a significantly dry spell in July, during which rainfall was 49% below the long-run average, the largest monthly rainfall deficiency in recorded history (IMD, 2002).

Questions remain as to whether existing technologies—combined with improved crop management practices, diversification of crops, and improvements in on-farm value addition—can meet the demands of growing populations under these increased stresses. The development of DT traits for a variety of crops has been seen as a potential avenue through which human livelihoods can be at least partially insulated from the effects of droughts. However, drought resistance has, until recently, received relatively little attention from plant breeders. [2] Despite significant challenges and early setbacks, research on drought tolerance is proceeding in both the public and private sectors, and at both the global and national levels. Many agricultural scientists and development practitioners agree that DT varieties present a means of avoiding the increasing threat of droughts. An ex ante assessment by Mottaleb *et al.* (2012) suggests that the development of such rice varieties would provide significant benefits, both in terms of economic benefits to farmers as well as nutritional benefits to consumers, concluding that the monetized benefits of these advances exceed the costs of research and development necessary to bring these varieties to the market.

This is not to say that the dissemination and adoption of DT rice varieties, once developed, will be a rapid or straightforward process. Lybbert and Bell (2010) argue that the nature of drought—and crop responses to drought—make adoption pathways for DT varieties more complicated than those for varieties tolerant to other stresses, particularly insect-resistant crops. [3] Among other important differences, they argue that DT introduces non-monotonic benefits relative to non-DT varieties, which, as a productivity-*enhancing* (yield variability reducing) benefit rather than purely a productivity-*increasing* (yield increasing) benefit, introduces stochastic-relative benefit streams that may complicate the decision-making calculus of risk-averse farmers. But the benefits of DT rice may be nearly monotonic, as currently available DT rice varieties provide farmers with significant yield advantages over conventional varieties even under severe drought conditions. Thus, Lybbert and Bell (2010) should perhaps be interpreted as providing a caveat that interventions may be needed in order to expedite the widespread adoption of DT crops.

While current efforts in developing DT technologies have resulted in self-pollinating (inbred) DT varieties, this study also considers the possibility that drought-tolerance traits could be embodied in a hybrid background as an alternative solution. The relative yield advantage of hybrids under irrigated systems is well documented, with some studies estimating hybrids yielding 10–30% higher than varieties in India, China, and Bangladesh (see, e.g., Janaiah & Hossain, 2003; Li, Xin, & Yuan, 2010; Lin, 1991; Virmani, 2003; Virmani, Aquino, & Khush, 1982). Developing hybrids with both high yield potential and DT traits could both improve and stabilize yields in drought-prone environments (Villa, Henry, Xie, & Serraj, 2012).

In addition to higher yield potential, hybrids offer economic incentives to private innovators. The economic value of hybrids stems from the fact that yield gains and other benefits conferred by heterosis (hybrid vigor) decline dramatically after the F1 generation, thus compelling farmers to purchase new F1 seed each season if they want to continually realize these benefits. These purchases of F1 seed provide innovators—breeders and seed companies—with a means of recouping their investments in research and the high fixed costs of producing hybrids (e.g., seed multiplication). Where innovators can produce and market hybrids with desirable traits while also maintaining secrecy over hybrid's pedigree as a biological form of intellectual property protection, they are often able to operate at a profitable margin even in seed markets where farmers are relatively poor. This has been demonstrated with hybrid maize in Latin America and Southern and Eastern Africa (see Morris, 1998; Smale & Jayne, 2010), and hybrid rice in China (Li *et al.*, 2010).This has also been demonstrated