Global Chapter 9 Tables and Figures

Table 9.1. Total public agricultural research expenditures by region, 1981, 1991, and 2000

	Agricultural R&D spending			Shares in global total		
	1981	1991	2000	1981	1991	2000
	(*million 2000 international dollars*)			(*percentage*)		
Asia & Pacific (28)	3,047	4,847	7,523	20.0	24.2	32.7
China	1,049	1,733	3,150	6.9	8.7	13.7
India	533	1,004	1,858	3.5	5.0	8.1
Latin America & Caribbean (27)	1,897	2,107	2,454	12.5	10.5	10.7
Brazil	690	1,000	1,020	4.5	5.0	4.4
Sub-Saharan Africa (44)	1,196	1,365	1,461	7.9	6.8	6.3
West Asia & North Africa (18)	764	1,139	1,382	5.0	5.7	6.0
Developing countries, subtotal (117)	*6,904*	*9,459*	*12,819*	*45.4*	*47.3*	*55.7*
Japan	1,832	2,182	1,658	12.1	10.9	7.2
USA	2,533	3,216	3,828	16.7	16.1	16.6
Subtotal, higher income countries (22)	*8,293*	*10,534*	*10,191*	*54.6*	*52.7*	*44.3*
Total (139)	**15,197**	**19,992**	**23,010**	**100.0**	**100.0**	**100.0**

Source: Pardey et al. (2006a) based on Agricultural Science and Technology Indicators (ASTI) data at www.asti.cgiar.org.
Notes:The number of countries included in regional totals is shown in parentheses. These estimates exclude East Europe and former Soviet Union countries. The high income countries total excludes a number of high income countries such as South Korea and French Polynesia (which has been grouped in the Asia and Pacific total), Bahrain, Israel, Kuwait, Qatar, and United Arab Emirates (grouped in West Asia and North Africa), and Bahamas (Latin America and Caribbean). To form these regional totals we scaled up national spending estimates for countries that represented 79% of the reported sub-Saharan African total, 89% of the Asia and Pacific total, 86% of the Latin America and Caribbean total, 57% of the West Asia and North Africa total, and 84% of the high-income total.

Table 9.2. Variation in annual growth rates in total spending in 27 sub-Saharan African countries, 1991-2000

Positive	Stagnating	Negative
South Africa (1.8%)	Benin (-0.7%)	Burundi (-16.2%)
Mauritania (3.7%0	Kenya (0.6%)	Congo (-12.7%)
Gabon (4.1%)	Mali (1.1%)	Sudan (-11.0%)
Botswana (5.6%)	Ghana (1.1%)	Niger (-8.4%)
Mauritius (6.2%)		Madagascar (-7.9%)
Nigeria (6.3%)		Zambia (-7.3%)
Ethiopia (7.1%)		Gambia (-7.1%)
		Malawi (-5.5%)
		Togo (-4.4%)
		Côte d'Ivoire (-3.4%)
		Burkina Faso (-3.2%)
		Senegal (-3.1%)
		Guinea (-2.8%)

Source: Beintema and Stads (2006).

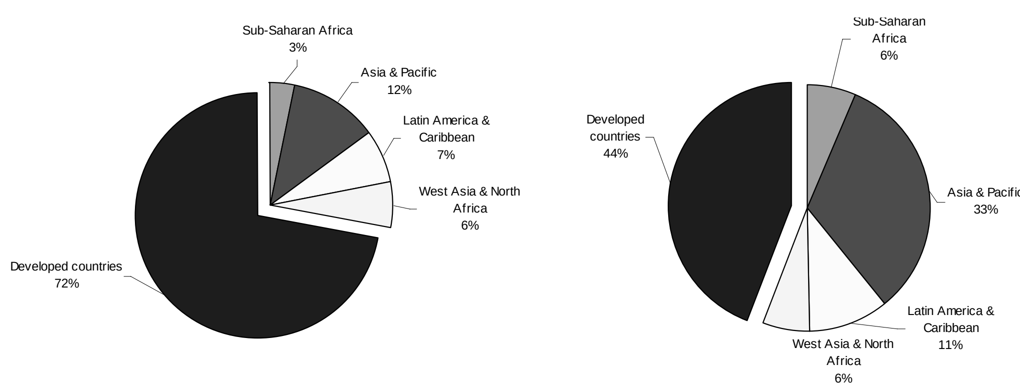
Note:Stagnating countries have annual growth rates between -1.5 and 1.5%. Annual growth rates are calculated using the least-squares regression method (see also endnote 3 on page #).

BOX 9.1. Investments in international versus U.S. dollars

Comparing economic data from one country to the next is very complex due to important price level differences that exist between countries. Purchasing power parities (PPP) are conversion rates that equalize the purchasing power of different currencies by eliminating the differences in price levels between countries. Therefore, a PPP rate can be thought of as the exchange rate of dollars for goods in the local economy, while the US dollar exchange rate measures the relative cost of domestic currency in dollars. A country's international price level is the ratio of its PPP rate to its official exchange rate for US dollars. Thus the international price level is an index measuring the cost of a broad range of goods and services in one country relative to the same bundle of goods and services in a reference country, in this case the United States. For example, Japan’s international price level (i.e. the ratio of PPP to exchange rate) of 1.57 in the year 2000 implies that the price of goods and services in Japan was 57% higher than the price of comparable goods and services in the United States during that year. In contrast, the corresponding 2000 ratio for Kenya of 0.20 in Kenya indicates that a bundle of goods and services that have cost $20 in Kenya would have cost $100 in the United States (Pardey and Beintema, 2001).

No fully satisfactory method has so far been devised to compare consumption or expenditures between countries, either in different points in time or at the same point in time. The measures obtained as well as their interpretation can be very sensitive to the choice of deflator and currency converter. Most financial figures in this subchapter have been expressed in ‘*international dollars*’ of the benchmark year 2000. At the country level, all expenditure and funding data have been collected in local currency units. These amounts were subsequently converted to 2000 international dollars by deflating the local currency amounts with each country’s gross domestic product (GDP) deflator of base year 2000. Next, they were converted to US dollars with a 2000 PPP index. Both the GDP deflators as well as the PPP values were taken from the World Bank’s *World Development Indicators* (2005). For convenience of interpretation, the reference currency—in this case an international dollar—is set equal to a US dollar in the benchmark year 2000. PPPs are synthetic exchange rates used to reflect the purchasing power of currencies, typically comparing prices among a broader range of goods and services than conventional exchange rates. Using PPPs as conversion factors to denominate value aggregates in international dollars results in more realistic and directly *comparable* agricultural research spending amounts in countries than if market exchange rates are used. This is because the latter tends to underestimate the quantity of spending used in economies with relatively low prices while overestimating the quantity for those countries with high prices. This is particularly a problem when valuing something like expenditures on agricultural R&D, where normally about two-thirds of the resources are spent on local scientist and support staff salaries and not on capital or other goods and services that are normally traded internationally.

Figure B.9.1 contrasts the regional expenditure shares both for public agricultural research expenditures using PPPs versus official exchange rates to do the currency conversion. The left-hand side of the figure denotes 2000 research spending in international dollars obtained using PPPs while the right-hand part of the figure reports the U.S. dollar estimates obtained using the same underlying R&D data together with official exchange rates. Taking the PPP estimates to be more representative of the amount of research resources committed to research, the U.S. dollar estimates overstate the share of developed-country agricultural research in the global total and grossly understates the African, Chinese, and other Asia and Pacific shares.

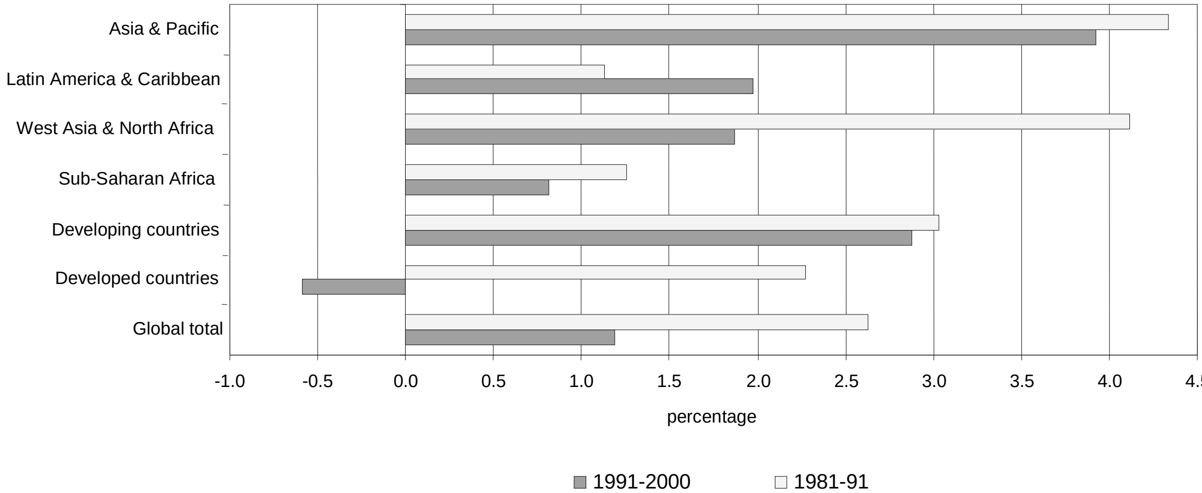


2000: $14.8 billion (2000 US dollars)

2000: $23.0 billion (2000 international dollars)

Source: Pardey et al. (2006a).

Figure 9.1: Growth rates of public agricultural R&D spending



Source: Pardey et al. (2006a) based on ASTI data.
Notes:Inflation-adjusted. Annual growth rates were calculated using the least-squares regression method, which takes into account all observations in a period. This results in growth rates that reflect general trends that are not disproportionately influenced by exceptional values, especially at the end point of the period.

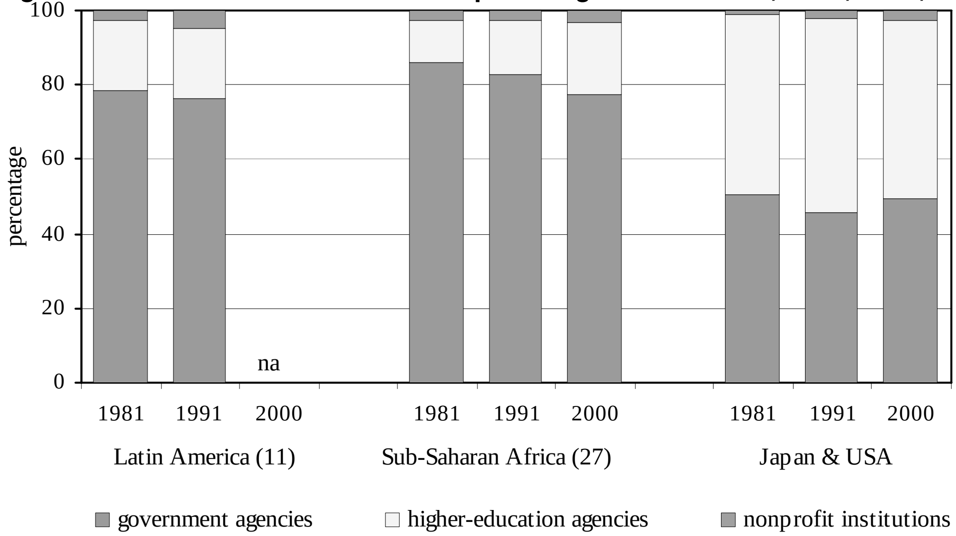
Table 9.3. Commodity focus by main research area , various years

	Asia-Pacific (10), 2002/03	Sub-Saharan Africa (26), 2000/01	Latin America (9), 1996	Total developing countries (45)
Major commodity area		(*percentage*)		
Crops	52.5	48.1	53.5	52.1
Livestock	13.2	17.8	17.9	14.7
Forestry	6.5	6.1	4.8	6.2
Fisheries	5.8	4.8	4.3	5.4
Post-harvest	3.6	6.5	3.9	4.1
Natural Resources	8.6	7.1	8.8	8.4
Other	9.8	9.5	6.7	9.2
Major crops				
Wheat	6.2	4.9	4.3	5.7
Rice	18.0	7.6	6.1	14.4
Maize	5.4	8.0	13.8	7.3
Cassava	0.6	5.8	2.2	1.6
Vegetables	9.4	9.0	18.6	11.0
Fruits	11.7	11.0	17.4	12.7
Sugarcane	5.0	4.9	3.7	4.7
Coffee	0.6	3.0	6.3	2.0
Other	43.3	45.7	27.4	40.7

Source: ASTI database (2007).

Note:Shares based on allocation of full-time equivalent researchers.

Figure 9.2: Institutional orientation of public agricultural R&D, 1981, 1991, 2000



Sources:Pardey et al. (2006a) based on ASTI data.
Note:The number of countries included in regional totals is shown in parentheses. The reported shares for Japan and the United States may understate the role of nonprofit institutions. n.a. indicates not available.

BOX 9.2. Plant breeding and biotechnology research

a. Trends in multinational plant and biotech research

One of the most rapidly growing areas of private sector agricultural research has been the plant biotech area. This research started in the 1970s, increased very rapidly in the late 1980s and 1990s to over a billion dollars of research in response to the technological opportunities offered by the breakthroughs of cellular and molecular biology and also due to stronger intellectual property rights particularly in the US. Some of this change was due to companies shifting research resources from chemical research to biological research.

Since 1999, several of the six largest biotech firms, which dominate private biotech research worldwide, have reduced their agricultural biotechnology research, and in the aggregate agricultural biotechnology research expenditures probably stagnated. Monsanto reduced its research expenditure, which is about 85% agricultural biotechnology and plant breeding, from US$588 million in 2000 to US$510 million in 2003 before increasing back to $588 million in 2005. Syngenta's plant science R&D expenditures declined from $161 million in 2000 to $109 million in 2003 and to $100 million in 2005 (Syngenta, 2006). In contrast Bayer and BASF seem to be increasing their investments in biotech. Bayer purchased Aventis Crops Sciences, which had a major biotech research program, in 2001. Bayer has made a substantial investment in Agricultural biotech R&D since then and now spends about $80 million on seed and biotech research expenses (Garthof, 2005). BASF spent approximately $82 million in 2004 (Garthof, 2005). They recently (2006) acquired the Belgium biotech firm CropDesign and have committed themselves to spending $320 million on biotech research over the new three years (Nutra Ingredients, 2006).

Public-sector investment in agricultural biotech growing rapidly in some large developing countries

Despite the controversy about transgenic crops and generally sluggish investments in biotechnology, government investments in agricultural biotechnology research and development are growing rapidly in some large developing countries. The most dramatic growth in public biotech investments is in China from under 300 million yuan in 1995 to over 1.6 billion yuan in 2003 (equivalent to US$ 200 million). This 1.3 billion yuan increase accounts for between 25 to 33% of the increase in all agricultural research in the same time period (Huang 2005). In addition Chinese cities and provinces have announced major government programs to commercialize the results of public sector biotech research such as the new center in Beijing which will invest US$160 million over the next three years to nurture 100 companies and 500 labs (Science 2006).

National governments in Brazil, Malaysia, and South Africa are also making major investments in agricultural biotech research and some provincial governments such as Sao Paolo in Brazil and Andhra Pradesh in India are also making substantial investments. In July 2006 the Brazilian government announced that it would invest US $3.3 billion over the next 10 years to develop biotechnology for health, industry, and agriculture (checkbiotech.org). Malaysia announced that it would invest US $3.12 billion in agriculture in the next plan period and that agricultural biotechnology would play a major role (Malaysia Economic News **year?, add in ref list**). Indian officials said in the spring of 2006 that it will invest US$100 million and the US will add US$24 million on agricultural biotechnology in India (Jayaraman, 2006). South Africa launched Plantbio (www.plantbio.org.za) in late 2004 to support the commercialization of plant biotech products.

Table 9.4. Estimated public and private agricultural R&D investments, 2000

	Expenditures			Shares	
	Public	Private	Total	Public	Private
	(*millions 2000 intl. dollars*)			(*percentage*)	
Asia & Pacific	7,523	663	8,186	91.9	8.1
Latin America & Caribbean	2,454	124	2,578	95.2	4.8
Sub-Saharan Africa	1,461	26	1,486	98.3	1.7
West Asia & North Africa	1,382	50	1,432	96.5	3.5
Developing countries, subtotal	12,819	862	13,682	93.7	6.3
Developed countries, subtotal	10,191	12,086	22,277	45.7	54.3
Total	**23,010**	**12,948**	**35,958**	**64.0**	**36.0**

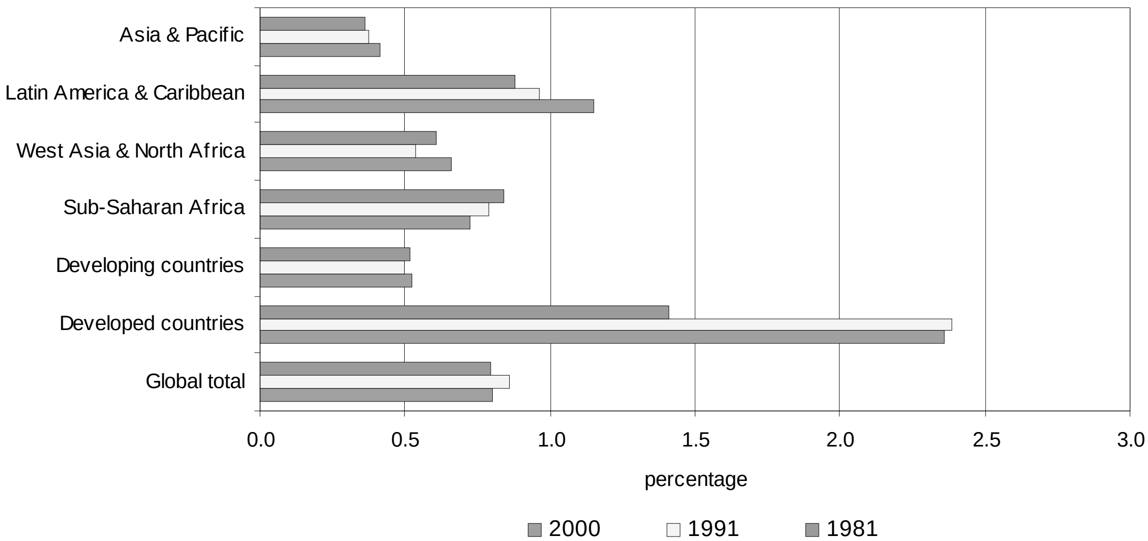
Source: Pardey et al. (2006a) based on ASTI data.

Table 9.5: Total S&T spending by region and shares agriculture in total, 2000

	S&T spending	Shares in global total S&T spending	Agricultural R&D as a share of total S&T spending
	(million 2000 international dollars)	*(percentage)*	
Asia & Pacific (26)	94,950	13.4	8.6
Latin America & Caribbean (32)	21,244	3.0	12.1
Sub-Saharan Africa (44)	3,992	0.6	37.2
West Asia & North Africa (18)	14,893	2.1	9.6
Developing countries, subtotal (120)	135,079	19.1	10.1
Higher income countries (23)	573,964	80.9	3.9
Total (143)	**709,043**	**100**	**5.1**

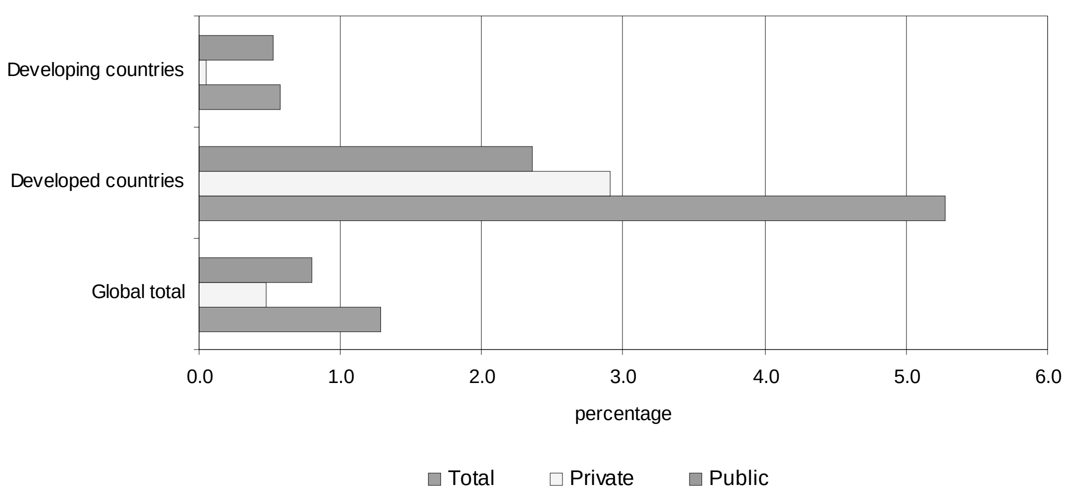
Source: Calculated from Table 9.1 and Pardey et al. (2006a).
Notes:These estimates exclude East Europe and former Soviet Union countries. The number of countries included in regional totals is shown in parentheses. Regional sample sizes are slightly different from those in Table 9.1.1.

Figure 9.3: Intensity of public agricultural R&D investments



Source: Pardey et al. (2006a) based on ASTI data
Note:The intensity ratios measure total public spending as a percent of agricultural output agricultural GDP.

Figure 9.4: Public, private and total agricultural research intensities, 2000



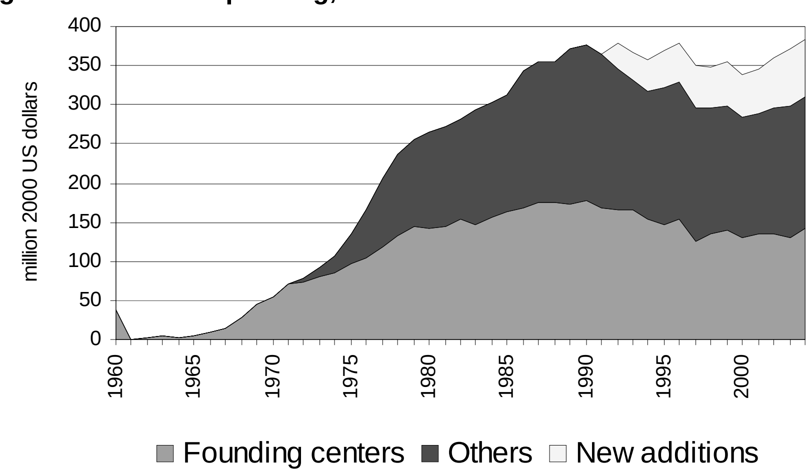
Source: Pardey et al. (2006a) based on ASTI data.
Note:The intensity ratios measure total public and private agricultural R&D spending as a percentage of agricultural GDP.

Table 9.6. Other intensity ratios, 1981, 1991 and 2000

	Public agricultural R&D spending					
	Per capita			Per capita of economically active agricultural population		
	1981	1991	2000	1981	1991	2000
	(*2000 international dollars*)					
Asia & Pacific	1.31	1.73	2.35	3.84	5.23	7.57
Latin America & Caribbean	5.43	4.94	4.96	45.10	50.54	60.11
Sub-Saharan Africa	3.14	2.69	2.28	9.79	9.04	8.22
West Asia & North Africa	3.24	3.63	3.66	19.15	27.30	30.24
Developing countries, subtotal	*2.09*	*2.34*	*2.72*	*6.91*	*8.14*	*10.19*
Developed countries, subtotal	10.91	13.04	11.92	316.52	528.30	691.63
Total	*3.75*	*4.12*	*4.13*	*14.83*	*16.92*	*18.08*

Source: Pardey et al. (2006a) based on ASTI data.

Figure 9.5: CGIAR spending, 1960-2004



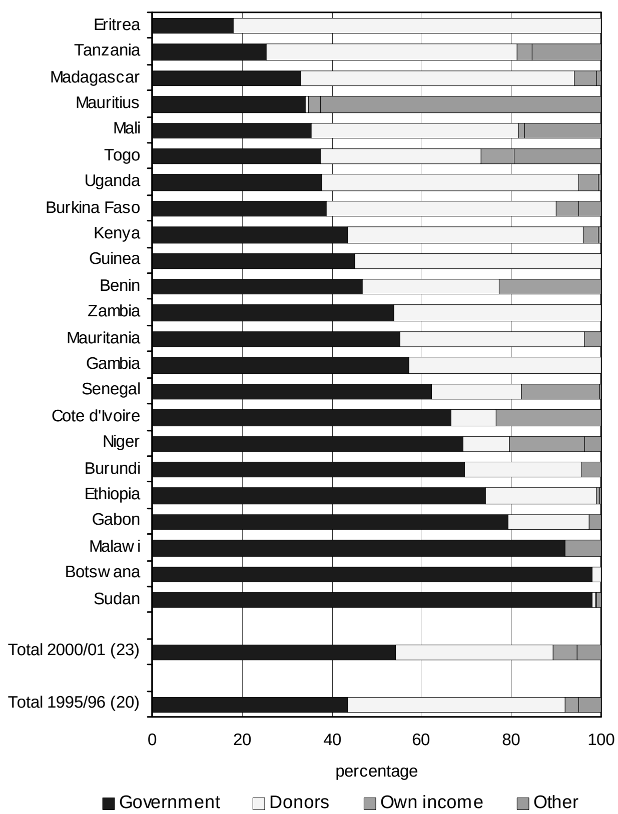
Source: Pardey et al. (2006a)

Table 9.7: Aid to agriculture, 1970–2004

Year	Total official development assistance (ODA)	Bilateral aid	
		Amount	Share to agriculture
	(*million 2000 U.S. dollars*)		(*percentage*)
1970	24,719	20,886	4.91
1975	35,448	26,233	11.13
1980	49,166	31,875	16.63
1985	41,773	30,782	15.93
1990	67,071	47,540	11.39
1995	64,077	44,129	9.82
2000	53,749	36,064	6.36
2003	65,502	47,222	4.22
2004	74,483[a]	50,700[a]	n.a.

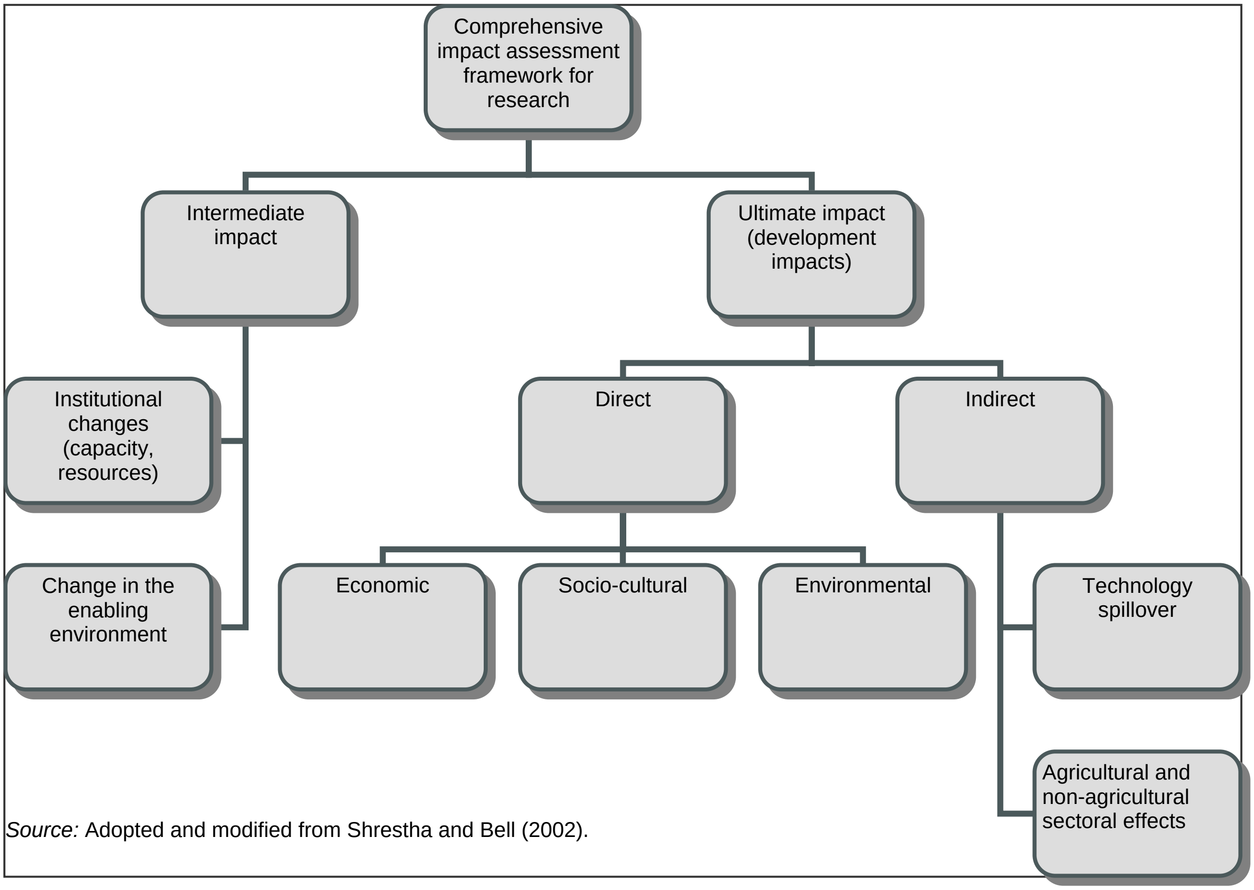
Source: Pardey et al. (2006a).
Note:n.a. indicates not available.
[a] Preliminary estimate

Figure 9.6. Country-level sources of funding in sub-Saharan Africa, 1995/96 and 2000



Source: Beintema and Stads (2006).
Notes:Figure includes only funding data from the main agricultural research agencies in each of the respective countries. Combined, these agencies accounted for 76% of total spending for the 23-country sample in 2000. Data for West Africa, with the exception of Nigeria, are for 2001.

Figure 9.7. Comprehensive impact assessment framework for R&D investment



Source: Adopted and modified from Shrestha and Bell (2002).

Table 9.8. Comparison of ROR for national agricultural R&D expenditure across sub-regions

Sub-regions	Countries	Mean ROR (%)	Weighted mean ROR (%)	Countries with Negative ROR
Africa	Algeria, Botswana, Ethiopia, Cote d'Ivoire, Ghana, Guinea-Bissau, Kenya, Lesotho, Mauritania, Morocco, Rwanda, Senegal, Tanzania, Tunisia, Uganda, Zambia, and Zimbabwe.	18	22	Lesotho, Senegal, and Tanzania.
Asia	Bangladesh, China, India, Indonesia, Jordan, Malaysia, Nepal, Pakistan, Philippines, Sri-Lanka, Thailand.	23	26	Sri-Lanka
Latin America	Bolivia, Brazil, Chile, Colombia, Costa-Rica, Dominican Rep., Guatemala, Honduras, Jamaica, Mexico, Panama, Peru, Venezuela.	10	-6	Brazil, Dominican Republic, Jamaica, Mexico, Panama, Peru, Venezuela.

Source: Thirtle et al. (2001).

Table 9.9. Costs-benefits and internal rate of return for NARS and IARC CGI programs by region

	NARSs		IARCs	
	Estimated benefits		Estimated	Lower range
	IRR	B/C	IRR	B/C
Latin America	31	56	39	34
Asia	33	115	115	104
West Asia-North Africa	22	54	165	147
Sub-Saharan Africa	9	4	68	57

Source: Evenson and Rosegrant (2003).

Table 9.10. Summary of IRR estimates

	Percent distribution							
	Number of IRRs reported	0-20	21-40	41-60	61-80	81-100	100+	Approx. median IRR
Extension								
Farm observation:	16	.56	0	.06	.06	.25	.06	18
Aggregate observations	29	.24	.14	.07	0	.27	.27	80
Combined research and extension	36	.14	.42	.28	.03	.08	.16	37
By region:								
OECD	19	.11	.31	.16	0	.11	.16	50
Asia	21	.24	.19	.19	.14	.09	.14	47
Latin America	23	.13	.26	.34	.08	.08	.09	46
Africa	10	.40	.30	.20	.10	0	0	27
All extension	81	.26	.23	.16	.03	.19	.13	41
Applied research								
Project evaluation	121	.25	.31	.14	.18	.06	.07	40
Statistical	254	.14	.20	.23	.12	.10	.20	50
Aggregate programs	126	.16	.27	.29	.10	.09	.09	45
Commodity programs:								
Wheat	30	.30	.13	.17	.10	.13	.17	51
Rice	48	.08	.23	.19	.27	.08	.14	60
Maize	25	.12	.28	.12	.16	.08	.24	56
Other cereals	27	.26	.15	.30	.11	.07	.11	47
Fruits and vegetables	34	.18	.18	.09	.15	.09	.32	67
All crops	207	.19	.19	.14	.16	.10	.21	58
Forest products	13	.23	.31	.68	.16	0	.23	37
Livestock	32	.21	.31	.25	.09	.03	.09	36
By region:								
OECD	146	.15	.35	.21	.10	.07	.11	40
Asia	120	.08	.18	.21	.15	.11	.26	67
Latin America	80	.15	.29	.29	.15	.07	.06	47
Africa	44	.27	.27	.18	.11	.11	.05	37
All applied research	375	.18	.23	.20	.14	.08	.16	49
Pre-invention science	12	0	.17	.33	.17	.17	.17	60
Private sector R&D	11	.18	.09	.45	.09	.18	0	50
Ex-ante research	*87*	*.32*	*.34*	*.21*	*.06*	*.01*	*.06*	*42*

Source: Evenson (2001).

Table 9.11. Ranges of rates of return

Sample	Number of observations	Rate of return				
		Mean	Mode	Median	Minimum	Maximum
	(*count*)	(*percentage*)				
Full sample[a]						
Research only	1,144	99.6	46.0	48.0	-7.4	5,645
Extension only	80	84.6	47.0	62.9	0	636
Research and extension	628	47.6	28.0	37.0	-100.0	430
All observations	1,852	81.3	40.0	44.3	-100.0	5,645
Regression sample[b]						
Research only	598	79.6	26.0	49.0	-7.4	910
Extension only	18	80.1	91.0	58.4	1.3	350
Research and extension	512	46.6	28.0	36.0	-100.0	430
All observations	1,128	64.6	28.0	42.0	-100.0	910

Source: Alston et al. (2000a).
[a] The original full sample included 292 publications reporting 1,886 observations. Of these, 9 publications were dropped because rather than specific rates of return they reported results such as >100% or <0. As a result of these exclusion, 32 observations were lost. Of the remaining 1,854, two observations were dropped as extreme (and influential) outliers. These two estimates were 724,323% and 455,290% per year.
[b] Excludes outliers and observations that could not be used in the regression owing to incomplete information on explanatory variables.

Table 9.12 Rates of return by commodity orientation

Commodity orientation	Number of observations	Rate of return				
		Mean	Mode	Median	Minimum	Maximum
	(*count*)	(*percentage*)				
Multicommodity[a]	436	80.3 (110.7)	58.0	47.1	-1.0	1,219.0
All agriculture	342	75.7 (110.9)	58.0	44.0	-1.0	1,219.0
Crops and livestock	80	106.3 (115.5)	45.0	59.0	17.0	562.0
Unspecified[b]	14	42.1 (19.8)	16.4	35.9	16.4	59.2
Field crops[c]	916	74.3 (139.4)	40.0	43.6	-100.0	1,720.0
Maize	170	134.5 (271.2)	29.0	47.3	-100.0	1,720.0
Wheat	155	50.4 (39.4)	23.0	40.0	-47.5	290.0
Rice	81	75.0 (75.8)	37.0	51.3	11.4	466.0
Livestock[d]	233	120.7 (481.1)	14.0	53.0	2.5	5,645.0
Tree crops[e]	108	87.6 (216.4)	20.0	33.3	1.4	1,736.0
Resources[f]	78	37.6 (65.0)	7.0	16.5	0.0	457.0
Forestry	60	42.1 (73.0)	7.0	13.6	0.0	457.0
All studies	1,772	81.2 (216.1)	46.0	44.0	-100.0	5,645.0

Source: Alston et al. (2000a).
Notes:See Table 9.10. Standard deviations are given in parentheses. Sample excludes two extreme outliers and includes only returns to research only and combined research and extension, so that the maximum sample size is 1,772. In some instances further observations were lost owing to incomplete information on the specific characteristics of interests.
[a] Includes research identified as all agriculture or crops and livestock, as well as unspecified.
[b] Includes estimates that did not explicitly identify the commodity focus of the research
[c] Includes all crops, barley, beans, cassava, sugar cane, groundnuts, maize, millet, other crops, pigeon pea or chickpea, potato, rice sesame, sorghum and wheat.
[d] Includes beef, swine, poultry, sheep or goats, all livestock, dairy, other livestock, pasture, dairy and beef.
[e] Includes other tree and fruit and nuts.
[f] Includes fishery and forestry.

Table 9.13. Rates of return by geographical region or research performer

Geographical region	Number of estimates	Rate of return				
		Mean	Mode	Median	Minimum	Maximum
	(*count*)	(*percentage*)				
Developed countries	990	98.2	19.0	46.0	-14.9	5,645
		(278.1)				
North America[a]	740	102.4	22.0	46.5	-14.9	5,645
		(306.9)				
Europe	85	93.9	19.0	62.2	0.0	1,219
		(152.0)				
Australasia[b]	154	83.7	20.0	28.7	-1.3	1,736
		(177.9)				
Other developed countries[c]	11	55.6	22.2	37.4	22.2	125
		(36.1)				
Developing countries	683	60.1	46.0	43.0	-100.0	1,490
		(84.1)				
Africa	188	49.6	10.9	34.3	-100.0	1,490
		(113.0)				
Asia and Pacific	222	78.1	49.0	49.5	6.0	1,000
		(93.2)				
Latin America and Caribbean	262	53.2	46.0	42.9	3.0	325
		(39.3)				
West Asia and North. Africa	11	44.2	28.0	36.0	28.0	80
		(19.6)				
Multinational	74	58.8	32.0	34.0	-47.5	677
		(98.3)				
International agricultural research centers	62	77.8	26.0	40.0	9.9	1,490
		(188.6)				

Source: Alston et al. (2000a).

Notes: Standard deviations are given in parentheses, Sample excludes two extreme outliers and includes only returns to research only and combined research and extension, so that the maximum sample size is 1,772. In some instances further observations were lost owing to incomplete information on the specific characteristics of interest.

[a] Unites States and Canada; [b] Australia and New Zealand; [c] Japan and Israel.

Table 9.14. Summary of results of Economic Assessment of African R&D Investments

Author	Type of Analysis	Number of Observations	Range of RORs	Range of B/C ratio	Geographical Coverage
Oehmke et al. (1997)	Ex-post	27	< 0 to 135	—	Sub-Saharan Africa-
	Ex-ante	19	< 0 to 271	1.35 :1 to 149 :1	
	Combined	46	< 0 to 271	1.35 :1 to 149 :1	
Anandajayasekeram et al. (2006)	Econometric methods	25	2 – 113	—	East and Southern Africa
	Non econometric methods	61	< 0 to 109	1.35:1 to 149	
	Combined	86	< 0 to 113	1.35:1 to 149	

Source: Oehmke et al. (1997); Anandajayasekeram et al. (2006).

BOX 10.3. The hypoxic zone in the northern Gulf of Mexico is the largest observed in the estuarine and coastal regions of the western hemisphere.

Although the precise cause and effect relationship between fertilizer use and the hypoxic zone in the Gulf of Mexico is still uncertain, research suggests that fertilizer leaching and run-off from upriver agricultural sources may be the main sources of nutrients. For example, USGS states that 56% of the Mississippi River's nutrient loading results from fertilizer runoff, with an additional 25% of the Mississippi River nitrogen coming from animal manure (municipal and solid wastes account for 6%, atmospheric deposition for 4%, and unknown sources for 9%). Research also confirms that nitrogen input to the Mississippi River Basin increased faster than the amount of nitrogen harvested in the crops in the 1960s and 1970s. And the nitrogen that not taken up by plants becomes available to leach into groundwater and rivers.

To date, no studies have investigated the linkage between fishery declines and hypoxic episodes in the Gulf, but some evidence suggests the dead zone may force fish and shrimp further offshore as well as into shallow nearshore areas. Shrimp production declined by 23%, or almost 20 million pounds annually, when the hypoxia zone sharply expanded between 1985 to 1998, according to a study by National Marine Fisheries Service biologists.

Source: White House Office of Science and Technology Policy (1998).

Table 9.15 General trends in environmental impacts of agricultural technologies

Does the specific agricultural technology impact:	Individual Farmer and/or Household	Local Community	Downstream Community	Global Society
Biodiversity Loss Off and on-farm species and plant genetic recourses	++	++	+	+++++
Erosion and soil quality	++++	+	++++	+++++
Run-off of agro-chemicals	0	+	+++++	+++
Pesticides and impact on non-target species	+	+++	++++	+++
Water table loss	+	++	+++++	+
Fossil Fuel Use:Non-renewable and climate change impact	++ (financial cost)	0	0	+++++

Source: ??
Note:Degree of impact:+ is minimal; ++ moderate; +++ high; ++++ very high,and +++++ very high likelihood of some irreversibility.

Table 9.16. Estimates of negative externalities of productivity-enhancing technology* in developing countries:Evidence from the literature.

Negative Externality	Evidence from the literature	Estimates of area/extent of a given problem	Environmental/economic implications
oss of enetic ariabili ty	Discussed in the literature but evidence not substantiated for crops. Evidence documented globally via the DAD-IS [spell out] database for animal genetic resource.	Globally many domestic animal breeds have become extinct. 35% of remaining domestic mammal breeds and 63% of avian breed are at risk of extinction. 60% of them in developing countries ndividual estimates available for countries and crops. For example, in Nepal, hybrid eeds of cabbage have totally replaced the ndigenous seeds; 95% of Greece's native wheat, have become extinct. 75% of crop diversity lost. Modern varieties have supplanted traditional varieties for 70% of the word's corn, 75% of Asian rice, and half of the wheat in Africa, Latin America, and Asia	Loss of biodiversity Declining crop productivity
Salinity and water logging	Evidence of this problem in irrigated areas available and well documented. Evidence in areas where intensive shrimp aquaculture exist	45 million ha globally suffer from salinity and water logging problems 20-30% of irrigated land in developing countries has been damaged by waterlogging or salinization	Land abandoned Declining land productivity Migration of farmers from rural areas
Changes in the level of water table	Evidence of both increase and decrease in water table level is found in the literature; evidence scattered and location specific	Water table increase reported in the range of 0.1 to 3.0 million per year in some irrigated project areas. Reported water table decline range from 0.4 to 1.0 million per year in some regions.	Declining land productivity
Loss of soil fertility/ erosion	Evidence documented for rice in Asia; evidence of linkage in other crops not substantiated	30-40 ton/ha/year in Asia, Africa and South America Land degradation affects two-thirds of the world's agricultural land. Soil erosion is responsible for about 40% of land degradation worldwide.	Declining land productivity Abandonment of croplands.
Water pollution	Most evidence found in developed countries; scattered evidence in Developing countries	No global estimates available 60 to 70% of the rural population in the developing world have not access to a safe and convenient source of water	Increased health and water treatment costs; loss of aquatic flora and fauna. Increased of water-borne diseases. 5 million deaths/year
Air pollution	Discussed but not substantiated in Developing countries	No global quantitative estimates available	Increased health costs; lower factor productivity
Food conta-mination	Scattered evidence in Developing countries	No global estimates available	Increased health costs
Impacts on human and animal health	Case-specific evidence on this linkage available. Most evidence relates to pesticides and its health effects	Globally 3 million cases of pesticide poisoning each year resulting in 220,000 deaths.	Increased health costs and social/economic costs associated with lower labor productivity
Effects on pest population	Case-specific examples and scattered evidence	No global estimates available	Increased costs of production (pesticides) and declining crop productivity

Source: Adapted from Maredia and Pingali (2001) and completed with other sources:Myers, N. (1999), Upreti and Upreti (2002); Pimentel et al. (1995), FAO (2001), Picone and van Tassel (2000); Churchill (1987); Gleick (2002).

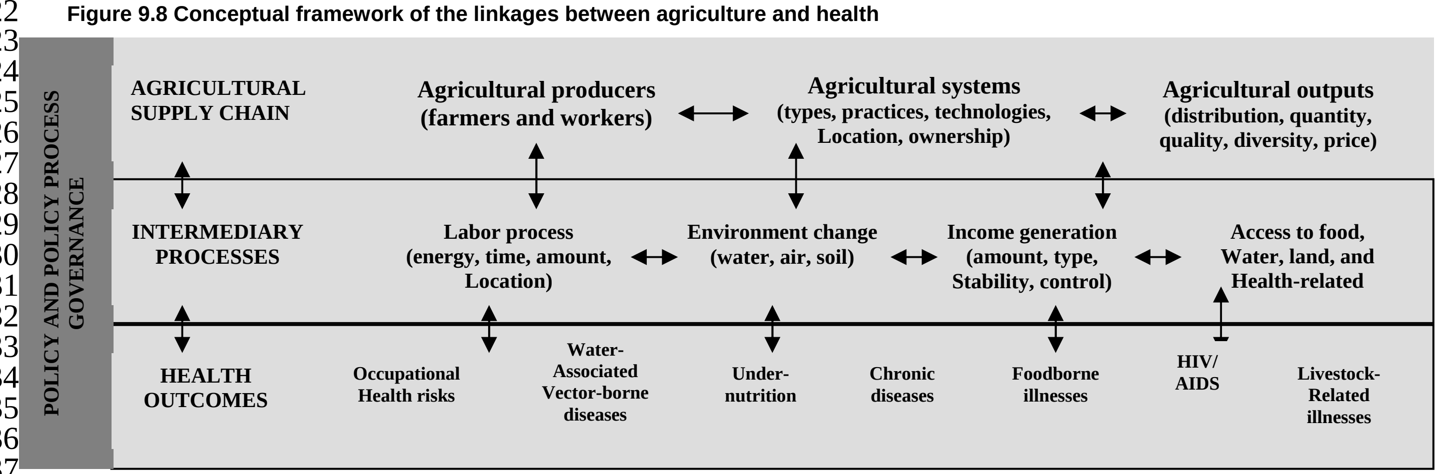
* The technologies considered were yield-enhancing technologies, variability reducing technologies and labor saving technologies

Table 9.17. Estimates of negative environmental consequences and land-use implications of irrigation-induced soil salinity problems in developing countries, late 1990s

Potential area impacted by externality			1000 ha
A.	Total irrigated area –1998[a]		205,000
B.	Estimated area with salinity problem[b]		
	1.	Light	20,000
	2.	Moderate	10,000
	3.	Strong	11,500
	4.	Extreme	200
Total			*41,700*
Negative environmental consequences			
C.	Land abandoned due to salinity (1000 ha) (strong + extreme degradation) [c]		11,700
D.	Decrease in yields due to salinity [d]		20-50%
Land use implications [e]			
E.	Area needed to produce the same amount of production if light and moderate salinity problem did not exist		??
F.	Area that could have been saved if light and moderate salinity problem did not exist (difference between problem area and the area needed to produce the same amount of output)		9,000
Total land savings that could have occurred in the absence of salinity problems [f]			*20,700*

A. FAO (2005b).
B. Oldeman et al. (1991) estimate the global extent of human-induced salinization that has resulted in light, moderate, strong and extreme degradation to be about 35, 21, 20, and 0.8 M ha respectively. Out of this about 5 M Ha are in Europe, Australia and North America. Adjusting the remaining land area estimates in each category for irrigation-induced soil salinity problems (which is 60% of the total salt-affected area based on Ghassemi et al (1995, p. 42) calculations, we derive the figure of 20, 10, 11.5 and 0.2 M ha as an educated guess for total area affected by different degrees of salinity degradation in irrigated areas of developing world.
C. The figures for India and Mexico based on studies cited in the literature (**list refs**) estimate 7 million ha and 0.5 million ha, respectively as land abandoned due to salinity. But no global estimates on land abandoned due to salinity are available. We assume the last two categories of degradation unsuitable for cultivation and therefore a close estimate of land abandoned.
D. An average 20% yield loss for light degradation and 50% yield loss for moderate degradation is an educated guess of the authors based on the various empirical evidences discussed in the **elaborated paper on the topic by Panel members** (**author names-add in ref list**, forthcoming).
E. Calculated by **Panel members??** based on above estimates.
F. Sum of C and F.

Figure 9.8 Conceptual framework of the linkages between agriculture and health



Source: Adapted from ???.

Table 9.18. Economic impact studies:Private sector R&D spill-in and pre-invention science spill-in

Study	Country/ region	Period of study	Productive structure	IRR
Private sector R&D spill-in:				
Rosegrant and Evenson (1993)	India	1956-87	PD	Dom 50+ For 50+
Huffman and Evenson (1993)	USA	1950-85	PD	Crops 41
Ulrich et al. (1985)	Canada		PD	Malting barley 35
Gopinath and Roe (1996)	USA	1991	CF	Food processing 7.2 Farm machinery 1.6 Total social 46.2
Evenson (1991)	USA	1950-85	PD	Crop 45-71 Livestock 81-89
Evenson and Avila (1996)	Brazil	1970-75-80-85	PD	NC
Pre-invention science spill-in:				
Evenson (1979)	USA	1927-50 1946-71	PD PD	110 45
Huffman and Evenson (1993)	USA	1950-85	PD	Crops 57 Livestock 83 Aggregate 64
Evenson et al. (1999)	India	1954-87	PD	Domestic Foreign
Evenson and Flores (1978)	Int. (IRRI)	1966-75	PD	74-100
Evenson (1991)	USA	1950-85	PD	Crops 40-59 Livestock 54-83
Azam et al. (1991)	Pakistan	1966-68	PD, T	39

Source: Evenson (2001).

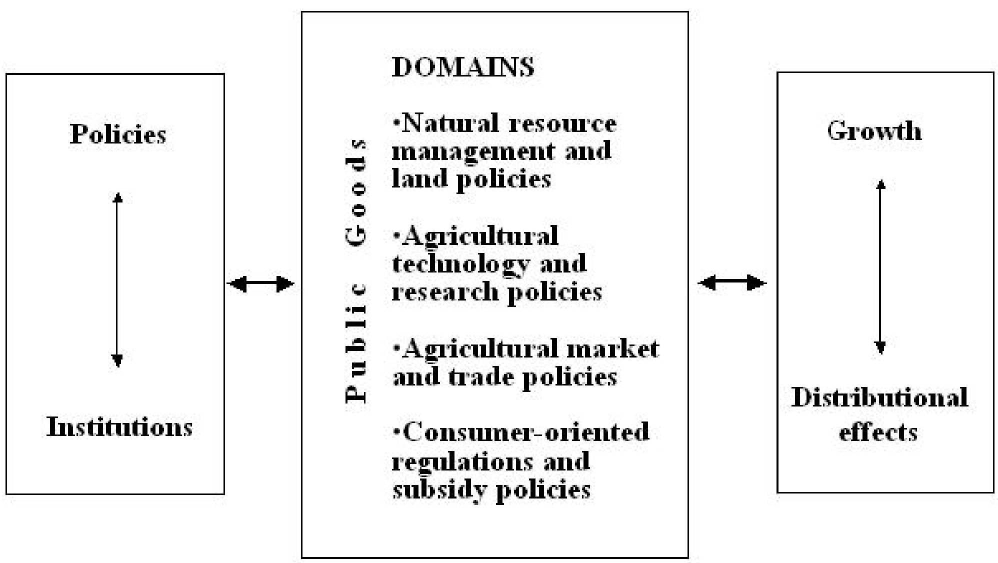
Table 9.19. Ranking of public investment effects in selected Asian and African countries

	China	India	Thailand	Vietnam	Uganda	Tanzania	Ethiopia
	Ranking of Returns in Agricultural Production						
Agricultural R&D	1	1	1	1	1	1 (52.46)	3
Irrigation	5	4	5	6			
Education	2	3	3	3	3	3 (9.00)	2
Roads	3	2	4	4	2	2 (9.13)	1
Telecommunications	4			2			
Electricity	6	8	2	5			
Health		7			4		
Soil and water conservation		6					
Anti-poverty programs		5					
	Ranking of Returns in Poverty Reduction						
Agricultural R&D	2	2	2	1	1	3*	
Irrigation	7	7	5	6			
Education	1	3	4	3	3	2*	
Roads	3	1	3	4	2	4	
Telecommunications	4			2		1	
Electricity	5	8	1	5			
Health		6			4		
Soil and water conservation		5					
Anti-poverty programs	6	4					

Source: Fan et al. (2005, 2004a, b; 2000); Fan and Zhang (2004); Mogues et al. (2006).

* The number of poor reduced per million shillings for education and agricultural research were 43.10 and 40.89, respectively.

Figure 9.9. The conditioning of agricultural growth and distributional effects (von Braun, 2003)



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2006).

BOX 9.4. On the theoretical framework to analyze governance.

There are different streams of theoretical literature informing the discussion on governance. One such framework is that of New Institutional Economics (NIE), an extended framework of neoclassical economics. It takes into account demand factors such as the role of relative prices since such prices play an important role in deciding what is an appropriate institution in a given context. However NIE admits the possibility that the evolution of appropriate institutional innovation need not be an automatic process. There can be social, political, and even institutional reasons that distort' or blunt the evolution of appropriate institutions. There has been significant development in institutional analysis during the last two decades highlighting the possibilities of persistence of institutional inefficiency due to reasons of path dependence, political economy and informational problems. An alternative framework is that of` the national innovation system (NIS) (Freeman, 1987; Lundvall, 1992). It treats R&D as an innovation system in which both the producers and users are seen as parts of the same system and attempts to identify certain patterns in system relationships, governance, capacity-building or learning, evolving roles, and wider institutional contexts (Hall and Yoganand, 2002). However from the point of view of NIE, NIS approach lacks a coherent theoretical framework, and thus is unable to develop consistent stories or explanations of different institutional changes taking place in different socio-economic contexts. Meanwhile, the criticism of the innovation system proponents on the NIE-based approach would be that the latter is inadequate to handle power structures and learning. However the issues of incorrect learning and information problems have become part of the agenda of NIE increasingly in the nineties (North, 1991) and the New Political Economy takes into account the role of power struggles in facilitating or blocking beneficial institutional changes.

Table 9.20. Guiding questions for institutional assessment on governance

Issue/Actor	Guiding Question
Governance	1. What are the appropriate intervention strategies in different sectors given the overall social objectives?
	2. What is the appropriate intervention given the objectives in the agricultural sector?
	3. What is the problem of market failure to be addressed?
	4. What is the institutional mechanism required given the problem of market failure?
	5. How to ensure that governance decisions are accountable and transparent?
Institutions	6. Is the institutional arrangement capable of meeting the objective?
	7. Is the institutional arrangement capable to internalize the requirements or demands of its potential clients?
	8. Is the institutional arrangement leading to efficient decisions given its alternatives?
	9. Does the arrangement have flexibility to evolve in tune with the changing socio-economic realities?
Organizations	10. What kind of feedback is likely to be generated by the organizations operating within this institutional framework?
Individuals	11. Are the incentives (monetary as well as other non-monetary rewards) of the individual actors aligned with the stated objectives of the organizations?

BOX 9.5. A new public-private partnership paradigm for African agriculture:The African Agricultural Technology Foundation

The African Agricultural Technology Foundation (AATF) is an African-led not-for-profit organization headquartered in Nairobi, Kenya. The AATF aims to facilitate partnerships to remove the constraints on transfer and use of appropriate agricultural technologies. It negotiates free access to proprietary technologies and mediates the formation of partnerships between public and private institutions in Africa, North America and Europe for the adaptation and delivery of such technologies to smallholder resource-poor farmers in sub-Saharan Africa.

AATF's founding funding agencies are Rockefeller Foundation, DFID and USAID. Dow Agro, Du Pont, Syngenta and Monsanto have agreed to share their patented technologies for free. An independent board is responsible for selecting projects. The initial AATF business plan for first 10 years, proposes a total funding requirement of US$65.5m (undiscounted). The plan assumes that the AATF projects will attract US$58m in matched funding from public and private sector partners and stakeholders. Projected AATF project expenditure will total US$44m over 10 years and overheads will amount to just under US$2.5 million per annum, or 13% of total project costs by year 10. The financial projections also assume that the AATF does not receive any revenues (e.g. from product royalties) over the first 10 years of activity. The business plan projections envisage AATF involvement in 9 projects over the first 5 years, with the first 4 starting in 2004. Thereafter, the number of additional projects is assumed to be between one and two per annum. In 2003, total AATF expenditure was projected to be US$2.473 million to cover both overheads and the expenditure required to develop 4 projects.

The first financial report publicly available (September 2003-December 2004) describes two projects in progress: Striga control in Maize and Cowpea productivity; three projects under development, banana and plantain improvement, Mycotoxin reduction in food grains, cassava improvement and two which had been discontinued: provitamin A enhancement in maize and insect resistant maize. The reasons for discontinuation are not provided in annual report but it would be useful to document the reasons for not proceeding to learn lessons (i.e., technical problems, lack of matched funding or inappropriate technology).

New institutional arrangements are emerging from this new partnership paradigm. For example charitable status for the AATF has been achieved through the UK Charity Commission. This status was essential if AATF was to receive core funding by Rockefeller Foundation; without it the foundation could only fund projects. Charitable status also means that the AATF will be able to apply for US tax exempt status. Other partnerships may have to be explored to overcome new hurdles; for example liability protection issues emerge from new technologies. AATF may need insurance to protect against future liability claims possibly through a corporate insurance policy.

Box 9.6. Experience of new funding options in African countries

Many African countries have implemented new governance enhancing strategies such as; separation of policy making, funding and service provision, decentralization of public administration, deconcentration of service provision, and empowerment of communities and farmers organizations. Experience from Tanzania and Benin (Heemskerk and Wennink, 2005) have shown that local R&D funding schemes have contributed significantly to financial diversification for agricultural innovation. However, real and substantial empowerment of farmers' organizations in controlling financial research for adaptive research and pre-extension is still low. Although downward accountability has improved, real client control of funds has stagnated and Farmers' representation in management teams of competitive grant schemes remains weak due to traditional top down attitudes of researchers and research managers.

Decentralization and deconcentration of local innovation development funds have been more successful in technology generation, and in fostering the competitive element, which has enhanced the quality of research and the sense of ownership. Nonetheless, other concerns such as; developing more viable mechanisms for client representation, priority focus and pro-poor focus of available funds, level of co-sharing and cost sharing are all yet to be resolved. In addition, some of the competitive grants and commodity based innovation development funds are insufficiently integrated into the national financing system.

In terms of effectiveness and efficiency, there is evidence that more adaptive technologies are flowing to farmers under competitive funding, but there is no effective mechanism to systematize the information on the innovation adoption process. There has also been improvement in priority setting, planning and implementation, but not as much in monitoring and financing. Competitive grants tend to spread resources too thinly. Experience in Tanzania showed that effectiveness of competitive grants could be improved by focusing on a single theme using the value chain approach. Another disadvantage in the African context is that competition may be limited due to insufficient numbers of competent researchers. In addition, competitive funds in African have been dependent on donors, whose pledges by donors have sometimes not been forthcoming. Also short term funding from donors sometimes leads to abrupt closure of on-going research activities (Gotoette-Hodounou et al, 2005). Co-financing from local sources has also been unpredictable. Competitive funds are also expensive to operate due to high transaction cost especially for monitoring and evaluation (Lema and Kapange, 2005a, b).

Table 9.20. Summary of the meta-analysis of rates of return to research

	Median of ROR of meta studies	
	Evenson	Alston et al.
All crops	57	44
Wheat	51	40
Rice	60	51
Maize	56	47
Other cereals	57	Na
Fruits and vegetables	67	Na
Livestock	36	53
Forestry	Na	14
Forest products	37	Na
Tree crops	Na	33
Resources	Na	17
Developing countries	37-67	43
CGIAR	39-165	40
Private	50	34??

Sources:Evenson (2001) and Alston et al. (2001a).

Table 9.21 Environmental impacts of productivity increasing research and mitigation research

	Agricultural research and technology	**Environmental impact**	**Mitigation research**	**Education and extension solutions**
Crops	Over use of fertilizers	Water pollution from fertilizer run-off	Integrated soil management research, Organic techniques, biofertilizers	Teach principles and techniques of management
	Irrigation with poor drainage	Reduce/increase water table. Salinity/alkalinity	Water management techniques	Extend best techniques
	Chemical pesticide use - Intensive cultivation, susceptible varieties	Water pollution, air pollution	Integrated pest management, organic techniques, biopesticides	Pest scouting & management
	Machinery powered by fossil fuels	Carbon dioxide, global warming	Low-tillage management systems, biofuels	Extend low-till systems
Trees	Plantations replace forests	Reduce biodiversity, CO2 production	Better forest management can reduced impacts	Less destructive techniques for clearing forests
	Plantations replace crops	Reduce greenhouse gas	Management that increase carbon sink	
Livestock	Intensive livestock systems	Water pollution from manure run-off, Air pollution (smell), Methane from ruminants a greenhouse gas	Improved manure management, increase productivity of extensive system	
Aquaculture	Intensive shrimp farming	Mangrove destruction		
	Intensive fish cultivation	Water pollution	Integrated fish-crop farming systems	

Source: Analysis in subchapter 9.2

Table 9.22. Summary of impacts of productivity increasing technology – economic returns, externalities and spillovers

	Median of ROR for Productivity Increases		Environmental externalities	Health externalities	Impact on poor
	Evenson (2001)	Alston et al. (2001a)			
All crops	57	44			0
Wheat	51	40	- - Irrigation with poor drainage + high yields reduce need to clear forest	0/+	++
Rice	60	51	- - over irrigation & high pesticide use + high yields reduce need to clear forest	- pesticides	++
Maize	56	47	- - over irrigation & high pesticides + high yields reduce need to clear forest	- pesticides	++
Other cereals	57	Na			++
Fruits and vegetables	67	Na	-- high pesticide use	-- high pesticides affect laborers & consumers + improves nutrients in diet	+ home gardens/-commercial
Livestock	36	53	-- for intensive livestock production which can lead to nitrogen and phosphorus pollution of water	- zoonotic diseases - food poisoning + increases protein & minerals in diet	+ if subsistence or milk coops - if intensive or contract production???
Forestry	Na	14			
Forest products	37	Na			?
Tree crops	Na	33	- plantations that replace uncultivated land can reduce biodiversity + plantations that replace crops could be a carbon sink		- if plantations
Resource management	Na	17	++ for more effective management which substitutes labor for chemicals	+ if reduce use of pesticides	+ if saving resources of poor or tech is labor intensive
Developing countries	37-67	43			
CGIAR	39-165	40			++
Private	50	34??	-- intensive livestock and pesticide use, but management & biotech can reduce chemical pesticides	- if increases pesticide use + if it reduces pesticide use	- or 0

Source: Evenson 2001 and Alston et al (2000a) and the judgments of the authors
Notes - small negative impact, -- large negative impact, + small positive impact, and ++ large positive impact.