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Dynamics of variety change on wheat farms in Pakistan: A duration analysis

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ABSTRACT

Decades after the Green Revolution, sustaining wheat productivity remains an important policy goal for the government of Pakistan. Understanding the speed of diffusion of new wheat varieties can contribute to this goal. We apply duration analysis to identify the factors that shorten the time until a farmer replaces one modern variety by another, and test hypotheses concerning two recurring themes of the Green Revolution: farm size differences and the role of information sources in seed diffusion. We find that time to adoption averages only 4 years, but is shorter on larger farms. Factors that speed variety change also differ by farm size. Extension and media sources of information significantly influence adoption among larger farmers relative to information gained through social relationships, but this is not the case for marginal farmers. Traits related to consumption quality speed adoption on smaller wheat farms, where families both sell and consume their wheat; higher yields drive adoption for the most subsistence-oriented, marginal group.

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Introduction

The irrigated areas of the Province of Punjab, Pakistan are the historical locus of the Green Revolution in wheat. Known in the narrowest sense by the swift diffusion of short-statured, higher-yielding wheat varieties during the 1960s, Pakistan's Green Revolution also entailed public investments in irrigation canals and tubewells, fertilizers, and market development. Technical change generated welfare benefits for farmers and consumers beyond adopting farmers in high-productivity environments like those of Punjab (Renkow, 2000). The wheat economy and rural society were transformed; the specter of famine receded (Hazell, 2010; Otsuka and Larson, 2013).

Despite such acclaimed progress, sustaining the productivity of wheat, which remains the staple food of the Pakistani population, depends on the steady released and successful diffusion of improved varieties that are resistant to known and unknown stresses. The government of Pakistan still needs to understand the process of wheat variety adoption, and how it differs by target population. During the Green Revolution, wheat farmers replaced tall-statured improved varieties or farmers' landraces with new, semi-dwarf wheat varieties that were more responsive to fertilizer under favorable moisture conditions. Decades after the Green Revolution, most farmers already grow modern ("high-yielding") varieties of wheat. In today's Pakistan, "adoption" refers to a change from one previously adopted modern variety to a more recently released modern variety.

Previous research has documented that the slow rate of variety replacement by farmers has posed a major challenge in promoting new wheat varieties in Pakistan (e.g., Heisey, 1990; Farooq and Iqbal, 2000; Iqbal et al., 2002). One consequence has been the concentration of wheat area in a few popular varieties, which can depresses yield potential and aggravates the crop's vulnerability to plant disease, including endemic strains of wheat rust (Heisey et al., 1997). For example, in 1997, six years after its release, Inqilab was sown to an estimated 4.22 mill ha in Pakistan alone—an estimated 51% of all wheat area in Pakistan and 53% of the area planted to either semi-dwarf wheats or tall wheats with pedigrees (Smale et al., 2002). Inqilab remained the most popular wheat variety until the release of Seher in 2006. A recent stochastic frontier analysis by Battese et al. (2014) confirms that slower variety replacement reduces the technical efficiency of wheat production in the Punjab of Pakistan. To supply modern varieties that can sustain productivity gains on farms in Pakistan and elsewhere, wheat breeders must continually address new strains of plant disease, adapt varieties to new forms of abiotic stress such as excessive heat or saline conditions, and surpass current yield potential in order to facilitate yield advances on farms.

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Several salient features in the scholarly discourse about the Green Revolution are potentially relevant to the analysis of variety change in today's Pakistan. One is the role that transfer of seed and variety information from one farmer to another played in diffusion of the first generation of semi-dwarf wheat varieties and in their replacement by newer, improved releases (e.g., Hussain et al., 1994). Although investment in public extension services was instrumental for delivering information about new seed, widespread diffusion depended on informal, socially-mediated exchange. A second is the way that farm size shapes the process of seed-based technical change. A large body of theoretical and empirical research has explored the association of farm size with endowments of various types of capital (human, physical, social, political), and via these endowments, access to market infrastructure, including sources of information (e.g., Feder et al., 1985; Feder and O'Mara, 1982; Lipton and Longhurst, 1989). More recently, Battese et al. (2014) found that the large-scale farmers are more productive and more efficient than smaller-scale farmers. A third was recognition of the importance to some farmers of variety attributes other than grain yield, such as fodder production (e.g., Renkow and Traxler, 1994).

In this analysis, we revisit these questions. Our objective is to contribute to the understanding of wheat variety adoption in today's Pakistan. By adoption, we refer to the replacement by a farmer of one modern variety by another, rather than a switch from wheat landraces or improved tall varieties to semi-dwarf wheat, as was the case in the initial phases of the Green Revolution.

Our conceptual approach is a trait-based model of seed (variety) choice derived from the theoretical framework of the agricultural household, which also recognizes the importance of variety information sources as farmers learn about variety attributes (Hintze et al., 2003; Edmeades and Smale, 2006). We apply the conceptual approach with a duration model, which enables us to model explicitly the timing of the adoption event as a function of variety traits, farmer, and market characteristics. Duration analysis includes both time-varying and time-invariant parameters in order to combine insights from cross-sectional and time-series data and account for potential biases caused by unobserved lengths of time in 'spells' or states, such as unemployment (Kiefer, 1988). Widely applied by economists to a range of topics (Van den Berg, 2001), the approach has been used relatively infrequently to model adoption of agricultural innovations. Examples include studies of resource-conserving technologies by Fuglie and Kascak (2001), organic horticultural practices by Burton et al. (2003), adoption of cross-bred cows by Abdulai and Huffman (2005), and crop technology adoption in developing countries by Dadi et al. (2004) and Matuschke and Qaim (2008).

This study updates previous analyses of wheat variety adoption in Pakistan, re-testing key hypotheses from the Green Revolution and post-Green Revolution periods concerning the role of farm size and information sources in variety change. Unlike earlier studies published on this topic, we apply a duration model to identify the factors that shorten the time until a farmer replaces one modern (high-yielding) variety by another (rather than switching from landraces or improved tall varieties to modern varieties). Rapid turnover among modern varieties is required to ensure resistance to diseases of wheat and support yield potential. Today, the seed replacement rate is a parameter recognized in Pakistan's seed policy (Rana, 2014).

Conceptual framework

Hypotheses from earlier adoption literature

The Green Revolution in the Asian subcontinent stimulated a vast literature about the adoption of agricultural innovations in developing economies, which built particularly on the seminal research conducted in the US by Griliches (1960) and Rogers (1962). Exhaustive reviews of the first few decades of this literature were conducted by Feder et al. (1985) and Feder and Umali (1993). Given the role of farmer knowledge and complementary inputs (fertilizer, adequate moisture) in the optimal performance of the first short-statured, high-yielding varieties, early empirical studies focused on the characteristics of farmers (education), access to credit, irrigation, and land. A major theoretical paradigm of this period was farmer decision-making under risk, depicting a farmer's land allocation between "modern" and "traditional" as a portfolio decision determined by risk aversion and the stochastic structure of relative yields (Just and Zilberman, 1983). Safety-first and other motivations related to risk were also proposed (e.g., Roumasset et al., 1979). Learning models were another hallmark of this early literature, in which farmers resolved uncertainty by accumulating knowledge about higher-yielding varieties through experimentation and experience, often portrayed as a Bayesian process (e.g., Heibert, 1974; O'Mara, 1971; Feder and Slade, 1984; Leathers and Smale, 1991). Lindner et al. (1979) applied this framework in analyzing the time to adoption.

Variety choice models of this type are less relevant in today's Pakistan because the adoption decision no longer involves the technology shift from a "traditional" (tall-statured, higher-yielding variety or heterogeneous, wheat landrace) to a "modern" (short-statured, fertilizer-responsive variety. Especially in the irrigated areas of Punjab, Pakistan, wheat farmers have now experienced many generations of modern varieties. Adoption of wheat varieties in today's Punjab Province is about replacing one modern variety with another, based on whether it performs better than the current modern variety given a farmer's particular growing conditions and objectives. Farmers are more educated and have more access to public information; capital investments are not needed to change modern varieties.

On the other hand, the decision to grow a newly released wheat variety is still a process that depends on how individual farmers seek and acquire information. Farmers "learn by doing" and they learn from others (Feder and Slade, 1984; Foster and Rosensweig, 1995). A major paradigm in recent adoption literature articulates the influence of social learning, social networks, and social capital in the choices made by individual farmers (Besley and Case, 1997; Conley and Udry, 2003; Munshi, 2004; Bandiera and Rasul, 2006). A principle in this literature is that costs, and access to information about a new technology, are related to capital endowments, such as farm size. In Punjab, Pakistan, public extension agents are more likely to work with larger-scale growers.

Further, each new release has a unique configuration of traits. A segment the variety choice literature demonstrated empirically that early utility-based models of decision-making omitted variety traits, which are relevant factors in the decision-making for semi-subsistence farmers. Because of a focus on higher yields and yield stability, these models often ignored the role of traits such as grain and storage quality or fodder yield in farmer decision-making. Some researchers tested the importance of variety attributes, such as pest resistance and suitability for food preparation, by including them in econometric models alongside farmer characteristics and other determinants (e.g., Adesina and Zinnah, 1993; Smale et al., 2001). More complete models were then derived in the framework of the household farm by Hintze et al. (2003) and Edmeades and Smale (2006), in which traits are hypothesized to influence decision-making in the non-separable version of the model. Examples of recent applications among poor farmers include Katungi et al. (2011), Otieno et al. (2011) and Timu et al. (2012). Useche et al. (2013) developed and applied a trait-based model to model choice of GM crops in the US.

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