
Deregulating the Transfer of Agricultural Technology: Lessons from Bangladesh, India, Turkey, and Zimbabwe

David Gisselquist • John Nash • Carl Pray

Many transition and developing economies have reduced direct public involvement in the production and trade of seed and other agricultural inputs. This trend creates opportunities for farmers to realize improved access to inputs, including technology from international private research. Unfortunately, input regulations often derail these opportunities by blocking private entry and the introduction of private technology. This study looks at the experience in Bangladesh, India, Turkey, and Zimbabwe to see whether regulations make a difference in agriculture and input industries in developing economies. In all countries, companies and farmers responded to regulatory reforms by introducing and adopting more new technology and by expanding the production, trade, and use of inputs. The increased use of private technology has brought higher yields and incomes, allowing farmers and consumers to reach higher levels of welfare. These results challenge governments to open their regulatory systems to allow market entry and the introduction of private technology through seeds and other inputs.

For many years, discussions about technical change in agriculture in developing economies have focused on public research and extension. However, a number of studies have shown that private input companies can also be important channels for the introduction of technology in the agricultural sector in these countries. Pray and Echeverria (1988) find that maize yields in 50 countries responded to private research and seed imports. Narrod and Pray (1995) show the relation between livestock productivity and the introduction of private technology. And Evenson and others (1999) present evidence for India that private research contributes to total factor productivity growth in agriculture.

This article looks at regulatory barriers that restrain private technology transfer and the changes that follow when governments reduce some of those barriers. The study was motivated by findings of widespread regulatory barriers to private intro-

duction of input-embodied technologies (Gisselquist 1994). The first section introduces the hypothesis that guides this study. The second section describes regulatory reforms and impacts on input industries in Bangladesh, India, Turkey, and Zimbabwe. The third section looks at downstream impacts on agricultural production and incomes. The fourth section concludes with recommendations for governments, donors, and the Consultative Group on International Agricultural Research (CGIAR) to improve farmers' access to the world's flow of new (often private) agricultural technology.

Hypothesis: Regulations Make a Difference

All countries regulate inputs, and regulatory designs and practices vary widely across countries. However, to our knowledge, only two studies have dealt directly with the costs and benefits of regulating technology transfer in agriculture. Both studies deal with seeds: for wheat in Canada (Ulrich and others 1987) and for cotton in California (Constantine and others 1994). These studies show large losses in the form of forgone gains when governments do not allow farmers to adopt new input-embodied technologies. We have found no studies dealing with the costs and benefits of input regulations in developing economies. In other words, the empirical basis for debates about how best to regulate inputs in developing economies is extremely weak.

To estimate the costs and benefits of closed versus open systems (that is, open to the introduction of private technology) in developing areas, we looked for countries that had recently eased barriers to the introduction of private technology. We found five countries with significant shifts in input controls. Using data from four countries—Bangladesh, India, Turkey, and Zimbabwe—we tested the following hypothesis: Regulatory reforms reducing obstacles to the introduction of new agricultural technology stimulate technology transfer and have a significant net positive impact on productivity and incomes. (The fifth country, Chile, was cut from the study due to funding constraints.)

Most industrial market economies allow private companies to introduce new technology for most industries—including computers, computer programs, and electronic consumer goods—without government preview and approval as long as there are no major problems with externalities or public health. These same general principles guide agricultural input regulations. Organisation for Economic Co-operation and Development (OECD) countries generally allow companies to introduce new technology for seeds, fertilizers and farm machinery. Although performance tests may be a formality in some countries, they are seldom obstacles. However, for classes of inputs with significant externalities or public health impacts—such as pesticides and livestock medicines—most OECD governments balance data on performance against risks in deciding whether to allow a new technology.

By contrast, regulators in many transition and developing economies, motivated by widespread distrust of private companies and misunderstanding of market processes, often suppress market entry and competition. This leaves farmers heavily dependent on public research for new technology and on regulators to monitor and enforce input quality. Many agricultural experts recommend that governments of poor countries should control the private introduction of new input-embodied technology based on government assessments of the performance of the technology, even when externalities are not a factor. For example, one expert, raising the specter of “a disastrous effect on food supplies . . . from the extensive use of a poor-yielding variety,” urged governments to protect farmers “against exploitation by those who might try to market an unsatisfactory variety simply to recoup breeding costs” (Kelly 1989, p. 43). One of the expert reviewers for this research project worried about “the moral hazard problem that arises with asymmetric information between consumers (farmers) and producers (private input suppliers),” noting that farmers in developing economies “do not have access to the wide range of written and broadcast information available to farmers in developed countries.”

Fears that farmers might lose from uncontrolled private introduction of new technology continue to influence the design of input regulations. However, we have not been able to find any studies that investigate those fears empirically. During this project, we looked for instances of farmer loss from inappropriate technology.

Government controls on private technology impose two costs: the direct costs that governments and companies incur in regulatory processes and forgone gains that farmers and consumers lose when regulators block or delay the sale of productive inputs. Even a very efficient agency takes some time to evaluate input performance and to decide whether to permit a new technology. Too often, regulators take a long time and make many bad decisions, imposing significant costs in the form of forgone gains. In some cases, processes to test and assess new technologies are not much more than a cover to protect public or private monopolies or oligopolies.

Whether governments are closed or open to new private companies and technology, essentially all governments share some common practices in regulating inputs. For example, most (if not all) governments regulate truth in labeling, list allowed pesticides based on risk and efficacy data, and supervise seed imports to block seedborne pests and diseases (see table 1). The question about whether governments allow private technology introduction is not about deregulating inputs—that is out of the question—but rather about focusing input regulations on externalities and public health. Arguably, focusing in this way allows more effective protection against externalities.

General economic and regulatory reforms in Bangladesh, India, Turkey, and Zimbabwe have reduced but not eliminated barriers to technology transfer for seeds and other inputs. Reforms in Turkey date from the early 1980s, in Bangladesh and India

Table 1. Common Regulatory Practices with Respect to Efficacy and Performance

<i>Input</i>	<i>Regulatory practices</i>	<i>Comments</i>
Seeds	<p>Three systems are common in the world:</p> <ol style="list-style-type: none"> 1. Voluntary variety registration. Companies can sell seeds that government has not tested and listed, although governments may test and recommend varieties. 2. Compulsory variety registration for specified crops, with multicountry lists. This is the pattern in the E.U. For specified crops, E.U. governments do not allow the sale of seed except for varieties that have passed performance tests. However, each government automatically accepts varieties tested and listed by any other E.U. government. 3. Compulsory variety registration for specified crops, with single-country variety lists. Many developing economies maintain their own national lists of allowed varieties based on in-country performance tests. 	Voluntary registration facilitates private introduction of new cultivars. Voluntary variety registration also allows the sale of seed for unregistered land races, traditional varieties, and public varieties from world trade.
Pesticides	Virtually all governments list allowed products (formulations with brand names) based on risk and performance; some accept risk data from other countries; and most require in-country performance tests. The United States registers new biopesticides without performance tests.	Options to facilitate private technology transfer include accepting efficacy data from other countries and waiving efficacy data for biopesticides and low-risk products.
Livestock medicines	Most countries list allowed products (formulations and brands) based on risk and efficacy; many countries accept data on risk and efficacy from prior tests in other countries.	
Fertilizers and livestock feeds	Some countries list allowed products based on expert decisions about optimum nutrient compositions; other countries allow dealers to sell any composition but insist on truth in labeling.	Allowing markets to determine compositions facilitates private technology transfer.
Agricultural machinery	Some countries list allowed makes and models based on official performance tests; other countries allow sales of new makes and models without any tests.	Allowing markets to determine models favors private technology transfer.

from the late 1980s, and in Zimbabwe from the early 1990s. In all four countries, regulatory changes closely followed or coincided with more general economic reforms that established market access to foreign exchange, removed nontariff barriers for broad classes of imported goods, and improved the environment for domestic and foreign private investment. In some cases (for example, agricultural machinery in Zimbabwe), general economic reforms have been sufficient by themselves to allow private technology transfer and competitive markets.

The Impact of Regulatory Reforms on Input Industries

Input companies compete at least in part by offering farmers a menu of interesting technologies and by continually adding new technologies to that menu. The costs and returns of identifying and introducing new technologies determine the rate at which a company will do so. The research effort required to introduce new technologies varies from field testing imported technologies to in-country development of new cultivars, chemicals, and farm machinery.

There are three major cost factors. The first is the cost of available technology. For agriculture as well as other activities, technology that is useful in one country comes from a worldwide process of public and private research. The supply of technology available for spill-in (that is, adoption of the technology, with or without adaptation) into any one country depends on its distance from other countries (due to differences in climate, tastes, wage rates, and other factors that affect the acceptability of imported technologies). A company may access technology through various channels, including imports of inputs or capital goods, licensing agreements and exchange of information among researchers. Public research within a country can also increase the flow of technology for private firms to develop for the market.

The second major cost factor is research efficiency. A company's ability to take advantage of available technology to identify or develop new technology for a particular market depends on several factors, including research efficiency. Research efficiency depends in turn on the skills available in the company as well as the labor market and the existence of supporting institutions, including public universities and research institutes and private seed and fertilizer associations. Countries with high research efficiencies tend to access and apply available spill-ins more quickly and also develop more new technology for domestic as well as foreign markets. Multinationals operating in multiple countries locate research activities in countries with high research efficiencies.

The third major risk factor is regulatory barriers. From a company's point of view, regulatory barriers impose significant costs, including direct expenditures to pass regulatory hurdles and forgone income due to delayed sales.

There are two major return factors. The first is market size. Expected sales and profits for an input with new technology depend on population, average income, and other factors that determine market size. In low-income countries, a large share of agricultural gross domestic product (GDP) comes from food staples. As incomes rise, consumers want higher-value foods, so that markets for vegetable seeds, baby chicks, and livestock feed premixes tend to grow over time at rates that significantly exceed overall GDP growth.

The second major return factor is appropriability. A company's profits from selling inputs embodying new technology depend also on the share of total social benefits the company is able to collect. One factor that influences appropriability is the

nature of the technology. With hybrids, for example, companies can protect ownership of technology by physical control of parent lines, as in India (see later discussion). Another factor that influences appropriability is the existence of legal channels to register and enforce intellectual property rights (IPRs), including patents and plant variety protection (PVP) or plant breeders' rights.

Seed Reforms and Seed Industries

For seeds, the regulatory reforms in Bangladesh, India, Turkey, and Zimbabwe repeat some common themes but are far from identical (see table 2). Prior to the reforms under review, both Bangladesh and Turkey had compulsory variety registration (that is, for a new variety, seed sales are not allowed until the government has approved the variety). Bangladesh reduced barriers to new varieties by making variety registration voluntary for all but five major crops (rice, wheat, jute, potatoes, and sugarcane). Turkey reduced barriers to private varieties by cutting required performance tests to one year, allowing companies to submit data from their own tests, and establishing a practice of readily approving almost all varieties proposed for registration. India and Zimbabwe had voluntary variety registration for several decades. India continues this policy. Zimbabwe has imposed compulsory variety registration for 11 major crops since 1993, about the same time that general economic reforms created the possibility (threat) of market entry and real competition in seed markets.

Relaxation of seed import controls has played a major role in improving technology transfer in India and Turkey. Since 1988, India has allowed imports of commercial seed, parent seed, and germ plasm for vegetables, coarse grains, and oilseeds. However, for many other crops (for example, wheat, rice, and potatoes), the country continues to block private imports—including germ plasm for breeding—based on nonphytosanitary factors, including performance. Turkey's reforms since the early 1980s have gone much further, allowing even commercial seed imports (albeit with some difficulties) for essentially all crops. In Bangladesh, import controls are no obstacle to new varieties; seeds of new varieties for five crops cannot be imported, but the obstacle comes from variety controls rather than import controls. Zimbabwe blocks seed imports for major crops, which can slow the introduction of new varieties.

Improving the access of private companies to public lines has been an issue. Since 1986, India has set procedures for seed companies to buy breeders' seeds from public research institutes. By contrast, Zimbabwe continued agreements into the mid-1990s that gave one private company exclusive rights to lines from public breeding for major crops.

In India, relaxation of investment controls has had an important impact on private investment in seeds. The 1969 Industrial Policy Act restricted Indian firms with more than Rs 1 billion in total assets (about \$130 million in 1969) to a list of core industries that did not include seeds; since 1979 the government has also restricted

firms with more than 40 percent foreign equity to core industries. In 1986, the government made seeds and biotech core industries, and in 1991 general reforms eased controls on foreign investment. In 1991, the government relaxed restrictions on technology transfer and foreign investment for the entire economy.

All members of the World Trade Organization have agreed to introduce IPRs for varieties and genes, but developing economies were given 10 years—until 2004—to comply. Whether to comply is not the issue because both public and private researchers look to make money from owning new technology. Zimbabwe's PVP law dates from 1973 and Turkey's from 1994, but neither country is a member of the major treaty organization that sets PVP standards, which suggests some difficulty with design or implementation. India's ongoing attempts to draft a PVP law continue to generate political controversy. New laws and regulations are also required to regulate and protect IPRs for genetically modified organisms.

Bangladesh. Prior to the 1990 seed reforms, private seed companies in Bangladesh focused almost exclusively on vegetable seeds. Government lists of allowed cultivars absolutely blocked all varieties for some crops and severely limited farmer choice for many others. For example, listed varieties included only two open-pollinated varieties of maize and no hybrids, only two soybean varieties, and no sunflower hybrids. The lists protected lucrative markets for companies with listed varieties for popular produce (for example, seedless watermelon and cauliflower). The government dominated seed production and trade for field crops.

Since 1990, nongovernmental organizations (NGOs) and other companies have entered seed trade and introduced a large number of new varieties for vegetables and some field crops. New varieties allow off-season production and introduction of new vegetables, including sweet corn. New papaya varieties have improved quality and cut cost to consumers. Two large NGOs, Grameen Krishi Foundation and Bangladesh Rural Advancement Committee, promoted hybrid maize through contract growers. In 1994/95, Bangladesh imported 65 tons of hybrid maize seed (enough for 3,300 hectares). Companies have also tested hybrid sunflower, canola, and sorghum.

Import and distribution of vegetable seed continues to dominate the private seed industry. Among field crops, jute and potato seed are financially important, but private seed production and trade for these crops are held back by compulsory variety registration. Private companies and NGOs screen imported varieties and lines for vegetables and a number of field crops for suitability to local conditions. In addition, in the mid-1990s, a new joint venture began planning to breed vegetables in Bangladesh.

Despite large public research programs, the pace and quality of government variety releases for the five crops with compulsory variety registration—rice, wheat, jute, potatoes, and sugarcane—leaves opportunities for additional gains from private introductions. However, the government has resisted introducing private varieties. Well over half of the jute area is planted in Indian public varieties for which seeds are ille-

Table 2. Seed Reforms and Impacts on Technology Transfer and Seed Industries

<i>Country</i>	<i>Reforms</i>	<i>Post-reform regulations</i>	<i>Impact on technology transfer</i>	<i>Impact on seed production and trade</i>
Bangladesh	In 1990, the government ended compulsory variety registration for all but five crops (rice, wheat, jute, potatoes, and sugarcane).	<ul style="list-style-type: none"> • No barriers to new varieties for most crops • High barriers remain for nongovernment varieties of rice, wheat, jute, sugarcane, and potatoes 	<ul style="list-style-type: none"> • Many new vegetable varieties introduced • Hybrid maize and sunflower introduced 	<ul style="list-style-type: none"> • More competition in vegetable seed • Modest increase in trade of field crop seeds • Limited market entry by foreign companies (only one Thai-Bangladesh joint venture)
India	<p>In 1986, the government included seed and biotech companies as core industries, allowing large companies to enter.</p> <p>In 1986, the government established procedures for public research agencies to sell breeder seed to companies.</p> <p>In 1988, the government eased barriers to seed and germ plasm imports for vegetables, coarse grains, and oilseeds.</p> <p>In 1991, the government eased barriers to technology purchase and foreign investment for the entire economy.</p>	<ul style="list-style-type: none"> • Low to no barriers to new private varieties for vegetables, coarse cereals, and oilseeds • Import barriers for seeds and breeding material block introduction of new private varieties for other crops 	<ul style="list-style-type: none"> • Huge increase in rate of introduction for vegetable, cotton, coarse grain and oilseed hybrids (e.g., more than 100 new cotton hybrids introduced in 1996); for these crops, technology nears or sets world best standards 	<ul style="list-style-type: none"> • Significant market entry by large Indian and foreign firms and by new Indian firms • Private seed companies take larger share of seed trade • Moderate growth in volume of private seed trade, but large growth in value

Turkey	<p>In 1983, the government ended seed price controls.</p> <p>In 1983, the government cut performance tests to one year, allowed companies to do their own tests and established a pattern to accept most private varieties.</p>	<ul style="list-style-type: none"> • Low barriers to new private varieties for all crops 	<ul style="list-style-type: none"> • Large increase in rate of introduction of new varieties; for example, starting in 1982 to 1987, sunflower hybrids increased from 3 to around 30 and soybean varieties increased from 2 to more than 40 	<ul style="list-style-type: none"> • Significant market entry by foreign and domestic firms; number of private seed companies increased from fewer than 5 before the reforms to about 80 by 1990, including several subsidiaries, some joint ventures and many international licensees • Private companies took over major shares of the seed market; public sales continue to dominate some crops (e.g., wheat)
Zimbabwe	<p>Around 1990, the general economic reforms improved the environment for private companies.</p> <p>In 1993 (policy reversal), the government made variety registration and seed certification compulsory for 11 major crops, but accepted most varieties without tests.</p>	<ul style="list-style-type: none"> • Low barriers to new varieties from established companies • Market entry difficult for small local companies • Maize open-pollinated varieties not allowed 	<ul style="list-style-type: none"> • Large increase in rate of introduction of new varieties for maize; less impact on other crops 	<ul style="list-style-type: none"> • Some market entry by large foreign firms, limited entry by domestic firms • Seed Coop's hybrid maize monopoly eroded starting in the mid-1990s

gal because the government of Bangladesh has not registered the varieties. Similarly, farmers in border areas plant unregistered, short-duration Indian rice varieties. The introduction of Indian varieties could be more efficient through legal (private) seed trade.

India. The Indian seed industry has developed within a large national market. Three national seed associations have a total of more than 300 members, a large share of which are seed producers, and many smaller seed companies are not members. In the public sector, agriculture is a state (versus federal) subject, so that state universities and research organizations contribute to public breeding and state seed corporations compete in national markets. Over the past several decades, Indian public breeders have developed and released thousands of varieties, although only a small share has been commercially significant.

The government has relaxed controls on foreign and domestic investment and technology contracts and Indian public research and foreign sources have improved access to germ plasm. These developments have led large local firms and joint ventures already in India to move into seeds and some foreign seed companies to establish new joint ventures or subsidiaries. Reforms also stimulated new entry by small and medium local companies.

Reforms have significantly accelerated the introduction of technology. However, because companies introduce most of their new hybrids and varieties without variety registration, it is not possible to give comprehensive figures on the number of cultivars introduced over time. Industry sources report that more than 100 new cotton hybrids were introduced in 1996 alone. Most of these were private hybrids developed from public parent lines, much as the U.S. hybrid maize industry began with public lines. Public lines—many from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)—are also important for sorghum and millet hybrids. Maize and sunflower hybrids have gained from imported parent lines. Major improvements in quality have brought large changes in market share. In sunflower hybrids, for example, the share for one firm dropped from over 80 percent in 1990 to less than 20 percent by 1996. Despite lack of PVP, at least one multinational has introduced its best maize germ plasm for low latitudes into the Indian market, relying on physical control of hybrid parent lines to protect ownership. In 1997, several companies reported plans to screen 100–800 new tomato hybrids in the coming year. When asked who has the largest market share in tomatoes, a seed executive answered, “It depends on who has the best new hybrid that year.”

In the mid-1990s, industry representatives estimated that since 1984–85 the private sector had been responsible for about 50–60 percent of the value of seed sales. Other recent estimates show private seed gaining significantly larger market shares in some crops and states. For example, from 1985–89 to 1990–95, the area under private hybrids in Karnataka grew from 33 to 61 percent for maize and from 24 to

54 percent for sunflower hybrids. In Andhra Pradesh, the area under private hybrids increased from 10 to 33 percent for pearl millet and from 9 to 29 percent for sorghum (Pray and Ramaswami 1998). Most private seed company revenues come from hybrids, whereas public companies dominate markets for relatively low-value nonhybrids. However, private companies also produce and sell nonhybrid seed (for example, wheat), and public companies have been important in cotton and sorghum hybrids.

Turkey. Among the four countries studied here, market entry has been most dramatic in Turkey, where the number of private companies increased from fewer than 5 in 1982 (before reforms) to more than 80 in the early 1990s. New entrants include subsidiaries and joint ventures of major multinationals, but most are wholly locally owned companies, often with (multiple) licensing contracts with foreign companies.

New companies have introduced new cultivars, screening material from breeding in other countries. Relaxation of variety controls has been a major factor in market entry and has led to a large increase in the rate of introduction of cultivars. In sunflowers, for example, the number of cultivars increased from 3 to about 30 during 1982–87. Among field crops, maize and sunflower hybrids are by far the most important seeds for private companies. However, as of 1993, private companies have also introduced new varieties and produced several thousand tons of seed for sugarbeet hybrids as well as nonhybrids of potatoes and soybeans, and about 10,000 tons of nonhybrid wheat seed. Reforms have brought much faster technology introduction for nonhybrids and hybrids. For example, the aggregate number of approved soybean varieties increased from 2 to more than 40 during 1982–87, and the government approved an average of 5 new wheat varieties each year during 1984–94, compared with a cumulative total of 21 varieties approved through 1982. As of the mid-1990s, farmers planted private maize hybrids on about 170,000 hectares (a third of maize area) and private sunflower hybrids on about 450,000 hectares (90 percent of sunflower area), all from cultivars introduced after and because of the reforms. For many other crops and vegetables, the shift to post-reform private cultivars has been at least as dramatic as for maize.

Almost all private research is limited to screening imported lines. However, some companies with international connections (including license partners) work with foreign breeders to develop material for Turkey. For example, one company reported sending materials from Turkey for breeding in the United States. Budgets and staff for public agricultural research fell when Turkey liberalized trade in inputs. Although the flow of introduction of technology has increased with liberalization, even more may have been possible with continued strong public research.

Zimbabwe. Throughout the early 1990s, Seed Coop held a near monopoly in hybrid maize seed—Zimbabwe’s major seed market—and there was little competition for other seeds. Three major foreign companies—Pannar, Pioneer, and Cargill—began

hybrid maize research or seed sales before 1990; two other foreign companies—Pacific Seeds and DeKalb—entered after 1990 with local partners. Other local and foreign companies have entered niches in the seed industry (especially production for export).

In 1990, farmers had access to about a dozen maize hybrids, most of them relatively old ones from public breeding, and Seed Coop had an estimated 98 percent of the market. Reforms brought a large increase in private breeding, which got under way in at least four companies (primarily for hybrid maize but also including other crops), compared with little or no private breeding through the mid-1980s. In 1997, farmers had access to almost 30 hybrids from four companies, and the share for Seed Coop (now Seed Company) had fallen to about 80 percent.

Since 1993, new regulations—compulsory variety registration and seed certification—have obstructed market entry for small local companies and blocked the introduction of some specific technology. For example, a local NGO has been organizing small farmers to produce sorghum seed. Sorghum seeds must be certified, which involves laboratory testing. However, there are only two laboratories in the country approved for tests, one in the government, which is overcommitted and underfunded, and the other in Seed Company. Seed Company tests, processes, and packages the seed, after which it is too expensive for Zimbabwe's small farmers and goes instead for export. In addition, some available technology continues to be explicitly barred. Compulsory variety registration for maize gives the government a legal instrument to ban the sale of nonhybrid maize seed, forcing farmers to buy more expensive hybrid seed. Hence, although suitable nonhybrid varieties are readily available, the seed is illegal.

The impact of seed reforms on private research. Regulatory and other reforms cut costs to introduce new cultivars. Other things equal, this leads to more private breeding. However, the impact of regulatory reforms on private research depends also on other factors that influence returns to research investments, such as available technology, research efficiency, market size and appropriability.

Multinationals, which account for a major share of breeding investments, carry out breeding activities in some countries, but sell their products in many other countries as well. For most crops, the areas of applicability for new cultivars cross political boundaries, so that a purely national breeding strategy is inefficient. For example, Bangladesh is so close to India that companies could breed in either one for both, but India has a much larger market (with 900 million people) and higher research efficiency. Similarly, Turkey is agroclimatically close to Western Europe and the Great Plains in the United States, regions with large markets and high research efficiency, so that companies breed elsewhere for Turkey. Because the African highlands—from Ethiopia through Zimbabwe—are distant from other maize markets, companies that want to compete must breed there. All private hybrid maize breeding for highland

Africa is done in Zimbabwe, which offers the highest research efficiency and a medium-size market (10 million people for whom maize is the major staple).

Ownership of hybrids does not depend on PVP legislation; companies can keep physical control of parent lines, selling only the hybrid or crossed seed. Therefore, for many years companies have been able to realize high returns to research on such crops as maize for which hybrid seed is possible. Because hybrid maize accounts for a major share of world seed sales and profits, companies invest heavily in maize research. In the four companies in this study, private maize breeding is important in India and Zimbabwe, whereas companies active in Turkey and Bangladesh limit in-country research to testing lines bred elsewhere. For other crops and vegetables, India is the only one of the four countries with significant private breeding. Since 1994, the one private breeding program in Turkey has taken advantage of the presence of the orobanche parasite to breed resistance into sunflower hybrids intended for international markets.

India, with its large population, presents one of the largest potential seed markets in the world, rivaling the E.U., U.S., and Chinese markets. Breeding efficiency is also high, with high skills, strong scientific support, and low wages. Reforms in the late 1980s relaxed restrictions on joint ventures, technical collaborations, entry by large firms, and imports of commercial and research seeds. Analysis of data from a 1987 ICRISAT survey and another 1995 ICRISAT survey (done as a part of this study) suggests that private research has responded positively to these changes. Between 1987 and 1995, private research expenditures increased from US\$1.2 million to US\$4.7 million, the number of doctoral scientists increased from 31 to 111, the number of master's of science degrees increased from 45 to 140, and the area of experimental stations increased from 400 to 1,200 hectares.

Some of the total increase in Indian private research spending is in a handful of large local firms and foreign subsidiaries or joint ventures that could not enter before the reforms. Another share is in new, small companies that entered after the reforms but could have entered at any time. Allowing imports of research seed was one factor that made small research programs viable. The 1995 survey also found a large increase in research expenditures by incumbent firms, often linked to new foreign collaborations, suggesting that policy change had a crucial role to play here as well. Although new spending by incumbent firms was more important than new entry in accounting for the overall increase in private research, the effect of entry must not be underestimated. It was probably the post-reform threat of entry by technologically superior foreign companies that led the incumbent firms to seek collaborations.

Parastatal seed companies. Bangladesh, India, and Turkey began reforms with seed parastatals; Zimbabwe began with a private monopoly. In all four countries, the overall pattern of reform—insofar as it has followed any pattern—has been to reduce barriers to entry for new companies and technology, with little or no attempt (at least

initially) to privatize or reduce the operations of seed parastatals. In crops where technology introduction has been most rapid—primarily high-value seeds, including vegetables and hybrids—private companies have been able to enter and expand market shares against parastatals (which continue to operate) and Zimbabwe's pre-reform monopoly. Private companies also sell some nonhybrid seeds in all four countries.

Fertilizer Reforms and Industries

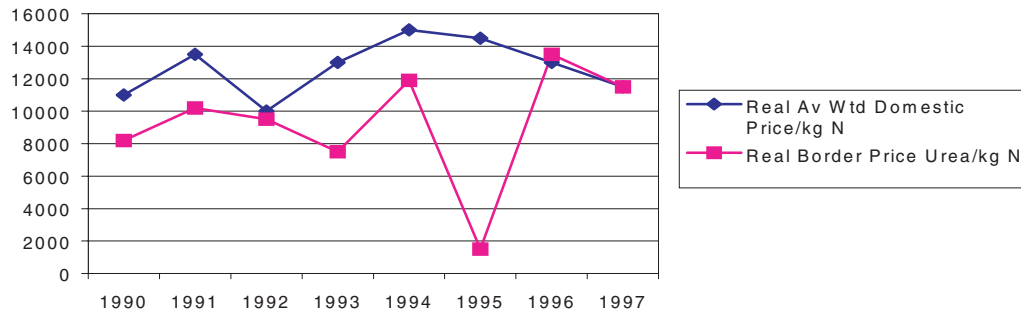
Bangladesh, Turkey, and Zimbabwe have ended fertilizer price controls and relaxed import controls, reducing barriers to company and product entry (see table 3). Turkey and Zimbabwe have maintained controls on fertilizer compositions allowed for domestic trade, and Bangladesh has introduced them. These controls are based on the argument that on their own farmers might not choose products that meet soil deficiencies (Zimbabwe) or might be fooled by cheaper products that have less impact on soil fertility, such as low-analysis products (Bangladesh). Nevertheless, governments have allowed private companies to introduce some new compositions.

All three countries produce much of their own fertilizer. Turkey's industry includes public and private companies; Bangladesh has several public plants and one new private urea plant; and Zimbabwe's fertilizer production is all public. Fertilizer reforms left production patterns intact—at least for the short term—but removed barriers to private trade starting in 1990 in Bangladesh, 1986 in Turkey (with more liberalization in 1994), and 1995 in Zimbabwe. Reforms allowing private imports brought company entry, new products and lower margins.

In Bangladesh, expansion of private trade brought a shift from triple super phosphate (TSP, with 46 percent phosphoric acid) to single super phosphate (SSP, with 18 percent phosphoric acid and 12 percent sulfur) along with a large increase in gypsum (18 percent sulfur). The sulfur content of fertilizer sales grew steadily from 14,000 tons (1.5 percent of all nutrients) in 1989/90, the last year before reform, to 89,000 tons (7 percent of nutrients) in 1995/96. This shift makes sense in light of the widespread sulfur deficiency, and suggests that pre-reform products—with production and imports controlled by the government—did not address soil deficiencies. Aggregate fertilizer sales have continued to grow after reform at least as fast as they did before reform, despite three years of low rice prices (1992/93, 1993/94, and 1996/97).

Omnia, a major South African fertilizer company, entered Zimbabwe with new compositions in 1995. Existing companies responded with their own new compositions. Omnia offers soil tests and made-to-order bulk blending for large customers. In Turkey, reforms in 1986 established oligopolistic competition, which brought more products into the market, but left presubsidy prices far above border prices. Since 1994, further import liberalization has brought real competition, so that domestic presubsidy fertilizer prices fell to border-parity levels (see figure 1 for nitrogen fertilizers; results for phosphorous are nearly identical).

Figure 1. Unsubsidized Nitrogen Prices in Turkey, 1990–97
(constant lira)



Source: State Institute of Statistics, Turkey; International Fertilizer Developer Center, Muscle Shoals, Ala.

Agricultural Machinery Reforms and Industries

In Bangladesh, Turkey, and Zimbabwe, pre-reform controls blocked new technology and competing makes of agricultural machinery (see table 4). For example, the government of Bangladesh maintained a list of specific models of diesel engines that were tested and approved (standardized) for minor irrigation and a similar list of approved models of power tillers. Machinery not on the list could not be imported for agriculture. The government did away with these lists in early 1989, allowing traders to import and sell any diesel engine for irrigation and also any power tiller. In Zimbabwe, administrative distribution of scarce foreign exchange through an association of established dealers allowed the association to control allowed makes and models and to limit competition as well. These controls crumbled around 1994 with general economic reforms that gave new dealers market access to foreign exchange and freedom to import and sell new makes and models. In Turkey, in about 1985, the government removed nontariff barriers and price controls on machinery trade.

Trade liberalization in Bangladesh and Zimbabwe brought market entry and a significant increase in the range of products and sales for engines and engine-powered machinery (such as tractors). In Bangladesh during 1988/89, dozens of traders began importing engines and power tillers from China. Compared with choices that the government had previously enforced, traders and farmers shifted to cheaper makes and a wider range of models, including especially smaller diesel engines. Competition also lowered trading margins. During 1988/89, investment costs for common minor irrigation installations (a diesel engine, 100-mm diameter pump, and well) and power tillers fell by about 50 percent. From the three years before reform to the three years after (1986–88 to 1989–91), sales increased by 400 percent in diesel engines and by more than 1,000 percent in power tillers. The public share of diesel engine imports and

Table 3. Fertilizer Reforms and Impacts on Technology and Fertilizer Industries

<i>Country</i>	<i>Reforms</i>	<i>Post-reform regulatory situation</i>	<i>Impact on technology transfer</i>	<i>Impact on fertilizer industry and trade</i>
Bangladesh	<p>In 1988–90, the government shifted most domestic fertilizer sales from factories and ports to private traders (most wholesale and retail trade was already in private hands).</p> <p>In 1990, the government allowed the import of private triple super phosphate and muriate of potash without permits.</p> <p>Around 1991, the government allowed private import of all other fertilizers without permits.</p> <p>In 1995 (policy reversal), the government assigned markets to each fertilizer dealer, banning sales outside assigned markets.</p> <p>Around 1996 (policy reversal), the government began to limit (list) fertilizer compositions allowed for sale.</p>	<ul style="list-style-type: none"> • In 1991–95, no barriers to new compositions and low barriers to market entry • Starting in 1995, moderate to major barriers to new products and market entry 	<ul style="list-style-type: none"> • Traders introduced new products (e.g., single super phosphate and micronutrients) to address soil deficiencies 	<ul style="list-style-type: none"> • In the early 1990s, private traders took over import trade; there was significant new entry in fertilizer wholesale trade (wholesale and retail trade already competitive)

Turkey	<p>In the early 1980s, the government established a workable foreign exchange market.</p> <p>In 1986, the government ended fertilizer price controls and allowed four private companies to import fertilizers; subsidies continued.</p> <p>In 1994, the government opened fertilizer imports to all large companies; subsidies continued.</p>	<ul style="list-style-type: none"> • Low barriers to new technology started in 1986 • Low barriers to market entry started in 1994 	<ul style="list-style-type: none"> • Competing oligopolists introduced new compounds in the mid-1980s 	<ul style="list-style-type: none"> • Starting in 1986, there was some increase in competition at all levels of fertilizer trade • Starting in 1994, internal prices (before subsidies) fell to border parity
Zimbabwe	<p>In 1994, the government established a workable foreign exchange market.</p> <p>In 1993–95, the government ended all fertilizer price controls.</p>	<ul style="list-style-type: none"> • Incomplete but workable reforms starting around 1995 • Moderate barriers to introduction of new technology • Moderate to major barriers to competition 	<ul style="list-style-type: none"> • Significant increase in number of compositions offered starting around 1995 	<ul style="list-style-type: none"> • Some market entry and significant competition starting in mid-1995

Table 4. Agricultural Machinery Reforms and Impacts on Technology and Machinery Trade

<i>Country</i>	<i>General and regulatory reforms</i>	<i>Post-reform regulatory situation</i>	<i>Impact on technology transfer</i>	<i>Impact on agricultural machinery industry and trade</i>
Bangladesh	In 1985–87, the government established a workable foreign exchange market and ended many nontariff barriers (nontariff barriers continued for diesel engines for irrigation and power tillers). In 1988, the government eliminated import taxes on standardized (approved for agriculture) diesel engines and power tillers. In 1989, the government ended standardization, allowing import without taxes for all 3–20-hp diesel engines and all power tillers.	• No barriers to new makes and technology	• Large increase in variety of diesel engines available, including wider range of horsepower and quality	• Large increase in number of makes of diesel engines and power tillers available, bringing competition and much lower prices • Average annual diesel engine sales increased over 400 percent from three years before reform to three years after reform • Average annual power tiller sales increased about 10 times from three years before to three years after reform
Turkey	In the early 1980s, the government established workable foreign exchange markets. In 1984, the government abolished price controls on agricultural machinery. In 1985, the government abolished rules for domestic content for agricultural machinery manufactured in Turkey. Around 1985, the government removed nontariff barriers on imports of tractors, harvesters, and other machinery.	• No barriers to new brands and technologies for all machinery	• Accelerated introduction of new technology, including pneumatic seed drills, drip irrigation equipment, and dryers	• Consolidation in the domestic tractor industry, possibly to meet stronger international competition • Competitive domestic producers for nonpowered equipment improved product lines
Zimbabwe	Around 1994, the government established workable foreign exchange markets.	• No barriers to new brands and technologies for all machinery	• Introduction of more makes, including cheaper options • Introduction of new technology, including better seeders	• New companies and more competition in machinery import and trade brought lower prices for tractors and other imported equipment • Significant increase in tractor imports (from 1300/year in 1988–93 to 3000/year in 1994–96)

retail sales fell from over 90 percent in 1986–88 to almost none in 1992–94. Liberalization brought a large increase in private imports and sales, although formal credit was rarely available to farmers buying engines from private traders.

In Zimbabwe, the removal of trade barriers brought about a similar increase in the range of makes and models of tractors and other equipment. The number of tractors sold increased from an average of 1,300 per year in 1989–93 to 3,000 in 1994–96. Farmers also report an improvement in seeders and other equipment.

Pesticide Reforms and Industries

Consistent with standard international practice, Bangladesh, Turkey, and Zimbabwe maintain lists of allowed pesticide products, approving new entries based on information about pesticide risks and efficacy. All three countries accept all or most data on risks from tests in other countries but ask for local efficacy tests. The government of Turkey allows companies to do their own efficacy tests, and accepts results from one year of tests (at two sites). By contrast, Bangladesh and Zimbabwe require three years of tests; even then approvals are time-consuming and problematic. Turkey has significantly cut the cost and time required to introduce new pesticide technologies; Bangladesh and Zimbabwe have not. For competing brands of off-patent formulations that are already on the market, Zimbabwe requires three years of redundant efficacy tests, whereas Turkey approves competing products on the basis of chemical analysis alone. Zimbabwe's excessively expensive and slow approval for competing products—notably approving only one product for one company through early 1996—suggests that there is abuse of pesticide regulations to protect market shares for existing major companies. Across all three countries, procedures to approve new low- and zero-risk products remain as time-consuming and strict as for conventional medium and high-risk pesticides.

In Turkey, changes in pesticide regulations brought more active ingredients, competition, and sales. The average annual number of new active ingredients approved for sale increased from 9 in 1980–84 to 20 in 1985–92. The country deregistered some dangerous active ingredients over the same period. From 1980 to 1992, the number of active ingredients available in Turkey increased from 100 to 300, which compares with 700 in the United States in the mid-1990s and 200 in a number of middle-income countries in Latin America and Southeast Asia around 1990 (Gisselquist and Benbrook 1996). Turkey also has more products for each active ingredient. In the 1970s, the government approved an average of three new products for each new active ingredient; starting in 1980, this ratio jumped to nearly five, suggesting increased competition (although individual firms may offer multiple products with the same active ingredient).

In 1989, Bangladesh removed import limits on approved pesticides, allowing more competition among companies with registered products. Zimbabwe established mar-

ket access to foreign exchange, which similarly removed limits on imports for approved products and allowed more competition among established companies. However, in both countries, registration of new and competing products remains a barrier not only to the introduction of technology but also to market entry.

Impact on Productivity and Incomes

The hypothesis we set out to test is that regulatory reforms have a significant net positive impact on productivity and incomes. We establish a direct line of causation from reforms (for example, removal of compulsory variety registration), to changes in the rate of introduction of technology (for example, more private maize hybrids), to changes in input trade (for example, more sales of hybrid maize seeds), to changes in productivity and incomes (for example, higher maize yields and farm incomes). The crucial steps in this argument are the first two, in which regulatory reforms lead to the introduction of more new technology than would have occurred without reform, and this technology reaches farmers through inputs. If these points can be established, then we can be reasonably sure that the observed income gains from selected agricultural outputs would not have occurred in the absence of the regulatory reforms.

To quantify the impact on yields and incomes, we tailor the analysis to the available data so that our methodology varies by input and country. We could not quantify benefits in all markets; however, there were significant positive impacts for selected outputs and minor negative impacts across the agricultural sector. Our method of analysis does not focus on sector output. Therefore, we avoid questions about the relative impact of regulatory reforms compared with other reforms, such as extension and investments in rural roads.

The impact on overall welfare is an important consideration regarding regulatory reforms in the agricultural sector. Because the introduction of new technology is equivalent to an essentially costless expansion of the production possibility frontier, reforms that allow more productive technology have a positive impact on overall welfare. This is true regardless of whether other policies and conditions are ideal in the agricultural sector or other sectors. Regulatory reforms caused a switch from technologies essentially selected by governments to those selected by farmers; there were no real resource costs involved in the switch. Although market distortions may have affected the size and distribution of welfare gains, the introduction and adoption of the new technology was sufficient to enhance welfare qualitatively. In those cases for which we quantified the benefits, we did so using appropriate shadow prices—that is, border prices—so that measured benefits do not depend on uneconomic or distorted prices.

From a more dynamic viewpoint, we also found that regulatory reform often created pressures that worked against subsidies and other economic distortions. For

example, the private companies that entered seed markets in Bangladesh, India, and Turkey undermined parastatal seed sales and subsidies. Post-reform private trade in diesel engines and power tillers in Bangladesh replaced parastatal sales and subsidies and undermined donor and public support for enormously wasteful large-scale surface irrigation projects. An additional consideration is that better technology lowers production costs and thereby undermines the rationale for protection in the form of subsidies or trade barriers against imports. In these and other ways, regulatory reforms have encouraged fewer distortions and better policies.

Case Studies

Case studies from Bangladesh, India, Turkey, and Zimbabwe demonstrate that the reforms brought about improvements in productivity and incomes.

Irrigation in Bangladesh. Between 1988, the last year before the reforms, and 1996, farmers bought and installed 394,000 (net) new shallow tubewells and low lift pumps, an average of 50,000 per year. This compares with average annual increases of 20,000 in the four years before the reforms. Hence, the reforms brought an additional 30,000 new small pumps each year. Estimating that each pump irrigates 4.0 hectares, 30,000 additional pumps extend irrigation to an additional 120,000 hectares, or 1.2 percent of net cultivable area each year. In a regression of cereal production (tons) against irrigation (hectares) using 1972/73–1986/87 district data, the coefficient for standard small pumps is 10.8 (Gisselquist 1991). With this figure, 30,000 additional pumps each year boosts annual cereal production by 320,000 tons, equivalent to 2 percent of 1988 cereal production or 1.6 percent of the much higher 1996 cereal production. This comes on top of other gains from irrigation expansion that would have occurred without the reforms (that is, 20,000 new pumps each year) and increased use of fertilizers.

Based on these estimates, cereal production in 1996 was about 13 percent (1.6 percent compounded over eight years) above what it would have been without reform.¹ By 1996, higher post-reform irrigation expansion had increased net annual farm income from cereals alone by more than \$500 million. This is based on an estimated 2.6 million tons of additional rice at \$250 per ton—a conservative figure because the average import parity price exceeded \$300 per ton during 1991–97—and subtracting off-farm expenses estimated at 20 percent of the gross value of production. This estimate ignores additional farm income from other irrigated crops and fisheries.

Private hybrids in India. Our analysis covers cotton, maize, sunflowers, sorghum, and pearl millet. The empirical model for our partial productivity analysis is similar to the models of total factor productivity analysis in the literature (Evenson and others

1998). The independent variables in our analysis include a measure of the spread of high-yielding varieties expressed as a proportion of the crop area devoted to all varieties, a measure of the spread of private varieties, and other standard variables that affect yields. With this model, the impact of private hybrids on yields is positive and statistically significant in five of the nine crops and provinces analyzed and close to significant in a sixth case.

This evidence that private hybrids and research have had an impact on crop yields is particularly impressive because the region examined is in the semi-arid tropics, where private research is often not expected to have much impact. For maize and sunflowers, companies can draw on large private foreign research programs. In Maharashtra, private varieties and crop profitability have been the major factors explaining higher yields. In Karnataka, where the coefficient for private varieties is not significantly different from zero, the coefficient for public high-yielding varieties is large and could be picking up some of the impact of private varieties. Sunflower yields in Karnataka have been virtually stagnant despite an expansion in the share of area with private varieties. However, the sunflower area grew rapidly, which may explain the low increase in average yields because areas with lower marginal yields were brought into production. Maize yields increased only modestly in Karnataka.

Private maize hybrids in Turkey. We modeled maize yields in tons per hectare as a function of private hybrids, fertilizer, irrigation, rainfall, and trend. Using the model, we projected maize yields without private hybrids, then subtracted projected yields from actual yields to estimate yield and income gains (see Gisselquist and Pray 1999). The gap between actual and projected yields was greatest in 1990 at almost two tons per hectare. During 1990–92, the farm-level annual gross financial value of additional production was about \$130 million (\$255 per hectare over 515,000 hectares). Taking into account higher costs for hybrid seed and for harvesting and drying a larger crop and adjusting farm-level maize and fertilizer prices to international prices, the annual net economic benefit to the country from private maize hybrids in 1990–92 was \$74 million. This is equivalent to 23 percent of the gross value of maize production for the country.

Maize and tractors in Zimbabwe. We estimated the impact of reforms on maize yields in Zimbabwe from the share of area planted to post-reform hybrids and the average yield of new and old hybrids in multiyear field trials. This approach circumvents problems with year-to-year fluctuations in rainfall and other factors affecting national yields as well as inexact national production estimates, which can overwhelm the impact of even very large changes in yield due to new technology (Feyerham and others 1984).

In 1996, farmers planted 52 percent of maize area to post-1996 hybrids, for which the weighted average yield is 5.6 percent above the weighted average yield for pre-

1990 hybrids. Assuming that in the absence of reform all of the area would have been planted to the same pre-1990 hybrids, post-1990 hybrids are responsible for an almost 3 percent increase in national average maize yield and production. This figure compares with estimated annual increases in yield potential due to breeding of roughly 0.67 percent in industrial countries and well over 1 percent in selected developing economies with relatively new private breeding programs.

The reforms have had a large impact on Zimbabwe's stock of tractors. During 1987–89, Zimbabwe had a total of 20,400 tractors, only 3 percent more than in 1977–79 (World Resources Institute and others 1992:274). In the first three years after market access to foreign exchange, 1994–96, aggregate tractor imports were 9,200, equivalent to 45 percent of total tractors in Zimbabwe at the end of the 1980s. Assuming that half of the new tractors replaced older ones going out of service, farmers had more than 20 percent more tractors in 1996 due to the reforms. If these trends continue for another three to six years, the impact of more tractors may be evident in national and survey data on planted area, fertilizer use, timeliness of planting, and field-to-market transport costs. However, considering large fluctuations in agricultural activities due to erratic rainfall and other factors, we did not analyze the impact on planted area or aggregate production through 1996.

Costs of Reform

Disregarding the minor administrative costs of the redesign of regulations, we considered the costs of the regulatory reforms in three main areas: nonperforming technology, fraud, and externalities. We also looked at fears that local input industries might lose sales and that increased private technology flows might undermine funding for public research.

Nonperforming technology. For inputs and countries where changes in regulations brought a large increase in the introduction of technology, farmers shifted out of older technologies. This shift tended to be one-way and progressive, with the number of farmers adopting new technologies increasing over time. The pattern of these shifts suggests that farmers were not negatively surprised about the performance of the new technologies and that farmer adoption of inferior technology from the limited list of pre-reform options became less likely with reform.

This finding agrees with what could be predicted from the literature on markets with incomplete information. The theoretical analyses indicate, for example, that markets are more susceptible to misleading claims when the products being sold have “credence” characteristics, that is, qualities that are not apparent in normal usage (Lynch and others 1986). However, these risks are limited with frequently purchased experience goods, that is, goods whose quality is clear when they are used (Posner 1979). Other studies show that, under many conditions, sellers develop reputations

that improve market information and reliability for all parties (Allen 1984; Klein and Leffler 1981; Shapiro 1982).

Markets for seeds and other agricultural inputs (for example, livestock feed) clearly fit the model of a frequently purchased experience good, the quality of which can be cheaply ascertained. Given the high fixed costs of market entry (breeding, research, and building dealer networks), sellers must depend on reputations to generate repeat business. Farmers are quite capable of judging the attributes of a new variety from seeing it in others' fields (including company demonstrations). If necessary, farmers can test a variety in a small area before planting it on a large scale. Generally, information that farmers obtain this way is a more accurate predictor of their own future results than are data from a small number of government test plots. Of course, government testing may provide additional useful information and may justify government expenditure to develop and disseminate information. However, it does not justify government controls that force farmers to forgo new varieties while government officials collect data from multiyear trials.

Fraud. Some experts argue that in poor countries—where inadequate legal systems mean that farmers cannot sue—reforms that lead to market entry and more private input trade increase the risk of fraud. This argument overlooks the fact that increased competition gives farmers more opportunities to enforce quality through market choice. For example, without competition, seed parastatals are not afraid to lose sales if germination is below what is claimed; market entry changes this situation. In India, for example, it is generally recognized that seed quality improved during the 1990s as private companies with proprietary cultivars expanded their share of the market against public cultivars that were often produced and sold as commodities with little attention to brand name.

The only alleged case of large-scale fraud that we came across in the country studies occurred in Bangladesh. Government experts asserted that fertilizer traders cheated farmers by selling SSP in place of TSP, and that farmers did not fully appreciate differences in phosphoric acid content (18 percent versus 46 percent). Largely on the basis of this charge, in the mid-1990s, the government of Bangladesh introduced new regulations that imposed prior government approval on all fertilizer compositions allowed for trade. The government could have addressed the concern by enforcing truth in labeling for packaged fertilizers. (An alternative interpretation of the increase in SSP sales is that farmers were not fooled but rather appreciated the sulfur content of SSP and that government officials have been confused about the relative impacts of TSP and SSP on yields.)

Higher externalities. Just about anything that leads to agricultural growth—rural roads, regulatory reforms, or public research—will also lead to higher levels of commercial input use. Therefore, growth challenges the government to adjust regula-

tions to focus more effectively on externalities. Well-designed regulatory reforms not only allow more technology and input trade but also focus and strengthen controls that limit externalities. This has happened to some extent in Turkey, and less so in the other three countries. Overall, there has arguably been some increase in pesticide externalities due to insufficient efforts to shift farmers to safer pesticides and to control the use of more dangerous products.

In India, Bangladesh, and Turkey, seed reforms led to some increases in seed imports and hence possible phytosanitary problems. However, the share of planted seed that is imported is still far below common OECD practice in all four countries. Seed smuggling into Turkey fell with reforms, improving phytosanitary protection. However, none of the countries has yet implemented a consistent, science-based phytosanitary system. Overall, evidence suggests little or no shift either way in terms of phytosanitary threats from seed imports. However, governments could have done more to reduce such threats with more focused import controls.

Weaker local input industries. In general, reforms lead to increased company entry and technology, not only expanding input markets, but also taking market shares away from parastatals and some existing private companies. This can present a threat to people with a stake in the pre-reform situation, including government breeders, input parastatals, and existing private companies that are protected by regulations (for example, Seed Coop in Zimbabwe or the sole dealer for Sai Feng power tillers in Bangladesh before the reforms).

For most countries and inputs, we found that reform led to overall growth in the production and trade of inputs, with more links to international industries and technology. In some cases, new companies and technology helped national input industries to compete in world markets. For example, immediately after the reforms, Turkey imported hybrid maize and sunflower seeds; within several years, the country became a net exporter. By contrast, Turkey's fertilizer exports fell because the reforms reduced hidden export subsidies. However, it is important to keep concerns about impacts on input industries in context. Restraints on trade to protect an upstream activity, such as input production, can impose large losses on downstream activities, including agricultural production and processing industries.

Effect on public research. The impact of promarket reforms on public research budgets is another common concern. Before the reforms, regulations blocked private technology introduction, and the government dominated research. Reforms that allow the introduction of private technology stimulate private research (including screening imported technology for local applicability). For OECD countries with relatively much higher levels of private as well as public agricultural research, estimates of returns to public research are consistently high. This suggests that public research remains a good investment, even after reforms stimulate the introduction of more private technology.

Regulatory reforms present an opportunity to revitalize public-sector research. Arguably, a significant share of public research in many developing and transition economies currently has negative returns. In some cases, government scientists waste their time testing and regulating new private technologies or developing inferior technologies that farmers use only because they cannot choose more productive technologies that regulators do not allow. Reforms that bring more private companies and technology allow public research to shift effort into areas not covered by private companies. Such reforms create opportunities for public–private collaboration, create a competitive environment that makes it easier for public research managers to assess and manage staff and research programs, and increase returns to complementary public research (for example, greater use of high-yielding varieties increases returns to soil science research). Thus, the kinds of reforms discussed could lead to redirecting and increasing public research budgets. What actually happens depends directly on decisions within government, not on trade in private inputs.

Recommendations

These findings suggest some specific steps that developing economy governments and supporting institutions can take to more effectively support agricultural growth. First, governments should reduce regulatory barriers to the introduction of private technology. Governments should focus input regulations on fraud and externalities and allow markets to decide questions about performance. Table 5 summarizes some of the most common regulatory obstacles and suggested reforms for major inputs.

Reforms are especially important for products with small markets. Where the potential sales and profits to a private company are small, the high fixed costs incurred in overcoming regulatory hurdles deter the introduction of technology. Most African economies are small markets where high barriers to entry for local as well as foreign companies and varieties have essentially blocked development of private seed industries. These barriers have left farmers with short lists of improved varieties from national research institutes and poor access to seeds, often from monopoly parastatals. Even in large economies, low-risk biopesticides have only small niche markets because they are targeted to specific pests and crops. Forcing them through the same tests as high-risk poisons amounts to a bias in favor of high-risk products. The United States and some other OECD countries have taken steps to adjust regulatory processes to favor biopesticides. Governments in developing economies could consider similar changes.

Second, when donors design a project to support government agricultural research or extension in a developing economy, they should assess whether regulations present an obstacle to the introduction of private technology. If so, the donors should press governments to allow private technology. It makes little sense to pay for public research if government blocks the introduction of commercially available technology.

Table 5. Reforms toward Optimal Regulations: Focusing on Externalities and Fraud

<i>Input</i>	<i>Common excessive or inadequate regulations</i>	<i>Suggested reforms</i>
Seeds	<ul style="list-style-type: none"> a. Case-by-case import permits based on government estimates of seed production and requirements as well as phytosanitary concerns. b. Case-by-case export permits based on government estimates of seed production and requirements. c. Compulsory variety registration: seed sale not allowed until government has approved the variety, often after several years of tests. d. Compulsory seed certification: seed sale not allowed unless government officials have visited and approved fields and tested seed. e. Government permission for new companies to enter the market is based on unreasonably strict objective criteria or arbitrary decision. 	<ul style="list-style-type: none"> a. Focus import controls on realistic phytosanitary concerns. b. Do away with export permits. c. Make variety registration voluntary; test only as a service to farmers and companies. d. Make certification voluntary; do away with minimum standards or make them voluntary; enforce truth in labeling. e. Set low objective requirements for new companies, just as in other sectors (e.g., tax registration).
Pesticides	<ul style="list-style-type: none"> a. Efficacy tests required for all new formulations, including low- and zero-risk biopesticides. b. All pesticides—including low- and zero-risk products—subject to similar controls on sales, storage, transport, and use. c. Residue testing of food products in trade, but often focused on products for export to OECD countries with high standards. 	<ul style="list-style-type: none"> a. Accept efficacy tests from comparable countries; reduce or eliminate efficacy tests for low- and zero-risk biopesticides. b. Adjust trade and use controls according to risk. c. Increase residue testing for food products intended for domestic markets.
Fertilizers	Government approval required for new components and compositions.	Allow companies to sell any combination of nutrients, except for limits on heavy metals and other harmful items; enforce truth in labeling.
Livestock feeds	Government approval required for new nutrients and compositions.	Allow companies to introduce new components and compositions, except for limits on classes of components that threaten health externalities, such as nonvegetable proteins, hormones, and antibiotics; enforce truth in labeling; and increase testing for banned components in feeds and residues in livestock products.
Agricultural machinery	Government tests and approvals required for new makes and models.	Allow companies to introduce new machinery; test only as a service to companies and farmers.

Third, CGIAR should challenge the governments of developing economies to allow all resident companies and NGOs unrestricted access to CGIAR germ plasm and to multiply seed for sale without first having to gain approval from a government regulatory committee. Donors fund the CGIAR system to develop technology for farmers in developing economies. Unfortunately, much of that technology is illegal in many of the countries (where governments enforce compulsory variety registration and have at the same time registered only a small fraction of CGIAR lines). Returns to investments in CGIAR research could be much higher if technology could reach more farmers faster.

Notes

David Gisselquist is an independent consultant. John Nash is advisor for commodities and trade in the Agriculture and Rural Development Department at the World Bank. Carl Pray is a professor in the Agricultural Economics Department at Rutgers University. David Gisselquist can be reached via e-mail at david_gisselquist@yahoo.com; John Nash at jnash1@worldbank.org; and Carl Pray at pray@aesop.rutgers.edu.

1. Estimates of changes in cereal production based on changes in minor irrigation agree with Mitchell's (1997) estimate based on demand-side evidence that rice production grew 3.2 percent per year over 1991–97. During 1991–97, the population grew at 1.6 percent per year, income per capita increased 3 percent per year, and rice prices fell. Imports were minimal in 1991 and 1997. Similarly, field surveys by the Bangladesh Institute for Development Studies (Hossain and others 1996) for 1987 and 1994 show minor irrigation expanding from 20 to 37 percent of net cultivable area, average rice yields rising from 2.44 to 3.22 tons per hectare, and annual rice area increasing from 122 to 139 percent of net cultivated area (on average, 1.39 rice crops were planted each year on the same land in 1994). Official data show rice production growing less than 0.4 percent per year over FY91–97; however, the basis for the official data is weak.

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