Title: Private sector agricultural technology transfer into Bangladesh, Kenya, Senegal, Tanzania, and Zambia

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Acknowledgements, role of the funding source: This work was supported by the Bill and Melinda Gates Foundation, award number 52149, Measuring Private Research and Innovation in South Asia and Sub-Saharan Africa. The funding source had no influence on the paper's contents. All opinions expressed in this article are solely those of the authors.

Abstract

For five countries in Asia (Bangladesh) and Africa (Kenya, Senegal, Tanzania, and Zambia) this report describes private sector technology transfer and introduction and considers interactions between technology transfer and private research. Information in this report comes from surveys of 126 private organizations, interviews, documents, and other studies.

Across all study countries, private companies introduce most new technologies for pesticides, machinery, poultry, fertilizers, and processing. Private companies deliver a steady flow of new maize hybrids in all countries except Senegal, new rice hybrids in Bangladesh, and new vegetable cultivars in Bangladesh, Kenya, Senegal, and Zambia. However, for other field crops in the African countries in this study and for five crops in Bangladesh, governments control private cultivar introduction.

Most companies reported introducing at least some technologies from other countries. Private technology transfer led to and supported private research. Fifty-seven of 126 surveyed private organizations reported in-country research.

Public support for private technology introduction is widely accepted in principle. Governments and donors are gaining experience with grants and other initiatives to promote private research. Governments provide educated staff and technical assistance and advice. However, government controls on introduction of several categories of agricultural inputs, especially cultivars, discourage private technology introduction. Additional studies are required to get a better picture of linkages between local and foreign agribusinesses, private technology transfer, and impact of private technology transfer on private research.

Keywords: agricultural technology, technology transfer, innovation, technology spill-in, Bangladesh, Africa

1 Introduction

The objective of this study is to advance understanding of the private transfer of agricultural technology into developing countries, the factors that facilitate or inhibit such transfers, and the interaction between technology transfer and private in-country research. To do so, this report looks at private technology introduction in five countries with small to medium economies: Bangladesh in Asia, and Kenya, Tanzania, Senegal, and Zambia in Africa.

Although technology transfer is fundamental to technological progress in all countries, this focus on five small- to medium-sized economies is useful for several reasons. First, the contribution of technology transfer is more exposed in smaller economies with less in-country research than in larger economies, such as China, India, or Brazil; this makes data collection and analysis more tractable. Secondly, the insights provided by this study are immediately relevant to a large number of countries in Asia, Africa, and Latin America that are characterized by similar sized economies, regulatory regimes, and policy challenges.

This study does not attempt to recommend appropriate roles or responsibilities for public or private research or technology transfer. There is no question public research and technology transfer contribute to agricultural development and that private in-country research is important in some countries. The task for this paper is to fill in some of the picture of private technology transfer so this source of technology for development can and will be better understood and more systematically considered in the future.

Conceptual framework: As a normal part of doing business, companies search for, assess, and introduce technologies. These may be from any public, private, foreign, or in-country source, and may be proprietary or non-proprietary (off-patent or other public) technologies. The terms “private technology transfer” and “private technology introduction” in this paper are short-hand for the transfer and introduction of technologies from any source by private organizations, and do not refer to only private, proprietary technology.

This discussion of private technology transfer organizes information around three questions.

First, is technology available? One common theme in papers on agricultural technology for development has been that differences in agro-ecologies, wages, and other factors limit the availability of suitable technology for import, especially for poorer countries in low latitudes. Optimal technologies vary according to location (Evenson and Westphal, 1995; Maredia et al., 1995). Various metrics show agro-ecological differences between countries (Pardey et al., 2007). Development experts cite these differences in appeals for governments and donors to fund public research to adapt foreign technologies for local use.

Studies also show success with spill-ins. For example, 50 percent of wheat varieties introduced into 38 developing countries during 1966-90 came from the International Maize and Wheat Improvement Center (CIMMYT) or from other countries without any additional in-country breeding (Maredia et al., 1995). Similarly, 23 percent of 1,709 rice varieties introduced into 40 developing countries came directly from the International Rice Research Institute (IRRI) or from other countries (Evenson and Gollin, 1995). An analysis of factors contributing to agricultural productivity growth across states in the US found that public research in other states had a bigger impact than in-state research (Yee, 2001).

While agro-ecologies and other factors are obvious limits to technology spill-ins, the significance of these limits cannot be determined in the abstract. The only reliable information on the potential for spill-ins through private organizations is to see what happens when governments allow it – that is, when policies do not block private technology introduction from spill-ins or any other source.

Second, what government policies facilitate or inhibit private companies to transfer and introduce technologies? This question involves a number of issues. For example, do governments allow companies to enter markets? For technologies posing no environmental or health threats, do governments regulate and obstruct technology introduction based on official assessments of technology performance? Do governments protect intellectual property (patents, plant breeders’rights, trademarks, trade secrets). Does government assist or support private companies with technical advice and collaboration and scientific education? Government policies and programs that affect private technology transfer also facilite or discourage private research (Pray et al., 2012).

Third, what are the interactions between technology transfer and research? What effect does private technology transfer have on private research? What effect does private research have on private technology transfer? Essentially all technologies coming from in-country research are based, at least in part, on imported technology. Moreover, the interaction is bi-directional: in-country research not only builds on but also guides and stimulates technology transfer. Notably, scientifically advanced countries characteristically welcome foreign technology to boost both production and research. For example, foreigners accounted for 50 percent of applications for plant breeders’ rights (PBRs) in the United States (US) during 2001-05 (Pardey et al., 2007).

Methodology: Data and information for this study came from: a 2009-10 survey of companies and other private organizations; unstructured interviews with experts including donor and government staff and staff of surveyed organizations; and a review of academic and grey literature, government documents, statistics, and company reports.

In each country we surveyed a non-random sample of private organizations chosen to cover all important agricultural sub-sectors, including inputs, large-scale production (e.g., plantation or estate farming, ocean fishing), and processing. The survey questionnaire asked about: company characteristics; innovations over the previous 5 years; R&D budgets and staff; and experiences with government policies and programs. Although the survey was intended to examine introduction of private technology from any source, we purposively included organizations known to have in-country research (surveys in Kenya, Senegal, and Tanzania targeted exclusively organizations with in-country research). During 2009-10, study teams distributed questionnaires in person or by email or mail to 223 organizations across the five countries. One hundred and twenty-six private organizations returned at least partially completed questionnaires, including: 117 companies (Table 2 reports number of companies by country), 5 NGOs (2 in Bangladesh, 3 in Zambia), 3 producers' cooperatives (in Tanzania), and a trade association (in Zambia).

The findings from this study are limited by survey design as well as by conceptual and practical difficulties. The survey captures an important but unknown proportion of agri-business activity. Because the survey is non-random, some of the results (such as average size of firm, and proportion of firms involved in specific sub-sectors) cannot be generalized to all agri-businesses in a country. Furthermore, the costs and sources of transferred technology are often kept as company secrets. However, the uncertainties around survey data are less important than conceptual and other challenges. For many types of technology, the "flows" of technology transfer and introduction are difficult to measure quantitatively in ways that can be compared across sectors, time, or countries.

Outline: Section 2 introduces the five countries. Section 3 describes private companies and their introduced technologies. Section 4 examines the contribution of technology transfer to private technology introduction (responding to question 1). Section 5 considers some of the ways that private technology transfer stimulates private research (responding to question 3). Section 6 examines government policies and programs that impact private technology transfer through market access, revenues, and costs (responding to question 2). Section 7 presents conclusions and recommendations.

2 Overview of the agricultural economy in five countries

All five countries in this study are low or lower middle income countries, with gross domestic product (GDP) per capita ranging from US$503 in Tanzania to US$1,023 in Senegal (Table 1). The percentage of the population that is poor – that lives on less than 2005 constant purchasing power parity dollars (PPP$) 1.25 per person per day – is lowest in Kenya, at 20 percent, and highest in Tanzania, with 68 percent. Bangladesh, with a population of 162 million, has the largest GDP of US$89 billion. The four African countries taken together have a combined population of 108 million and a combined GDP of US$76 billion.

Agriculture value added (in crops, livestock, forestry, and fisheries) is 11 percent of GDP in Senegal and 18-26 percent in the other four countries. However, this understates the value of agricultural production at the farm gate (which includes cost of inputs) and even more so at the retail or export point (including transport, trade, and processing). Employment and rural population are better measures of the importance of agriculture in these countries. The proportion of the labor force in agriculture ranges from 34 percent in Senegal to 75 percent in Tanzania. Societies are predominantly rural, with 57-78 percent of the population living in rural areas.

In all five countries, existing and projected domestic demand for food can absorb large and sustained increases in agricultural production. Bangladesh's food imports were 27 percent of agricultural value added; while Senegal's were 70 percent. For the other three countries, the value of food imports were 9.5-15 percent of agricultural value added. Due to low incomes, the income elasticity of demand for food is high at 0.79-0.81 across all five countries (Economic Research Service, 2011); thus, local food demand grows almost as fast as GDP.

Reported annual growth in agricultural value added during 2000-09 ranges from only 0.8 percent in Zambia to 4.4 percent in Tanzania. In 4 out of 5 countries – Tanzania is the exception – reported agricultural growth is less than calculated annual growth in food demand (calculated from population and income growth; see Table 1). Reported low rates of agricultural growth – and the apparent failure of agriculture to grow as fast as demand for food – may be due, at least in part, to failure to accurately measure changes in agricultural production, especially small farm production of high value crops and animal protein sold through informal markets.

Population density and cropping patterns vary across the five countries. Bangladesh has more than 20 people per arable hectare, which is among the highest ratios in the world. High pressure on land motivates Bangladeshi farmers to invest in inputs and technologies for high yields. More than 60 percent of Bangladesh's arable land is irrigated (World Bank, 2011). Rice dominates cropping patterns, accounting for more than 75 percent of gross cropped area (Bangladesh Bureau of Statistics, 2010). In the four African countries, the ratio of people per arable hectare ranges from 3.6-7.3. On the other hand, only 2-5 percent of crops are irrigated (World Bank, 2011). Although maize is the major staple in Kenya, Tanzania, and Zambia, sorghum, rice, cassava and sweet potatoes are also important in one or more of these countries. Senegal's staples include all of the above along with millet.

Table 1: Selected country population, economic, and agricultural data[a]

Indicator	Bangladesh	Kenya	Senegal	Tanzania	Zambia
Population (millions, 2010)	162	38.9	12.5	43.7	12.9
Population growth, 2000-09 (%/year)	1.6%	2.6%	2.6%	2.8%	2.4%
% of population that is rural	72%	78%	57%	74%	64%
GDP (US$ millions)	89,400	29,400	12,800	21,400	12,800
GDP growth, 2000-09 (%/year)	5.8%	3.6%	4.0%	5.2%	5.2%
GDP per capita (US$)	551	732	1,023	503	990
% of population living on less than PPP$1.25/day [data year]	49.6% [2005]	19.7% [2005]	33.5% [2005]	67.9% [2007]	64.3% [2004]
Agriculture					
Arable land (million hectares)	7.9	5.3	3.5	9.6	2.4
% of employment in agriculture	48%	NA	34%	75%	72%
Value added (US$ millions)	16,200	7,304	1,940	5,560	2,670
Agricultural value added growth, 2000-09 (%/year)	3.3%	2.2%	2.8%	4.4%	0.8%
Food demand and supply					
Income elasticity of demand for food	0.80	0.79	0.79	0.81	0.81
Calculated growth in food demand[b] (%/year)	5.0%	3.4%	3.7%	3.9%	4.7%
Food imports (US$ million)	4,430	1,460	1,360	530	220
Food imports as % of agricultural GDP	27%	20%	70%	9.5%	9.7%

Agricultural raw material and food exports					
Total (US$ million)	1,450	2,600	670	1,500	390
As % of value added in agriculture	9.0%	35%	35%	28%	15%
As % of GDP	1.6%	8.8%	5.2%	7.0%	3.0%

[a] Data are for the latest available year (most often 2009), except where otherwise indicated.
[b] Population growth plus growth in per capita demand for food (growth in GDP per capita multiplied by the income elasticity of demand for food [Economic Research Service, 2011]).
Source: World Bank (2011).

Agricultural exports are more important for Kenya, Senegal, and Tanzania (28-35 percent of agricultural value added and 5.2-8.8 percent of GDP) than for Bangladesh and Zambia (9-15 percent of agricultural value added and 1.6-3 percent of GDP)(Table 1). Categorizing exports by 4 digit harmonized system codes, agricultural and food industry exports account for 1-6 of the top ten exports from each country. However, export values exceed 1 percent of GDP for only a handful of categories: none in Bangladesh; tea and cut flowers in Kenya; fish in Senegal (combining two categories); tobacco in Tanzania; and sugar in Zambia (United Nations Statistics Division, 2011).

3 Study findings: Private technology introduction

Innovation is business as usual for companies in competitive markets. Input companies compete for market share with new technologies embodied in seeds, pesticides, machinery, and fertilizers. Processing companies introduce new technologies to cut costs or improve products. Some technologies are new to a company but not the country – e.g., a pesticide company might introduce a generic pesticide to compete with similar products already in the market.

Organization size, ownership, and activities: The 126 organizations ranged in size from 3 to 52,000 employees and from US$2,000 to $435,000,000 in annual sales. The median size by country ranged from 26 employees in Tanzania to 500 in Senegal and from annual sales of US$28,000 in Tanzania to US$28,000,000 in Kenya. Survey samples in all countries included large and medium and often small organizations. Most large companies are in processing, large-scale production, and pesticides.

A major difference between Bangladesh and the four African countries is the percentage of surveyed companies that are subsidiaries (Table 2). In Bangladesh, 2 (4 percent) of 49 companies are subsidiaries of parent companies based in Sri Lanka and Switzerland. In contrast, 29 (43 percent) of 68 companies surveyed in Africa are subsidiaries. The headquarters for some of these companies are outside Africa, in the European Union (EU), India, the US, China, and elsewhere, while other headquarters are within the region, in South Africa, Zambia, Zimbabwe, Kenya, Senegal, Uganda, and elsewhere.

Cross-border ownership links agribusiness activities across Africa. Twenty-two of 68 companies in the African sample are linked by ownership to companies in other African countries. This includes 6 locally owned companies with subsidiaries elsewhere in Africa, and 16 subsidiaries of companies with headquarters or subsidiaries in other African countries. Over the last 10 years seed companies such as SeedCo from Zimbabwe, Pannar from South Africa, and FICA from Uganda have extended activities and sales into other African countries. Similar regional expansion has occurred among companies dealing with other inputs, large-scale farming, and processing.

Table 2: Companies by foreign or local ownership and ownership of subsidiaries, 2009-10

	Bangladesh	African countries				
		Kenya	Senegal	Tanzania	Zambia	Africa total
Private company, of which:	49	8	15	18	27	68
Locally owned	47	4	10	15	10	39
With subsidiaries in regional countries	0	2	1	0	3	6
Subsidiary of a foreign company	2	4	5	3	17	29
With headquarters or subsidiaries in other regional countries	2	3		2	11	16
Total companies with offices in multiple regional countries	2	5	1	2	14	22

Note: This table excludes NGOs and other non-profit private organizations. One local NGO in Bangladesh has foreign branches, and two foreign-headquartered NGOs operating in Zambia have branches in other regional countries.
Source: Authors, based on 2009-10 survey data.

Providing some type of agricultural input was the main activity for 62 percent of the surveyed organizations; large-scale agricultural production was the main activity for 17 percent of surveyed organizations, and agriculture processing for 21 percent (Table 3). However, many organizations were involved in multiple activities; for example, some companies such as sugar companies managed large farms and also processed crops and/or organized out-growers, selling them seeds, fertilizers, and pesticides. Other companies sold multiple inputs. Considering both major and minor activities, 55 (44 percent) of 126 surveyed organizations sold seeds, while 24-28 percent sold fertilizers, produced crops on a large scale, or processed crops.

Table 3: Organizations by activity and country, 2009-10

Activity	Number of organizations by major activity (by major or minor activity)[a]					
	Bangladesh	Kenya	Senegal	Tanzania	Zambia	Total
Total number of organizations	51	8	15	21	31	126
Inputs supply	29	6	6	14	23	78
Seeds	13 (18)	4 (6)	1 (6)	10 (12)	6 (13)	34 (55)
Fertilizers	2 (10)	1 (3)	1 (4)	1 (5)	2 (8)	7 (30)
pesticides	6 (8)	(1)	1 (4)	(3)	5 (8)	12 (24)
Machinery	4 (7)	(1)	1 (2)	2 (3)	4 (10)	11 (23)
Livestock and fisheries inputs	4 (12)	1 (1)	2 (2)	1 (3)	4 (9)	12 (27)
Advice	0	0	0	(4)	2 (13)	2 (17)
Large-scale production	12	2	2	2	3	21
Crops	7 (11)	2 (3)	(2)	2 (10)	3 (9)	14 (35)
Livestock	3 (6)	(1)	0	(4)	(4)	3 (15)
Fish	1 (3)	0	2 (4)		0	3 (7)
Processing	10	0	7	5	5	27
Crops	7 (8)	(2)	3 (6)	3 (11)	4 (7)	17 (34)
Livestock products	2 (3)		0	2 (3)	1 (3)	5 (9)
Fish	1 (1)		4 (4)			5 (5)

[a] Many organizations reported multiple activities, e.g., selling seeds and fertilizers.
Source: Authors, based on 2009-10 survey data.

Technology introduction: The survey asked each organization to report up to five product innovations and five process innovations. Companies of all sizes reported innovations in questionnaires and interviews. Most innovations involved the introduction of new technologies, such as a new cultivar; a small minority involved things like changing package size, with no change in technology. While the number and variety of innovations went far beyond what companies could report or we could record in a survey such as this, Table 4 reports some examples, categorized by sub-sector.

Table 4: Examples of new products or processes introduced, 2004-09

Sector, Activity	Examples of innovations
Inputs supply	
Seeds	Bangladesh: cultivars for potatoes, hybrid rice, hybrid maize, vegetables, other crops African countries: cultivars for hybrid maize, drought-tolerant bean and maize, indigenous vegetables, true potato seed, seed processing and packaging equipment, micro-packaging
Fertilizers	Bangladesh: super granular urea, earthworm compost, green manure African countries: automated fertilizer blending, improved packaging of *Rhizobium* inoculants, soil testing kits, custom blending, granular fertilizer, blends for vegetables, liquid fertilizers
Pesticides	Bangladesh: pheromones, aluminum phosphide fumigant African countries: neem, new active ingredients, and new products with active ingredients malathion, chloramphenicol, and chlorpyriphos-ethyl
Machinery	Bangladesh: corn sheller, ripper, thresher, straw bundle cutting machine, seeder African countries: drip irrigation, treadle pump, sorghum huller and forage hopper, two-side plough for maize and beans, jab planter for maize and beans
Livestock, fisheries inputs	Bangladesh: artificial insemination, fishmeal, poultry feed African countries: cattle breeds, computer program to match cows with bulls providing imported semen, goat breeds, quail feed, heat-tolerant vaccines, software to formulate livestock feed
Large-scale production	
Crops	Bangladesh: cultivars for gladiolas, strawberries, grapes, guava, jujube, durian African countries: sugarcane, tea, coffee, jatropha, and eucalyptus cultivars, tea harvesting and pruning machines, soil aerating machines, vegetable cultivars targeted to the EU market
Livestock	Bangladesh: Shahiwal and Freisian cows, Sonali poultry
Fishery	Bangladesh: fish species, duckweed feeding protocols
Processing	
Crop	Bangladesh: rubber roller, color sorter, and grader for rice processing, solvent extraction for oil seeds and rice bran African countries: vitamin A fortified sugar and vegetable oil, bio-diesel, ethanol, packaging machine for mass production of banana wine (washing, filling and crowning wine bottles)
Livestock	Bangladesh: flavored milk, ultra-high-temperature processed milk African countries: poultry meat processing (freezing, smoking), change in packaging materials and process, small scale milk processing
Fishery	Bangladesh: Individually quick frozen shrimps Senegal: mechanical fish filleting, cooling, storing, and packaging, cuttlefish skewer trays for export

Source: Authors, based on 2009-10 survey questionnaires and interviews.

The scale of technology introduction is difficult to measure through company surveys such as this, not only because innovations are so common, but also because it is not clear what to measure. Many changes can be arbitrarily described as one innovation or as multiple linked innovations. Furthermore, companies prefer to keep some secrets. Nevertheless, across all countries, it was evident from interviews, documents, questionnaires, and other studies that private organizations – not the public sector – introduce most technologies for pesticides, machinery, poultry, vegetables, at least some field crops, fertilizers, and processing.

Several objective measures of technology introduction are available from government records. One measure useful in countries with developed industrial sectors is the number of patent applications. However, companies have little to gain by applying for patents in countries that would not in any case produce what the patents would protect. The five countries in this study reported only 23-299 annual patent applications for all industries (299 in Bangladesh; 71 in Kenya; 23 in Tanzania, 31 in Zambia, and no data for Senegal), which can be compared to more than 25,000 for India and 300,000 for China (latest available data, World Bank, 2011). The small number of patent applications does not reflect the scale of agricultural technology introduction in these countries.

Another measure that can be useful in some cases is applications for plant breeders' rights (PBRs; alternately described as plant variety protection [PVP]). Three countries in this study (Kenya, Senegal, and Tanzania) issue PBRs; among these countries, PBRs are a good indication of the scale of cultivar introduction only for selected crops in Kenya. During 1997-2008, well over half of the 980 PBR applications in Kenya were for roses, other flowers, and vegetables for export (Sikinyi, 2009). In Senegal, the private sector has had only a small role in cultivar introduction (see below). Through 2011, most of Tanzania's few PBRs protect government tea cultivars.

Other measures of technology introduction are available from government agencies that regulate the introduction of agricultural technologies. Essentially all governments maintain lists of allowed pesticides, veterinary medicines, genetically modified organisms (GMOs), and exotic fish species. Some governments list allowed fertilizers, feeds, and livestock breeds. One such measure that is particularly relevant for the countries in this study, as well as for other low and middle income countries in Africa, is the number of allowed crop cultivars.

All four African governments in this study regulate introduction of new cultivars from conventional breeding (i.e., non-GMO cultivars) for all food field crops; Tanzania and Senegal but not Kenya or Zambia do so for vegetables and pasture crops as well. Bangladesh regulates the introduction of new cultivars for five major crops only (rice, wheat, potatoes, jute, and sugar cane)(Government of Bangladesh, 1993). Lists of registered (allowed) cultivars are important measures of technology introduction, because they elucidate what can be a crucial obstacle to agricultural growth (Table 5).

For field crops considered together, private organizations introduced more new cultivars during 2000-08 in Bangladesh and Zambia, while public organizations introduced more cultivars in Kenya, Senegal, and Tanzania. Among crops for which governments in this study control the introduction of cultivars, hybrid rice in Bangladesh and maize in Africa are the only ones with a reasonable flow of new cultivars.

Private companies in Bangladesh introduced 76 rice hybrids during 2000-2010, while government introduced an additional 18 hybrids and varieties (for a combined average of 9 per year). As for maize, the average rate of introduction of new cultivars in Kenya, Tanzania, and Zambia ranged from 9-15 per year during 2000-08; in contrast only 8 public and 2 private maize cultivars entered Senegal during 2000-08, an average of only 1.1 per year. Although companies can and do introduce maize cultivars into Bangladesh without going through the registration process, government nevertheless reports 52 maize cultivars (44 private, 8 public) registered during 2000-08; a non-systematic survey of seed stores in 2008-09 found 70 cultivars, but even this is likely an undercount of what is available (Harun-Ar-Rashid, personal communication).

South Africa, which lists but does not control introduction of new maize cultivars, registered 342 new cultivars during 2002-06, an average of 68 per year (Setimela et al., 2009).

For controlled field crops other than hybrid rice in Bangladesh and maize in Africa, farmers see few if any new cultivars year by year. The pace of cultivar introduction is greater than 1 per year for one crop in Senegal (rice), no other crops in Tanzania, one controlled crop in Bangladesh (potatoes) and for only a few crops in Kenya (common bean, sugar care) and Zambia (wheat, soybeans, and common bean). Notably, there are few cultivars from the private sector in any of these controlled crops, except for Zambia (e.g., 13 private cultivars for wheat, 11 for soybeans).

Table 5: Cultivars from public and private organizations registered in 2000-08, selected crops

Crops	Bangladesh[a]			Kenya			Senegal[b]			Tanzania			Zambia		
	Private	Public	Total	Private	Public	Total	Private	Public	Total	Private	Public	Total	Private	Public	Total
Cereals															
Maize	44	8	52	67	70	137	2	8	10	37	10	47	105	8	113
Rice	76	18	94		7	7		16	16		5	5		2	2
Wheat		6	6		7	7					5	5	13	4	17
Sorghum	6	0	6	1	7	8					2	2	1	3	4
Barley		3	3	1		1				2		2			0
Finger millet		2	2		1	1								1	1
Pearl millet		1	1		3	3						0		3	3
Other food crops															
Sweet potato		2	2		5	5					6	6		5	5
Cassava					9	9					5	5		4	4
Potato		11	11										3		3
Sunflower	2		2		3	3	3		3	2	3	5	6	0	6
Soybeans		1	1		5	5							11	2	13
Cowpea				1	3	4					1	1		1	1
Groundnut		2	2			0		7	7			0	4	1	5
Common bean					12	12					8	8	6	4	10
Sugar cane		8	8		10	10	1		1						
Fibers, drinks, drugs															
Tea				1	4	5									
Coffee						0					9	9			
Tobacco										3		3	6		6
Cotton		12	12				2		2					1	1
Jute		3	3												
Total[c]	128	77	205	71	146	217	8	31	39	44	54	98	155	39	194
Number of private organizations with registered cultivar[c]	23			10			5			10			10		

[a] For Bangladesh, data for rice and wheat are for 2000-2010; data for all other crops are for 2000-08; for crops with shaded squares, the government does not control or list cultivars, so that the numbers of cultivars from the private sector may be under-counted.

[b] For Senegal, data for groundnuts are for 2000-09.

[c] These totals are for crops in the table only; governments of Kenya, Senegal, Tanzania, and Zambia control and list cultivars for some or all other crops.

Sources: Compiled by authors based on data from: the Kenya Plant Health Inspectorate Services (2008); Senegal’s Institut Sénégalais de Recherches Agricoles (2000-2009); Tanzania Official Seed Certification Institute (2008); Zambia Seed Control and Certification Institute (2008); Harun-Ar-Rashid et al. (2011); Bangladesh Seed Certification Agency (2007); Bangladesh Department of Agricultural Extension (2003-11); and key informant interviews.

4 Study findings: technology transfer

Companies want new technology at the least possible cost. If a suitable technology is available elsewhere, importing and then multiplying or copying it is generally less costly than developing something new. Private sector assessment and introduction of foreign technology extends even to the farm level; farmers in border regions commonly recognize and adopt good cultivars from neighboring countries.

The survey asked companies about the source of each reported innovation. Among organizations that reported innovations, large majorities of respondents both in Bangladesh and in African reported importing at least some of their new technology (Table 6).

Table 6: Innovations by source of introduced technology

	Bangladesh					Four African countries				
Activity	Number of organizations reporting innovations	Source of innovations (number of organizations reporting each source; organizations may report >1 one source)				Number of organizations reporting innovations	Source of innovations (number of organizations reporting each source; organizations may report >1 one source)			
		Developed in-country		Imported from			Developed in-country		Imported from	
		Own R&D	Other R&D	Parent company	Other source		Own R&D	Other R&D	Parent company	Other source
Input supply										
Seeds	13	5	2		9	24	6	4	10	8
Fertilizers	6	1			5	4	2	1		1
Pesticides	6			2	4	10	3		4	5
Machinery	5	3			2	7	3	3	3	1
Livestock, fishery inputs	4	3			1	7	4		3	2
Large-scale production										
Crops	9	3	1		6	6	2	2	3	2
Livestock	3	0			3					
Fish	2	1			1					
Processing										
Crop	6	5			2	5	3			2
Livestock	3	1			2	3	2	1		
Fishery	1	0			1	3	3		1	

Source: Authors, based on 2009-10 survey data.

Foreign parent companies were less important as a source of technology in Bangladesh than in Africa. Only two companies in Bangladesh – the only two subsidiaries in the survey sample – reported importing technology (pesticides and cultivars) from parent companies, while 31 organizations reported accessing technology from other foreign sources. In a recent survey of Bangladeshi seed companies (including one NGO) for the International Finance Corporation, 21 of 30 reported international collaborations: 9 reported collaborations with 1 country; 2 reported collaborations with 2 countries; 9 with 3-5 countries each; and 2 with 8-9 countries (Kabir and Huda, 2009). The 15 countries involved in these collaborations were: Australia, China, France, Germany, Hong Kong, India, Italy, Japan, South Korea, Nepal, the Netherlands, New Zealand, the Philippines, Taiwan, Thailand, the US, and Vietnam.

On the other hand, 29 of 68 companies interviewed in Africa were subsidiaries. Even so, almost as many African companies reported technology from other foreign sources (21) as from parent companies (24). Subsidiaries have favorable access to technology from one company, but parent companies may block other linkages. On the other hand, locally-owned companies can access foreign technology as they wish. Companies in Zambia imported farm machinery from parent and other companies in Brazil, China, and India.

During interviews, we heard various methods to assess imported technology. For broad spectrum pesticides, experts can make good guesses about what will work in a country based on conditions in other countries where the pesticide is used, so that adaptive research may be limited to official trials. A company in Zambia scouted cassava processing in West Africa before importing machinery from there. One seed company in Bangladesh sends imported vegetable lines to experienced farmers, who grow the lines and give their views.

Companies are able to introduce a lot of technology from foreign sources with little or no change. Direct introduction is common for cultivars, pesticides, farm machinery, fertilizers, and livestock breeds. Some of the best evidence for this is the substantial values of agricultural inputs in international trade (Table 7). For example, the values of seed imports into Kenya and Tanzania were equivalent to 20-28 percent of seed sales. While data on imports show farmers using foreign technology, such data do not show the pace of change, i.e., the introduction of new technologies over time.

Table 7: Selected data on imports and sales of agricultural inputs, 2009, or latest available year

	Bangladesh	Kenya	Senegal	Tanzania	Zambia
Seeds					
Domestic seed sales (US$ millions)	125	60	17	15	20
Seed import (US$ millions), of which	NA	17	6	3	NA
Vegetable seeds (US$ millions)	NA	7	4	1	
Imports of selected other agricultural inputs					
Agricultural machinery (US$ millions)	76	76	17	NA	39
Pesticides (US$ millions)	51	84	9	NA	28
Bovine semen (US$ millions)	0.018	0.20	0.002	0.01	0.15
Cf: agricultural value added (US$ millions)	16,200	7,304	1,940	5,560	2,670

NA: not available.
Sources: World Bank (2011); UN (2011); International Seed Federation (2010); for Senegal, data collected by authors from Agence Nationale de la Statistique et de la Démographie and private companies; authors' estimates for seed sales in Bangladesh.

A company's cost to access foreign technology may be arranged as licensing fees or royalties. Alternately, the cost may be included in the price of what is imported, such as seeds, pesticide, or processing equipment. Most relevant technologies compete with nearly equivalent technologies from multiple foreign companies and countries. Thus, even when a technology gives a high return on investment, competition limits what foreign companies can charge for proprietary technology; the only major exception for countries in this study is proprietary pesticides.

A handful of companies in Bangladesh and Africa reported that some of their technology came from R&D in other local institutions (Table 6). For example, Zamseed has exclusive rights to sell seed for some cultivars developed by the Zambia Agricultural Research Institute. Similarly, several companies in Bangladesh sell seed of popular rice varieties developed by the Bangladesh Rice Research Institute; the companies do not have exclusive rights to the varieties, but rather compete with other private companies offering the same seed as well as with subsidized seed from the Bangladesh Agricultural Development Corporation, a parastatal.

Large minorities of surveyed companies in Bangladesh and Africa reported own R&D as a source for at least some of their innovations (Table 6). In some cases, this seemed misleading. For example, some companies reported that pesticides came from their own in-country R&D,

even though virtually all pesticides come from multinational companies. On the other hand, trials to screen imported technologies are a form of in-country R&D.

5 Study findings: synergies between technology transfer and private research

Technology transfer and in-country private research are intertwined. Formal research can be part of the technology transfer process. On the other hand, once research is underway, the questions and opportunities that arise lead to a demand for more foreign technology. This section explicitly considers some of the ways that private technology transfer stimulates private research. (Of course, many factors other than technology transfer determine the scale of private research; another paper from this study considers other factors [Pray et al., 2012]).

Competitive technology transfer leads to in-country research: When a country's agribusiness sub-sectors are weakly linked to international markets, it is characteristically easy to find foreign technologies that will out-perform what is available. However, when those same sub-sectors are closely linked to international markets – when businesses have been bringing in foreign technologies for some time – it may be more difficult to find technology that will outperform what is already available. This is a bigger challenge for industries that are research-intensive on a global scale – such as the seed industry – so that local companies looking for the best foreign technology are chasing a moving target.

In Bangladesh, for example, a change in seed regulations around 1990 allowed private companies to introduce maize hybrids. Kushtia Seed Store, the first company to do so, had no trouble finding several maize hybrids from Thailand that gave farmers much better yields than they could get with available open-pollinated varieties. However, as more companies brought in more maize hybrids, it became more difficult to identify new ones that farmers would prefer to what was already available. Thus, programs to find and screen foreign hybrids became more systematic; informal research progressed to formal research. At some point, several companies and an NGO began to breed hybrid maize in-country. Currently, breeding and screening foreign maize hybrids go side by side, with foreign-bred hybrids holding most of the market.

A similar progression occurred for maize hybrids in eastern and southern Africa. At the beginning of the 1990s, a number of large companies with research potential sold hybrid maize seed in eastern and southern Africa. However, all of these companies operated in protected national markets, and so had little incentive to find or develop new hybrids. In Zimbabwe, as late as the 1990s, the Zimbabwe Seed Cooperative's (currently SeedCo) most popular hybrid was SR52 (Southern Rhodesia 52), which had been released in 1960. From the late 1990s, countries in the region opened their maize seed markets to other companies. Competition has had a huge impact on private R&D and technology introduction. In Kenya, for example, only 17 maize cultivars were registered in the 25 years from 1975 through 1999, an average of only 0.7 new cultivars per year; in contrast, as regulators allowed new companies to enter the market, Kenya registered 137 maize cultivars during 2000-08, an average of 15 per year.

Imported technologies require supporting location-specific research: Most imported technologies require formal or informal tests or trials. Some require minor adjustments. Even when technologies can be directly introduced without change, adoption may stimulate related research. In Zambia, for example, one company producing sugarcane and another producing vegetables and flowers for export imported their preferred cultivars and then conducted local research to develop agronomic practices that best suited those cultivars.

Opportunities to sell inputs into foreign markets increase returns to research: Private research is naturally oriented to markets defined by agro-ecological conditions and other non-political factors. In large countries such as India, some companies may find that revenues from national markets are large enough to pay for research. However, in smaller countries, potential profits from national markets may not pay for much research. Companies in small countries look across borders, to see if they can sell research products in larger regional markets.

In Africa, the relaxation of barriers to introduction of maize cultivars in many eastern and southern African countries starting in the 1990s motivated companies to expand breeding programs not only to meet competition in their own countries but also to sell maize seed in other regional countries. In this study, organizations with a regional business orientation were more likely to have research programs. In Kenya, for example, of the seven surveyed companies with research programs, two were local companies with subsidiaries in regional countries, and three were subsidiaries of multinationals with subsidiaries in other regional countries as well.

Opportunities for technology transfer allow companies to take advantage of local conditions favoring research: Insofar as companies can move technology across borders, they can locate research on the basis of factors other than market size. For example, the center of origin for bottle gourd is in Bangladesh and the state of Assam in India; Bangladeshi seed companies take advantage of their location by breeding bottle gourd. Another factor that attracts private research investment is the availability and cost of educated and skilled research staff. This becomes more important as a country's agribusiness industries become more integrated into international trade, so that researchers and companies can compete with others around the world for private research funds. Some locations may be accidents of history. For example, in the 1970s, Yugoslavia established its winter maize breeding program in Zambia; several decades later, this contributed to the emergence in Zambia of the Maize Research Institute, a private company with one of the strongest maize breeding programs in Africa.

Private research staff, budgets, and trends: Fifty-seven of 126 surveyed organizations reported at least one employee designated as a researcher. Although the survey missed many companies with research programs, and some surveyed companies known to have research programs did not answer questions about research staff or budgets, information from the survey nevertheless reliably demonstrates significant and expanding private research activities in all 5 countries. The seed sub-sector accounts for the most reported private research. Other sub-sectors with substantial numbers of researchers in one or more countries include pesticides, large-scale crop and livestock production, and crop, livestock, and fish processing.

Among the 51 organizations surveyed in Bangladesh, 12 reported having a research program in 2001, while 23 reported the same for 2008. Private investments in seed research respond not only to anticipated profits associated with hybrid rice seed, but also to the industry's improving skills and expanding markets for vegetable, potato, and hybrid maize seeds. As of 2008, 23 surveyed companies with research programs employed a total of 119 researchers and expended a total of US$10.8 million on R&D, of which the seed industry accounted for US$ 9.7 million.

In 2008, all 15 companies surveyed in Senegal had research programs, but only 9 of 15 reported one or more research staff. During 2001–08, total R&D staff in these companies increased from 44 to 61 (including 19 in one seed company, 13 in three fish processing companies, and 9 in a company managing large scale crop production). The 9 companies reported spending a total US$ 3.4 million on research in 2008.

Seven organizations in Zambia, including two seed companies and others focused on machinery, livestock inputs, and crop processing, provided information on research. The number of private researchers in these companies (excluding technicians and other support staff) increased from 16 in 2001 to 25 in 2008; and 2 companies initiated research programs after 2001. Three organizations – two companies and an NGO – reported spending a total of US$ 1.3 million on research in 2008.

Other papers from this study detail survey data on private research staff and budgets in all five countries (Pray et al., 2011; Harun-Ar-Rashid et al., 2012; Stads and Sène, 2012; Mwala and Gisselquist, 2012).

6 Study findings: policies and programs impacting private technology introduction

One of the objectives of this study was to obtain information from questionnaires, interviews, and secondary documents on public policies and programs that favor private technology introduction. Study findings direct attention to five issues: general economic reforms; focusing regulations on risks, not performance; building technical capacity; financial assistance; and protecting intellectual property.

General economic reforms, privatization: In all five study countries, general economic reforms during the 1980s and 1990s relaxed controls on private companies, allowing them to import and to take other initiatives without step by step government approvals. Privatizing agribusiness parastatals has been a prominent part of economic reforms in Senegal, Tanzania, and Zambia, but less so in Bangladesh and Kenya.

Although privatization can save government money and reduce unfair competition for private companies, it is neither necessary nor sufficient to spur private technology introduction and private sector development. For example, Bangladesh's private seed industry has developed much faster than Tanzania's even though the Bangladesh Agricultural Development Corporation, a parastatal, expanded seed sales, while Tanzania closed its parastatal Tanseed. Bangladesh controls cultivar introduction for only five crops while Tanzania controls all crops. This suggests that cultivar controls have a much bigger impact on seed industry development than the amount of government seed sales.

Focusing regulations on risks, not performance: Governments in all five countries implement standard regulations to protect public health and the environment. These regulations include: phytosanitary controls on seed imports to block introduction of plant pests and diseases; zoosanitary controls on livestock and semen imports to block imports of livestock diseases; and listing allowed pesticides to protect public health and the environment.

However, for important classes of agricultural technologies with minimal or no public health or environmental threats – cultivars, fertilizers, livestock feeds, and livestock breeds – surveyed companies reported that government approval to introduce new technologies was based on agricultural and economic performance (Table 8). Approvals involved time, fees, and often arbitrary decisions. Approvals (whether required or not) were not an obstacle for processing and processed products.

Table 8: Time and fees for performance-based government approvals of input technologies, selected countries and inputs ,2008

Country, input	When required	Fees[a]	Time[a]
Seeds			
Bangladesh	Rice, wheat, potatoes, jute, and sugarcane	US$500	2 yrs
Kenya	All field crops except pastures and forages	US$750-1,500	3-5 yrs
	Tree and plantation crops	US$250-300	3 mos-2 yrs
Senegal	All crops, including vegetables		

Tanzania	All crops, including vegetables	US$150-400	7 mo-3 yrs
Zambia	All field crops except pastures and forages	US$900-6,000	2-3 yrs
Fertilizers			
Bangladesh	New product	US$150-300	1 mo
Kenya	New blend	US$500	2-3 wks
Feeds			
Bangladesh	Required for all formulations	US$400	3 mo
Breeds			
Senegal	Required		
Zambia	Required	US$100	1 wk

[a] As reported by surveyed companies.
Source: Authors, based on 2009-10 survey data.

As described in Section 3, above, governments of the five countries control introduction of cultivars from conventional breeding for 5 or more crops. Surveyed companies reported fees from US$150 to US$6,000 and 3 months to 5 years to process a proposed cultivar, and even then the cultivar may be rejected (see also Langyintuo et al., 2008). Companies anticipating high profits with hybrid maize seed in Africa or hybrid rice and maize seed in Bangladesh are willing to pay and wait. But for minor crops with hybrid seed (sunflower and sorghum in Table 5) as well as for open-pollinated or self-pollinated seed that farmers can recycle (all other crops in Table 5), companies expect lower returns with new cultivars, and are therefore less willing to pay and wait for official approvals. Performance-based controls can effectively block private companies from trying to introduce non-hybrid cultivars for field crops.

Among the countries in this study, Senegal and Tanzania extend performance tests to vegetables, with similar results. Tanzania, with “high climate diversity…making it possible to produce temperate, sub-tropical and tropical vegetables” (p. 59 in: Ellis-Jones et al., 2008a) needs a lot of cultivars. Yet, as of 2008, Tanzania had registered only 99 cultivars for 41 vegetable species, including one each for asparagus, broccoli, collards, lettuce, parsley, papaya, peas, and pumpkins (Ellis-Jones et al., 2008b).

One common defense of these controls is that the EU does the same. But that is not so; all EU governments automatically accept cultivars from all other EU countries. Similarly, South Africa automatically accepts cultivars with no attention to performance (requiring only one season of tests to show that the proposed cultivar is distinct, uniform and stable [DUS tests]; “the rationale for not requiring [performance tests] is…that market forces should determine the best varieties. If a farmer buys a variety that performs poorly…the company loses that particular customer forever” (p. 8 in: Setimela et al., 2009).

For more than a decade, African governments have been discussing various schemes to create regional lists of allowed cultivars modeled on the EU’s Common Catalogue. Discussions have been organized in West Africa through UEMOA (Union Economique et Monétaire Ouest Africaine) and ECOWAS (Economic Community of West African States), in East Africa through ASARECA (Association for Strengthening Agricultural Research in Eastern and Central Africa), and in Southern Africa through SADC (Southern African Development Community). As of 2011, countries in West Africa have reached technical agreements to merge national lists of allowed cultivars into regional lists (UEMOA, 2009; ECOWAS, 2008), but agreements have not been implemented.

Arguably, the pursuit of regional harmonization has diverted attention from the always available option for individual governments to unilaterally relax barriers to cultivar introduction.

In the early years of the Green Revolution, politicians in India, Pakistan, and Turkey intervened to allow introduction of wheat from Mexico against objections from public sector scientists biased against better cultivars from foreign breeding (Ganzel 2007). Such biases of local scientists and regulators continue. In addition, large companies may support controls on cultivar introduction to suppress competition from small and start-up companies. It remains for other lobbies – farmers, consumers, processors, exporters, donors – to push the public interest for access to available cultivars.

Some of the countries in this sample require performance tests for feeds, fertilizers, and breeds. Just as for cultivars, governments can reasonably leave private companies and farmers to assess performance of these inputs. For fertilizers, the requirement for government to approve each product interferes with companies adapting blends to specific situations and can also interfere with cross-border trade. Notably, the Abuja fertilizer summit recommended that regulations should be designed so that fertilizers approved in one country can trade freely into neighboring countries (Abuja Declaration 2006).

Relaxing performance-based controls can have a large and favorable impact on technology introduction. In this study, farmers in Bangladesh see more varieties for most field crops than do farmers in the four African countries (Section 3). In other studies, relaxing performance-based controls on hybrid maize led to large gains in maize production and farm income in Bangladesh (Harun-Ar-Rashid et al, 2012) and Turkey (Gisselquist et al., 2002), and relaxing performance-based controls on imported diesel engines accelerated expansion of irrigated area in Bangladesh (Hossain, 2009). Moreover, focusing regulations on risks rather than performance could improve protection against risks.

Debates about whether to allow GMOs focus on environmental and/or public health risks; influential lobbies claim there are no major risks (Paarlberg, 2008), while others say there are. This debate can be resolved over time through scientific investigations into alleged risks. As of 2011, none of the five countries allows sale of GMO seeds; Kenya and Bangladesh have approved field tests for specific GMOs.

Building technical capacity: Government support for higher education and public research builds capacity in the private sector to assess and adapt the world's agricultural technology. Strengthening universities to provide degree training in science and economics is basic to building technical capacity. As of 2011, the Alliance for a Green Revolution in Africa (AGRA) proposes PhD scholarships for 80 breeders, 170 MSc scholarships for agronomists, and strengthening 10 African universities (AGRA, 2011). Much more is required. During interviews for this study, a seed company executive in Zambia noted (to DG and MW) that AGRA was training breeders for the public sector and challenged the University of Zambia to train breeders for the private sector.

Education is only one of the ways the public sector provides technical staff to private agri-businesses. Experienced government (including university) scientists are a resource for private agribusinesses. Some work with companies as short-term consultants; others shift to the private sector mid-career; and some shift when they retire from government jobs.

Governments also extend technical assistance through memoranda of understanding and other formal and informal arrangements that give private companies access to germplasm, other technologies, and laboratory equipment. During surveys, private organizations reported multiple formal arrangements for collaborative research with public universities and research agencies. Donors sponsor or promote some of these arrangements. For example, a USAID project funds collaboration between the Bangladesh Agricultural Research Institute, Lal Teer Seed company, Cornell University, and other institutions to insert a *Bacillus thuringiensis* (Bt) gene into several brinjal cultivars (Cornell, 2011). International institutes such as CIMMYT and IRRI make their germplasm available to all comers, private as well as public.

One form of public support for private technology transfer and research that this study found in several countries is the establishment of hybrid institutions funded by the government but intended to work closely with private companies, including: Zambia's Golden Valley Agricultural Research and Cotton Development Trusts; the Tanzania Coffee Research Institute and Tea Research Institute of Tanzania; and Kenya's Tea Research Institute.

Financial assistance: Several governments in this study have funds that make grants to private companies for agricultural research. At the end of the 1990s, the government of Senegal established the National Fund for Agricultural and Agro-Industrial Research (FNRAA; *Fonds National de Recherches Agricoles et Agro-alimentaires*). With World Bank support, FNRAA has made research grants to public as well as private companies. In 2007, the government of Bangladesh, with support from the World Bank, established the Agricultural Research Foundation (KGF; *Krishi Gobeshona Foundation*). As of 2011, KGF has already approved several rounds of competitive research grants to public and private organizations.

Several companies asked for tax breaks for research and/or designating the seed industry for special tax treatment or credit programs. These across-the-board forms of financial assistance treat all companies equally, avoiding the political intrigues and challenges to pick winners that are unavoidable with research grants.

Intellectual property protection: The 1994 agreement establishing the World Trade Organization (WTO) included the Trade Related Aspects of Intellectual Property Rights (TRIPS) agreement, which mandated countries to protect intellectual property. With various clauses, low income countries had years to establish patents and PBRs. All countries in this study are members of the WTO. All have systems to register patents, but systems are not heavily used, as discussed earlier. During interviews, no company mentioned any concern about patents to protect intellectual property.

Kenya, Senegal, and Tanzania have laws establishing PBRs. Senegal is a member of the West African Intellectual Property Organization (OAPI); Tanzania is a member of the African Regional Intellectual Property Organization (ARIPO) for countries in Southern and East Africa. Private companies use Kenya's PBR system to protect intellectual property in flowers and export vegetables. Otherwise, PBR laws in these three countries have been little used, and have likely had little impact on technology introduction (see Section 3).

Bangladesh and Zambia have draft PBR laws. During interviews, seed company executives in Zambia expressed strong interest in PBRs to protect non-hybrid wheat and soybean cultivars; they expected PBRs to stimulate introduction of cultivars for such crops.

7 Conclusions and recommendations

In a 1981 overview of agricultural development, Roger Bates observed that "the failure of…technologies to 'diffuse'… …has little to do with the attitudes of the village farmers themselves, as is commonly claimed. The problem instead is that the inputs are often not available" (Bates, 1981, p. 55).

The situation that Bates described in 1981 has changed. Private companies in the five countries in this study have been delivering input-embodied technologies for poultry, vegetables, field crops (as allowed), and pesticides to small farmers through expanding networks of agri-input dealers. Agricultural technologies introduced by private companies have had a big impact on agricultural growth and small farm incomes. Unlike what happened in past decades, private companies no longer focus only on cash crops and exports – although exporting companies continue to be active in technology transfer and in-country research.

In a recent paper, a team of international experts speculated that: "Investing in research elsewhere in the world and spurring the necessary institutional innovation to enhance technological spill-ins into Sub-Saharan Africa may be just as critical to technical progress in Africa as enhancing the capacity to develop home-grown technologies throughout the region" (Pardey et al., 2007, p. 67). From this study, we can confirm that speculation. We can also say that once local agribusinesses get linked into competitive international markets, no matter how small and poor their home country, many will sooner or later invest in in-country research.

The notion that governments should variously encourage and promote private introduction of agricultural technology – and especially private research – is widely accepted. Private agribusinesses look to government to provide educated staff and technical advice. For more than a decade, governments and donors have been implementing programs supporting private agribusiness. Along these lines, the private sector should be more involved in priority setting for government agricultural R&D. Countries should establish sustainable and competitive funds to stimulate private sector R&D and public-private interaction.

However, some existing regulations work at cross-purposes with the widely endorsed goal to encourage private technology introduction. Regulations controlling introduction of several categories of agricultural inputs – especially cultivars from conventional breeding – on the basis of performance can be major obstacles to technology introduction. Such policies not only restrain farm and agri-business production, exports, and consumer welfare, but also handicap rather than promote local research.

This study of private technology introduction emphasizing technology spill-ins confronts a common unspoken bias against technology import – that it is a second-best alternative for poor countries that cannot afford in-country research. This bias is based on ignorance; technology transfer is essential for efficient private research, it is not an alternative. Additional studies of private agricultural technology transfer are required to get a better picture of linkages between local and foreign agribusinesses, technology, and research. Who imports technology – local companies, regional multinationals, or other multinationals? How much and how do companies pay to acquire foreign technology? How much imported technology is off-patent or other public technology? To get a better picture of private technology transfer future in-depth studies could focus on specific agribusiness subsectors in specific countries.

References

Abuja declaration on fertilizer for the African green revolution, 2006. Abuja. Available at: http://www.afdb.org/en/topics-sectors/initiatives-partnerships/african-fertilizer-financing-mechanism/abuja-declaration/ (accessed 30 August 2010).

Alliance for a Green Revolution in Africa (AGRA). 2011. AGRA's programme for Africa's seed systems. Available at: http://www.agra-alliance.org/section/work/seeds/ (accessed 16 August 2011).

Bangladesh Bureau of Statistics (BBS). 2010. Statistical Pocket Book of Bangladesh 2009. Dhaka: BBS.

Bates, R. 1981. Markets and States in Tropical Africa: the political basis of agricultural policies. Berkeley: University of California Press.

Cornell University. 2011. Agriculture Biotechnology Support Protect II. Available at: http://www.absp2.cornell.edu/ (accessed 14 June 2011).

Department of Agricultural Extension (DAE). 2003-2011. Krishi Diary. Dhaka: DAE.

Economic Research Service (ERS), United States Department of Agriculture. 2011. International Food Consumption Patterns. Data Sets <http://www.ers.usda.gov/Data/InternationalFoodDemand/> (accessed May 29, 2011).

ECOWAS, Sixtieth Ordinary Session of the Council of Ministers, 2008. Regulation C/Reg. 4/05/2008 on harmonization of the rules governing quality control, certification and marketing of plant seeds and seedlings in ECOWAS region. Abuja: ECOWAS.

Ellis-Jones, J., Stenhouse, J., Gridley H., Hella, J., Onim, M. 2008a. Vegetable Breeding and Seed Systems for Poverty Reduction in Africa: Baseline Study on Vegetable Production and Marketing. AVRDC. Available at: http://www.avrdc.org/fileadmin/pdfs/Baseline-synthesis-study-Oct08.pdf (accessed 28 August 2010).

Ellis-Jones, J., Stenhouse, J., Gridley, H., Hella, J., Onim, M. 2008b. Vegetable Breeding and Seed Systems for Poverty Reduction in Africa: Baseline Study on Vegetable Production and Marketing. Appendix 4: Tanzania and spoke countries. AVRDC. Available at: http://www.avrdc.org/fileadmin/pdfs/Tanzania-baseline-Oct08.pdf (accessed 16 August 2011).

Evenson, R.E., Westphal, L.E. 1995. Technology change and technology strategy. In: Behrman, J., T.N. Srinivasan. Handbook of Development Economics, vol III. Amsterdam: Elsevier.

Evenson, R. E., Gollin, D. 1995. Genetic resources, international organizations, and rice varietal improvement. In: Gisselquist, David, and Jitendra Srivastava, eds. Easing Barriers to Movement of Plant Varieties for Agricultural Development. World Bank Discussion Paper No 367. Washington DC: World Bank. Pp 87-102.

Ganzel, B. 2007. India and Pakistan. Available at: http://www.livinghistoryfarm.org/farminginthe50s/crops_16.html (accessed 8 August 2011).

Gisselquist, D., Nash, J., Pray, C.. 2002. "Deregulating the Transfer of Agricultural Technology: Lessons from Bangladesh, India, Turkey, and Zimbabwe." *World Bank Res Obs*. 17: 237-265.

Government of Bangladesh. 1993. Bangladesh Seed Policy for the Development of Seed Industry. Dhaka: The Bangladesh Gazette, 8 April 1993. Available at: http://faolex.fao.org/docs/pdf/bgd36224.pdf (accessed 22 May 2011).

Harun-Ar-Rashid, Julfiquar, A.W., Ali,S. 2011. A study on hybrid rice in Bangladesh: history, impact and current system of hybrid rice research, development and delivery in Bangladesh. Washington, DC: IFPRI.

Harun-Ar-Rashid, Ali, M., Gisselquist, D. 2012. Private-sector agricultural research and innovation in Bangladesh: overview, impact, and policy options. Washington, DC: IFPRI. Available at: http://www.asti.cgiar.org/pdf/private-sector/Bangladesh-PS-Report.pdf (accessed 10 November 2012).

Hossain, M. 2009. The impact of shallow tubewells and *boro* rice on food security in Bangladesh. Washington DC: IFPRI. Available at: www.ifpri.org/millionsfed.

Institut Sénégalais de Recherches Agricoles (ISR$A). 2000-2009. Annual Report. Dakar: ISRA.

International Seed Federation. 2010. Estimated value of the domestic seed market in selected countries (updated August 2010). Available at: http://www.worldseed.org/cms/medias/file/ResourceCenter/SeedStatistics/Domestic_Market_Value_2010.pdf (accessed 8 June 2011).

Kabir, K.A., Huda, M.N. 2009. IFC-SEDF Baseline Surveys and Sector Studies in Agribusiness, Light Engineering and Textiles & Apparels Sectors in Bangladesh. Sector: Agribusiness. Subsector: Seed. Dhaka: International Finance Corporation – SouthAsia Enterprise Development Fund (IFC-SEDF).

Kenya Plant Health Inspectorate Services. 2008. National Crop Variety List – Kenya 2008

Langyintuo, A.S., Mwangi, W., Diallo, A.O., MacRobert, J., Dixon, J., Banziger, M. 2008. An analysis of the bottlenecks affecting production & deployment of maize seed in Eastern and Southern Africa. Harare: CIMMYT

Maredia, M., Ward, R., Byerlee, D. 1995. Assessment of the international transfer of wheat varieties. In: Gisselquist, D., Srivastava, J., eds. Easing Barriers to Movement of Plant Varieties for Agricultural Development. World Bank Discussion Paper No 367. Washington DC: World Bank. Pp 73-86.

Mwala, M., Gisselquist, D. 2012. Private-sector agricultural research and innovation in Bangladesh: overview, impact, and policy options. Washington, DC: IFPRI. Available at: http://www.asti.cgiar.org/pdf/private-sector/Zambia-PS-Report.pdf (accessed 10 November 2012).

Paarlberg, R. 2008. Starved for Science: how biotechnology is being kept out of Africa. Boston: Harvard University Press.

Pardey, P., James, J., Alston, J., Wood, S., Koo, B., Binenbaum, E., Hurley, T., Glewwe, P. 2007. Science, Technology and Skills. St. Paul: International Science and Technology Practice and Policy (INSTEPP) center, University of Minnesota. Available at:

https://openknowledge.worldbank.org/bitstream/handle/10986/9201/WDR2008_0026.pdf?sequence=1 (accessed 9 December 2012).

Pray, C.E., Gisselquist, D., Nagarajan, L. 2012. Policies to facilitate private agricultural innovation and R&D. Unpublished paper submitted to the Bill and Melinda Gates Foundation. New Brunswick: Rutgers University.

Pray, C., Gisselquist, D., Nagarajan, L. 2011. Private investment in agricultural research and technology transfer in Africa. Accra: ASTI/IFPRI-FARA Conference: Agricultural R&D: Investing in Africa's Future, 5-7 December 2011, conference paper no. 13. Available at: http://www.asti.cgiar.org/pdf/conference/Theme4/Pray.pdf (accessed 10 November 2012).

Seed Control and Certification Institute (SCCI), Zambia. 2008. Official Variety Register – 2008. Lusaka: SCCI.

Seed Certification Agency (SCA), Bangladesh. 2007. Approved Crop Varieties (fourth edition). Chittagong: SCA.

Setimela P.S., Dadu-Apraku, B., Mwangi, W. 2009. Variety testing and release approaches in DTMA project countries in sub-Saharan Africa. Harare, Zimbabwe: CIMMYT.

Sikinyi, E.O. 2009. The impact of plant variety protection system in Kenya. 2nd World Seed Conference, Rome: 8-11 September 2009.

Stads, G.-J., Sène, L. 2011. Private agricultural research and innovation in Senegal: recent policy, investment, and capacity trends. Washington DC: IFPRI. Available at: http://www.asti.cgiar.org/pdf/private-sector/Senegal-PS-Report.pdf (accessed 10 November 2012).

Tanzania Official Seed Certification Institute (TOSCI). 2008. Tanzania Variety List Updated to 2008. Unpublished document.

Union économique et monétaire ouest africaine (UEMOA). 2009. Règlement N°03/2009/CM/UEMOA portant harmonisation des règles régissant le contrôle de qualité, la certification et la commercialisation des semences végétales et plants dans l'UEMOA. Available at: FAOLEX.

United Nations (UN). 2011. UN Comtrade. Available at: http://comtrade.un.org/ (accessed 7 June 2011).

United Nations Statistics Division. 2011. 2010 International Trade Statistics Yearbook: Volume 1 – Trade by Country. New York: UN. Available at: http://comtrade.un.org/pb/CountryPagesNew.aspx?y=2010 (accessed 2 August 2011).

World Bank. 2011. Data. Available at: http://data.worldbank.org/indicator (accessed 7 June 2011).

Yee, J., Huffman, W. 2001. Rates of return to public agricultural research in the presence of research spillovers. American Agricultural Economics Association Meetings, Chicago 5-8 August 2001.

Zambia, Seed Control and Certification Institute (SCCI), 2008. Official Variety List – 2008. Lusaka: SCCI.