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The Architecture of the Pakistani Seed System: A Case of Market-Regulation Dissonance

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Introduction

Applications of modern science to the improvement of cultivated crop varieties ("cultivars") have yielded tremendous gains for food security in Pakistan since the 1960s. The introduction of semi-dwarf rice and wheat cultivars—alongside strategic investments in the distribution of synthetic fertilizers, provision of irrigation, advice on crop management, and price support policies—encouraged rapid intensification in Pakistan's high-potential areas in a manner that is still recognized as one of the country's greatest development achievements. But since that moment in history, a constant onslaught of new threats to productivity growth—new pests and diseases, diminishing natural resource stocks, weather shocks and climate volatility, changing demands from farmers and consumers, and new market forces—has highlighted the need for continuous innovation in cultivar improvement and seed provisioning strategies for farmers. By most accounts, innovation has fallen short of the challenge.

The breeding and provision of improved cultivars is often viewed as a "first-best" means of inducing technological change in agriculture, and historical evidence suggests that genetic improvement in major food staple crops has been a primary driver of productivity growth in developing countries (Evenson and Gollin 2003). There are several factors underlying this observation. First, realization of the benefits from improved cultivars is generally neutral with respect to landholding size and scale, meaning that smallholder farmers can often benefit from the technology in the same way that larger farmers might (Lipton 1989). This has been a consistently important dimension of Pakistan's experience with improved cultivars since small and marginal farms (operating less than 5 acres of land) currently account for 64 percent of all private farms in Pakistan (GoP 2010).

Second, realization of the benefits from improved cultivars is mostly sustained from season to season through farmers' practices of saving grain from harvest for subsequent use as seed,[1] and their practice of readily exchanging seed embodying desirable traits with other farmers. These nearly costless practices augmented the efforts of public research, seed multiplication programs, seed enterprises, and extension services to disseminate the semi-dwarf rice and wheat varieties introduced during Pakistan's "Green Revolution" of the 1960s and 1970s.

Since that time, however, circumstances have changed in Pakistan. On the demand side, farmers have been slow to switch into newer varieties of wheat, cotton and rice, and their preferences have concentrated around a few top-performing varieties (Farooq and Iqbal 2000; Khan et al. 2002; Heisey et al. 1997, 1993; Heisey 1990). Many of the adoption constraints facing Pakistan's farmers reflect what is already highlighted in the extensive literature on this topic, relating primarily to institutional and behavioral characteristics—farmers' experience with new technologies, their risk preferences, exposure to peer effects, or other socio-psychological factors—or incomplete markets for land, labor, inputs, commodities, credit and insurance (Jack 2011; Feder and Umali 1993; Feder et al. 1985; Feder and Slade 1984). Many of the early studies on these topics were, in fact, first investigated in Pakistan (e.g., Smale et al. 1998; Heisey et al. 1997, 1993; Heisey 1990).

On the supply side, Pakistan faces real challenges to maintaining and expanding the system architecture required to continuously supply improved cultivars to farmers, particularly resource-poor, small-scale farmers. A modern seed industry requires long-term investments in science—plant breeding, agronomy, biological and molecular sciences—and constant revision of seed production, regulation, and distribution systems. Decisions made on how to build that industry must balance a complex set of social and economic tradeoffs which, in effect, are captured in the struggle to ensure farmers' access to affordable seed of improved cultivars, on the one hand, and the need to incentivize investment in breeding, seed production, and marketing, on the other. These tradeoffs raise a host of issues, for example, the appropriate roles for the public and private sectors in the seed industry; the distribution of the gains from

[1] This is the case for many, but not all, crops, and also depends partly on the capacity of farmers to collect and store seed in a way that minimizes the presence of pests, diseases, and foreign material in saved seed. Hybrids are an important exception. Hybrids are plants that exhibit a high level of genetic vigor (heterosis) that is associated with an increase in yield or uniformity resulting from the crossing of inbred parental lines. However, yield gains conferred by heterosis decrease substantially after the first generation is planted from hybrid seed. This compels farmers to purchase seed—rather than save harvested grain as seed—in order to continually realize yield gains conferred by heterosis. Hybrids of maize and many horticulture crops are commonly cultivated worldwide, while hybrids of sorghum, pearl millet, cotton, and rice have also been developed and marketed extensively. The reproductive biology associated with hybrids contrasts with open pollinated varieties (OPVs), self-pollinating inbred varieties, and vegetatively propagated varieties, for which harvested grain or plant parts can be stored and used by farmers as seed in the following year.

innovation across plant breeders, entrepreneurs, seed companies, public research organizations, and farmers, and the marginal cost of rules and regulations designed to encourage innovation, ensure quality, protect human and environmental health, or otherwise steer seed industry development (Spielman et al. 2014; Byerlee and Fischer 2002). As Pakistan's seed industry continues to grow in terms of volume, value and coverage, these tradeoffs become increasingly important. Unfortunately, there has been too little analysis of these tradeoffs to date.

This paper fills this knowledge gap with a close examination of the legislative and institutional framework governing cultivar improvement and seed provision in Pakistan. It underscores the need to give greater attention to the institutional and organizational architecture of Pakistan's seed system—to identify the appropriate roles for the public and private sectors, their political and economic interests in continuing or changing the existing system, and the available policy solutions to improve investment policies, regulatory systems, and opportunities for entrepreneurship.

This paper is divided into seven sections. Section 2 identifies data sources for this study. Section 3 provides a brief history of the development of seed business in Pakistan. Section 4 describes the existing legal and institutional structure to regulate seed provision, and identifies gaps that constrain private sector's participation in seed provision. Section 5 identifies key actors in the sector, explores their respective interests in and capacity to influence potential reform, and briefly discusses important professional networks that these actors can deploy to pursue their interests. Section 6 discusses recent efforts to reform the legal framework, which it contends have so far been unsuccessful, largely because the proposed legislation merely extends regulatory oversight over the working of the private sector without offering anything in return. Section 7 concludes the paper by highlighting that the boundary between the formal and the informal is more blurred in Pakistan than is often recognized.

Data and data sources

This paper draws on data from four distinct sources: (1) the Federal Seed Certification and Registration Department (FSC&RD), (2) academic papers and industry reports, (3) key informant interviews, and (4) the first rounds of the Pakistan Rural Household Panel Survey (RHPS) conducted in 2012. These sources are discussed in further detail below.

Data from the FSC&RD—the seed industry's principal regulator and a department of the federal Ministry of National Food Security and Research (MNFS&R)—are used to gain insight on the formal (organized)

seed industry in Pakistan.[2] This includes data on variety releases, seed provider operations, seed supply requirements, seed certification, imports, and exports, as well as rules and regulations governing the formal seed industry. Significant gaps exist in FSC&RD's data, but nonetheless provide enough insight on levels and trends to inform the analysis in this paper.

To augment FSC&RD data, this paper draws on academic papers and industry reports. Unfortunately, rigorous policy analyses of Pakistan's seed sector are scarce, and the topic has not attracted much academic interest in Pakistan. Most of the recent work focuses on specific crops or technologies, such as genetically modified insect-resistant Bt cotton (e.g. Rana et al. 2013; Kouser and Qaim 2013; Nazli et al. 2012; Ali and Abdulai 2010; Ali et al. 2007), rather than on the institutional and governance framework that enables or impedes this diffusion. Few studies examine the seed sector holistically beyond the usual litany of complaints (e.g. Hussain 2011; Sarwar 2007). Nevertheless, these academic papers and industry reports provide useful insights into specific aspects of seed provision, especially when considered alongside papers and reports from other developing countries that explore how public policies and regulatory frameworks have evolved elsewhere (see Byerlee and Fischer 2002).

The third source—officials from the seed corporations, federal ministry officials, provincial agriculture departments, seed companies, and farmers—is a particularly valuable source for understanding the nuances of Pakistan's seed industry. These key informant interviews were conducted over the course of 2012–2014 in a relatively open-ended manner under a range of circumstances including one-on-one interviews, discussions at public policy forums, telephone conversations, and other forms of interaction and correspondence.

Finally, household data are drawn from the first round of the Pakistan Rural Household Panel Survey (RHPS) conducted in 2012 (IFPRI/IDS 2012). Data on seed sources and quantities are specifically drawn from a sub-sample of 942 agricultural households across three provinces surveyed in November 2012 under RHPS Round 1.5. The RHPS was undertaken by the International Food Policy Research Institute (IFPRI) and Innovative Development Strategies (Pvt.) Ltd. (IDS), under the auspices of the Pakistan Strategy Support Program (PSSP). The aim of the survey was to collect information on poverty dynamics

[2] Throughout this paper, we refer to Pakistan's seed "industry" to describe the sector of the economy in which seed and other planting materials are produced for use by farmers. This term can be used interchangeably with other common descriptors such as: "seed system" which suggests a greater focus on the public service dimensions of the industry, for example, the research and regulatory systems; "seed market" that suggests a greater focus on exchanges, for example, at the wholesale or retail levels; or "seed sector" that suggests the importance of strategic planning by government to ensure national food security. We choose the term "seed industry" merely to convey an emphasis on the growing role of private companies in the development, production, and marketing of seed.

and micro-level constraints on income generation and economic growth for rural households in Pakistan. See Nazli and Haider (2012) for complete details.

The survey covers topics that are standard to most household income and expenditure surveys in developing countries, while extending its coverage to health and nutrition; agricultural production; natural resource management; gender and labor issues; and topics related to security, governance, and access to public services. The sample universe of RHPS Round 1 included all households in rural Punjab, Sindh, and Khyber Pakhtunkhwa (KPK) provinces. Balochistan and the Federally Administered Tribal Areas (FATA) were dropped from the sample selection due to security reasons, while Gilgit-Baltistan—Pakistan's northernmost territory—was excluded due to logistical reasons.

To ensure that the sampling frame captured Pakistan's rural population, the RHPS uses data on enumeration blocks provided by the 1988 Population Census, as well as population projections to the year 2030, to identify revenue villages (*mouzas*) for possible inclusion in the sample.[3] The RHPS used a multistage, stratified sampling technique to capture variation in Pakistan's rural population. In the first stage, probability proportionate to size (PPS) was used to select districts, ensuring that districts with more rural households have a greater chance of being selected. The proportion of rural households in each province determined the number of districts chosen from the province. Across the three provinces, 19 districts were selected (12 from Punjab, 5 from Sindh, and 2 from KPK). In each district, 4 *mouzas* were selected, resulting in a total of 76 *mouzas:* 48 from Punjab, 20 from Sindh, and 8 from KPK. In each, an equal probability systematic selection method was used, so that *mouzas* with smaller populations had the same probability of being selected as highly populated *mouzas.* One enumeration block was randomly selected from each *mouza,* and a complete household listing was conducted to randomly select 28 households from each block. In the end, 2,124 households were randomly selected and, with 34 refusals to participate, the final sample totaled 2,090 households.

In November 2012, a follow-up survey round (hereinafter referred to as "RHPS Round 1.5") was conducted on a subsample of households from the original 2,090 households. The subsample consisted of 981 households (47 percent of the original sample) that cultivated land at any point during the year prior to the survey. These households that were specifically engaged in production were surveyed with a questionnaire on agricultural production for each crop and for each individual plot under cultivation during the *kharif* 2011 and *rabi* 2011/2012 seasons. While the RHPS Round 1.5 sample is not

[3] All enumeration blocks classified as "urban" in the 1998 population census were removed from consideration. All enumeration blocks where the projected population in 2011 exceeded 25,000 were also removed from consideration, in an effort to reduce the possible sampling of mouzas that were originally rural in 1998 but had become largely urban by 2011.

representative of households engaged in agricultural production in Pakistan, because it is extracted from a larger representative sample of rural households, it does capture a useful level and degree of variation with which to conduct the analysis presented in this paper.

A historical perspective on Pakistan's seed industry

Pakistan's seed industry has passed through four different phases. The first phase—1947 to the late 1950s—was characterized by small-scale research and development (R&D) in the public sector and a continuation of the colonial focus on a few major crops in the rich alluvial plains of Pakistan's two agricultural provinces, Punjab and Sindh. The second phase—late 1950s to the mid-1970s—was characterized by development of an elaborate network of public-sector organizations designed to develop and deliver improved cultivars. The third phase—mid 1970s to the mid-1990s—was a period of legal and institutional development. The fourth phase—mid 1990s to date—has seen rapid growth of the private sector and a gradual shift of functions from seed companies and other actors. A brief discussion of each phase follows.

When Pakistan was established in 1947, the only (public or private) organization that carried out agricultural research was the Punjab Agricultural College and Research Institute, Lyallpur (later renamed Faisalabad). New cultivars were developed as public goods. Since their commercialization was not intended, no formal system of cultivar approval and registration existed at the time. New cultivars were simply handed over by breeders to the provincial agriculture departments for seed production and distribution to farmers. While seed certification was not an entirely unknown concept, the absence of an appropriate legal and institutional framework meant that formal certification operations could not be put into operation. Overall, the Lyallpur Institute played a small role in seed provision, and farmers mostly depended on their own seed production (Ali and Ali 2004).

Pakistan's ambitious development planning of the 1950s and 1960s warranted an increase in agricultural productivity to feed economic growth. This necessitated the establishment of elaborate arrangements for agricultural research and seed production. The government responded through two major initiatives in 1961. One was the bifurcation of the Lyallpur College and Institute into an Agricultural University at Lyallpur and the Ayub Agricultural Research Institute (AARI). The other was the establishment of the West Pakistan Agricultural Development Corporation (WPADC).[4] These organizations grew quickly and emerged as dedicated institutional hubs for agricultural research and teaching, cultivar development, and seed production, respectively. Given the nature of these activities, overlaps were inevitable. The

[4] Punjab, Sindh, Balochistan, Northwest Frontier Province (now Khyber Pakhtunkhwa), and tribal areas were merged in 1954 into one unit called West Pakistan. The one unit was dissolved in 1970.

University at Lyallpur started academic programs in multiple disciplines, AARI upgraded and expanded the existing system of cultivar development, and WPADC established seed farms and developed a system of seed certification.

AARI and WPADC provided a convenient conduit for transmitting to farmers new cultivars and related technologies developed by the international agricultural research system. However, AARI and WPADC were constrained in what they could achieve given the resources available at the time. Capacity limitations—mainly a shortage of skilled scientific and technical expertise and a low base from which operations were scaled up—meant that they could only concentrate their R&D on a few major crops and focus only on the high-potential irrigated areas in Punjab and Sindh to the exclusion of other provinces that now comprise Pakistan. While AARI continued to grow in the third and the fourth phase, WPADC was wound up in 1972 soon after West Pakistan was divided administratively into provinces. The function of seed production and marketing was assigned to provincial organizations, namely, the Punjab Agricultural Development and Supplies Corporation and the Sindh Agricultural Supplies Organization. Balochistan and the Northwest Frontier Province (NWFP, now KPK) continued to rely on seed produced by Punjab- and Sindh-based organizations and on farmers' saved seed.

Until the promulgation of Pakistan's first seed law—the West Pakistan Seeds and Fruit Plants Ordinance, 1965—AARI and WPADC operated in the absence of a legal framework that set out procedures and protocols of variety approval. The Ordinance was a very basic instrument that provided for the registration of growers for production of certified seeds and establishment of nurseries. Registered growers could voluntarily apply for certification. Certified seed was to be sold to the government, while only leftover certified seed could be sold in the open market. The Ordinance did not prohibit production of uncertified seed (other than the seed of fruit plants), which meant that seed producers could develop seed for the market, but had to register with the government and maintain standards if they wished to have their seeds certified.

The third phase started in 1973 when the Pakistan government sought help from the World Bank to review its seed provision system and formulate recommendations for comprehensive reform (Salam 2012; Ahmad and Nagy 1999). This was the beginning of Pakistan's first large-scale seed industry project under which wide-ranging legal and institutional reforms were undertaken to improve seed provisioning to farmers.

The most salient feature of this project was the enactment of the Seed Act in 1976, which specified procedures for variety registration and seed certification. The Act also created elaborate institutional infrastructure for its implementation, including the National Seed Council, provincial seed councils, and

two separate agencies (under the federal Ministry of Agriculture) for variety registration and seed certification. These agencies were merged in 1998 to constitute the FSC&RD as it stands today. The mandate of Punjab and Sindh corporations for agricultural supplies was redefined, and these were converted into Punjab and Sindh Seed Corporations, respectively. In NWFP, an Agriculture Development Authority (ADA) was established, which was mandated to produce seed for local consumption. In Balochistan, no separate institutional arrangements were made, and the provincial agriculture department continued to provide seed on a limited scale.

A shift from the previous tradition during this Phase was to assign a formal role—albeit marginal—to the private sector, viz. seed multiplication on farmers' fields. But this was how far the Act went. It assigned all other functions in the seed development chain–cultivar development; production of breeder nucleus seed, pre-basic seed, and basic seed;[5] seed testing; and seed certification–to the public sector. It also did not provide for registration of private seed companies. Such exclusive focus reflected broader economic policy designed around broad-spectrum nationalization of industry in the 1970s. Several projects carried out in the 1970s to strengthen the public sector involved establishing seed production farms, setting up seed-testing laboratories, installing seed processing plants, and training seed technologists.

The fourth phase in the development of seed industry in Pakistan began in the late-1970s when FSC&RD—consistent with the broader government policy of agricultural market and trade liberalization—proactively attempted to promote private sector participation in the seed business. The first seed company was formally registered in 1981. Another eight seed companies—all based in Punjab—launched their business in the next few years (Sarwar 2007).

The pace picked up in the 1990s. In 1994, the seed business was formally categorized as an industry (Ali and Ali 2004) and was granted privileges associated with that designation. By 2000, 291 private seed companies had registered with FSC&RD (Ali and Ali 2004). Sindh, KPK, and Balochistan had their first seed companies in 1996, 1996, and 1998, respectively. Four multinational corporations (MNCs) established their Pakistan affiliates during the 1980s and 1990s and the total number of companies engaged in seed production and marketing grew to more than 960 by 2012.

Initially, Pakistani seed companies were limited to multiplication of basic seed obtained from public seed corporations. Very quickly, however, they established their own breeding programs and brought a number of new cultivars to the market. As their operations grew, they started to displace public-sector

[5] Breeder nucleus seed is the pure seed of an improved cultivar produced by a breeder. This seed is in very small quantity. It is multiplied to produce pre-basic seed, which in turn is multiplied by the breeder or another seed producer to produce basic seed. Seed purity declines somewhat in each multiplication.

corporations from the market. Several companies also started to import and export planting material. Gradually, they became the lead provider in several crops—cotton, vegetables, oilseeds, maize, and fodders. The leadership of the Pakistani seed industry, thus, quietly shifted to the private sector during the past two decades.

The governance framework

Cultivar improvement and seed provision activities in Pakistan are governed by the Seed Act of 1976, which is a federal legislation. Under the 1973 Constitution of Pakistan, agriculture is a provincial subject. *Ipso facto*, only a provincial government can legislate on matters related to agriculture. So when the federal government sought to regulate seed provision in Pakistan, it had to persuade provincial governments to surrender their legislative authority to this extent to the federal government under Article 144 of the Constitution. This enabled the federal government to enact the Seed Act of 1976 and provide a uniform structure for seed sector activities in all provinces. This is an important feature of the Seed Act, which affected the seed sector in several ways.

The Seed Act's specific objective is to regulate seed quality, and to do so, it establishes a set of institutions, specifies procedures for registering new cultivars and producing seed, defines breaches of the laws, and sets out penalties for committing them. The Act creates three institutions: (1) the National Seed Council, (2) provincial seed councils, and (3) FSC&RD. Chaired by the federal Minister of Agriculture, the National Seed Council is required to perform a range of regulatory and advisory functions.[6] These include specifying seed standards, regulating the interprovincial movement of seed, guiding the administration of seed quality standards, advising the government in general on seed policy, and ensuring and protecting investment in the seed industry. Provincial seed councils perform similar functions in provinces. FSC&RD is responsible for registration of new cultivars and for seed certification.

The Act prohibits the stocking or sale of seed of a notified cultivar (that is, a cultivar approved by the government and notified in the official gazette) unless it conforms to seed quality standards and bears a label describing the required information. It is important to note that this stipulation is only for notified cultivars. The Act also specifies procedures for seed certification, but does not make it mandatory for seed producers. In other words, seed producers *may* register their new cultivars with FSC&RD and *may* get seed of their registered cultivars certified, in which case they are subject to seed quality standards. By implication, they may as well carry out their seed provision activities without registering a cultivar and/or without certifying their seeds. The Act allows seed officials to inspect seed production facilities, collect

[6] Both national and provincial seed councils are composed principally of public officials. Farmer representation is limited to one farmer nominated by the respective government in each case.

samples and carry out necessary tests to see whether or not seed quality standards are being met. Violating any provision of the Act or preventing lawful functioning by a duly appointed person is declared an offense punishable with fairly nominal fines, imprisonment, or both.

The Act does not provide for registration or regulation of private seed companies. The only role it assigns to the private sector is seed multiplication, for which FSC&RD is required to register seed growers. When official policy shifted to market and trade liberalization in the late-1970s, FSC&RD also started exploring ways and means to encourage private sector's participation in seed provision beyond seed multiplication. The legal basis for such enhanced participation could be provided by amending the Seed Act of 1976. But agriculture being a provincial subject, the federal government wanted to consult provincial governments before comprehensively amending the Seed Act to reflect changes in the policy paradigm. As a stop-gap arrangement, the federal government's Economic Coordination Committee, in a meeting dated December 31, 1979, constituted an Inter-ministerial Working Group to register or deregister new seed companies (Hussain 2011). The objective was to formalize private sector's organized participation in the seed business. In effect, however, this added a layer of complexity to private investment in the seed sector as it required companies to establish themselves both under existing instruments of law (e.g., the Companies Ordinance, 1984) and through an application for registration with the Working Group.

To facilitate the implementation of the Seed Act, the federal government framed the following three sets of rules: (1) Seed (Registration) Rules, 1987; (2) Seeds (Truth-in-Labelling) Rules, 1991; and (3) Pakistan Fruit Plants Certification Rules, 1998. While the latter two sets of rules are fairly standard provisions in any seed system, the first set of rules does raise several issues.

The Seed (Registration) Rules establish a Federal Seed Registration Committee charged with evaluating candidate varieties for compliance with variety registration standards. Rule 7 of the Seed (Registration) Rules of 1987 requires a new variety to be both (1) superior to existing varieties in at least one important aspect, and (2) at least satisfactory in other major characteristics. Rule 9[7] prohibits the production or certification of seed of any variety of a crop included in a Schedule to the Rules,[8] unless the variety is validly registered with FSC&RD.

This prohibition is unusual. Rules—being subordinate legislation carried out by the government without recourse to the Parliament (or a provincial assembly)—are meant to elaborate and explain, rather than add

[7] According to rule 9 of the Seed (Registration) Rules of 1987, "Effect of non-registration—No variety of the crop specified in Schedule 1 shall be eligible for seed production and certification in any Province of Pakistan or part thereof unless the said variety has been registered and the necessary certificate to that effect has been obtained from the National Registration Agency."

[8] The schedule is an extensive list and includes all major and minor crops.

to or contradict the parent legislation. But by prohibiting production of seed of unregistered varieties, Rule 9 is effectively an unlegislated addition to the Seed Act, which is silent on the production of seed of unregistered varieties.

Read alone (which was definitely the case between 1976 and 1987), the Act indicates that if a breeder wants to register his variety with FSC&RD, he *may* apply in the prescribed form and the variety will be registered if it meets the criteria. Once the variety has been notified, he *may* seek certification of its seed. But both are optional for the breeder. If he does not seek registration of his variety, he may market it at his own risk and cost. Read with the Seed (Registration) Rules, 1987, the Seed Act indicates that if a breeder does not register his variety or his application fails, seed of such variety cannot be produced.[9]

Another important component of the seed sector's legal framework is the Pakistan Biosafety Rules and National Biosafety Guidelines of 2005. Framed under the 1997 Pakistan Environment Protection Act, these rules regulate various aspects relating to genetically modified organisms (GMOs). They prohibit the import, export, sale, purchase, or trade of GMOs and their products without a license from the federal government. They also provide for the establishment an inter-ministerial National Biosafety Committee (NBC) and a Technical Advisory Committee (TAC) at the federal level as part of the Ministry of Climate Change.

NBC's functions include granting approvals for the import, export, trial, and commercial release of GM cultivars. It reviews recommendations from the TAC charged with reviewing biosafety data and analysis of GM products submitted for commercialization. So far, the NBC has only approved the commercial release of Bt cotton,[10] although it has allowed limited trials for a range of genetically modified (GM) crops, including drought-tolerant wheat and herbicide-tolerant and insect-resistant maize developed by both public and private entities.[11]

From the above discussion, FSC&RD and NBC emerge as two key institutions for governance of the seed sector. Both have suffered a few years of institutional uncertainty in the aftermath of the 18th Constitutional Amendment of 2010, which devolved several federal functions to provinces. The devolution led to abolition of the federal Ministry of Agriculture and Livestock, and the Ministry of

[9] Since this rule prohibits seed production, rather than sale or offering for sale, technically, farmer seed saving should also be problematic. Because not all farmer-saved seed varieties are registered or notified, at least theoretically, farmers will violate Rule 9 when they produce traditional seed varieties. However, this strictly legal interpretation is unlikely in practice.

[10] The first approval of genetically modified cotton was granted in 2010 for cotton containing genes from the soil bacterium *Bacillus thuringiensis* (Bt). The genes confer resistance to certain types of insects, namely bollworms and other insects in the lepidopteran order.

[11] Developed by the National Institute of Biotechnology and Genetic Engineering and Monsanto, respectively.

Environment. Yet, the federal bureaucracy was able to make a successful case for re-creating the dissolved Ministries into the new Ministry of National Food Security and Research (MNFS&R) and the Ministry of Climate Change (Rana 2013). FSC&RD, whose responsibilities were initially expected to be delegated to provinces, was first assigned to the Ministry of Science and Technology and later to the MNFS&R in 2011. Similarly, following a few months of administrative confusion, NBC was assigned to the new Ministry of Climate Change.

Seed markets and actors

Pakistan's seed system—similar to seed systems in most countries—is comprised of a research system, regulatory agencies, and seed producers. They interact in a market that is difficult to estimate in terms of value or volume, though Hussain (2011) approximates the total value of the Pakistani seed market at US$845 million in 2008–2009.

Broadly, the Pakistani seed system comprises two segments; viz. the formal seed system and the informal seed system. The former comprises breeding institutes, seed corporations, seed companies, regulatory organizations (i.e. the seed councils and FSC&RD; also NBC for GM crops), agricultural inputs dealer and farmers. The latter also comprises these actors and other farmers, implying thereby that the formal sector actors also operate as part of the informal sector to the extent of part of their seed business. Figure 1 graphically depicts flow of seed and its information from one actor to the other in the seed system. Role of various actors in the formal and the informal segments is described in the following pages.

As is evident from the flow diagram below, a key component of this system is Pakistan's public agricultural research system, which is one of the larger agricultural research systems among developing countries with an estimated 3,513 full-time-equivalent researchers (Flaherty et al. 2012). The main research entities at the federal level include the Pakistan Agricultural Research Council (PARC), Pakistan Central Cotton Committee (PCCC), and agricultural research institutes of the Pakistan Atomic Energy Commission (PAEC). At the provincial level, the Punjab government's AARI stands out as a key research entity: AARI has led the system's most productive breeding program, accounting for 39 percent of the total varieties released to date (Table 1).

<<Figure 1 here>>

In addition to these federal and provincial entities, five major agricultural universities in Pakistan carry out R&D activities, the largest of which is University of Agriculture, Faisalabad (UAF) with about 12,000 students and employing 593 faculty members of whom 49 percent hold a PhD degree (UAF 2013; Flaherty et al. 2012). The academic programs of these universities conduct research across a range of

disciplines and provide a trained workforce for the seed industry and other agribusinesses.

<<Table 1 here>>

Four important observations about the research system's contribution to Pakistan's seed industry are worth noting here. First, the public sector accounts for 96 percent of all cultivars released to date (Table 2). The private sector has only recently started developing its own cultivars for commercial release—that too for a small number of crops such as transgenic Bt cotton (Rana 2013). Second, breeding activities are limited to a small set of crops. Even in these crops, cotton and wheat account for 40 percent of all cultivars released to date (Table 2). Such narrow R&D focus condemns farmers to rely on unimproved traditional cultivars for other crops. Third, Punjab-based institutes and companies have developed almost half of all cultivars. KPK-based institutes and companies have also developed a large number of cultivars. But the relatively small number of new cultivars developed in Sindh and Balochistan shows that farmers in these provinces have to rely on breeding programs in agro-ecologically different Punjab and KPK.

<<Table 2 here>>

Fourth, there is significant overlap and duplication among the federal, provincial, and university breeding programs. Perhaps the most obvious case is PCCC's Central Cotton Research Institute (CCRI) in Multan. CCRI has elaborate plant-breeding facilities, and has developed several popular cotton cultivars. Situated across the road from CCRI is AARI's premier Cotton Research Station, which pursues the same mandate and has similar facilities. Yet the two institutes exist as separate entities and rarely communicate.

Finally, the release of new crop varieties and hybrids peaked during the 1990s and 2000s, which was also the period when most seed companies were established (Table 3). Although public sector entities were still releasing new varieties and hybrids during this period, the private sector's growing participation seems to have played a key role in Pakistan's seed market development. Private-sector participation not only increased market size, but also—and more importantly—generated awareness and demand among farmers for differentiated products.

Beyond research and the release of new varieties, the task of seed multiplication, distribution and marketing falls to several actors in Pakistan's seed system. Among the public seed producers established in the 1970s, only the Punjab Seed Corporation remains as a significant seed producer.[12] PSC has an impressive infrastructure for the production and distribution of seed across a wide range of crops. Its infrastructure includes seed farms on 7,303 acres, processing plants with a capacity of 72,000 metric tons,

[12] The ADA in KPK was disbanded in 2001 and operations of the Sindh Seed Corporation (SSC) were suspended in 2002. Although, operations were revived in 2006, SSC plays a very marginal role in seed provision at present.

ginning capacity of 22.5 bales per hour, delinting capacity of 13,500 metric tons, storage capacity of 6,700 metric tons, more than 1,200 registered growers, and a marketing network of 1,136 dealers and 19 sales points in Punjab and 70 dealers in other provinces (PSC 2008). That said, PSC faces many of the challenges associated with running a large state-owned seed enterprise: difficulties in estimating demand and managing inventories, a governance structure that struggles to balance commercial considerations with government development priorities, and farm management issues.[13]

<<Table 3 here>>

Alongside the PSC is a vibrant private sector, although exact numbers are difficult to come by.[14] A total of 963 Pakistani seed companies have registered with FSC&RD since 1981, although 213 companies were deregistered over the years after they were found to be involved in irregularities (Salam 2012) (Table 4). Several of these companies were started by contract growers of a provincial seed corporation with sufficient experience in producing seed for the public sector, or by successful farmers who had been providing seed in the neighborhood and wanted to formalize the arrangement. Other companies were established by members of the value chain (e.g., a ginning factory, an exporter, or an agrochemical company) seeking to diversify their business portfolio. Another five companies are Pakistani subsidiaries of leading multinational enterprises: (1) Monsanto Pakistan Agritech; (2) ICI Pakistan; (3) Pioneer Pakistan Seed; (4) Bayer CropSciences; and (5) Syngenta Pakistan. Although none host significant R&D activities in Pakistan, they are popular suppliers of (mostly imported) hybrid seeds of maize, sunflower, fodder, canola, alfalfa, and sorghum (Hussain and Hussain 2007).

Available data suggest several important trends. First, Pakistan's seed business is concentrated in Punjab, with 82 percent of companies having their registered offices there (Rana 2013). Most of these companies are located in Southern Punjab, which enables them to also serve the markets in Sindh and Balochistan. Second, the total number of companies is large and growing, although there is little evidence indicating the emergence of strategic behavior—mergers, acquisitions, joint ventures, and technical collaborations—that often accompanies seed industry growth (Table 4).

<<Table 4 here>>

[13] For example, since 2006–2008, tenants on PSC's largest farm in Khanewal have illegally occupied a large part of the farm and refused to grow seed or pay rent. As a result, more than 5,000 acres are effectively lost to PSC.
[14] It is common for seed companies to enter and exit the seed business. Hence, not all registered seed companies may be currently active. In 2003–2004, FSC&RD circulated a questionnaire to update its database: only 73 companies responded (Hussain and Hussain 2007), indicating exactly how difficult it is to maintain updated figures.

Third, MNCs have played a key role in introducing hybrid seed. Monsanto and Pioneer were central to introducing hybrids of maize and sorghum, while ICI introduced a canola hybrid to Pakistan. During the 1990s, Pioneer also invested in wheat, and Monsanto in wheat, cotton and rice, although both have withdrawn from these markets due to their limited profitability and other issues (Rana 2010; Hussain and Hussain 2007). Fourth, seed companies have positioned themselves to influence policy decisions related to seed regulation, biotechnology, biosafety, and a range of related policy issues in Pakistan. They have done so both individually and through several industry associations, including one formed exclusively by the MNCs (ARM 2008; FSC&RD 2001). The most active of these associations, the Seed Association of Pakistan, has used the platform to present seed companies' perspective on pending seed legislation that is discussed in detail below.

Table 5 presents data on the private sector's share in the provision of certified seed of selected crops, showing seed companies dominate the certified seed market. Their market share (measured in terms of local production plus imports) ranges from 72 percent for wheat to 100 percent for vegetables and fodders. Clearly, private companies have begun to eclipse public seed enterprises in the certified seed market. And for crops such as cotton, maize and vegetables, some of the seed sold by the private sector originates from its own registered cultivars. For example, 10 out of 17 Bt cotton varieties approved for commercial cultivation in Pakistan were developed by (and are registered with FSC&RD in the name of) Pakistani seed companies.[15]

<<Table 5 here>>

In the case of cotton, recent surveys (e.g. Rana et al. 2013) suggest that these private companies compete not only on genetics—on the genetic superiority of the company's particular cultivar—but also on quality of service—purity and germination of seed, timeliness of delivery, quality of packaging, brand reputation, or other such dimensions. This is particularly important for those companies that do not invest in breeding programs and confine their business to the multiplication and marketing of public varieties. Rana et al. (2013) found in their survey of cotton seed in Sindh that companies sell seeds of the same varieties of Bt cotton at substantially varied rates. This suggests that farmers are willing to pay a premium for quality, and that brand names have started to emerge in the Pakistani seed market.

Another way to illustrate the presence of competition is to examine prices paid by farmers for seed in the RHPS data. As shown in Table 6, there is significant variation in cotton, maize, and rice seed prices both

[15] The actual number of Bt cotton varieties developed by the private sector may be larger, given that companies often enter the market directly without recourse to FSC&RD. See Rana (2010).

within and across provinces, possibly reflecting the presence of competitive pricing and product differentiation between companies, although other price determinants such as transport costs may also account for these differences. Wheat, on the other hand, exhibits far lower price variation, which is again unsurprising given the difficulty companies face in differentiating and marketing publicly developed open-pollinated varieties that can also be easily saved and exchanged between farmers. An analysis of the determinants of seed prices for wheat, cotton, maize, and rice seed using a Heckman (1976, 1979) selection estimation model suggests the following, with a complete discussion provided in Appendix A. First, price is significantly associated with variety type for all three crops, although variations in this variety-price relationship exist between wheat and cotton, on the one hand, and rice, on the other hand. Second, while farmer contact with an extension agent is also correlated with price, although these correlations are again crop-specific. Third, other variables that might explain price variation—for example, landholding size and farmer experience, which could proxy for bargaining power in seed purchasing and pricing—are insignificant, suggesting that farmers are generally price-takers in the seed markets for these major field crops.

<<Table 6 here>>

Companies operating in Pakistan's seed market face several constraints. Limited access to breeder seed from public-sector research institutes is a continuing issue for many companies who multiply and market public varieties or use public germplasm in their breeding programs. The relatively small size of the domestic market is a likely disincentive to investment, particularly given the barriers to seed trade with India which could otherwise open doors to massive opportunity in an integrated regional market. The absence of intellectual property rights (IPR) protection—the combination of legislation and enforcement of both plant breeders' rights and patents for transgenic events—may also disincentivize private R&D investment.

But perhaps the most salient constraint is the inadequate legislative and institutional framework governing Pakistan's seed system. The challenges begin with FSC&RD, Pakistan's premier agency for regulating seed provision that is responsible for (1) registration of seed companies, (2) registration of varieties, (3) seed certification, and (4) enforcement of the 1976 Seed Act. In 2013-14, FSC&RD employed around 434 seed professionals and support staff in the Islamabad office and field outlets and had a total budget of Rs. 160.4 million. In that year, cost of maintaining these employees was 93 percent of the total expenditure (Ministry of Finance 2014), which left little for other activities, such as training, facilitation of seed providers, seed market surveillance, or development of databases. FSC&RD is seriously under-staffed, especially given the prevalent regulatory framework in which each variety is to be evaluated and

registered before it can be sold, and seed lots are examined for certification at the production stage. It is practically impossible for the professional staff (about 30% of the total) at FSC&RD to expeditiously process applications for company and cultivar registration, and seed certification. The result is inordinate delay in some cases and poor oversight in others. This is what the 2012-13 Year Book of MNFS&R (2013) lists as the tasks undertaken by FSC&RD during 2012-13: 1) registration of 61 new seed companies; 2) registration of 24 new cultivars after observing their performance during trials; 3) inspection of 524,564 acres for seed certification purposes; 4) sampling and testing of 206,273 metric tons of seeds of various crops; and 5) field testing of 20% seed lots of all certified seed of cotton, wheat and rice. It will be quite a herculean task to meaningfully accomplish all this with a professional and support staff of only 434 people and a budget of mere Rs. 160.4 million.

The case of NBC is similar. NBC is a small set-up tasked with the important job of evaluating GM cultivars for biosafety. Limited technical capacity, understaffing and administrative confusion during 2011-13 (discussed above) resulted in delayed processing of breeders' applications for biosafety approvals for cultivar trials and commercialization. Spielman et al. (2014) note that the NBC could not convene during 2011-13; resultantly, out of a total of 34 GM cultivars for which biosafety approval has so far been granted, 21 cultivars received biosafety approval 1-2 years *after* the PSC had granted its approval.

The end result is a slow and cumbersome cultivar registration process, which renders new cultivars vulnerable to misappropriation by unscrupulous handlers at various stages of testing. This has effectively discouraged many breeders in the public and private sectors from registering their new varieties with FSC&RD. For example, 10 out of 14 cotton varieties under large-scale cultivation in 2012 in Sindh were not registered with FSC&RD (Rana et al. 2013).

Since seed of only registered cultivars can be certified by FSC&RD, such common practice of commercial release of cultivars without FSC&RD registration translates into a consistent shortfall in supply of certified seed. Data presented in Tables 4.5 and 4.7 show that certified seed production represents a small proportion of the country's total seed requirement in most crops. In potato and pulses, it is 1-2 percent; even in cotton and wheat, it is only 12 and 28 percent respectively (Table 7). The only two exceptions are vegetables and rice, where supply of certified seed has grown in recent years due to increase in imports of vegetable seed and adoption of hybrid seed for rice. For other crops, e.g. cotton and oilseeds, availability of certified seed has declined over the years (Rana 2014). The rest of the seed requirement is supplied from farmer-saved seed and uncertified seed sold by agricultural input dealers and seed companies.

<<Table 7 here>>

It is noteworthy, however, that although certified seed represents only about 20 percent of the total seed market in Pakistan, quality seed may comprise a much larger share. To clarify this point, a distinction should be made between quality seed and certified seed. The two are not the same thing: rather, certified seed is a subset of quality seed. The key concept here is seed quality, rather than official sanction. Pure seed of non-notified varieties *may* also be quality seed, despite being uncertified. Similarly, seed of a notified variety not presented for certification for any reason *may* also fall in this category. A prime example of this situation is the Bt cotton seed supplied by a few reputable private companies during 2005–2010 without certification but nonetheless with in-house quality assurances.

Uncertified seed, amounting to about 80 percent of the country's total seed requirement every year, is provided by a very large informal sector comprising (1) farmer-to-farmer seed exchange on a non-commercial basis, (2) small-scale farmer-to-farmer seed sale, (3) farmer-saved seed for planting in subsequent years, and (4) medium- to large-scale sale of seed in "brown bag" exchanges (Figure 1). Farmer-to-farmer exchange on a non-commercial basis and small-scale sales are not rare, but the volume of such exchange or sale is negligible as a proportion of Pakistan's total seed requirement. The third and fourth categories constitute the bulk of the informal sector.

Sometimes, seed companies also sell uncertified seed—usually because the variety is unapproved but otherwise ready for market. Companies sell uncertified seeds through their own outlets, as well as through the vast network of input dealers. The undocumented character of such transactions places them in the informal, rather than the formal, category. Sometimes these seeds are sold in company packaging bearing a company label. Weak enforcement of seed laws allows companies to conduct their operations in the informal sector. Usually, however, uncertified seeds are sold through brown bag exchanges, meaning that little indication of source or quality accompanies the seed. Farmer, input dealers, and other value chain actors (e.g., cotton ginners and sugar mills) also engage in such transactions, often without official sanction and sometimes in violation of express injunctions.

Data from the RHPS provides a more nuanced sense of the role played by various seed providers in the formal and the informal market. Table 8 shows that input dealers and seed companies are the main retail source of seed for Pakistan's four major crops. Given that these figures are fairly consistent across all four major crops, the implication is that both public seed enterprises and private seed companies rely on the private sector to distribute their varieties to farmers. Importantly, data from the RHPS also indicate that farmers' reliance on these private sector sources is fairly constant across landholding sizes, suggesting that the private sector services a wide range of farmer types and does not concentrate on particularly large

landholders (Appendix B). Input dealers are not a seed source per se; they are simply a convenient conduit between the farmer and the seed provider. Seed companies sometimes maintain their own sale points, but often market certified and uncertified seed through input dealers.

<<Table 8 here>>

Of the nine seed sources listed in Table 8, the top three *mostly* operate in the formal sector, whereas the rest are part of the informal sector to a varying degree. Even PSC, extension departments and research institutes—despite being government organizations—occasionally provide uncertified seed of unregistered varieties to meet market demand for the same. The next on the continuum are the seed companies and input dealers; they sell certified seed under company labels as well as uncertified seed with or without company labels. The remaining four are part of the informal sector. Thus, seed providers in Pakistan mostly operate in a grey area between complete formality and complete informality (see Figure 1).

Nothing illustrates the twilight zone operations of these seed providers better than the case of Bt cotton in Pakistan. Bt cotton seed first reached farmers' fields in Sindh in 2002–2003. They were brought by enterprising farmers from abroad and planted on a small scale. As the seeds provided effective protection against bollworms, their popularity grew. Simultaneously, several seed companies successfully crossed exotic Bt material with local cotton varieties to produce Bt varieties of their own. By 2005–2006, several companies were marketing their Bt varieties on a large scale. By 2007, Bt varieties accounted for 80 percent and 50 percent of the total area under cotton cultivation in Sindh and Punjab, respectively (Ali et al. 2007). Since the government had not approved any of the Bt varieties by then, the entire Bt cotton diffusion process in Pakistan had occurred in the informal market.

The spread of Bt cotton through the informal sector was the result of three factors: First, none of the Bt varieties were approved by the government, which did not approve seed for considerations other than quality.[16] Second, FSC&RD or provincial agriculture departments did not have the capacity to monitor or check the spread. Third, seed companies did not feel disadvantaged in the absence of the official notification that changed the status of their Bt varieties from unapproved to approved—they had discovered that the market did not care.

[16] There was some confusion in those days on Monsanto's IPRs on the transformation event used in Bt varieties. Since the government did not want to appear to violate Monsanto's IPRs, it withheld approval. See Rana (2010) for details.

Not wanting to be bypassed, public-sector research institutes and seed producers also joined the fray early on. At least two research institutes—the Centre of Excellence in Molecular Biology (CEMB) and the National Institute for Biotechnology and Genetic Engineering (NIBGE)—developed cotton varieties containing local transgenic events. Meanwhile AARI and other institutes had developed Bt varieties, while their breeders were also marketing Bt cotton seeds in the informal sector. Even the PSC was openly producing and marketing Bt cotton seeds in 2008–2010, while their production and sale were still illegal in Pakistan (Rana 2010). In short, the entire ensemble of seed providers—research institutes, breeders, seed corporations, seed companies, input dealers, and farmers—had become part of the informal sector, at least in the Bt cotton seed business.

In 2010, the situation changed with official approval of nine Bt varieties. One of these belonged to NIBGE, and eight to seed companies. While official approval hardly conferred a market advantage on these varieties, it enabled providers to market seeds under their label. This improved quality, as companies raised the quality of seed sold under their own brand names. Since all seed providers were using the same Bt gene, they had to compete on both germplasm and seed quality.

In due course, several of the approved varieties quickly disappeared from the market and were replaced by new varieties. The market was now populated by new cotton varieties that had not been registered with FSC&RD, transgenic cotton varieties that had yet to receive approval from NBC, and seed that was uncertified by FSC&RD (Rana et al. 2013; Spielman et al. 2014). But this did not necessarily mean that the seed was of low quality—company branding carried with it a quality signal to farmers.

Pakistan's Bt cotton experience demonstrated how imprecise the distinction between formal and informal can be, and how little value the regulatory system confers to farmers when it is not functioning properly (see also Rana 2010, 2014). It also exemplified how an inadequate and archaic regulation constrained the operations of an active informal market. For better part of the last decade, the development of new Bt varieties and production of seed had to stay in the shadows simply because the regulatory framework was not dynamic enough to catch up to ground realities and market demands.

Addressing the dissonance between markets and regulation frameworks

When the Seed Act was enacted in the 1970s, all important aspects of seed provision—breeding, cultivar evaluation, germplasm imports, and seed certification—occurred within the public sector. The Act and its subordinate legislation addressed only notified varieties and certified seed. With the entry of the private sector in the seed system by the mid-1990s, the Act was largely unable to provide guidance on aspects key to private investment, for example, timely varietal testing and registration processes, plant breeders rights, branding, trademarks, market surveillance, and other issues that were pillars of a competitive seed

market. Several examples illustrate today's growing dissonance between the market and the legislative framework.

Under the existing procedures, a new variety is tested for at least two years for distinctness, uniformity and stability (DUS) as well as for value in cultivation and use (VCU) at various research stations and in farmers' fields. As long as breeding was conducted only by the public sector, this system worked well. But when companies entered into breeding, they were reluctant to hand over their germplasm for testing at competitor institutes. They also found varietal evaluation procedures to be time consuming and bureaucratic. Since approval of a variety did not bring any value to their business—it did not create intellectual property that could be protected under existing laws—several companies started releasing their varieties directly into the market without recourse to FSC&RD approval.

In response, FSC&RD necessarily felt that seed companies were releasing varieties of dubious quality—unstable trait expression, poor germination rates, or susceptibility to pests and diseases. FSC&RD was also critical of the growing practice of introducing exotic (imported) germplasm without proper testing and adaptation. Clearly, the companies and FSC&RD were at odds over one important aspect: the companies thought they were operating in an over-regulated environment, whereas FSC&RD thought the regulation lacked the necessary safeguards needed to maintain seed quality and protect farmers from poor seeds and traits. Albeit for different reasons, both agreed that the legal framework was inadequate.

In another example, a key FSC&RD function was to certify seed, which was performed through field inspections during the production stage. Upon successful completion of the inspection, FSC&RD issued tags, which seed distributors were required to display prominently as a mark of quality. The private sector, however, viewed the process differently, arguing that it had the necessary know-how to produce quality seed and did not require intrusive and time-consuming FSC&RD inspections. Since a brand name, rather than an official FSC&RD tag, seemed to carry more weight in the market, private companies found seed certification of little value to their business. Companies still obtained these tags from FSC&RD, but to avoid unwarranted inspections, rather than for any value that these might add to their business. Moreover, since seed certification was possible only for notified varieties, its relevance diminished as the number of unregistered varieties in the market grew.

Clearly, a comprehensive reform was warranted to remove the growing dissonance between the law and the market. Two types of responses emerged: (1) a comprehensive reform proposal from FSC&RD to make regulation more effective and to include the private sector in its ambit, and (2) a proposal for a regulatory shift to a truth-in-labelling system for quality assurance.

Several proposals have been put forth by various stakeholders during the past two decades to amend the 1976 Seed Act. The latest is a 2014 draft bill from FSC&RD proposing three key amendments to the Act. First, the bill substantially expands the Act's mandate over a wide range of actors in the seed system, and extends the Act's writ over registering entrants into any aspect of the seed sector with the FSC&RD. Second, the bill is more explicit in prohibiting several activities with more appropriate punishments, including: (a) doing seed business without registration; (b) selling, importing, stocking, bartering, or otherwise supplying seed of an unregistered variety; and (c) selling misbranded seed. Third, it imposes more stringent biosafety requirements for the commercialization of GM varieties.[17] The bill aims to extend regulatory oversight to all aspects of seed provision in Pakistan, and is an unsurprising response from FSC&RD to the current free-for-all environment in Pakistan's seed system, which FSC&RD finds severely debilitating for dealing with delinquency.

At the time of writing this paper, the bill had passed from the federal cabinet to the Parliament for discussion. If approved by the Parliament, the Bill will place the seed business—both public and private—firmly under FSC&RD's regulatory control. For farmers, the proposed amendments offer some protection against spurious seed and false claims on product performance. For the private sector, however, the amendment's implications are less clear. On one hand, the existence of a legal framework makes the seed business more predictable for the seed industry, forcing all players to compete on a level, well-regulated playing field rather than in an ambiguous, informal, unregulated segment of the market. On the other hand, a legal framework subjects the seed business to external oversight on minimum standards for operations and performance, while also limiting its ability to introduce nominally differentiated varieties to the market—a key marketing strategy for many seed companies in recent years (Rana 2010). As such, the proposed amendment offers little incentive for private investment in Pakistan's seed market, and seems to address few of the issues described above that relate to the wider legal and institutional framework. Therefore, the private sector is not enthusiastic about its approval. Similar previous efforts by FSC&RD to push through legislative reform in the face of only lukewarm support from private seed providers ended in failure. The fate of this effort will become clear in the coming months.

Meanwhile, the Government of Punjab has also considered its own legislative and institutional reform to improve seed provision in the province, leveraging its capacity to amend the Seed Act of 1976 to the

[17] Section 22(G) of the Bill proposes that no application for registration of a GM variety will be accepted unless it is accompanied by (1) an affidavit that it does not contain a gene involving terminator technology and (2) a certificate from the National Biosafety Committee that the variety will have no adverse effect on the environment, human, animal, or plant life and health.

extent of its territorial jurisdiction. Several drafts have been prepared since 2010–2011 that substitute FSC&RD procedures with provincial ones. However, one proposal—the draft Punjab Seed Act, 2011—goes beyond this in several respects. First, the draft Act states quite clearly its intentions of supporting "the development of a vibrant seed industry in the province" and seeks to establish a Punjab Seed Council in which private individuals hold a majority over provincial officials (GoPb 2011). The draft Act also seeks to relieve most crops from varietal registration and shift them to a truth-in-labelling-based regulatory system. This will shift seed inspections to the sale point, thereby enabling a small field force to monitor seed quality throughout the province. The purpose is to mitigate the current imbalance between legal responsibility and institutional capacity of the seed regulator without recruiting an army of inspectors to police the seed sector. However, the draft has not made much headway, and remains in the official files of the Punjab Agriculture Department.

Another important piece of legislation currently pending with the federal government is the draft Plant Breeders Rights (PBR) Act. The first draft was prepared by FSC&RD in 1999, and several versions have appeared since then. One draft was presented to the Cabinet in 2007. This draft is based on the 1991 International Union for the Protection of New Varieties of Plants (UPOV) model law, which aims to create IPRs for development of new plant varieties and ensures that Pakistan is compliant with its international obligations under the agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS). Toward this end, the draft law proposes the creation of a Plant Breeders' Registry to be attached to the federal Ministry of Agriculture (and housed in FSC&RD). The Registry will perform several functions, such as registering new plant varieties, ensuring that the seed of registered varieties is available to farmers, documenting, and cataloguing. Any seed producer may apply to the Registrar for registration if the variety is novel and meets the DUS criteria. This will dispense with the VCU criteria and allow breeders to differentiate products by means other than utility. Since VCU criteria are already meaningless in practice due to routine breeder practice of artificial differentiation for the purposes of registration, the proposal will only convert the *de facto* into the *de jure*.

Housing of the PBR Registry has been a subject of turf war between FSC&RD and the newly created Intellectual Property Organization (IPO) of the federal government. The former's claim was based on its historical role since 1976, and the latter's claim emanated from its being a specialized agency to create and enforce IPRs. In 2007, the Cabinet decided to house the PBR Registry in IPO (DG FSC&RD 2008). This decision not only denied FSC&RD an opportunity to extend its portfolio, but also required it to redefine itself as a mere seed certification agency. The draft legislation is still pending with the government. FSC&RD still has an interest in the PBR Registry as a means of extending its control over the seed system. IPO is also promoting the legislation; however, being a new entrant to the regulatory

framework, IPO may require some time to develop the necessary networks to push the legislation through the Cabinet and the Parliament. Pakistani seed companies are generally supportive of the legislation, but are skeptical of the government's willingness and ability to effectively enforce PBRs, and possibly torn between their desire to protect their germplasm through PBRs and their desire to use others' germplasm in their breeding programs. MNCs have an interest in a stronger IPR regime, but their influence has been thus far constrained by their small numbers and limited field operations in Pakistan.

The above discussion of Seed Act amendments and PBRs exemplify how progress on legal reform is the subject of conflicting interests and contested claims between and among seed system actors, and is characterized by tensions between archaic regulation and entrepreneurs in a growing market. These conflicts and tensions have created a situation where 4/5th of market operations occur in a contested space between the formal and the informal. Clearly, reform of the seed sector governance framework is long overdue. Given the demonstrated capacity of various actors to stall reform, any meaningful effort for the same must involve identification of key actors, their interests, and how they are served or affected by existing and proposed legal and institutional arrangements.

Formalizing the informal

The key message from the above discussion is that the legal and institutional structure for cultivar improvement and seed provision in Pakistan is inadequate and internally inconsistent. Developed four decades ago to support a state-led provision of seed, it has long exhausted its potential to foster the growth of Pakistan's seed industry. The need to reform the legal and institutional regime is clear, but there are deep divisions on how to move forward toward this end. Various actors—the seed business, scientists, and regulators—deploy their professional networks to steer the reform process in their favor. This lack of internal agreement has hampered efforts to rewrite the regulations to suit needs of a growing and competitive market.

A key question posed by the above discussion is regarding the realistic objective of seed legislation in a dynamic, growing and loosely monitored seed system. Should the objective be to strengthen government control and oversight on seed operations, or should it be to facilitate the private sector and to cede more space to its operations? These objectives are not mutually exclusive, but they suggest different focus in each case and reflect different theoretical positions in the age-old state-vs-market debate. Since the overarching goal is to provide quality seed to the farmer, Punjab Government's proposed truth-in-labeling regime seems to offer a middle ground, as it seeks to regulate the market in a manner that farmers can make informed choices.

Several policy recommendations emerge from the discussion in this paper. Importantly, there is a strong and urgent case for redesigning the regulatory framework. The framework should be redesigned in a manner that farmers are able to choose seed that best suit their site-specific agro-climatic conditions. This will require the state to redefine its role from an entity that certifies, approves, registers, and licenses to an entity that defines benchmarks, enables accreditation services, and ensures compliance with benchmarks. The draft Punjab Seed Act, 2011 may be a good starting point to move forward in this direction. Its proposal to establish a private-sector-led, independent regulatory authority and to deal with scheduled and other crops differently merits consideration.

Additionally, variety release procedures should be simplified and made more transparent. In the current milieu, breeders find these procedures time consuming and unwarranted. They are also reluctant to submit their seed to institutes for evaluation because the two compete in the market with similar products. Ideally, variety registration should be voluntary—any breeder claiming to have a marketable cultivar meeting required standards should be able to enter the market directly without recourse to the regulator. But even if an approval regime must be put in place for commercially important crops, it should aim at formalizing, rather than penalizing, the informal sector.

Related to this is the need to re-evaluate the role of seed certification. Given that seed certification has become largely irrelevant—as much for the lax implementation regime as for farmers' reliance on their judgment, rather than a tag issued by an official displayed on the seed bag—it should be replaced with a truth-in-labelling regime. This will strengthen regulation by making it reflect current seed business practices. It is practically impossible for a 434-strong FSC&RD to inspect seed production fields of 759 companies and countless farmers, breeders and agri-input dealers producing 1.6 million metric tons of seed annually. A meaningful job at field-based inspections will require maintaining an army of seed inspectors with prohibitive costs. In comparison, the number of company sale points and agri-input dealers providing seed to above two-thirds of farmers (Table 8) is much smaller. Enforcement of standards at these outlets will be far easier for FSC&RD than is the case presently.

Finally, there is the need to position the farmer at the center of policy debates. Currently, farmers are almost entirely absent from the discourse. They appear to be the passive recipients of development within the seed industry. Farmers' lack of representation in important policy forums, such as the national and provincial seed councils or in the proposed PBR Registry, confirms that they play a limited role in setting agendas, determining priorities, and monitoring seed quality.

Putting the farmer first will reorient policy analyses to the informal sector. Rather than investing in collecting and analyzing data on provision of certified seed, which constitutes only 20 percent of the total

seed requirement, investing in understanding the dynamics of the use and provision of uncertified seed will yield more productive results. Determining how seed providers compete on seed quality in a market with an unusually large number of providers will be instructive. It will also be useful to explore ways to support farmers in saving their seed, which will continue to be an important source of seed for most crops in coming decades.

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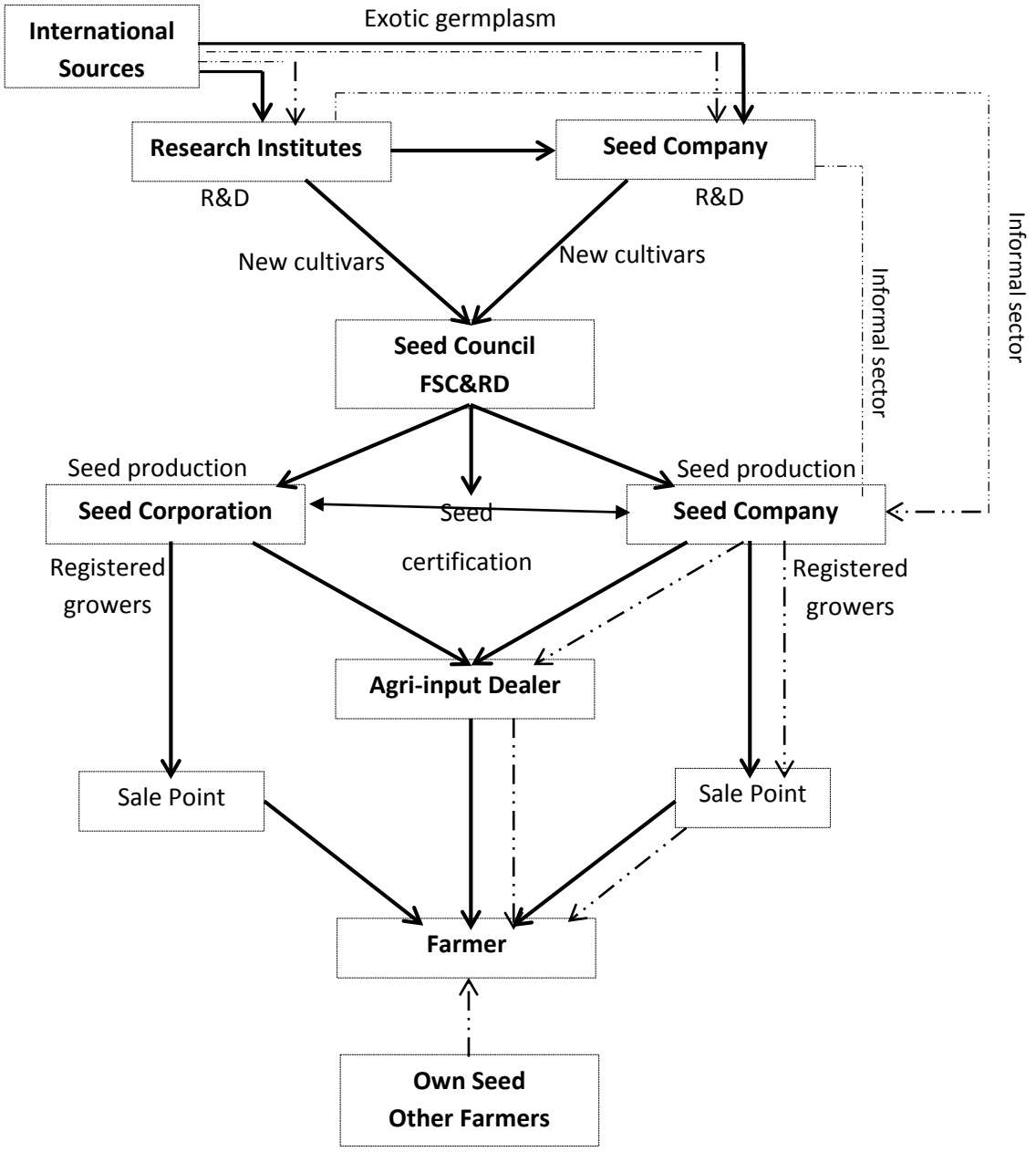
Figure 1: Flow diagram of seed provision in the formal and the informal sectors



Source: Authors
Note: dotted line shows informal sector operations.

Table 1: Institute shares in variety release (cumulative up till June 2013)

Institute	Share of all varietal releases (%)
Ayub Agricultural Research Institute (AARI)	39
Pakistan Agricultural Research Council (PARC)	2
Pakistan Atomic Energy Commission (PAEC)	8
Central Cotton Research Institute (CCRI)	9
Agricultural Research Institute (ARI)	13
Others	29
Total	**100**

Source: Authors, based on FSC&RD data.

Table 2: Number of new cultivars registered with FSC&RD (cumulative up till June 2013)

Crop	Public sector[a]					Private sector	Total
	Punjab	Sindh	KPK	Balochistan	Islamabad		
Wheat	59	24	40	8	3	–	**134**
Cotton	74	21	1	–	–	13	**109**
Pulses	43	4	19	1	5	–	**72**
Oilseed	20	5	22	–	8	5	**60**
Vegetables	36	1	12	8	–	–	**57**
Sugarcane	14	8	16	–	–	1	**39**
Fodder	27	–	7	1	–	2	**37**
Rice	16	13	06	–	–	–	**35**
Fruits	2	–	33	–	–	–	**35**
Maize	11	–	12	–	–	2	**25**
Barley	3	–	3	4	–		**10**
Total	**305**	**76**	**171**	**22**	**16**	**23**	**613**

Source: Authors, based on FSC&RD data.
Notes: [a] As per the geographic location of the research institute that developed these varieties.

Table 3: Release of varieties and hybrids (1933–2013)

Crop	Pre-1970	1970–1979	1980–1989	1990–1999	2000–2009	2010–2013	Total
Wheat	0	13	20	35	44	22	**134**
Cotton	2	9	11	28	32	27	**109**
Pulses	0	0	8	26	32	6	**72**
Oilseed	0	0	8	31	15	6	**60**
Vegetables	3	2	2	30	15	5	**57**
Sugarcane	0	0	3	15	15	6	**39**
Fodder and forage	0	0	10	6	14	7	**37**
Rice	5	3	10	8	8	1	**35**
Fruit	0	0	0	7	20	8	**35**
Maize	0	5	2	9	5	4	**25**
Barley	0	0	3	3	2	2	**10**
Total	**10**	**32**	**77**	**198**	**202**	**94**	**613**

Source: Authors, based on FSC&RD data.

Table 4.4: Number of seed producers registered with FSC&RD, 1981-2012

Type of company	Punjab	Sindh	KPK	GB and Ibd	Baloch-istan	Total
Public sector	1	1	1	–	1	4
Private (national)	621	98	23	3	5	750
Private (multinational)	4	1	–	–	–	5
Total registered	626	100	24	3	6	759
Deregistered	182	23	5	–	3	213
Total	**808**	**123**	**29**	**3**	**9**	**972**

	Before 1991	1991-95	1996-2000	2001-05	2006-10	2011-12
No. of companies registered by period	6	56	229	257	312	103

Source: Authors, based on FSC&RD data.
Notes: "GB" denotes Gilgit Baltistan; "Ibd" denotes Islamabad.

Table 5: Availability of certified seed, 2012–2013

Crop	Total estimated seed requirement	Total certified seed availability	Certified seed produced domestically			Certified seed imported by the private sector[b]	Private sector production as a share of total produced domestically	Private sector imports as a share of total certified seed availability	Certified seed available as a share of estimated requirement
			Total	by the public sector	by the private sector				
	mt	mt	mt	mt	mt	mt	%	%	%
Wheat	1,085,400	259,904	259,904	72,112	187,792	–	72	0	28
Rice	42,480	49,492	45,767	5,068	40,699	3,725	82	8	116[a]
Maize	31,914	14,008	3,705	245	3,460	10,303	25	74	44
Cotton	40,000	4,630	4,630	801	3,829	–	83	0	12
Potato	372,725	4,621	63	34	29	4,558	0	99	1
Pulses	47,496	917	916	24	892	–	97	0	2
Oilseed	10,582	1,866	582	134	448	1,284	24	69	18
Vegetables	5,070	5,418	241	4	237	5,177	4	96	107 [a]
Fodder	40,138	21,279	26	12	14	21,253	0	100	53
Total	**1,675,804**	**362,137**	**315,834**	**78,434**	**237,400**	**46,300**	**--**	**--**	**--**

Source: Authors, based on FSC&RD data.

[a] This means that either total seed requirement for rice and vegetables is more than what FSC&RD estimates, or some of the certified seed remains unused.

[b] The public sector does not import seed, such that all seed imports are conducted by the private sector.

Table 6: Average price paid for seed (Rs.kg), by crop and province, 2012

	Mean (std. dev.) price of seed (Rs./kg)			
	Wheat n= 414	**Cotton n= 266**	**Maize n=54**	**Rice n= 259**
Punjab	37.4 (8.8)	236.2 (306.3)	276.6 (240.4)	108.1 (46.8)
Sindh	36.5 (7.9)	191.8 (126.3)	--	202.3 (271.4)
KPK	36.7 (6.7)	--	447.5 (414.4)	--

Source: Authors, based on data from IFPRI/IDS (2012).

Table 7: Certified seed availability for selected crops, 1996–2013

Years	**Wheat**			**Paddy**			**Maize**		
	Require-ment	**Avail-ability**	**%**	**Require-ment**	**Avail-ability**	**%**	**Require-ment**	**Avail-ability**	**%**
1995–96	1,005,180	78,929	8	30,265	1,848	6	18,774	1,854	10
1996–97	973,092	73,618	8	31,515	1,378	4	18,554	1,961	11
1997–98	1,002,552	78,544	8	32,442	2,047	6	18,652	1,498	8
1998–99	987,588	104,213	11	33,930	2,281	7	19,244	3,028	16
1999–00	1,015,560	106,379	10	35,216	3,845	11	19,234	2,564	13
2000–01	981,708	159,220	16	33,272	2,106	6	18,882	2,119	11
2001–02	966,900	134,954	14	29,599	3,541	12	18,832	2,636	14
2002–03	964,068	120,610	13	31,153	4,678	15	18,710	4,040	22
2003–04	985,944	135,499	14	34,448	7,547	22	18,942	5,321	28
2004–05	1,002,960	173,557	17	35,274	9,840	28	19,456	8,867	46
2005–06	1,013,748	166,627	16	36,700	12,157	33	20,840	9,063	43
2006–07	1,029,384	203,837	20	36,137	10,727	30	20,338	8,647	43
2007–08	1,025,976	188,879	18	35,216	11,474	33	21,034	9,951	47
2008–09	1,085,520	196,029	18	41,476	22,688	55	21,042	12,380	59
2009–10	1,095,792	284,344	26	40,363	22,253	57	18,702	9,785	33
2010–11	1,085,400	319,023	29	42,480	28,895	68	31,914	9,041	28
2011–12	1,085,400	259,904	24	42,480	34,528	81	31,914	12,550	39
2012–13	1,085,400	259,904	24	42,480	49,492	116	31,914	14,008	44

Sources: Salam (2012) and data from FSC&RD.

Table 8: Source of purchased seed, by crop, 2012

Source	**Wheat (%) n= 414**	**Cotton (%) n= 266**	**Maize (%) n= 54**	**Rice (%) n= 261**
Punjab Seed Corporation	2	3	0	0
Agriculture extension department	2	0	7	0
Research institute	1	1	3	0
Private seed company	33	28	46	24
Input dealer	38	55	27	32
Landlord	12	7	0	35
NGO/ Relief agency	2	0	11	0
Cooperative society	0	0	0	1
Friend/relative/neighbor	11	6	6	7

Source: Authors, based on data from IFPRI/IDS (2012).
Note: Figures may not add to 100 percent due to rounding.

Appendix A

Seed price and its determinants, Pakistan Rural Household Panel Survey, Round 1.5

Farmers who cultivate major field crops either purchase their seed or use seed saved from the previous season.[18] Data from the RHPS sample indicate that approximately 70 percent of rice-growing households, 81 percent of cotton-growing households, and 49 percent of wheat-growing households purchased seed in the sample. Moreover, these data indicate significant variation in the price paid for seed by sampled farmers, particularly, in the case of rice and cotton varieties.

In this appendix, we estimate determinants of this price using a two-step selection model based on Heckman (1976, 1979) using crop-specific data from RHPS Round 1.5. The model specification addresses the issue of a dependent variable (seed price) that is observable only for a restricted, nonrandom sample (farmers who purchase seed) and is not observed for a separate nonrandom sample (those who do not purchase seed). The model assumes and underlying relationship exists an underlying regression relationship,

$$p_i = \beta X_i + u_{mi} \quad (1)$$

where p_i denotes the price paid for seed by the i^{th} farmer as a function of some vector of explanatory variables (X_i) and a normally distributed, mean-zero random disturbance (u_{mi}). However, because the price paid for seed is not observed where farmers save (rather than purchase) seed, then the dependent variable is only observed for

$$z_{iy} + u_{ri} > 0 \quad (2)$$

where z_{iy} is an indicator variable denoting the farmer's decision to purchase ($z_{iy}=1$) rather than save ($z_{iy}=0$) seed, and where and u_{ri} is a mean-zero random disturbance that is joint-normally distributed with u_{mi}. Estimation of this model provides consistent, asymptotically efficient estimates for all parameters.

This estimation model is employed here for wheat, rice, and cotton for which variety-specific data are available in the RHPS data. Note that we exclude maize from these estimations because variety-specific data are not available in the RHPS data.

Crop-specific summary statistics are given in Tables A1-A3 below. The key variable that we expect to be associated with seed prices paid by farmers is crop variety, which is a proxy for genetic characteristics

[18] A mixed strategy of cultivating crops with both purchased and saved seed is uncommon in the RHPS sample. Of the 679 households cultivating wheat in the sample, only 3 households (0.4 percent) used both purchased and saved wheat seed. Of the 292 households cultivating cotton in the sample, only 7 households (2.4 percent) used both purchased and saved cotton seed for cultivation. No households used a mixed strategy in rice cultivation.

such as yield potential, duration, resistance to pests and diseases, and consumption qualities. To capture the relationship between variety and seed price, we include the most popular varieties for each crop[19] as dummy variables, and combine all remaining varieties due to the small number of observations available across a large number of relatively less popular or obscure varieties.

An additional variable of interest is contact with an extension agent, which may capture the extent to which extension agents facilitate farmers' access to seed at some price above or below what the market may otherwise offer. For example, if the genetic or physical qualities of the variety are correlated with the price of seed, then farmers may choose to purchase expensive seed base on a recommendation from an extension agent. Alternatively, it may be the case that access to subsidized seed, low-cost seed starter packs, or new varietal releases that are freely distributed is contingent on the recommendation of an extension agent.

Additional variables included in the estimation conducted here are fairly standard in technology adoption studies (Feder et al. 1985; Jack 2011). For example, we include age and educational status of the head of household as a proxy for experience in farming; landholding size to capture household wealth; land tenure arrangement, which is divided between direct ownership and other arrangements, namely renting in, sharecropping in, or mortgaging in the land; and household income, which is captured by total monthly expenditure on food and non-food items. Provincial controls are also included to capture province-specific differences associated with seed market performance or provincial policy regimes.

[19] For wheat, we include the top five varieties, whereas for rice and cotton, we include the top four varieties due to collinearity in price between several top varieties.

Table A1: Summary statistics for wheat-growing households

Variable	Obs.	Unit	Mean	S.D.
Seed price	413	Rs./kg	37.37	8.06
Top wheat varieties				
Seher-06	863	1/0	0.44	0.50
Bhakhar-02	863	1/0	0.12	0.32
Abdul Sattar	863	1/0	0.10	0.31
Inquilab-91	863	1/0	0.06	0.24
Watan-93	863	1/0	0.07	0.26
Province dummies				
Punjab	863	1/0	0.63	0.48
Sindh	863	1/0	0.18	0.38
KPK	863	1/0	0.20	0.40
Plot characteristics				
Landholding size	863	acres	19.90	28.42
Farmer characteristics				
Age of farmer	863	years	47.74	13.14
Tenure status of plot				
Tenure status = owned	863	1/0	0.66	0.47
Tenure status = rented in/sharecropped/mortgaged	863	1/0	0.34	0.47
Household characteristics				
Household head attended school	863	1/0	0.57	0.50
Household member met with an extension agent in the previous year	863	1/0	0.21	0.41
Household size	863	No.	7.00	3.22
Total monthly expenditure	863	Rs./month	20,691	10,178

Source: Authors using RHPS 1.5, plot-crop level data (2012).

Table A2: Summary statistics for cotton-growing households

Variable	Obs.	Unit	Mean	S.D.
Seed price	263	Rs./kg	251.74	351.04
Top cotton varieties				
MNH-886	329	1/0	0.35	0.48
Ali Akbar-703	329	1/0	0.05	0.21
Ali Akbar-802	329	1/0	0.06	0.24
B-821	329	1/0	0.06	0.24
Province dummies				
Punjab	329	1/0	0.87	0.34
Sindh	329	1/0	0.13	0.34
KPK	329	1/0	0	0
Plot characteristics				
Landholding size	329	acres	27.11	30.24
Farmer characteristics				
Age of farmer	329	years	49.2	13.0
Tenure status of plot				
Tenure status = owned	329	1/0	0.62	0.49
Tenure status = rented in/sharecropped/mortgaged	329	1/0	0.38	0.49
Household characteristics				
Household head attended school	329	1/0	0.56	0.50
Household member met with an extension agent in the previous year	329	1/0	0.32	0.47
Household size	329	No.	7.24	3.71
Total monthly expenditure	329	Rs./month	20,808	12,516

Source: Authors using RHPS 1.5, plot-crop level data (2012).

Table A3: Summary statistics for rice-growing households

Variable	Obs.	Unit	Mean	S.D.
Seed price	260	Rs./kg	214.35	280.81
Top rice varieties				
Basmati Kernal	373	1/0	0.07	0.26
Basmati Super	373	1/0	0.13	0.34
KS-282	373	1/0	0.08	0.28
Irri-6	373	1/0	0.47	0.50
Province dummies				
Punjab	373	1/0	0.28	0.45
Sindh	373	1/0	0.71	0.45
KPK	373	1/0	0.01	0.07
Plot characteristics				
Landholding size	373	acres	13.93	15.74
Farmer characteristics				
Age of farmer	373	years	43.13	13.00
Tenure status of plot				
Tenure status = owned	373	1/0	0.50	0.50
Tenure status = rented in/sharecropped/mortgaged	373	1/0	0.50	0.50
Household characteristics				
Household head attended school	373	1/0	0.41	0.49
Household member met with an extension agent in the previous year	373	1/0	0.31	0.47
Household size	373	No.	6.25	2.81
Total monthly expenditure	373	Rs./month	17,131	8,302

Source: Authors using RHPS 1.5, plot-crop level data (2012).

Column 1 in Tables A4-A6 provides results from an ordinary least squares (OLS) estimation of seed price determinants with provincial fixed effects. These results are included for comparison against the Heckman selection model results in Column 3 of the same tables. But before exploring these results, first consider the seed-purchasing decision, or the correlates of whether a farmer purchased, rather, than saved, seed in the RHPS data. Column 2 in Tables A4-A6 provides probit estimation results from the first-step selection equation. We report here the marginal effects, or the probability that the decision to purchase (rather than save) seed is conditioned on the variables of interest. Results indicate that estimated coefficients of variables such as age, tenancy status, and income are statistically significant and therefore associated with the decision to purchase (rather than save) seed. This indicates a systematic difference between farmers who purchase seed and those who save seed, further suggesting the presence of sample selection bias. To address the presence of such bias, we construct and include an Inverse Mills Ratio in the second-step ordinary least squares (OLS) regression and estimate its coefficient (λ).

Estimation results from the selection equation (Column 2 in each table) also indicate that a majority of the estimated coefficients for top-variety dummy variables are statistically significant and positive for all three crops. This indicates that farmers who cultivate top varieties are more likely to purchase seed when compared to all other farmers. For example, we observe that farmers who cultivates Seher-06 wheat are 17 percent more likely to purchase seed as compared to farmers who cultivate any other wheat variety. Similarly, farmers who cultivate MNH-886 cotton are 8 percent more likely to purchase seed when compared to farmers cultivating other varieties. Results also indicate that farmers who own their land are less likely to purchase seed than farmers who rent in, sharecrop in, or mortgage their land for all three crops. Relatedly, farmers with larger landholdings are less likely to purchase seed, but only in the case of wheat and not cotton or rice.

Column 3 in Tables A4-A6 provide OLS estimation results from the second-step equation on seed price correlates. First, we observe that the seed price paid by farmers is generally higher for the top varieties. For example, we see that among farmers who purchased wheat seed, those who purchased Abdul Sattar and Inquilab 91 varieties paid a slightly higher seed price on average as compared to all other wheat varieties. Similarly, the price paid by cotton farmers cultivating MNH-886 farmer was Rs. 56.23/kg higher than the price paid for other cotton varieties, while cotton farmers cultivating Ali Akbar-703 paid Rs. 104.9/kg more. Only in the case of rice do we observe that the seed price paid by farmers for the top varieties being generally lower than all other varieties. This may warrant further exploration of the rice seed market structure and dynamics.

Second, we observe that contact with an extension agent is significantly associated with seed prices paid by farmers. For wheat farmers who met with an extension agent in the previous cropping year the price paid for seed was Rs.2.6/kg greater than the price paid by farmers who had no contact with an extension agent. Similarly, cotton farmers who met with an extension agent paid Rs.18.9 more per kg as compared to farmers who had no contact with extension. Again, the case of rice yields contrary results: on average, farmers who had contact with an extension agent paid Rs. 274.6 less per kg in comparison to those farmers who had no contact with an extension agent. From a policy perspective, this suggest a relationship between lower-cost seed and extension access in Pakistan's rice market that is worth studying further.

Second, we observe that provincial determinants of price variation is insignificant in the case of wheat, but significant in the case of rice, with seed prices being lower in Punjab than Sindh.[20] This may reflect

[20] Provincial fixed effects could not be estimated for cotton because (1) all cotton farmers in Sindh purchased seed; and (2) the variety FH-901 (the fifth most popular purchased variety of cotton in the sample) was only found in Sindh, with seed for FH-901 having been entirely purchased in Sindh. Hence, we exclude province and FH-901

the crop-specific nature of seed marketing channels, differences in the extent of seed market development in individual provinces, and the crop- and province-specific role of the public and private sectors in the distribution of seed. These issues are explored in greater depth throughout the paper.

Finally, note that the results using the Heckman selection model improve on the biased OLS estimates presented in Column 1 of the same table. A comparison of Columns (1) and (3) shows that the estimated coefficient on the top five varieties, particularly for several rice and cotton varieties, changes significantly with use of the Heckman selection model. For example, we observe that the coefficient on the cotton variety MNH-886 drops to 56.23 from 92.83 in the seed price regression, implying that due to the selection bias in the uncorrected model, the correlation between price and MNH-886 may have been exaggerated. For wheat, however, the results remain somewhat consistent between the two models.

dummies from the estimation model for cotton. Similarly, for rice, the second most popular variety, "Pukhraj," was entirely purchased in all provinces, while the small number of observations in KPK had all saved seed.

Table A4: Correlates of price paid by farmers for wheat seed: OLS and Heckman selection model estimations

Dependent variable=Price of wheat seed	OLS estimation	Heckman estimation	
	(1)	(2)	(3)
Explanatory variables	Seed price (Rs./kg)	Purchased (0/1)	Seed price (Rs./kg)
Seher-06	0.92	0.17***	0.68
	(1.39)	(0.06)	(1.63)
Bhakhar-02	1.45	0.31***	1.03
	(1.41)	(0.05)	(2.04)
Abdul Sattar	3.69**	0.25***	3.36*
	(1.46)	(0.06)	(1.87)
INQILAB 91	4.96***	0.23***	4.64**
	(1.86)	(0.08)	(2.19)
Watan-93	1.50	0.20***	1.20
	(1.64)	(0.08)	(1.95)
Punjab	-0.73	-0.13**	-0.45
	(1.12)	(0.05)	(1.47)
Sindh	-0.54	0.33***	-0.94
	(1.11)	(0.06)	(1.77)
Landholding	-0.01	-0.00**	-0.00
	(0.01)	(0.00)	(0.02)
Met with an extension agent	2.50*	-0.06	2.57*
	(1.40)	(0.05)	(1.40)
Has household head ever attended school?		0.02	
		(0.04)	
Age (years)		-0.004**	
		(0.00)	
Tenancy status=owned (baseline=rented in/ sharecropped in/ mortgaged)		-0.08*	
		(0.04)	
Household size		-0.01	
		(0.01)	
Total monthly expenditure		0.00***	
		0.00	
λ			-1.03
			(3.59)
Constant	36.04***		36.94***
	(1.28)		(3.40)
Observations	413	863	413
R-squared	0.04		0.04

Source: Authors. *Notes:* Robust standard errors are in parentheses. Column 1 reports marginal effects, while Column 2 reports OLS regression coefficients. Coefficient estimates are significant at the * 10 percent, ** 5 percent, and *** 1 percent levels, respectively.

Table A5: Correlates of price paid by farmers for cotton seed: OLS and Heckman selection model estimations

Dependent variable=Price of cotton seed	OLS estimation	Heckman estimation	
	(1)	(2)	(3)
Explanatory variables	Seed price (Rs./kg)	Purchased (0/1)	Seed price (Rs./kg)
MNH-886	92.83*	0.08*	56.23*
	(51.00)	(0.04)	(33.00)
Ali Akbar-703	190.4***	0.15***	104.90
	(28.72)	(0.05)	(67.89)
Ali Akbar-802	59.09*	0.10	-41.19
	(32.49)	(0.06)	(64.69)
B-821	41.62	0.15***	-67.26
	(34.97)	(0.05)	(96.31)
FH-901	96.89*		
	(55.47)		
Punjab (baseline=Sindh)	25.01		
	(25.15)		
Landholding	-0.01	-0.00	0.19
	(0.47)	(0.00)	(0.39)
Met with an extension agent	144.00**	-0.03	182.90*
	(69.50)	(0.05)	(93.73)
Has household head ever attended school?		-0.07	
		(0.05)	
Age (years)		-0.00	
		(0.00)	
Tenancy status=owned (baseline=rented in, sharecropped in, or mortgaged)		-0.13***	
		(0.05)	
Household size		-0.00	
		(0.01)	
Total monthly expenditure		0.00	
		0.00	
λ			-332.80
			(254.60)
Constant	130.3***		278.70***
	(18.73)		(88.82)
Observations	263	329	263
R-squared	0.06		0.08

Source: Authors. *Notes:* Robust standard errors are in parentheses. Coefficient estimates are significant at the * 10 percent, ** 5 percent, and *** 1 percent levels, respectively.

Table A6: Correlates of price paid by farmers for rice seed: OLS and Heckman selection model estimations

Dependent variable=Price of rice seed	OLS estimation	Heckman estimation	
	(1)	(2)	(1)
Explanatory variable	Seed price (Rs./kg)	Purchased (0/1)	Seed price (Rs./kg)
Basmati Kernal	-192.90**	0.24***	43.46
	(78.87)	(0.04)	(79.99)
Basmati Super	-227.00***	0.08	-154.30**
	(81.56)	(0.09)	(73.37)
KS-282	-521.60***	-0.06	-497.00***
	(48.22)	(0.17)	(36.01)
Irri-6	-534.20***	-0.32***	-583.90***
	(43.16)	(0.07)	(42.67)
Pukhraj	-98.37		
	(60.45)		
Punjab (baseline=Sindh)	250.80***	-0.61***	-464.40***
	(79.45)	(0.11)	(88.48)
Landholding	-0.14	0.00	1.71
	(0.98)	(0.00)	(1.09)
Met with an extension agent	-132.70***	-0.30***	-274.60***
	(31.79)	(0.06)	(41.40)
Has household head ever attended school?		0.07	
		(0.05)	
Age (years)		0.00	
		(0.00)	
Tenancy status=owned (baseline=rented in, sharecropped in, or mortgaged)		-0.13**	
		(0.05)	
Household size		0.01	
		(0.01)	
Total monthly expenditure		0.00*	
		(0.00)	
λ			289.40***
			(71.42)
Constant	623.2***		544.70***
	(43.41)		(33.19)
Observations	260	373	260
R-squared	0.60		0.62

Source: Authors. *Notes:* Robust standard errors are in parentheses. Coefficient estimates are significant at the * 10 percent, ** 5 percent, and *** 1 percent levels, respectively. All estimates are rounded off to the nearest two decimal places. See Footnote 3 for an explanation of why "Pukhraj" variety and KPK province are not included in the Heckman specification.

Appendix B

Table B1: Quantities of seed purchased, by crop, source and landholding size, cotton (n=266)

	Landholding size				
Source	**<=5 acres**	**5-12.5 acres**	**12.5-25 acres**	**25-50 acres**	**>50 acres**
Relative	5.7	-	-	-	-
Friend/Neighbor	6.4	7.8	5.0	-	-
Input dealer	7.1	6.4	6.7	6.3	-
Landlord	8.2	8.7	-	-	-
Research institute	-	5.0	-	-	-
Punjab Seed Corporation	6.8	6.3	6.4	-	7.0
Agriculture extension department	-	-	5.0	-	-
Private seed company	7.2	6.7	6.9	6.3	5.7
NGO/ Relief agency	-	-	-	-	-

Source: Authors, based on data from IFPRI/IDS (2012).
Note: Figures may not to 100 percent due to rounding.

Table B2: Quantities of seed purchased, by crop, source and landholding size, wheat (n=414)

	Landholding size				
Source	**<=5 acres**	**5-12.5 acres**	**12.5-25 acres**	**25-50 acres**	**>50 acres**
Relative	60.2	60.0	-	-	-
Friend/Neighbor	54.9	73.7	40.0	-	-
Input dealer	57.4	54.4	51.4	50.0	-
Landlord	67.8	72.0	66.7	-	-
Research institute	-	51.7	40	-	-
Punjab Seed Corporation	54.2	-	60.0	-	2.0
Agriculture extension department	56.3	66.7	64.2	-	-
Private seed company	58.1	53.8	50.2	52.2	-
NGO/ Relief agency	58.1	-	55.0	-	

Source: Authors, based on data from IFPRI/IDS (2012).
Note: Figures may not to 100 percent due to rounding.

Table B3: Quantities of seed purchased, by crop, source and landholding size, rice (n=261)

	Landholding size				
Source	**<=5 acres**	**5-12.5 acres**	**12.5-25 acres**	**25-50 acres**	**>50 acres**
Relative	40.0	10.7	-	-	-
Friend/Neighbor	8.0	6.2	-	-	-
Input dealer	5.3	5.0	4.0	-	-
Landlord	6.2	4.9	3.1	-	-
Research institute	-	-	-	-	-
Punjab Seed Corporation	6.3	3.3	-	-	-
Agriculture extension department	-	-	-	-	-
Private seed company	6.4	9.8	4.8	3.4	5.0
NGO/ Relief agency	-	-	-	-	-
Cooperative society	-	2.5	-	-	-

Source: Authors, based on data from IFPRI/IDS (2012).
Note: Figures may not to 100 percent due to rounding.

Table B4, Table B1: Quantities of seed purchased, by crop, source and landholding size, maize (n=54)

	Landholding size				
Source	**<=5 acres**	**5-12.5 acres**	**12.5-25 acres**	**25-50 acres**	**>50 acres**
Relative	-	-	-	-	-
Friend/Neighbor	16.9	-	40.0	-	-
Input dealer	23.8	22.7	18.0	-	-
Landlord	-	-	-	-	-
Research institute	10.7	14.0	-	-	-
Punjab Seed Corporation	-	-	-	-	-
Agriculture extension department	26.0	-	-	-	-
Private seed company	17.8	16.9	25.0	20.5	-
NGO/ Relief agency	17.0	-	16.0	-	-

Source: Authors, based on data from IFPRI/IDS (2012).
Note: Figures may not to 100 percent due to rounding.