ReSAKSS asia
FACILITATED BY IFPRI

WORKING PAPER 02 | NOVEMBER 2014

Seed Industry Analysis in Asia

TOWARD BETTER METRICS AND POLICYMAKING

DAVID J. SPIELMAN AND ADAM KENNEDY

INTRODUCTION

Our ability to select desirable biological characteristics of plants through applications of modern science creates remarkable abundance in agriculture and is also the uncomplicated reason why many governments in industrialized and developing countries have historically invested in improving cultivated crop varieties ("cultivars") through applications of modern science. When combined with other modern inputs and good crop management practices, improved cultivars can enhance crop yields significantly and subsequently drive agricultural productivity growth (Evenson and Gollin 2003; Rosegrant and Hazell 2000; Rosegrant and Evenson 1992). Public investments in cultivar improvement have also yielded high rates of return (Renkow and Byerlee 2010; Raitzer and Kelley 2008; Alston et al. 2000; Fan and Pardey 1997). In turn, the resulting productivity growth has also contributed to broader agricultural development and poverty reduction efforts among both small-scale, resource-poor farmers and food-insecure consumers in developing countries (Adato and Meinzen-Dick 2007; Hazell and Haddad 2001; Fan 2000; Fan et al. 2000).

While cultivar improvement is not the only element in a far-sighted agricultural development strategy, it is often presented as an "easy win"—easily packaged, easily measurable, and directly attributable interventions that many developing countries can readily pursue. Thus, governments, donors, international research centers, and non-governmental organizations throughout the developing world often prioritize the promotion of discrete, scale-neutral packages of improved cultivars and inorganic fertilizers that can be integrated into existing crop management practices.

However, the reality underlying these packages is far more complicated. There is significant complexity in building and maintaining a system that continuously supplies improved cultivars to resource-poor, small-scale farmers across diverse agroecologies and fragmented markets. A modern seed system requires long-term investments in science—plant breeding, agronomy, biology, and genetics—as well as in industrial systems for seed production and distribution that supply affordable quantities of high-quality seed of improved cultivars to farmers who often have limited access to competitive markets. Policy decisions on how to build a modern seed industry—the science and business of a seed system—must balance a complex set of societal and economic tradeoffs. This includes allocating appropriate roles for the public and private sectors in the industry, defining optimal levels of regulation, and distributing the gains from innovation across different industry actors. As a country's seed industry grows in size and value, these tradeoffs become increasingly important to all industry actors: Plant breeders, entrepreneurs, seed companies, public research organizations, regulators, state extension services, farmers' organizations, farmers, and consumers.

In recent years, some thought has been given to these tradeoffs in light of rapid changes in the fields of both technology and industry. These issues are raised in a series of studies on topics such as seed regulations (Tripp 2001; Tripp and Louwaars 1997), intellectual property rights (Kolady et al. 2012; Binenbaum et al. 2003), technology transfers (Spielman 2007; Byerlee and Fischer 2002), public versus private investment (Fuglie et al. 2011; Gerpacio 2003); and industry structure (Ramaswami 2002), among others. All point to the urgent need to rethink policies that influence seed industry growth and development.

But the introduction, amendment, or reform of policies governing seed industry development have been slow to emerge in many countries, resulting in significant cross-country variation. Part of this variation may simply relate to the possibility that policymakers are insufficiently informed about the tradeoffs they face when designing laws and regulations to govern seed industry development. As a result, their decisions—and the analytical inputs they rely on—tend to get bogged down on points of principle, rather than practical dimensions of seed industry development. Examples of principled perspectives include the following.

1. Sentimentality, or an unrealistic emphasis on the notion of self-sufficient farmers who rely solely on their abilities to, select, save, and use seed.
2. Transformation, or an exaggerated view of seed as a silver bullet and a critical pillar of an agricultural transformation or food security strategy.
3. Legality, or an excessive focus on the laws, regulations, organizational mandates, and legal systems governing cultivar improvement, seed production, and seed marketing without analysis of counterfactuals and consequences.
4. Financing, or the belief that massive increases of public funding for cultivar improvement and seed production will solve wider systemic problems.
5. Numbers, or an over-reliance on aggregated statistics that are necessary but insufficient indicators of seed system performance, e.g., estimates of seed demand, seed production indents and quantities, seed replacement rates, certified seed use, and cultivated area under improved seed use.

While all of these perspectives might be valid in a policy decision-making process, they tend to overlook the broad realities underlying seed industry development: growth in private investment in cultivar improvement and seed production and marketing; stagnation in the capacity and contribution of public research (Table 1); and innovation in both science and business. These realities require new and far-reaching rules and regulations to capture the future opportunities for growth, encourage industry-wide change, and effectively distribute the gains from innovation.

There are well-documented benefits to smallholders arising from rapid growth of the high-value segment of Asia's seed markets where firms with strong scientific and production capacity have specialized in hybrids and advanced technologies such as genetically modified field crops. This is illustrated by the growth of markets for hybrids of rice, maize, sorghum millet and cotton in certain Asian countries (Spielman et al. 2013; Pray and Nagarajan 2010; Li et al. 2010; Gerpacio 2003; Janaiah et al. 2002; Morris 1998). There are also signs of innovation in the low-value seed market segment which typically hosts production-based firms that handle seed for self-pollinating crops (wheat, rice) or asexually propagated crops (potato, cassava) and generally rely on improved cultivars from public breeding programs (Tripp and Pal 2001).

Still, many of these successes—and the realities underlying these successes—are being overlooked by public decision-makers throughout Asia. Old seed laws remain in place, tedious regulatory procedures remain unchanged, and weak incentives for entrepreneurs and investors persist. This suggests the need for a better approach to analyzing the structure and performance seed industries in developing countries. This paper attempts to do so, stimulated in part by a series of papers on seed systems and markets in 12 Asian countries prepared in 2013-2014 for the Regional Strategic Analysis and Knowledge Support Systems in Asia (ReSAKSS-Asia; see http://www.resakss-asia.org/). In Section II, we offer a conceptual framing of seed industry development. This is followed in Section III by an exploration of indicators designed to capture the essential dimensions of seed industry development. In Section IV, the paper discusses policy solutions for supporting seed industry development. Conclusions and areas for further research are offered in Section V.

Table 1—Public investment in agricultural R&D, selected countries and periods

Country	Period	Growth rate of: public expenditure on agricultural research	Growth rate of: public researchers (full-time equivalents)
Bangladesh	1990-2009	2.33	1.10
China	1990-2007	6.49	--
India	1996-2009	5.71	-1.38
Indonesia	1994-2003	-5.39	0.20
Malaysia	1990-2002	4.64	1.58
Myanmar	1996-2002	-5.08	3.33
Nepal	1996-2009	0.41	0.34
Pakistan	1991-2009	-0.40	0.12
Philippines	1991-2002	4.43	2.34
Sri Lanka	1990-2009	0.40	--
Viet Nam	1991-2002	19.07	4.21

Source: ASTI 2014.

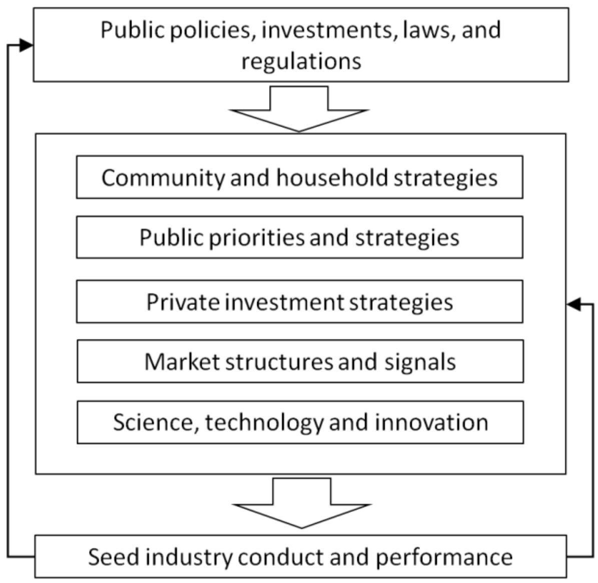
TOWARDS A BETTER ANALYSIS OF SEED INDUSTRY DEVELOPMENT

We present here a conceptual framework to help fix ideas around tradeoffs and policy options for addressing these tradeoffs. We begin with a schematic of a seed system which, in its simplest form, highlights the key elements of a modern industry (Figure 1). They are as follows.

1. Communities and households that decide on what types of cultivars to plant, from where to source their seeds, how much to pay, and how to manage risks associated with farming.
2. Public priorities and strategies that commit resources to the timely provision of quality seed of modern cultivars for these communities and households.
3. Private investment strategies in which firms and entrepreneurs decide what types of products to develop, produce and market to farmers.
4. Market structures and signals, which are the conditions that determine the prices at which firms sell seed—prices that are closely tied to the cost of complementary inputs such as inorganic fertilizer, and the price that the crop output receives in the market.
5. Science, technology and innovation, or the extent to which scientific discovery is translated into the practical application of plant breeding, biology, agronomy, and related disciplines.

Influencing all this are the public policies, investments, laws and regulations that (a) fulfill national priorities for agricultural development and equitable economic growth and (b) enable communities, households, and firms to participate in the development, production, distribution, and use of improved cultivars.

Figure 1—A simple schematic of a modern seed industry



Source: Authors.

In a modern seed industry, policymakers must decide how to manage seed as a critical input to national agricultural production and broader development goals. Governments invest in this industry through several channels. They may invest in research, specifically in plant breeding and related fields of agronomy, biology, and genetics. They may also invest in the production of seed—multiplying improved cultivars through state-owned enterprises. They may also invest in the promotion and popularization of new cultivars through rural extension and advisory services, through interventions such as seed distribution or seed subsidy programs, or through private retailing in competitive markets. They may also encourage a mix of strategies that distributes the roles and responsibilities for research, production, distribution, and marketing across the public and private sectors according to crop, geography, market segment, or other factors.

Government intervention in the seed industry is predicated on several arguments. The development practitioner's argument might point to persistent poverty and under-development as a straight-forward justification for government involvement. This argument is often compelling where farmers do not have enough information on seed attributes to protect themselves from fraudulent seed marketing practices, do not have the purchasing power needed to buy seed, cannot reach markets due to poor infrastructure, or are susceptible to shocks such as drought, flooding, price volatility, or conflict (see, e.g., Longley 2006; Sperling and Longley 2002; Longley et al. 2002). The argument also finds strong support among those who argue that seed represents the farmers' ownership of her means of production, and efforts to commercialize or commoditize seed and its embodied genetic traits necessarily disenfranchises and impoverishes the farmer. Extensive discussion around the political economy of seed industry development highlights many of these controversies (see, e.g., Kloppenberg 1998; FAC 2014).

The economist's argument might similarly suggest that persistent market failures justify government involvement in the seed industry. In this case, cultivar improvement by public research organizations makes sense where private innovators are unwilling to invest for several reasons. First, long-term, upstream research required to make cultivar improvement a viable business is beyond the profit-maximizing firm's time horizon. Second, such firms cannot make a viable business based on investments in cultivar improvement for open/self-pollinating or vegetatively propagated crops when farmers can save seed and replant it the next year, thus inhibiting the firm from appropriating a remunerative portion of the gains from innovation. Third, firms are unlikely to invest in cultivar improvement where markets do not exist, are costly to reach, or where prospective customers in these markets have limited purchasing power, for example, in remote, marginal agroecologies where crops are grown primarily for own-consumption.

Arguments made by private sector investors and entrepreneurs—by seed companies—are somewhat different. These actors often identify the absence of an *enabling business environment* to support seed industry development as a key area in need of strategic government involvement. This includes the legislation and enforcement of policies and regulations that encourage private investment in seed production and marketing, credit facilities for seed companies, tariff reductions for imported seed production equipment, or tax incentives for land used in seed production. Companies may also look to regulations—plant variety protection and other intellectual property rights—to protect their business from the theft of the research embodied in their improved cultivars, or regulations designed to encourage investments in the safe and effective application of advanced biotechnology.

Companies may choose a number of strategies in entering the seed market. To better understand the types of firms that enter the market, we suggest a simple typology of firms, as follows. *Production-based firms* are firms that tend to specialize in production, packaging, and distribution but do not invest heavily in research. Their role is typically associated with the multiplication and distribution of seed derived from cultivars that have been released through public breeding programs, although some may also multiply and distribute their own proprietary cultivars. Marketing may be done by the firm itself or through popularization efforts undertaken by public research and extension systems. Production-based firms include state-owned enterprises, cooperatives, and private firms. *Technology-based firms* are firms that integrate research—whether conventional plant breeding or advanced biotechnology—with seed production and marketing. These firms tend to develop their own proprietary cultivars and hybrids and market through their own distribution networks. While the leading multinational firms such as Bayer CropScience, Monsanto, Pioneer, and Syngenta are often most closely associated with this category of firms, there are many smaller domestic firms in developing countries that similarly operate integrated breeding and marketing operations.

For both types of firms to operate in a competitive seed market, some degree of government involvement is required. Necessarily, long-term government involvement in the seed market also presents tradeoffs for society and economy. Public breeding programs may not develop effective links with private seed producers. Seed regulations meant to protect farmers can also inhibit private investment and innovation. Seed production by state-owned firms can weigh heavily on government budgets and allocate scarce government funds away from other important public investments such as agricultural research or rural roads or schools or clinics.

Ultimately, governments shoulder the responsibility of designing policies, enacting laws and imposing regulations that ensure that seed markets act in an efficient and equitable manner. These policies, laws, and regulations can be grouped into four main categories:

1. Strategic oversight and policy implementation, where data, information, and analyses are used for strategic decision-making;
2. Research and development, where financial, scientific, physical, and human capital is allocated to cultivar improvement and crop management research;
3. Regulation, where quality standards, safety standards, testing and monitoring functions are carried out to ensure that farmers receive planting material of some acceptable level of use-value and quality; and
4. Production, distribution and marketing, or the market and non-market channels through which seed reaches farmers.

But to fully understand seed industry development, closer attention needs to be given to the decisions made by individual farmers and farm households. The farm-household prioritizes across a complex range of possibilities, i.e., maximizing yield or reducing production costs; maximizing income from farming and non-farming activities; conserving scarce soil nutrients, water, and biodiversity; or minimizing risk through farm diversification, off-farm unemployment, participation in social protection programs, and other plans. Implicit in these decisions are a set of tradeoffs that relate directly to the use of seed. For example, farmers might decide between saving seed from harvest for use for cultivation purposes in the next year, and purchasing seed from the market that is more costly but possibly better quality. Farmers might decide across a range of (sometimes mutually exclusive) traits they prefer, for example, higher yield, resistance to pests and diseases, or tolerance to climatic shocks such as extreme drought, flood, heat, or cold. Farmers must further decide on the portfolio of traits and cultivars, for example, planting a single cultivar that returns higher yields but is susceptible to specific pests, diseases, or climatic shocks versus cultivating many different cultivars with different yields and susceptibilities to minimize risk. These tradeoffs contextualize the decision process facing firms that seek to identify and invest in profitable opportunities in the seed market.

A starting point to improving the analysis of the seed industry in developing countries is to remove the basic assumption that farmers will always purchase seed of improved cultivars, or that farmers are passive recipients of government efforts to supply improved cultivars. Instead, consider the knowledgeable, informed farmer as having several, rather finite motives for why he might purchase seed, namely to:

1. obtain a better cultivar with superior genetic traits;
2. obtain better quality seed, assuming farmers cannot save seed without incurring significant costs and losses in saved seed viability or quality;
3. renew the availability of the genetic traits embodied in the cultivar, typically in the case of hybrids that lose their vigor when second-generation seed are saved; or
4. obtain seed when their own seed supplies and the supplies from their common sources have been destroyed or from some type of disaster.

With these motives in mind, a more accurate set of metrics can be developed to gauge the performance of an emerging seed industry and its contribution to a country's wider goals for growth and development.

BETTER METRICS FOR SEED INDUSTRY DEVELOPMENT

Conventional metrics used by policymakers to assess seed industry performance in many developing countries tend to be limited in terms of analytical value. Such metrics include quantity of seed produced, which is typically a crop-specific aggregate assembled from sector- or industry-level reports; estimated quantity of seed demanded, typically derived from crop-specific estimates of area under cultivation multiplied by recommended seeding rates; shortfalls and surpluses between estimated supply and demand (Table 2). But these highly aggregated metrics are rarely useful to policymakers. They lack insight into variety-level specifics of both supply and demand. They also tend to obscure the difference between seed replacement (improving the quality of inputs by purchasing fresh seed of either the same cultivar or a new cultivar) and varietal replacement (changing the genetic quality of an input by replacing seed of an older cultivar with seed of a new cultivar).

Table 2—Estimated seed demand and supply from various sources, selected countries

Country (year)	Crop	Estimated total seed demand (metric tons)	Production (metric tons)			Percentage of estimated total seed requirement		
			Public	Private	Informal[a]	Public	Private	Informal[a]
Bangladesh (2012)	Rice	319,500	181,428	6,392	131,680	56.8	2.0	41.2
	Wheat	55,700	39,840	0	15,860	71.5	0.0	28.5
	Maize	5,000	288	4,512	200	5.8	90.2	4.0
	Pulses	23,200	2,740	0	20,460	11.8	0.0	88.2
	Potato	600,000	19,606	28,214	552,180	3.3	4.7	92.0
	Vegetables	4,500	98	792	3,610	2.2	17.6	80.2
Pakistan (2012)	Wheat	1,085,400	72,112	187,792	552,180	6.6	17.3	50.9
	Rice	42,480	5,068	40,699	3,610	11.9	95.8	8.5
	Maize	31,914	245	3,460	28,209	0.8	10.8	88.4
	Cotton	40,000	801	3,829	35,370	2.0	9.6	88.4
	Potato	372,725	34	29	372,662	0.0	0.0	100.0
	Pulses	47,496	24	892	46,580	0.1	1.9	98.1
Thailand (2012)	Rice	1,009,230	245,000	300,000	455,000	24.3	29.7	45.1
	Maize	23,945	955	22,990	0	4.0	96.0	0.0
Vietnam (2008)	Inbred Rice	865,200	216,300		648,900			75.0
	Hybrid Rice	17,550	17,550		0			0.0
	Corn	21,358	19,200		2,158			10.1
	Peanut	50,920	20,370		30,550			60.0
	Soybean	19,010	11,470		7,540			39.7
	Cotton	164	160		4			2.4
	Vegetable	432	267		165			38.2

Source: Bangladesh: Naher and Spielman, 2014; Pakistan: Rana 2014; Thailand: Napasintuwong 2014; Vietnam: Nguyen Mau Dung 2014

[a] Informal includes seed purchased through informal markets, farmer-to-farmer exchanges, and farmer-saved seed.

Other commonly used metrics also fall short in capturing seed industry capacity. For example, seed replacement rates are commonly used to measure the proportion of seed that farmers purchase from the formal market rather than relying on saved or locally exchanged seed. They are typically based on aggregated national and sub-national data typically assembled from sector- or industry-level reporting. But at best, this metric indicates whether farmers purchase seed from the formal seed industry rather than save seed from their own harvest or exchange it with other farmers or informal sources of seed in local markets. But as a metric of industry performance, it fails on several fronts. First, it fails to identify either the quantity or quality of seed purchased by farmers to obtain better cultivars with superior genetic traits—a far more important metric of seed industry performance. Second, by simply measuring the purchase of seed of an unspecified quality of what may be cultivars of an unspecified age, it obfuscates any information on the seed industry's capacity to provide farmers with superior genetics or quality seed products. Third, it overlooks the distributional dimension of who actually purchases seed —what type of farmers in terms of land tenure, wealth, income, or geographic location. In short, policy and investment decisions taken to maximize seed replacement rates may be misinformed, potentially allocating scarce public resources for ambiguous ends.

Instead of relying on misleading metrics, we suggest a finite set of alternative metrics designed to help policymakers and other actors understand seed industry structure and performance and pursue policies and investments in support of industry growth. Our suggested metrics for seed industry performance aim to answer the question of whether the institutional architecture of a seed industry is efficient, effective, and dynamic enough to encourage more diverse provision strategies. To answer this question, better information is needed on seed industry structure, innovation, regulation, and performance. Specific metrics are detailed below.

SEED INDUSTRY PERFORMANCE

A basic set of indicators capturing seed industry performance should provide insight not only into volumes and values of the seed market, but also issues of seed quality and accessibility. Suggested metrics are as follows.

Seed sales and prices. Key metrics of volume and value are based on variety- and source-specific quantities of seed sold, areas under cultivation, and the prices at which seeds are sold. Such data need to be spatially disaggregated to provide any useful insights into seed industry performance, and further detail on farm size and social and economic characteristics of the farmer are also critical to analyzing the distributional outcomes of seed industry performance.

Seed quality. Advocates of commercial seed industry development often argue that farmer saved seed is inferior in quality to commercially purchased seed. Farmers are assumed to use poor selection, storage and preservation practices that lead to lower purity and germination rates when the seeds are used in cultivation. In fact, this assumption begs for empirical testing, and better metrics on seed quality for both commercial and farmer-saved seed would be useful in determining whether commercial seed (of a variety already being grown) actually benefits farmers. Simple seed quality assessments can be applied to ascertain such information, and as the costs of advanced diagnostics such as genetic fingerprinting come down, these more advanced tools might also be employed.

While both sets of indicators are maintained by government agencies and industry associations in some countries, there is a tendency to assemble data disaggregated by administrative region and, on occasion, farm or landholding size. Greater resolution on these indicators on a spatial and varietal level would provide more insight into decision-making around research priorities, public input provision programs, and incentives to encourage strategic investments. See DIIVA (2014) for an early attempt at assembling and analyzing higher resolution variety-specific data for Africa.

SEED INDUSTRY INNOVATION

Precise data on cultivar improvement activities are critical to understanding the level and rate of innovation in a given seed market. Suggested metrics are as follows.

Varietal releases and varietal age. A useful innovation indicator is the number of varieties/hybrids released, the year of release, and the quantities in which they are produced (Table 3). Public data are often attainable, although private seed enterprises are often reluctant to reveal sales data by variety. These figures can be used to construct a varietal age index for a given crop, in which the average age of cultivars in seed production (or cultivation) is calculated as the average age of varieties weighted by the quantity of production (or area under cultivation), with average age being inversely related to cultivar turnover and, implicitly, product innovation in the seed industry (see Smale et al. 2008; Brennan and Byerlee 1991).

Varietal adoption. Farm-level data from representative household surveys in which crop/plot-level data on varieties/hybrids under cultivation can provide an even more accurate snapshot of spatially disaggregated and socioeconomic patterns of adoption, although accurate responses are often constrained by poorly pre-coded lists of variety names for survey instruments or poor recall by farmers. Other methods such as expert opinion surveys and genetic fingerprinting of seed samples are also being explored currently. A similar indicator of varietal age index can be constructed from these data to proxy for product innovation in the seed industry.

Table 3—Varietal releases for selected crops, years and countries

Country	Crop	Years	No. of varieties released		Average no. of releases per year	
			Public	Private	Public	Private
Bangladesh	Inbred rice	1994-2012	40	3	2.1	0.2
	Hybrid rice	1994-2012	3	89	0.2	4.7
	Wheat	1994-2012	9		0.5	
	Potato	1994-2012	27		1.4	
	Sugarcane	1994-2012	14		0.7	
	Jute	1994-2012	8		0.4	
	Maize	1994-2011	19	98	1.0	5.2
	Vegetables	1994-2011	116	1064	6.1	56.0
	Pulses	1994-2011	50	4	2.6	0.2
Indonesia	Inbred rice	2006-2012	80		11.4	
	Hybrid rice	2006-2012	64		9.1	
	Maize, composite	2006-2012	8		1.1	
	Maize, hybrid	2006-2012	82		11.7	
	Soybean	2006-2012	11		1.6	
	Peanuts	2006-2012	6		0.9	
	Green beans	2006-2012	1		0.1	
	Cassava	2006-2012	1		0.1	
	Sweet potato	2006-2012	8		1.1	
	Sorghum	2006-2012	0		0.0	
	Wheat	2006-2012	0		0.0	
	Taro	2006-2012	1		0.1	
Pakistan	Wheat	1990-2013	101		4.2	
	Rice	1990-2013	17		0.7	
	Cotton	1990-2013	74	13	3.1	0.5
	Maize	1990-2013	16	2	0.7	0.1
	Sugarcane	1990-2013	35	1	1.5	0.04
	Vegetables	1990-2013	50		2.1	
	Barley	1990-2013	7		0.3	
	Fodder	1990-2013	25	2	1.0	0.1
	Oilseed	1990-2013	47	5	2.0	0.2
	Pulses	1990-2013	64		2.7	
	Fruit	1990-2013	35		1.5	

Table 4— Varietal releases for selected crops, years and countries, continued.

Country	Crop	Years	No. of varieties released		Average no. of releases per year	
			Public	Private	Public	Private
Philippines	Hybrid rice	2002-2011	18	23	1.8	2.3
Vietnam[a]	Rice	1977-2012	247		6.9	
	Maize	1977-2012	118		3.3	
	Potatoes	1977-2012	19		0.5	
	Soybean	1977-2012	39		1.1	
	Peanut	1977-2012	25		0.7	
	Tomatoes	1977-2012	26		0.7	
	Coffee	1977-2012	17		0.5	
	Sugarcane	1977-2012	14		0.4	
	Rubber	1977-2012	17		0.5	
	Tea	1977-2012	12		0.3	
	Cashew nut	1977-2012	10		0.3	
	Fruits	1977-2012	27		0.8	

Source: Bangladesh: Naher and Spielman, 2014; Indonesia: Jamal 2014; Pakistan: Rana 2014; Philippines: Sombilla and Quilloy; 2014; Vietnam: Nguyen Mau Dung 2014

[a] Figures for Vietnam are available on in aggregation for public and private sector releases.

SEED INDUSTRY STRUCTURE

Seed industry structures focus on that segment of the economy involving commercial entities engaged in the research, breeding, multiplication, and distribution of seed and other planting material. There is a division within the industry between what might be described as the downstream segment, where firms multiply and distribute seed, and the upstream segment, where firms work with advanced scientific tools and materials. The downstream segment often includes small- and medium-size enterprises facing relatively low capital requirements and operational costs in decentralized markets, while the upstream segment primarily includes multinational cropscience firms with high levels of scientific capacity and large global operations. Suggested metrics of seed industry structure include the following.

Formal versus informal seed sources. Estimated quantities and shares of seed that are purchased from formal versus informal sources (disaggregated by crop) provides a simple measure to gauge the size of the formal, commercial seed industry and its growth potential. This indicator provides a sense of market size and structure, for example, the amount of seed sold as formally packaged and labeled seed by retailers compared to seed saved directly by farmers or exchanged locally with other farmers or informal sellers.[1]

Public versus private seed producers. Another conventional metric is the estimated quantities and shares of seed that are purchased from public sources (parastatals/state-owned firms) versus private firms, disaggregated by crop. Within the latter category, farmers' organizations, cooperatives, community-based, and non-governmental organizations may constitute a further level of disaggregation. The indicator provides further information on market size and structure.

Market concentration. Two common indicators used to measure market concentration are the four-firm concentration (CR4) ratio and a Herfindahl-Hirschman index (HHI). The CR4 ratio measures the total market share held by the four largest firms in the industry. The HHI measures the size of firms in relation to the industry and is calculated as the sum of the squared market share of each firm in the industry. The HHI approaches zero when a market consists of a large number of firms of relatively equal size, and increases both as the number of firms in the market decreases and as the disparity in size between those firms increases. Because the HHI takes into account the relative size and distribution of the firms in a market, it is considered a more comprehensive and better indicator of concentration than the CR4 ratio (Rhoades 1995). When calculated on a crop-specific basis, these indicators may be used to measure concentration in downstream product markets using the value or volume of seed sales by firms in the seed industry. Or they may be used to measure concentration in upstream technology markets, for example, by measuring the number of field trials conducted by firms as a means of gauging market structure in the technology pipeline. While indicators from a single year can be useful to gauge concentration, trend data provide greater analytical insight (see, e.g., Fuglie et al. 2011; Fernandez-Cornejo 2004). An illustration of

[1] In some cases, a further level of disaggregation or analytical nuance is required, for instance, in the case of Pakistan where formal seed sources—registered seed companies—informally sell large quantities of unapproved genetically modified cotton varieties through their existing marketing channels (Rana 2014). This particular case clouds the line between formal and informal seed sources by highlighting a practice in which formal sources are responsible for supplying "informal" (i.e., unapproved transgenic) seed. While it is a rare practice, these issues are not uncommon in other countries where unapproved transgenic cultivars have entered markets through retail operations of known seed companies.

these measures is given in Table 5 for Nepal and Thailand, indicating fairly moderate concentrations in the rice seed market, particularly when compared to maize.

Table 5—Market concentration measures, Nepal (2012) and Thailand (2011)

Country	Herfindahl-Hirschman index (HHI) values (0-1)			Four-firm concentration (CR4) ratio (%)		
	Rice	Wheat	Maize	Rice	Wheat	Maize
Nepal	0.129	0.216	0.207	63.6	73.2	81.0
Thailand			0.170			76.0

Source: Authors, based on data for Nepal from Sah (2014) and Thailand from Napasintuwong (2014).

Seed distribution and marketing infrastructure. Another metric relates to the marketing end of the continuum and captures the mechanisms through which public and private entities actually distribute and market seed. For example, do they sell seed through their own retail shops, through independent retailers or stockists who operate on a commission basis, through state-run distribution warehouses, or through cooperatives and farmers organizations? Understanding the size and density of distribution networks helps understand market size and spatial distribution.

Seed market interventions and distortions. A key point of contestation in seed industry development is the extent to which private entrants to the market are able to compete with existing parastatal seed enterprises, and whether the public resources allocated to these enterprises confer an unfair advantage that distorts market competition. Such advantages are typically conferred via operational subsidies, tax breaks, or preferential access to improved germplasm from the public research system, well-endowed land for seed production, credit, credit guarantees, tariff exemptions and other essential factors of production. Other advantages may take the form of direct subsidy payment to farmers purchasing seed from parastatals, or indirect promotion of parastatal seed products by public extension services. In some countries, private firms may enjoy similar benefits, but in most cases, it would seem that private firms lack access to many of these advantages. However, careful accounting and descriptions of market interventions and distortions are rare in seed industry studies, and this weakens the evidence base on which discussions and decisions are made on seed market development and the optimal allocation of public resources.

SEED INDUSTRY REGULATION

Key indicators for seed industry analysis include the types of rules and regulations that govern the industry and the extent to which they encourage innovation and competition. We describe below the primary sets of regulations that require analysis.

Variety release and registration. All countries have some type of regulation regarding the varieties that may be offered for sale as seed. Often these rules focus on field crops but they sometimes extend to horticultural crops as well. In the past, the majority of field crop varieties were developed by the public research system, which imposed a set of rules governing variety release. As privately developed varieties of some crops have become increasingly available, countries have had to decide how to adjust variety release and registration requirements to accommodate this wider offering. The answers may range from a single testing and release system for all varieties to allowing private varieties to enter the seed market without any release requirements.

An analysis of the regulatory environment needs to describe the release and registration process and assess its performance. How efficient is the public release process; how much data and how many years of testing are required before a variety is released? If private varieties must go through the same process, are they treated on an equal basis with public varieties? Are imported private varieties on an equal footing? Are public varieties that have been released in other countries with similar ecologies offered a fast-track to release? The analysis should review the list of released or approved varieties and assess the rate at which new varieties are made available and statistics or estimates about the ages of the most widely used varieties.

To illustrate the importance of analyzing regulatory systems, consider the procedures found in the Asian countries highlighted in this study. While these countries shared a common set of procedures that revolved around value in cultivation and use (VCU) testing and distinctness, uniformity and stability (DUS) testing, there is significant variation in where the procedures are applied and the time involved. For example, whereas extensive VCU and DUS testing are required for all cultivars in most countries, Bangladesh does not require extensive testing for crops other than rice, wheat potato, jute, and sugarcane, or the strategically important “notified” crops that come under closer government scrutiny. And whereas Bangladesh and Vietnam have relatively short testing periods of just two to three years, countries such as Nepal can require a full five years of testing.

Seed quality and certification. Seed certification addresses the genetic identity of the seed while seed quality addresses physical attributes such as germination and purity, but these two separate issues are often described together and are usually the responsibility of a single agency. Certification includes examination of the documentary evidence regarding the source of the seed for the current seed crop, several inspections of the seed crop in the field, and sometimes grow-outs or laboratory analysis of harvested samples. Seed quality, on the other hand, is assessed with samples drawn at harvest, before bagging.

Seed quality control and certification address the fact that it is often difficult for farmers to assess the identity or quality of the seed they buy, but it is necessary to assess the extent to which a particular regulatory regime actually brings better quality seed to market and improves farmers' confidence. A competitive seed market may offer alternatives to formal certification and quality control, as companies are anxious to defend their reputations and may carry out inspections and controls that are more exacting than those of a state agency. It is also possible to share duties, and a government certification agency may accredit seed companies to carry out the majority of inspections while the agency retains an oversight role. Instead of mandatory certification seed may be sold under "truthful labelling" regulations, which require that the seed meets certain minimum standards (e.g. purity, germination) stated on the label. This may be a more viable alternative than mandatory certification but still requires competent oversight and enforcement.

Seed industry analysis should describe the quality control and certification procedures that are in place and, in cases of mandatory certification, assess whether public resources are sufficient for the agency to carry out the procedures mandated in the regulations. An inspection of agency records (e.g., proportion of rejected seed lots) or indeed the accessibility of such records provide indications of agency competence. Additional evidence on regulatory performance can be derived from conversations with seed companies about problems or advantages of the current system and examination of the level of complaints about inadequate seed in the market.

Consumer protection

Under any regulatory regime it is possible for errors or fraud to allow low quality seed to reach the market. One way to control this is for the regulatory agency to conduct frequent point-of-sale inspections. Although this is usually part of a seed regulatory agency's mandate it is worth analyzing how frequently it is done, the outcomes of such inspections, and how sanctions are applied. Specific measures such as the ratio of inspectors to the number retail outlets may also provide an indicator of the capacity of the regulatory agency to execute its mandate.

In addition, "truthful labeling" systems are predicated on the ability of a consumer to seek redress for low quality seed through mechanisms such as consumer courts. It is important to note if the legal system offers farmers this opportunity and if so, the frequency of complaints, the outcomes of such cases, and the penalties to offending seed providers and companies.

Plant Variety Protection (PVP)

All countries that are members of the World Trade Organization are required to offer intellectual property rights (IPRs) over plant varieties in a manner that is compliant with the agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS).

Such legislation allows plant breeders and seed companies to produce (or designate who can produce, e.g., through a licensing agreement) and sell seed of a variety for a specified period of time on an exclusive basis. National PVP systems may differ in several aspects such as the degree to which seed saving by farmers is permitted and the extent to which the variety may be used in other breeding programs (i.e., research exemptions). Most of these systems are relatively recent but it is worth assessing what, if any, impact they have had on the seed industry, whether they have provided any incentives for private plant breeding and seed production, the resources that are available for management and enforcement of the system, and whether there are any concerns about farmers' access to seed because of PVP.

Several Asian countries covered in this study have introduced legislation that protects plant breeders' rights through PVP and/or *sui generis* (stand alone) systems, are moving towards compliance with TRIPS, and have joined the International Union for the Protection of New Varieties of Plants (UPOV) as part of their commitment to plant breeders' rights (Table 6).

Table 6—UPOV membership, selected countries, 2014

Countries that are members of UPOV (year of joining)	Countries that have initiated the procedure for acceding to the UPOV Convention	Countries that have been in contact with UPOV for assistance in the development of laws
Kyrgyzstan (2000)	India	Cambodia
Vietnam (2006)	Tajikistan	Myanmar
	Philippines	Pakistan
		Thailand

Source: UPOV 2014.

Imports

International seed trade allows farmers broader access to good varieties. Many countries import considerable amounts of vegetable seed but there are also growing opportunities for the import of high-value seed of some field crops such as hybrid maize or rice. Seed industry analysis should include a description of the types and quantities of imported seed (and their sources); an assessment of any regulatory or legal barriers to seed import; and an examination of consumer protection mechanisms related to imported seed. Attention should also be given to any unsanctioned 'imports' such as seed trade across porous borders. If there is a private seed sector in the country it is worth examining if there are any import restrictions on equipment for seed conditioning.

Patents and biosafety. The capacity to provide seed of transgenic crops depends on the existence of appropriate IPR legislation as well as biosafety mechanisms. Seed industry analysis should describe the extent to which a country's patent laws and other IPR legislation allows firms to protect genes or gene sequences, tools and processes used in the development of transgenic crops. The analysis should also examine the status of biosafety legislation as well as the financial and technical capacity to enforce such legislation.

CHALLENGES FOR SEED INDUSTRY DEVELOPMENT

Strategy and priority setting. The first and most obvious issue for seed industry development is the need for better quality and more accessible data, information and analysis. Public policy on cultivar improvement and seed marketing needs to be based on empirical analysis rather than on pronouncements about quantities of seed produced or seed replacement rates. Many experts working on seed industry reforms have pointed to the absence of centrally managed, high-resolution data and information on key metrics like those described above. This includes better decision-making tools and more dedicated efforts to lay the groundwork for development of a commercial seed industry. It also means collection of spatially-disaggregated, variety-specific data for major crops to inform decision-making; information management systems and portals that make information available to industry actors; and clear policy messages in support of seed industry development by governments, industry associations, and farmer organizations.

Research and development. For national research systems supplying improved cultivars, the well-established constraint is one of resources—financial, capital, scientific, and human. Although investment in agricultural research (specifically cultivar improvement) has been repeatedly demonstrated to increase productivity and reduce poverty, funding for the public research systems in many of these countries remains insufficient relative to the needs and expectations of the country. Financing has been erratic, bureaucratic structures are inefficient, posts remain empty, and the current generation of senior scientists are heading into retirement without adequate succession plans.

The second constraint is more directly relevant to the seed industry. Although public breeding programs are an important supplier of improved germplasm for state-owned seed companies and farms, many private sector firms and farmer organizations argue that they do not have equitable access to that same germplasm. This limits the innovation pipeline from the research system to seed producers and, ultimately, to farmers in many countries.

In the research systems, there is a need for both greater investbment and deep structural reforms. This means:

- Strengthening public agricultural research focus on delivery of its improved varieties, i.e., widening the R&D pipeline with more and more frequent releases, and with increased access to breeder/foundation seed for all seed industry actors
- Increased, sustained investment in national research system – not just short-term, volatile donor project funding
- Reforms to research structures, management, funding systems

Regulation. There is much written on the disincentives posed by regulatory procedures involving multiple agencies that lead to significant delays, costs, and risk. Stringent regulations, strict test standards, cumbersome procedures and slow processing tend to limit the number of improved cultivars that can be registered and put into production. Relatedly, regulatory systems seem to have limited capacity to monitor seed quality once it reaches the market and is purchased by farmers: Poor quality seed, fraudulent seed, and bad business practices seem to be a concern in many countries.

In many of Asia's seed regulatory systems, there is probably a certain amount of rationalization that could be done to ease the burdens of time, effort, and cost associated with meeting regulatory standards. This should not be seen as a call for total deregulation. Rather, it suggests the need for

- Improvement in the capacity of regulatory agencies to manage testing procedures
- Identification of, and concentration on, high priority issues for monitoring and testing (e.g. foundation seed)
- Easing of notification lists and the varietal regulation standards, where appropriate

- Easing of taxation, tariffs, and non-tariff barriers that add significant cost to investing in the seed sector
- Improved market surveillance to identify and prosecute fraudulent seed production and marketing

Production and marketing. One of the larger issues found in many Asian countries is the role of state-owned seed companies and the struggle to find appropriate roles for the public and private sector. Private firms and cooperatives in the seed market cannot usually compete with the subsidized cost structures of state-owned firms, and this discourages entry of private investment into seed production and marketing. The public sector should pay particular attention to supporting the high-volume, low-margin end of the market where private investment incentives are weak but where small/medium enterprises, cooperatives, and farmers' organizations could play a significant role (e.g., not only for rice and wheat but also for legumes, pulses, oilseeds, etc). More creative public-private collaboration is required.

Less attention can probably be given to those markets where private firms are more likely to concentrate, i.e., the higher-value market for hybrids, horticulture crops, or genetically modified crops where farmers are likely to purchase high-quality seed each year. In these markets, the key is to maintain strong investment incentives by rationalizing the imposition of taxes, tariffs on imported equipment and materials, and ad-hoc non-tariff barriers seem to be discouraging investment.

There are still some difficult tradeoffs that need to be faced. For example, there is scope in many countries for a slow withdrawal of parastatals from certified/quality seed production and into foundation seed supply to private companies. This is a fiscally responsible solution to strengthening the seed market, but it assumes that private firms will step in to fill the gap. That is a strong assumption because the enabling environment may not exist, and crop reproductive biology may not provide sufficient incentives for private sector investment in open/self-pollinating and vegetatively propagated crops.

But a withdrawal of state-owned seed companies may work if accompanied by regulatory easing and business reforms that encourage private firms and cooperatives to invest in the seed industry. These reforms include tax incentives and tariff reductions for importation of production equipment and materials, as well as targeted financing from the public or private sector to encourage the industry.

Finally, there is a need for the private sector to advocate for its own growth and development. There are many companies doing business in this area, but they are poor advocates for themselves – better organization would allow them to advocate for favorable policies that would ultimately benefit agricultural production.

REFERENCES

Adato, M. and R. Meinzen-Dick, eds. 2007. *Agricultural Research, Livelihoods, and Poverty.* Baltimore: Johns Hopkins University Press.

Alston, J. M., C. Chan-Kang, M. C. Marra, Philip G. Pardey, and TJ Wyatt. 2000. *A Meta-Analysis of the Rates of Return to Agricultural R&D: Ex Pede Herculem?* IFPRI Research Report No. 113. Washington, DC: International Food Policy Research Institute.

ASTI (Agricultural Science and Technology Indicators). 2014. ASTI database. Accessed on June 4, 2014. http://www.asti.cgiar.org/.

Binenbaum, E., C. Nottenburg, P.G. Pardey, B.D. Wright, and P. Zambrano. 2003. "South-North Trade, Intellectual Property Jurisdictions, and Freedom to Operate in Agricultural Research on Staple Crops." *Economic Development and Cultural Change* 51(2): 309-335.

Brennan, J.P., and D. Byerlee. 1991. The rate of crop varietal replacement on farms: Measures and empirical results for wheat. *Plant Varieties and Seeds* 4: 99–106.

Byerlee, D., and K. Fischer. 2002. Accessing modern science: Policy and institutional options for agricultural biotechnology in developing countries. *World Development* 30 (6): 931–948.

DIIVA (Diffusion and Impacto f Improved Varieties in Africa (2014). About DIIVA. http://www.asti.cgiar.org/diiva, accessed July 2014.

Evenson, R.E., and D. Gollin. 2003. Assessing the impact of the green revolution, 1960 to 2000. *Science* 300(5620): 758–762.

Fan, S. 2000. Research investment and the economic returns to Chinese agricultural research. *Journal of Productivity Analysis* 14(2): 163-82.

Fan, S. and P.G. Pardey. 1997. Research, productivity, and output growth in Chinese agriculture. *Journal of Development Economics* 53: 115-137.

Fan, S., P.B.R. Hazell, and S. Thorat. 2000. Government spending, growth and poverty in rural India. *American Journal of Agricultural Economics* 82(4): 1038-51.

FAC (Future Agricultures Consortium). 2014. *Political Economy of Cereal Seed Systems in Africa Project.* Brighton, U.K.: FAC.

Fernandez-Cornejo, J. 2002. *The Seed Industry in U.S. Agriculture: An Exploration of Data and Information on Crop Seed Markets, Regulation, Industry Structure, and Research and Development.* Agriculture Information Bulletin no. 786. Washington, DC: Economic Research Service, U.S. Department of Agriculture.

Fuglie, K.O., P.W. Heisey, J.L. King, C.E. Pray, K. Day-Rubenstein, D. Schimmelpfennig, S.L. Wang, and R. Karmarkar-Deshmukh. 2011. Research Investments and Market Structure in the Food Processing, Agricultural Input, and Biofuel Industries Worldwide. Economic Research Report no. 130. Washington, DC: Economic Research Service, U.S. Department of Agriculture.

Gerpacio, R.V. 2003. The roles of public sector versus private sector in R&D and technology generation: The case of maize in Asia. *Agricultural Economics* 29 (3): 319–330.

Hazell P.B.R. and Haddad L. 2001. Agricultural Research and Poverty Reduction. Food, Agriculture, and the Environment Discussion Paper no. 34. Washington, DC: International Food Policy Research Institute.

Jamal, E. 2014 "The Seed Industry in Indonesia". Paper presented at the ReSAKSS-Asia Conference "Agricultural Transformation in Asia: Policy Options for Food and Nutrition Security". September 25–27, 2013, Siem Reap, Cambodia.

Janaiah, A., M. Hossain, and M. Husain. 2002. "Hybrid Rice for Tomorrow's Food Security: Can the Chinese Miracle Be Replicated in Other Countries?" *Outlook on Agriculture* 31 (1): 23–33.

Kloppenburg, J. 1988. *First the Seed: The Political Economy of Plant Biotechnology, 1492–2000.* Cambridge: Cambridge University Press.

Kolady, D., D.J. Spielman, and A.J. Cavalieri. 2012. Intellectual property rights, private investment in research, and productivity growth in Indian agriculture: A review of evidence and options. *Journal of Agricultural Economics* 63(2): 361-384.

Li, J., Y. Xin, and L. Yuan. 2010. "Hybrid Rice Technology Development: Ensuring China's Food Security." In *Proven Successes in Agricultural Development: A Technical Compendium to Millions Fed,* edited by D. J. Spielman and R. Pandya-Lorch. Washington, DC: International Food Policy Research Institute.

Longley, C. 2006. *Seed Vouchers in Emergency Programming: Lessons from Ethiopia and Mozambique. Humanitarian Policy Group Background Paper.* London: Overseas Development Institute.

Longley, C., C. Dominguez, M.A. Saide, and W. J. Leonardo. 2002. "Do Farmers Need Relief Seed? A Methodology for Assessing Seed Systems." *Disasters* 26(4): 343-355.

Mau Dung, N. 2014. "The Seed Industry in Vietnam". Paper presented at the Conference "Agricultural Transformation in Asia: Policy Options for Food and Nutrition Security". September 25–27, 2013, Siem Reap, Cambodia.

Morris, M. L. 1998. *Maize Seed Industries in Developing Countries.* Boulder, CO: Lynne Rienner.

Naher, F. and Spielman, D. 2014 Seeding the Future: Accelerating Seed System Development in Bangladesh.

Napasintuwong, O. 2014. "Maize Seed Industry in Thailand: Development, Current Situation and Prospect". ReSAKSS-Asia Working Paper, forthcoming.

Pray, C. E., and L. Nagarajan. 2010. "Pearl Millet and Sorghum Improvement in India." In *Proven Successes in Agricultural Development: A Technical Compendium to Millions Fed,* edited by D. J. Spielman and R. Pandya-Lorch. Washington, DC: International Food Policy Research Institute.

Raitzer, D.A. and T.G. Kelley. 2008. Benefit–cost meta-analysis of investment in the international agricultural research centers of the CGIAR. *Agricultural Systems* 96: 108–123.

Ramaswami, B. 2002. "Understanding the Seed Industry: Contemporary Trends and Analytical Issues." *Indian Journal of Agricultural Economics* 57(3): 417–429.

Rana, M.A. 2014. *The Seed Industry in Pakistan: Regulation, Politics and Entrepreneurship.* Pakistan Strategy Support Program (PSSP) Working Paper no. 19. Washington, DC: International Food Policy Research Institute.

Renkow, M. and D. Byerlee. 2010. The impacts of CGIAR research: A review of recent evidence. *Food Policy* 35(5): 391–402.

Rhoades, S.A. 1995. "Market Share Inequality, the HHI, and Other Measures of the Firm-composition of a Market." Review of Industrial Organization 10(6): 657–674.

Rosegrant M.W. and Evenson R.E. 1992. Agricultural productivity and sources of growth in South Asia. American Journal of Agricultural Economics, 74: 757–791.

Rosegrant M.W. and Hazell P.B.R. (2000). Transforming the Rural Asia Economy: The Unfinished Revolution. Oxford University Press: Hong Kong.

Sah, R. 2014. “The Role of Seeds in Transforming Agricultural in Nepal”. Paper presented at the Conference “Agricultural Transformation in Asia: Policy Options for Food and Nutrition Security“. September 25–27, 2013, Siem Reap, Cambodia.

Smale, M. J. Singh, S. Di Falco, and P. Zambrano. 2008. Wheat breeding, productivity and slow variety change: evidence from the Punjab of India after the Green Revolution. *Australian Journal of Agricultural and Resource Economics* 52: 419-432.

Sombilla, M. A. and Quilloy, K. 2014.“Strengthening the Philippine Rice Seed System“. Paper presented at the Conference “Agricultural Transformation in Asia: Policy Options for Food and Nutrition Security“. September 25–27, 2013, Siem Reap, Cambodia.

Spielman, D.J. 2007. Pro-poor agricultural biotechnology: Can the international research system deliver the goods? *Food Policy* 32(2): 189-204.

Spielman, D.J., D.E. Kolady, and P.S. Ward. 2013. The prospects for hybrid rice in India. *Food Security* 5(5): 651-665.

Sperling, L. and C. Longley. 2002. Editorial: Beyond seeds and tools: Effective support to farmers in emergencies. *Disasters* 26(4): 283-383.

Tripp, R. 2001. Can biotechnology reach the poor? The adequacy of information and seed delivery. *Food Policy* 26: 249–264.

Tripp, R., and N. Louwaars. 1997. Seed regulation: choices on the road to reform. *Food Policy* 22(5): 433–446.

Tripp, R., and S. Pal. 2001. “The Private Delivery of Public Crop Varieties: Rice in Andhra Pradesh.” *World Development* 29 (1): 103–117.

UPOV (International Union for the Protection of New Varieties of Plants). 2014. *Status in Relation to the International Union for the Protection of New Varieties of Plants (UPOV).* <http://www.upov.int/export/sites/upov/members/en/pdf/status.pdf>, accessed August 2014.

About the Authors

David J. Speilman is a Senior Research Fellow in the Environment and Production Technology Division, and **Adam Kennedy** is a Senior Program Manager, in the Development Strategy and Governance Division of the International Food Policy Research Institute (IFPRI), Washington, D.C.

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE
A member of the CGIAR Consortium | A world free of hunger and malnutrition
2033 K Street, NW | Washington, DC 20006-1002 USA
T: +1.202.862.5600 | F: +1.202.467.4439
Email: ifpri@cgiar.org | www.ifpri.org
www.ReSAKSS-Asia.org