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An Argument for Deregulating the Transfer of Agricultural Technologies to Developing Countries

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In the past few decades many developing countries have liberalized trade and investment, removing barriers to imports and allowing the introduction of new foreign technologies. Unfortunately, agriculture often remains outside this reform process. Regulatory obstacles continue to restrain the transfer of technologies through private trade in seeds and other inputs. Industrial countries characteristically allow the transfer of private and public technologies through multiple channels. Developing countries often force technology transfer through a single channel controlled by government agencies, with an emphasis on official performance tests. This article analyzes the institutional arrangements governing the international transfer of new agricultural technologies, examining the cases of agricultural machinery in Bangladesh and seed varieties in Turkey. The analysis shows that allowing the private transfer of technologies and refocusing input regulations on externalities could lead to significant productivity and income gains in developing countries.

In the past several decades many developing countries have liberalized their trade and investment regimes by eliminating barriers to imports and allowing in new foreign technologies. Some recent models suggest that the efficiency gains from relaxing trade restrictions on production inputs could be substantial (for example, Romer 1994). Unfortunately, agriculture often remains outside this reform process. Regulatory obstacles continue to impede the transfer of technologies through private trade in seeds and other inputs. With limited access to new technologies, many farmers in developing countries continue to rely on traditional or old crop varieties, inefficient livestock breeds and feeding technologies, and older and more dangerous pesticides. Barriers to the introduction of agricultural technologies are particularly worrisome for low-income countries that depend heavily on agriculture. And removing existing barriers may lead to substantial productivity and income gains. For example, in industrial countries plant breeding boosts poten-

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tial maize yields about 0.7 percent a year; in developing countries, where breeding has been less intense to date, the potential impact of new maize hybrids can be much greater.

This article addresses two questions regarding the transfer of technologies in developing countries: what are the institutional obstacles to the transfer of technologies mediated through the market, and are they based on convincing arguments? Apart from general import and investment barriers, whose consequences have been widely documented, many governments impede the private transfer of technologies in agriculture with specific regulations that block the sale of inputs—whether imported or domestically produced—except for technologies that they have approved after a review process that includes official performance tests. The impact of performance-based input regulations on productivity and income has not been measured for developing countries. If such regulations were benign or beneficial, countries that deregulated would not show any changes in technology flows, input sales, or productivity growth.

This article looks at two case studies—agricultural machinery in Bangladesh and seed varieties in Turkey. It asks whether regulatory reforms brought dramatic gains in technology transfer, input trade, and productivity. We note that markets should not be totally liberalized because any policy reform must explicitly consider safeguards to limit externalities. Specifically, we do not challenge performance-based tests for conventional pesticides and other inputs with substantial public health or environmental externalities.

I. The Generation and Transfer of Technologies in Agriculture

Agriculture has become a high-technology field, with rapid advances in crop and livestock genetics, pest and livestock management, and machinery. For many field crops the average market life of a variety is no more than five to seven years, and for vegetables it can be as short as two years. The use of conventional pesticides—broad-spectrum poisons—is giving way to a range of relatively low-risk pest management techniques (for example, insect growth regulators, pheromones, microbial pesticides, and inoculants).

Concurrently, private research has become more important. In the United States the private share of agricultural research expenditures, which was less than 50 percent in the mid-1980s, increased to 56 percent in 1992 (Clive 1996). Estimates for 1993 show that in most industrial countries the private sector provided more than 50 percent of agricultural research funds. This share was highest in the United Kingdom, at 62 percent (Alston, Pardey, and Roseboom 1998). In some areas, such as biotechnology, most research is financed by private sources.

Public research in industrial countries has responded to increases in private research by moving upstream into basic research that private companies can build on to develop new technologies for market application. Also, universities and other public research organizations have been applying for intellectual property rights and then selling or licensing new technologies to private companies. The global trend toward stronger intellectual property rights, as evident in the World Trade Organization agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS), promises further increases in the private sector's share of agricultural research and the generation and transfer of technologies.

The recent upsurge in private sector research comes at a time when many donors and developing-country governments have been restraining—if not cutting—their budgets for international and national public agricultural research. Threats to public research in developing countries raise strong concerns among agricultural experts. Alston, Pardey, and Roseboom (1998) note that private research spending in developing countries is seldom more than 10–15 percent of total agricultural research budgets. Returns to some types of agricultural research—for example, crop management to reduce losses to pests—are not appropriable, and hence private companies underinvest in them. Furthermore, evidence accumulated over decades shows high social returns to public investment in agricultural research (see Alston and others 1998).

The debate about the appropriate role of the state in agricultural research is background to this article, particularly the sections discussing the institutional framework (section II) and policy implications (section IV). For example, Byerlee (1998) discusses a new paradigm for national agricultural research systems, and Pray and Umali-Deininger (1998) assess the ability of the private sector to compensate for declines in public funding. However, the scope of our study is limited to international technology transfer, with a particular emphasis on performance tests. Taking the above trends as given, we focus on the specific problem of farmers' access to new technologies, whether they originate from public or private research.

The issue of access to foreign technologies is particularly important because, as in other high-technology fields, agricultural technology is now international. Leading countries continually borrow and build on research from other countries. Technologies move among people, organizations, and countries through publications, discussions, licensing agreements, and international sales. Despite some instances of institutional collaboration (for example, between international centers within the Consultative Group on International Agricultural Research, CGIAR), there is no master plan for research and dissemination. Coordination is achieved mainly through communication and marketing.

The mode of international technology transfer differs according to the types of inputs. Direct transfers through imports are common for high-value seeds, such as hybrid vegetables, new proprietary pesticides, and engine-powered machinery. In-country production using an imported design developed from foreign research also is common, particularly in large countries, for seeds of field crops (for example, a company may import breeders' seed to multiply in-country), out-of-patent pesticides, vaccines, or simple livestock feed additives. Finally, local research may adapt foreign technologies (for example, germ plasm or machinery) to local conditions; this can be particularly important for some categories of technology that depend on local crop management practices, such as integrated pest management.

Whatever the source, most new technologies reach farmers through marketed inputs. New varieties are embodied in seeds, new pest management technologies in pesticides or spraying equipment, and new feed technologies in pre-mixes. Companies extend technologies to farmers through test plots, demonstrations, and dealers. However, the diffusion of technologies has been uneven. Many developing countries lag behind, in part because of self-imposed barriers to the introduction of private agricultural technologies.

II. Channels for Transferring Technologies

Although regulations governing the transfer of agricultural technologies and the trade of inputs vary widely across countries, it is useful to identify two stylized patterns. Access to new technologies may come either through multiple channels, with regulations focusing on externalities, or through a single channel, with regulations based on performance tests. After characterizing this basic distinction, we discuss why the single-channel system, in spite of its restrictiveness, is still in force in many developing countries.

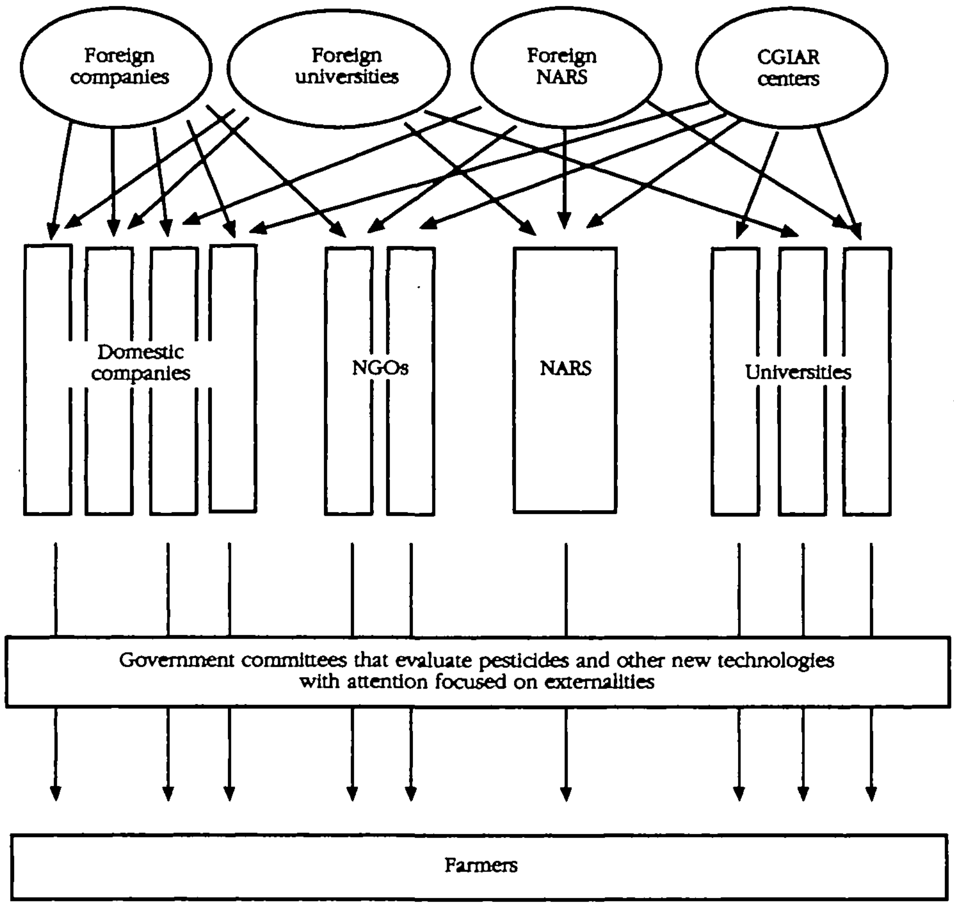
Two Institutional Frameworks

In industrial countries (and in some developing countries) governments maintain liberal trade regimes for foreign and domestic inputs, allowing multiple channels for the introduction of new technologies. Companies, universities, nongovernmental organizations, and government research institutes introduce new inputs that embody new technologies from their own or foreign research (figure 1). Governments regulate inputs to limit externalities (for example, by not approving dangerous pesticides), but otherwise allow companies to market new technologies, trusting that farmers and companies interacting through markets will be able to chose those that are most efficient.

Although all industrial countries allow multiple channels for introducing technologies, there are some differences in regulatory systems. In the European Union, for example, each member government tests plant varieties for performance and automatically accepts varieties approved by any other European Union government without further tests. By contrast, the United States, India, and some other countries allow the sale of seed without variety registration or official performance tests; registration is available, but optional. Despite some differences and special cases, regulatory systems in industrial countries share the same underlying logic, allowing markets to evaluate performance, while focusing regulations on externalities. This liberal approach to technology transfer is appropriate for agriculture, a field with rapid technical change and for which local conditions are critical in shaping the impact of new technologies.

In contrast to the market-friendly regulatory regimes common in industrial countries, many developing and transition countries strictly limit market access for new agricultural technologies. Restrictions are most common and problematic for seeds, but they also may interfere with machinery, fertilizers, low-risk

Figure 1. *Multiple Channels for New Agricultural Technologies*



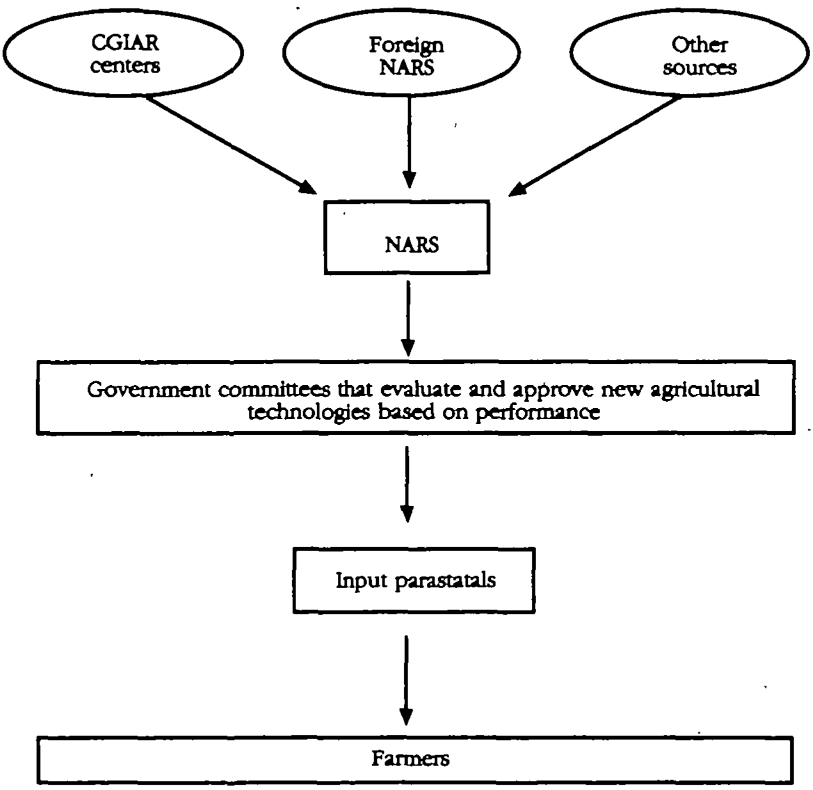
Note: NARS are national agricultural research systems. CGIAR is the Consultative Group on International Agricultural Research. CGIAR centers are the International Rice Research Institute (IRRI) and other international agricultural research centers associated with the CGIAR. NGOs are nongovernmental organizations.

pesticides, feed mixes, and other items. Many developing countries maintain positive lists of allowed inputs, even those for which externalities are not a serious concern. For example, many countries list allowed plant varieties, and some also list allowed models of machinery, compositions of fertilizers, and feed mixes based on official performance tests. Bhagwati (1978) and Krueger (1978) describe positive lists, which are common in foreign trade regimes that use quantitative restrictions. Positive lists are far more restrictive than negative lists, which allow anything not listed.

For most inputs environmental or public health concerns can be addressed with negative lists. For example, instead of approving each feed mix, governments can simply ban or limit potentially dangerous components, such as hormones. Although positive lists are standard across all countries for pesticides and veterinary medicines, countries differ in the conditions for registering new products. Many developing countries limit new products in ways that restrict competition and entry. For example, in 1984 Indonesia decreed that no more than three companies could sell pesticides with any particular active ingredient.

With regulations and policies that make it difficult for companies to enter and to operate, many developing countries effectively block almost all transfers of private technologies for seeds and other major categories of agricultural inputs. Thus government agencies are left as the dominant or only channel for technology transfer (see figure 2). Under this system a centralized government research establishment identifies new varieties and other new technologies, parastatals produce or import and sell inputs, and extension agents encourage farmers to take what is offered. Often a single-channel system operates for some, but not all, inputs.

Figure 2. *Single Channel for New Agricultural Technologies*



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A single-channel system severely constrains the flow of new technologies. In many developing countries with single-channel systems farmers are offered an average of less than one new seed variety a year for each major crop, while farmers in countries with multiple channels may see dozens of new varieties each year for a single major or minor crop or vegetable. Even where private companies are able to operate, regulatory costs limit the transfer of private technologies. Regulatory costs are particularly troublesome in small markets—small countries or minor crops—where companies may judge that registering a new technology is not worth the effort, leaving farmers with no access.

Arguments for Single-Channel Systems

Many developing-country governments and donor experts continue to promote, endorse, or accept single-channel systems and performance-based regulation of inputs, despite their limitations. The standard argument sustaining this position is that deregulation would lead to the diffusion of unsatisfactory inputs because farmers either lack the necessary information to discriminate or are susceptible to false marketing. Thus farmers should be protected from those who "might try to market an unsatisfactory variety simply to recoup breeding costs" (Kelly 1989: 43). Apart from underestimating the capacity of farmers to learn about inputs at a low cost, this argument is debatable on several counts. If lack of information is the issue, there certainly are more efficient ways to address it than through a registration process that limits the range of available inputs. Moreover, fears that giving farmers more choice will encourage the spread of inferior varieties—or fertilizer compositions or feed mixes—are not supported by experiences in India and other countries that allow the sale of untested seed varieties.

In some cases, such as that of low-risk pesticides, excessive reliance on performance tests may even exacerbate externalities. Conventional broad-spectrum poisons, which kill a wide range of pests outright, but which also threaten public health and cause environmental damage, are easy to manage in efficacy tests and have large markets for multiple pests. Nontoxic biopesticides that interfere with insect mating or maturation can be more difficult to manage, so that results from efficacy tests are misleading. In addition, they may be limited to specific insects and crops. Forcing low-risk pesticides to pass expensive efficacy tests can leave farmers with limited access to low-risk products (see Benbrook and Gisselquist 1996).

Many donor experts see deregulation to allow the introduction of private technologies as either irrelevant or threatening. Evenson and Westphal (1995: 2248–49) assert, "Important forms of adaptive agricultural R&D require a substantial commitment of resources dedicated to developing techniques for a particular set of agronomic conditions." This line of reasoning leads to the conclusion that deregulation has minimal impact because the private sector does little research in developing countries and offers few suitable technologies. However, casual observation shows that pesticides, fertilizers, machinery, livestock feeds, and breeds can move across borders. Recent studies of multinational adoption of CGIAR rice and wheat lines bred in Mexico and the Philippines show that crop varieties also move across borders (Maredia, Ward, and Byerlee 1997; Evenson and Gollin 1997).

Another common reservation about deregulation among donor experts is that private technology transfer might somehow undermine public funding or public research. This reservation is difficult to argue against because it is not rational. A decision to allow more private technologies through deregulation is essentially costless to the government. It would be entirely independent of any other government or donor decision about the extent of funding for public research. Even if deregulation leads to private technologies taking over some agricultural activity (for example, private fertilizer dealers could design compounds for particular crops and regions), public scientists could continue to work on whatever projects the government and donors support (for example, testing soils and fertilizers, presenting farmers with competing advice). If industrial countries serve as a guide, systems with multiple channels have more advanced agricultural technologies and higher levels of public research as a share of agricultural gross domestic product (GDP) than single-channel systems. Hence, to think of public research and private technology as an either-or choice is misleading; they are better thought of as complements.

Persistent Regulation of Technology Trade

The case for single-channel systems seems to be weak. However, single-channel systems have significant support among developing-country governments. This persistence may be explained by the influence of the beneficiaries of such systems. In some cases private monopolists or oligopolists may oppose opening the door to competition. An example is the Bangladeshi company that was the exclusive distributor of the only Chinese power tiller approved for import. The company suffered in 1989 when reforms allowed competing low-cost models to enter the market (see section III). Similarly, pesticide companies in Zimbabwe benefit from regulations requiring three years of (redundant) in-country efficacy tests for competing brands of old and out-of-patent pesticides. And in several Central European countries spokespersons for seed companies that have large market shares privately favor the compulsory registration of varieties to hold off competing firms.

However, the strongest call for governments to limit the transfer of private technologies characteristically comes from public sector scientists. Public sector scientists can be influential far beyond their numbers. They are the gatekeepers in a single-channel system. Often prestige and concerns about job security seem to be the major issues, although some scientists may also receive monetary benefits from testing fees or from bribes.

In countries with single-channel systems public sector scientists not only have blocked private technologies, but also have blocked technologies from CGIAR centers. For example, for several years in the 1960s government scientists in India and Turkey refused to approve dwarf wheat varieties from the International Maize and Wheat Improvement Center (CIMMYT), despite clear evidence of superior yields from field tests. In India government scientists reportedly falsified field test results to avoid having to approve CIMMYT wheat. Presumably, the scientists wanted to breed their own varieties, crossing CIMMYT and local wheat. However, breeding takes time; regardless of what is planned for local breeding, it makes sense to give farmers access to good varieties that are already available. In both countries donors helped to bring the issue to the attention of senior government officials, who pushed through the approval of CIMMYT varieties against domestic objections.

Bowing to the wishes of scientists in national agricultural research systems, the International Rice Research Institute (IRRI) and other CGIAR centers have adopted and maintain the fiction that they do not release varieties, but rather lines, which the national agricultural research systems then further develop into varieties. It is true that research systems play a large and positive role in introducing and adapting CGIAR technologies. However, many CGIAR lines are suitable for release and are widely released by the research systems after adaptive trials only, without further breeding. Incredibly, most CGIAR lines are illegal in many if not most developing countries—because scientists from the national agricultural research systems have not approved them for lists of registered and allowed varieties.

Donors also have supported single-channel systems, but their logic and motives are not clear. Allowing the introduction of private technologies in agriculture is consistent with widely accepted patterns in other sectors, such as computers and software, where private technologies move without government approval. However, donors have a history of paying special attention to agriculture, including a long involvement with public sector scientists in CGIAR centers and national agricultural research systems. Recently, public agricultural research has been under attack from budget cutters, despite continuing high returns to investment. Maintaining existing public research capacity is thus a challenge that legitimates and absorbs a significant share of donor effort and attention. But here again, there should be no confusion between the necessity of preserving public research and the gains from deregulation.

III. The Impact of Deregulation: Two Case Studies

Although the effects of trade liberalization are widely documented, there is little evidence on the impact of performance-based regulations. Two studies of industrial countries suggest that losses in terms of forgone income may be huge for cotton in California (Constantine, Alston, and Smith 1994) and for wheat in Canada (Ulrich, Furtan, and Schmitz 1987). To our knowledge, no similar estimates exist for developing countries. However, based on a sample of 50 mostly developing countries, Pray and Echeverría (1988) find that seed imports and private research are significantly correlated with maize yields.

One research strategy to measure the impact of deregulating inputs is to work with aggregate data, comparing levels or growth rates of agricultural production or total factor productivity across countries or over time. The most convincing cross-country argument is trivial: no research is required to establish that industrial countries as a group have more open and competitive input industries and higher levels of agricultural technology and production than low-income developing countries. However, it is difficult to interpret cross-country comparisons of growth rates because countries with restrictive systems can show fast growth from a low and constrained base (resulting in part from many years of obstructed technology transfer). Also, regulatory systems are varied and complex, so it takes time to understand what is going on in any one country; the result may be difficult to express numerically for econometric analysis. Another set of problems undermines intertemporal models that use aggregate data: changes in the regulation of inputs often occur in conjunction with other macroeconomic and microeconomic reforms. It can be difficult to disentangle the impacts of these reforms, along with climate and other factors, from the impact of regulatory reforms.

In this section we trace the impact of regulatory changes in Bangladesh and Turkey on technology transfer for a particular input, then on input sales, and finally on specific agricultural activities or outputs. These case studies are not designed to measure the aggregate impact of regulatory reforms on all of agriculture, but rather to show that reforms have a positive and not insignificant impact on selected outputs or activities. Therefore, if production increases with deregulation, then regulations on balance do not protect farmers from inferior technologies, and regulations are not irrelevant.

Agricultural Machinery in Bangladesh

The case of agricultural machinery in Bangladesh before reform constitutes an almost ideal illustration of the single-channel system. Prior to reform in the late 1980s, the Ministry of Agriculture listed "standardized" (tested and approved) models of diesel engines for irrigation and power tillers. The Bangladesh Agricultural Development Corporation, a parastatal, imported listed engines and sold them at subsidized prices. Models not on the list could not be imported.

Reform arrived in 1988–89. Along with modest tariff cuts on diesel engines for irrigation (from 15 to 0 percent), the Ministry of Agriculture did away with lists of engines standardized for irrigation, allowing all models. Subsidized parastatal sales continued for several years, but farmers increasingly shifted to private traders, who offered convenience along with a wide range of low-cost models. By the end of 1991 private traders clearly dominated the market. Regulatory reform—allowing the private import and sale of new and less-costly models of diesel engines and power tillers from China—was followed by a sharp increase in the sale and use of imported machinery.

Regulatory reform allowed farmers to choose cheaper equipment (see table 1). The retail cost for the most common minor irrigation investment (a 12 horsepower engine and a 100 millimeter diameter tubewell for lifting groundwater) fell below $500 by the end of the 1980s, less than half what it had been with

Table 1. *Impact of Deregulation of Imports of Agricultural Machinery in Bangladesh, 1988–96*

Type of input	*Fall in retail price*	*Impact on farm use*
Diesel engines for minor irrigation	More than 50 percent	Increase of 170 percent over eight years in the number of small pumps operating (extending new irrigation to an estimated 16 percent of gross cropped area)
Power tillers	More than 40 percent	Machinery cultivation extended from 0 percent in 1988 to 15–40 percent of cultivated area, depending on the season

Note: Regulatory reforms (1988–89) included trade liberalization of agricultural machinery and the suppression of compulsory registration.

Source: Government of Bangladesh, Ministry of Agriculture (1995a, b) and authors' calculations.

subsidies in 1981–82. After the reform minor irrigation expanded at record rates. From 1988 to 1996 the number of small power pumps lifting ground or surface water for irrigation increased by 170 percent, or 390,000 units, delivering new irrigation to roughly 16 percent of the gross cropped area (assuming that each new pump irrigated an average of 4 hectares). Markets also moved toward smaller equipment (4–8 horsepower engines and 75–100 millimeter diameter tubewells).

The 1988 pre-reform list of standardized power tillers included only one low-cost model from China (cost, insurance, and freight [CIF] import price about $1,000), one from the Republic of Korea (CIF about $1,700), and about 10 others from high-cost sources (CIF well over $2,000). Dealers for the two low-cost models dominated trade, taking advantage of limited competition to sell them for more than $2,000; with no duties in late 1988, dealers realized large profits. When standardization ended, multiple models from China, with CIF near $1,000, entered the market, and competition soon cut the retail price to about $1,300. Before the reform power tillers were so rare that an observer typically would not see any during a multi-day tour of rural areas. By 1996 power tillers prepared an estimated 15–40 percent of the land for cultivation, depending on the season (based on power tiller imports and assuming that each power tiller lasts five years and cultivates 25 hectares in a season).

Seed Varieties in Turkey

A 1963 Turkish seed law gave the Ministry of Agriculture authority over seed production and trade. Through regulations based on the law, the Ministry made variety registration and in-country performance tests compulsory for most crops, set seed prices annually, and extended import and export controls well beyond phytosanitary concerns. In practice, the Ministry limited the approval of varieties for most field crops to those sponsored by government research agencies; for vegetables, it allowed only a limited range of private varieties.

At the beginning of the 1980s difficulties with Turkey's single-channel system included widespread smuggling of vegetable seeds, failure to popularize hybrid maize, and expensive government agencies serving no more than 10 percent of the planted area. The government consequently revised seed policies to encourage private participation in seed production and trade. Between 1982 and 1984 the government removed seed price controls, relaxed foreign investment controls, and eased (but did not entirely dismantle) compulsory registration of varieties by reducing testing requirements and allowing private companies to conduct their own tests.

Reforms brought large increases in the number of varieties allowed for sale, as well as rapid expansion of participation by private companies (see table 2). Between 1982 and 1994 the number of allowed varieties increased 670 percent for hybrid maize, 2,400 percent for hybrid sunflowers, and 3,400 percent for soybeans. Most of these new varieties were direct transfers, often from parts of Western Europe and the United States that shared the same latitudes. Most were proprietary varieties, although some came from foreign or international public research. As a result, the share of commercial seed sales through private companies soared—in 1993 exceeding 90 percent for maize and sunflower hybrids, soybeans, and potatoes. The number of private companies increased from about 5 to 80 in 1980–94. During this period most major seed multinationals established a presence in Turkey through subsidiaries, joint ventures, or licensing agreements.

Trade reforms led to an initial increase in seed imports for some crops. For example, imports of hybrid maize seed exceeded production in 1985. Soon, however, local seed production expanded to meet local demand and then pushed into export markets as well. Exports of hybrid maize seed exceeded imports in 1988 and reached a quarter of total production in 1992. Similar trade shifts occurred for hybrid sunflower seed. Once reforms allowed seed technologies to enter, Turkey was able to exploit its comparative advantages of a good climate, developed scientific skills, and low labor costs.

Available data on maize yields allow for a rough estimate of the gains from private hybrids following the reforms. Gisselquist and Pray (1997) estimate a yield response function over 1961–91 (see table 3). Regressors include the percentage of maize area sown in private hybrids, annual fertilizer use, annual rain-

Table 2. *Impact of Deregulation of Trade in Seed in Turkey, 1982–94*

Crop	*Harvested area, 1990 (hectares)*	*Varieties available, 1982*	*New varieties introduced, 1982–94*	*Private share of commercial seed production (percent)* 1985	1994
Wheat	9,400,000	21	62	0.5	8.8
Hybrid sunflowers	715,000	3	74	88.9	98.9
Cotton	841,000	9	19	0.0	0.1
Hybrid maize	155,000	24	185	85.7	97.3
Potatoes	192,000	31	51	11.3	91.7
Soybeans	74,000	2	70	42.1	94.7

Source: Government of Turkey, SIS (1992) and Government of Turkey (various years).

Table 3. *Maize Yield Response Function, Turkey, 1961–91*

Explained variable	*Share of hybrid planted area*	*Fertilizers per hectare*	*National rainfall*	*Trend*	*Adjusted* R^2
Maize yield (tons per hectare)	2.89	1.4E-03	4.58E-04	5.34E-02	0.924
	(0.52)	(5.3E-03)	(7.14E-04)	(2.73E-02)	

Note: Numbers in parentheses are standard deviations.
Source: Gisselquist and Pray (1997).

fall, and a trend variable to control for other factors (such as transport improvements and extension). Data on the irrigated area for maize were not available.

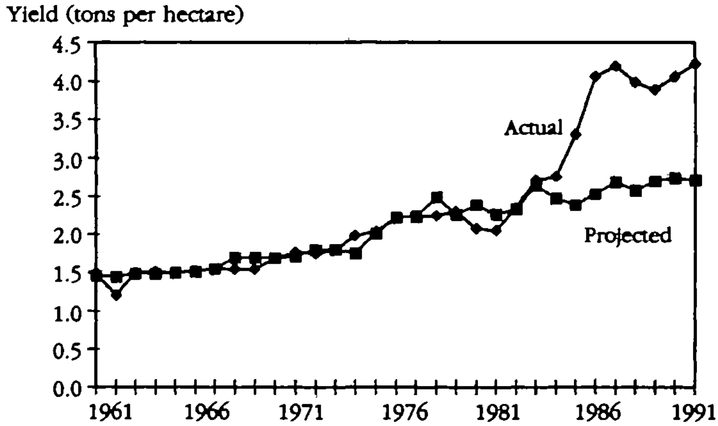
The explanatory power of the model is satisfactory. All coefficients exhibit the expected sign, but neither fertilizer nor rainfall is significant at the 95 percent level. Gisselquist and Pray simulate projected maize yields in the absence of reform using the estimated coefficients, but with zeros for post-reform hybrids. A comparison of actual yields and projected nonreform yields suggests that private maize hybrids boosted maize yields more than 50 percent (see figure 3).

Gisselquist and Pray use this result to estimate the magnitude of the income benefit from post-reform hybrid maize in Turkey. The increase in average net economic returns per hectare of maize during 1990–92 was $153, equivalent to 25 percent of the gross economic value (table 4). With a total maize area of 515,000 hectares, this result implies an annual net economic gain of $79 million for Turkey's maize farmers.

IV. Conclusions and Policy Implications

The evidence presented in this article suggests that deregulating the trade of inputs leads to significant increases in the range and quality of inputs available to

Figure 3. *Actual and Projected Maize Yields in Turkey, 1961–91*



Source: Gisselquist and Pray (1997).

Table 4. *Estimated Average Annual Net Economic Benefits from Hybrid Maize, Turkey, 1990–92*

Indicator	*Volume*[a]	*Change in volume due to hybrids*[a]	*Unit price*[b]	*Change in value due to hybrids (dollars per hectare)*
Average yield	4.13	1.43	148	211
Projected yield without hybrids	2.7[c]	n.a.	n.a.	n.a.
Cost				
Nonhybrid seed	37	−11.1[d]	0.148	−2
Hybrid seed	28	8.4[d]	2.97	25
Harvesting and drying[e]	n.a.	n.a.	n.a.	35
Net gain	n.a.	n.a.	n.a.	153

n.a. Not applicable.
a. Yields are in tons per hectare, and costs are in kilograms per hectare.
b. Yields are in dollars per ton, and costs are in dollars per kilogram.
c. Based on the yield response function described in the text.
d. Assumes that 30 percent of the maize area is planted in hybrids.
e. Estimated as one-sixth of the value of production.
Source: Gisselquist and Pray (1997).

farmers, which in turn raises productivity and income. From the case studies of Bangladesh and Turkey we recommend that countries with single-channel systems revise their regulations, especially performance-based regulations for approving new technologies, and move toward multiple channels for technology transfer. Evidence of large gains with a greater range of technical options agrees with results from trade models. Of course, our results would be more robust if we could support them with additional studies of similar reforms. Preliminary findings from ongoing World Bank studies of input reforms in Zimbabwe and India corroborate the conclusions and recommendations in this article.

The recommendation to reduce and revise regulations governing the trade of inputs should not be confused with full trade liberalization. Regulations to control negative externalities in terms of public health and environmental damage should be maintained and even reinforced in several countries. For example, in the case of new pesticides, governments might consider not only maintaining a positive list of allowed products, but also levying taxes on allowed pesticides, with rates determined according to externalities. More generally, existing regulations based on performance could be redesigned to focus on externalities (see table 5). For inputs with significant externalities, such as medium- and high-risk pesticides, performance could be taken into consideration in deciding whether the gains are worth the risks.

Serious consideration of regulatory reform requires time and effort to deal with specific situations and concerns. For example, even if people accept the principle of limiting regulations to externalities, in some situations they will debate the existence or magnitude of externalities.

Market power, another potential source of market failure, may be a concern in the reform process. The risk that monopolies and oligopolies will dominate

Table 5. *Reforming Regulation on the Transfer of Agricultural Technology*

Input	*Common regulatory barrier*	*Proposed reforms to focus regulation on externalities*
Seeds	Governments prohibit the sale of seed except for registered (approved) varieties based in part on performance tests	Allow the sale of seed without variety registration
	Governments block seed imports to protect domestic seed production (using unreasonable phytosanitary arguments or other nontariff barriers)	Focus phytosanitary controls on diseases that are present in the exporting country but not in the importing country and that threaten real economic damage
	Governments demand that companies submit samples of inbred lines before the governments will allow the sale of hybrid seed	Allow importation and sale without deposit of a seed sample; this regulation has nothing to do with externalities
Pesticides	Governments require in-country efficacy tests for new products before allowing them for sale	List allowed products; allow the sale of new no-risk or low-risk products without in-country efficacy tests
Fertilizers	Governments limit the types of fertilizers allowed for sale based on expert opinions about soil nutrient deficiencies	Allow companies to sell fertilizers with any combination of nutrients; enforce truth-in-labeling and ban dangerous impurities
Agricultural machinery	Governments limit imports to lists of approved models, basing approvals on performance tests	Allow importation of any model, leaving farmers to assess performance against cost and other factors
Livestock feed	Governments set minimum standards for various nutrients or components or require prior registration and approval for all feed mixes based on expert opinions	Allow companies to sell any combination of feed components without registration; enforce truth-in-labeling and ban or regulate feed additives with negative externalities (hormones and antibiotics)
Veterinary medicines	Governments do not allow the import of (private) vaccines, arguing that government production is adequate, diseases do not exist, or quality is not secure	List allowed products; allow private and competing products but regulate them to ensure quality (impurities in vaccines can spread other diseases)

input markets is more serious for small and low-income countries. For example, a minimum of 20–30 seed companies in a country may be required to ensure that farmers have access to world technologies for all crops through competitive seed markets. (Five or six seed companies ensure a competitive market for a single crop, but companies specialize, so several times that number is required to cover all crops.) National seed markets in most Sub-Saharan African countries are not large enough to support competitive, modern seed markets. But regulatory reforms can allow national markets to merge into regional markets that are large enough to ensure a competitive supply of seed for minor and major crops. Policies favoring regional seed markets in Africa include voluntary registration of varieties and limits on seed import controls to realistic phytosanitary concerns, allowing varieties and seeds to move more easily across borders.

Deregulation should not jeopardize efforts to maintain and increase local public research and mastery of technologies. Public research has been and can be a source of useful technologies, often adapting and improving foreign technologies for local conditions. Furthermore, some classes of agricultural technologies are public goods (for example, integrated pest management techniques that do not use broad-spectrum poisons), for which the social returns to research far exceed what can be recouped through the sale of inputs. Also, local research capacity strengthens the bargaining power of the country if prices for technology transfer are not competitive (Pack and Westphal 1986) and avoids a widening of the technological gap when spillovers from research and development are national rather than international (Grossman and Helpman 1991).

There may be good reasons to increase public research as the transfer of private technologies expands. The entry of more research-intensive input companies creates a competitive market for scientists and ideas, which improves the environment for managing public research. Research-intensive companies often work closely with the public sector and request more public research. And a commitment to boost funds for public research may help to blunt opposition to reform from government scientists who lose monopoly control over the transfer of technologies.

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