

# V SOURCES OF AGRICULTURAL GROWTH

## INTRODUCTION

As discussed above, the rural transformation across Asia has resulted in the decline in agriculture's share of gross domestic product. Agricultural output has nevertheless grown strongly in much of the region and continues to grow, albeit at lower rates than before. And while rural population growth rates have dropped, there are nonetheless more people in rural Asia than ever before. Today it is harder to increase agricultural productivity beyond what has already been achieved: input levels are often already high and marginal increments in yields are diminishing, so new investments to produce productivity-driven, rather than input-driven, agricultural growth are needed.

What is happening instead is that with agriculture in a less predominant economic position, agricultural growth and its attendant problems no longer command the same attention in policy-making circles as they did 20 years ago. Public investment in agriculture and in the rural areas has been falling since the 1980s and problems arising as a consequence of agricultural growth, like environmental degradation, are not being addressed. New investment in agriculture should go toward increasing productivity rather than continuing to increase inputs: public agricultural research and extension are the main sources of agricultural productivity growth. New public investment in agriculture should be in research; even private investment in such research, which can also have public benefits, should be promoted.

## AGRICULTURAL OUTPUT AND INPUT GROWTH

Asian agriculture grew rapidly during the past several decades. From 1967 to 1995, the rate of growth in agricultural output averaged 3.8 percent per year throughout the region, significantly more than the world average of 2.2 percent (Table V.1). This regional average masks a good deal of cross-country variation, however. The PRC had the highest rate of growth at 4.4 percent per year from 1967 to 1995, an impressive achievement considering the sheer size and limited natural resources of this country. Malaysia achieved the second highest rate of growth in overall agricultural output at 4.3 percent, due to the rapid diversification of its agricultural sector and a sharp increase in the export of tree crop products such as rubber, palm

**Table V.1: Growth in Net Agricultural Production  
(international 1989–91 dollars)**

Period	1967–82	1982–95	1982–89	1989–95	1967–95
	<i>(percent per year)</i>				
Bangladesh	1.44	1.83	2.17	1.43	1.62
PRC	3.43	5.45	4.95	6.04	4.36
India	2.98	3.39	3.68	3.06	3.17
Indonesia	3.95	4.19	4.91	3.37	4.06
Korea, Rep. of	4.17	2.64	2.86	2.38	3.46
Malaysia	4.61	3.97	4.70	3.14	4.31
Myanmar	4.26	1.98	-0.04	4.39	3.20
Nepal	2.36	3.35	4.41	2.14	2.82
Pakistan	3.26	4.61	4.95	4.22	3.89
Philippines	3.79	2.20	1.41	3.12	3.05
Sri Lanka	2.12	0.85	0.03	1.82	1.53
Thailand	4.12	2.15	2.31	1.96	3.20
Viet Nam	3.27	4.61	4.18	5.12	3.89
AVERAGE	3.32	4.36	4.18	4.57	3.80
World	2.29	2.15	2.35	1.93	2.22

*Note:* Net Agricultural Production is gross production minus feed and seed. Growth rates are 3-year centered moving averages.

*Source:* FAO FAOSTAT, 1998 (Agricultural Production Indices).

oil, and, increasingly, cocoa, as well as livestock products like poultry and pork. Bangladesh and Sri Lanka, on the other hand, had the lowest annual rates of growth, at 1.6 percent and 1.5 percent, respectively. Growth in agricultural output in the other Asian developing economies ranged from 2.8 percent per year (Nepal) to 4.1 percent per year (Indonesia) during 1967–95.

The growth performance of Asian agriculture has improved over time. Growth increased from an annual average of 3.3 percent during 1967–82 to 4.4 percent in 1982–95. Moreover, compared to 1982–95, growth accelerated during 1989–95 at 4.6 percent per year—a period when global agricultural output growth was slowing down. The PRC, Myanmar, Philippines, Sri Lanka, and Viet Nam contributed to this remarkable recent agricultural growth performance.

## Input Use Trends

Agricultural areas in the Asian developing economies span a wide range, from 1.9 million ha in Sri Lanka to 170 million ha in India (1995 data, see Table V.2). The expansion of agricultural land (defined as arable land and area under permanent crops) has contributed little to output growth in Asian developing countries, averaging 0.5 percent per year. Although annual growth in agricultural area actually increased between the two sub-periods, 1967–82 and 1982–95, from 0.3 percent to 0.8 percent, growth slowed considerably at the beginning of the 1990s, to 0.2 percent. The relatively high growth during the 1980s was due to increases in agricultural area in the PRC, Indonesia, and Malaysia. Over the 30-year period, agricultural area actually contracted in Bangladesh, Republic of Korea, and Myanmar, and growth in area was very small in India. Growth in agricultural land use was most significant in Malaysia, at 2.1 percent per year during 1967–95, due to a substantial increase in plantation production. Expansion of area was also relatively high in Nepal and Thailand, at 1.6 percent per year. These trends of negative or relatively low rates of growth in agricultural land area place the burden of output growth on improvements in land productivity.

Table V.2: Agricultural Land Use in Asia

Year/Period	1970	1995	1967-82	1982-95	1982-89	1989-95	1967-95
	(1000 hectares)		(percent per year)				
Bangladesh	9,097	8,800	0.05	-0.29	0.66	-1.39	-0.11
PRC	102,505	134,693	0.03	1.98	3.29	0.47	0.93
India	165,060	169,700	0.19	0.05	0.07	0.03	0.13
Indonesia	26,000	30,180	0.00	1.22	2.78	-0.57	0.57
Korea, Rep. of	2,298	1,985	-0.38	-0.70	-0.36	-1.10	-0.53
Malaysia	4,430	7,604	1.03	3.29	4.07	2.39	2.07
Myanmar	10,430	10,110	-0.21	0.03	-0.05	0.12	-0.10
Nepal	1,980	2,968	1.56	1.72	0.16	3.58	1.63
Pakistan	19,332	21,600	0.33	0.44	0.61	0.24	0.38
Philippines	6,952	9,520	1.72	0.53	0.40	0.68	1.17
Sri Lanka	1,894	1,886	-0.05	0.10	0.29	-0.13	0.02
Thailand	13,808	20,445	2.52	0.57	1.15	-0.11	1.61
Viet Nam	6,145	6,757	0.54	0.20	-0.44	0.96	0.38
TOTAL	369,931	426,248	0.28	0.80	1.34	0.18	0.52

Note: Land use includes the FAO categories 'arable area' and 'permanent crops'. Growth rates are 3-year centered moving averages.

Source: FAO FAOSTAT, 1998 (Land Use Domain).

Trends in irrigated area are shown in Table V.3. By 1995, Pakistan had a phenomenal 80 percent of its agricultural area covered by irrigation. Only the Republic of Korea has a similarly high share of area irrigated. Seven Asian developing countries cluster around 30 percent of agricultural area irrigated. Malaysia has the lowest proportion of irrigation coverage, mainly due to its tropical climate and the high proportion of unirrigated plantation agriculture. The average annual rate of growth in irrigated area in the major Asian developing countries was 1.8 percent during 1967–95. Growth varied substantially among the Asian countries. Whereas the South Asian countries of Bangladesh and Nepal achieved very rapid rates of growth, at 5.2 and 7.9 percent per year, respectively, growth was lowest in Indonesia, 0.6 percent annually, and the Republic of Korea, 0.1 percent per year. In the remaining countries, annual growth ranged from 1.2 percent in Pakistan to 3.6 percent in Thailand. With the exception of Bangladesh and Myanmar, the rate of growth in irrigated area slowed down significantly between the periods of 1967–82 and 1982–95, from 2.1 to 1.6 percent per year, on average. However, in six of the Asian developing countries, namely PRC, India, Indonesia, Malaysia, Myanmar and Viet Nam, there is some recovery in growth after 1989 compared to 1982–89.

The agricultural labor force increased more rapidly than agricultural area in all Asian developing countries except Malaysia (Table V.4). As a consequence, land-to-labor ratios declined throughout the region from an average of 0.57 ha per agricultural worker in 1970 to 0.45 ha per worker in 1995. The economically active population in agriculture reached 955 million people in 1995, up from 617 million in 1967, a reflection of the high rate of growth in the rural population throughout the region. In 1995, 75 percent of all labor employed in agriculture was located in the Asian developing economies, up from 68 percent in 1967. Annual growth in the agricultural labor force slowed significantly throughout the 30-year period, from 1.8 percent during 1967–82 to 1.4 percent during 1982–95. Indonesia and Viet Nam, however, both showed accelerated growth in the second period and declines at the beginning of the 1990s. In the Republic of Korea

Table V.3: Irrigated Area as a Percentage of Agricultural Area and Growth in Irrigated Area

Year/Period	1970	1995	1967-82	1982-95	1982-89	1989-95	1967-95
	(percent)		(percent per year)				
Bangladesh	11.63	37.56	4.95	5.39	6.35	4.29	5.16
PRC	37.18	37.02	1.59	0.79	0.36	1.28	1.22
India	18.44	31.82	2.64	2.42	1.55	3.44	2.54
Indonesia	15.00	15.18	0.65	0.49	0.22	0.80	0.58
Korea, Rep. of	51.52	60.76	0.73	-0.65	0.43	-1.89	0.09
Malaysia	5.91	4.47	2.34	0.22	0.19	0.26	1.35
Myanmar	8.04	15.38	1.87	3.37	-0.50	8.08	2.56
Nepal	5.91	29.82	12.55	2.67	5.51	-0.54	7.85
Pakistan	66.99	79.63	1.39	0.89	0.97	0.79	1.16
Philippines	11.88	16.60	3.80	1.33	2.08	0.46	2.65
Sri Lanka	24.55	29.16	1.91	0.21	0.01	0.45	1.12
Thailand	14.19	22.70	4.23	2.78	3.31	2.17	3.55
Viet Nam	15.95	29.60	3.71	1.29	1.11	1.49	2.58
TOTAL	25.17	33.24	2.05	1.56	1.10	2.10	1.82

Note: Growth rates are 3-year centered moving averages.

Source: FAO FAOSTAT, 1998 (Land Use Domain).

**Table V.4: Land to Labor Ratio and Growth in Economically Active Population  
in Agriculture**

Year/Period	1970	1995	1967-82	1982-95	1982-89	1989-95	1967-95
Bangladesh	0.33	0.25	1.07	1.03	0.87	1.22	1.05
PRC	0.31	0.27	1.92	1.39	1.99	0.70	1.67
India	0.94	0.68	1.59	1.21	1.03	1.42	1.41
Indonesia	0.86	0.64	1.41	2.01	2.52	1.42	1.69
Korea, Rep. of	0.41	0.68	-0.07	-4.64	-4.87	-4.37	-2.22
Malaysia	2.21	4.14	0.57	-1.13	-1.22	-1.03	-0.23
Myanmar	0.97	0.60	1.93	1.76	1.84	1.66	1.85
Nepal	0.36	0.32	1.82	2.34	2.16	2.56	2.06
Pakistan	1.32	0.88	2.41	1.72	1.46	2.02	2.09
Philippines	0.86	0.80	1.90	1.23	1.24	1.21	1.59
Sri Lanka	0.79	0.53	1.69	1.44	1.58	1.28	1.57
Thailand	1.00	0.99	2.17	1.10	1.61	0.51	1.67
Viet Nam	0.39	0.26	1.58	2.19	2.56	1.77	1.86
AVERAGE	0.57	0.45	1.76	1.36	1.66	1.02	1.57

Note: Growth rates are 3-year centered moving averages.

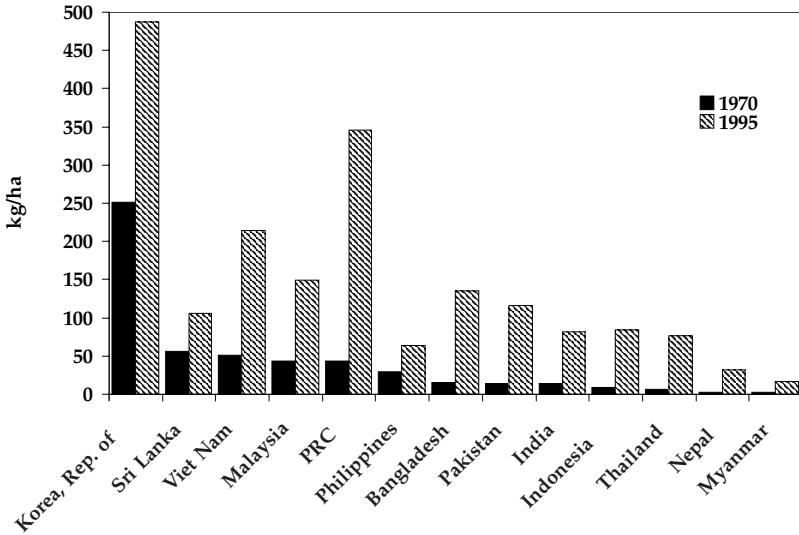
Source: FAO FAOSTAT. 1998 (Population Domain, Land Use Domain).

and Malaysia, the labor force in agriculture has actually contracted during the last decades, a trend that will probably be seen in all Asian developing countries in the longer term. The PRC's economic reforms, initiated in 1978, opened up new opportunities for farm workers to seek employment in rural nonfarm industries. Thus, despite a relatively rapid rate of population growth in rural areas, labor use in agriculture has increased only slowly, especially during the 1990s.

Labor use in South Asian agriculture has grown more rapidly than in East and Southeast Asia. Indeed, in Nepal, growth in agricultural labor has accelerated during the past three decades, with a growth rate of 2.1 percent per year, on average, during 1967–95. In Bangladesh, India, and Pakistan, growth accelerated at the beginning of the 1990s after a slowdown during the 1980s. Lack of rural nonfarm employment opportunities and a relatively rapid growth in the rural population contribute to this trend.

One of the most dramatic changes in Asian agriculture during the past several decades has been the sizable increase in the use of both chemical fertilizers and agricultural machinery (Figure V.1, Tables V.5 and V.6). In 1970, the average farm in an Asian developing country applied 24 kg of fertilizer per hectare of agricultural land, less than half the global average. By 1995, the application rate had increased to 171 kg per hectare, on average, more than two thirds above the global rate and virtually on par with the fertilizer application rate in the United States of 173 kg per hectare. The most rapid growth occurred during the onset and takeoff of the green revolution in the 1960s and 1970s (10.8 percent per year). Crop yields increased markedly in response to the adoption of new, fertilizer-responsive varieties released by national and internationally sponsored research programs. National policies designed to subsidize fertilizer use by farmers were also at their peak in most of Asia at this time. During 1982–95, growth slowed substantially, to 5.9 percent per year. It slightly recovered at the beginning of the 1990s, however, a time when global application rates actually contracted. This recovery was partly due to the significant slowdown of growth in agricultural area in the region.

Figure V.1: Fertilizer application per unit of land, 1970 and 1995



Note: Fertilizer includes Nitrogenous, Phosphate, and Potash fertilizers. Land is measured as arable land plus permanent crops.

Source: FAO FAOSTAT, 1998 (Means of Production Domain, Land Use Domain).

Fertilizer use has varied greatly throughout the region. The Republic of Korea stands out for its high fertilizer application rates. By 1970, it applied 2.5 times more fertilizer on a hectare of agricultural land than a typical developed country, and by 1995, it applied nearly five times more fertilizers. The PRC, a land-scarce and labor-abundant country, has a similarly high fertilizer application rate, at 346 kg per hectare in 1995. Viet Nam experienced the greatest growth in fertilizer application on a per hectare basis at the beginning of the 1990s, at 15.9 percent annually, resulting in an application rate of 214 kg per hectare in 1995, up from 51 kg per hectare in 1970. By 1995, Bangladesh, Malaysia, Pakistan, and Sri Lanka had also applied fertilizer in excess of 100 kg per hectare, whereas India, Indonesia, and Thailand had levels around 80 kg per hectare, and the Philippines close to 65 kg per hectare. Fertilizer application is quite low only in Myanmar and Nepal (Table V.5).

Table V.5: Fertilizer Application per Unit of Land, and Growth in Application

Year/Period	1970	1995	1967-82	1982-95	1982-89	1989-95	1967-95
	(kg/hectare)		(percent per year)				
Bangladesh	15.7	135.5	11.41	7.46	8.30	6.48	9.56
PRC	43	346.1	11.93	7.37	6.70	8.16	9.79
India	13.7	81.9	10.49	5.70	8.19	2.86	8.24
Indonesia	9.2	84.7	15.14	2.92	3.89	1.79	9.29
Korea, Rep. of	251.7	486.7	3.16	3.12	4.30	1.76	3.14
Malaysia	43.6	148.6	8.51	3.82	4.40	3.15	6.30
Myanmar	2.1	16.9	14.69	0.19	-7.59	10.09	7.71
Nepal	2.7	31.6	14.90	7.26	11.23	2.81	11.29
Pakistan	14.6	116.1	12.84	4.98	5.98	3.83	9.12
Philippines	28.9	63.4	5.17	4.10	6.40	1.47	4.67
Sri Lanka	55.5	106	2.32	2.01	3.01	0.86	2.18
Thailand	5.9	76.5	7.43	10.41	11.23	9.46	8.80
Viet Nam	50.7	214.3	7.28	12.95	10.52	15.85	9.87
AVERAGE	23.9	171.1	10.75	5.92	5.75	6.11	8.48
World	59.7	102.2	4.29	0.47	1.47	-0.69	2.50

Note: Fertilizer includes Nitrogenous, Phosphate, and Potash fertilizers. Land is measured as arable land plus permanent crops. Growth rates are 3-year centered moving averages.

Source: FAO FAOSTAT: 1998 (Means of Production Domain, Land Use Domain).

Table V.6: Tractors per Thousand Agricultural Labor and Growth in Use per Thousand Agricultural Labor

Year/Period	1970	1995	1967-82	1982-95	1982-89	1989-95	1967-95
	<i>(tractors/000 workers)</i>		<i>(percent per year)</i>				
Bangladesh	0.08	0.15	8.64	0.07	0.75	-0.73	4.57
PRC	0.38	1.36	11.13	-2.64	-1.38	-4.09	4.51
India	0.03	0.03	4.81	-0.52	4.75	-6.34	2.30
Indonesia	0.45	0.67	5.17	-0.38	0.12	-0.96	2.55
Korea, Rep. of	17.84	461.15	13.94	13.83	15.58	11.81	13.89
Malaysia	4.23	32.64	1.60	16.18	15.82	16.60	8.13
Myanmar	0.01	5.93	35.01	22.61	25.89	18.90	29.10
Nepal	0.78	4.65	5.31	10.66	13.22	7.75	7.76
Pakistan	0.05	0.19	10.24	2.49	5.77	-1.22	6.57
Philippines	2.59	25.61	14.22	5.90	9.02	2.37	10.28
Sri Lanka	2.83	3.25	2.18	-0.21	-2.44	2.46	1.06
Thailand	0.51	7.20	8.23	13.78	10.70	17.48	10.77
Viet Nam	0.18	3.74	14.76	7.81	-4.57	24.28	11.48
TOTAL	0.46	2.99	11.08	3.45	3.65	3.22	7.47
World	17.31	20.50	1.52	-0.13	0.64	-1.02	0.75

Note: Growth rates are 3-year centered moving averages.

Source: FAO FAOSTAT, 1998 (Means of Production Domain, Population Domain).

Although fertilizer application rates seem excessive in some Asian developing countries, in others there is a potential for considerable additional output increases from a judicious increase in fertilizer application.

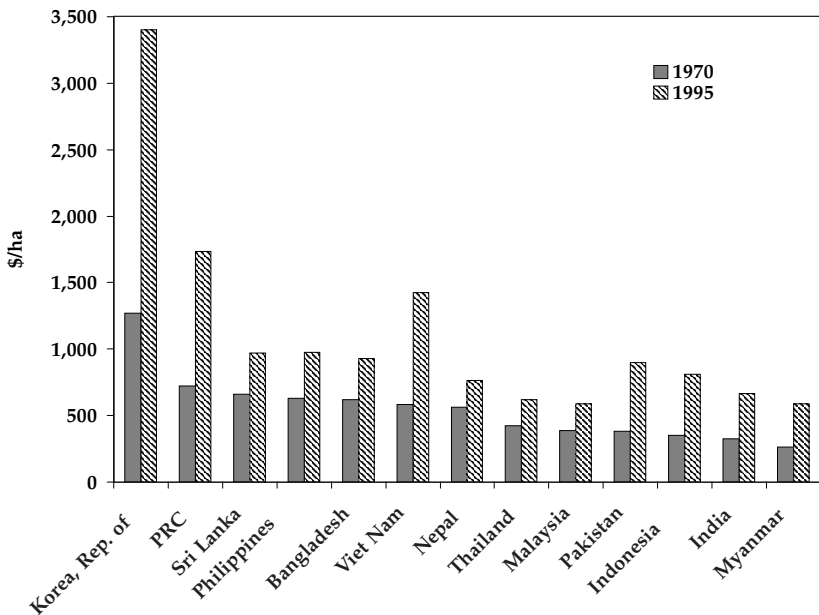
At the beginning of the green revolution, few tractors were in use in Asian agriculture. By 1970, only 18 tractors were available for every 1,000 people employed in agriculture in the Republic of Korea, 4 in Malaysia, and not quite 3 each in the Philippines and Sri Lanka (Table V.6). At that time, 1,000 people working in agriculture had access, on average, to about 17 tractors globally, 167 tractors in developed countries, and 1,372 tractors in the United States. The Asian developing economies rapidly increased the number of tractors per agricultural worker during 1967–95, at 7.5 percent annually, with the most rapid growth, 11.1 percent, concentrated during the green revolution. Only in Malaysia, Nepal, and Thailand was growth faster during the second period. Moreover, growth accelerated during 1989–95 in Malaysia, Sri Lanka, Thailand, and Viet Nam, compared to 1982–89, although this is partially due to the substantial slowing of growth in agricultural employment: rapid economic growth raises the opportunity cost of farm labor, thereby inducing a substitution of machine power for labor in agriculture. The Republic of Korea experienced the most thorough growth, with rates above 10 percent for all periods. By 1995, tractor use in Korea surpassed the average developed-country usage, but was still less than a third of use in the United States. Usage in the average Asian developing economy, however, was still far below global use rates. Tractor use has remained particularly low in the South Asian countries of Bangladesh, India, and Pakistan, with less than one tractor per one thousand laborers even in the 1990s.

## Land and Labor Productivity Growth

Figure V.2 shows the values for land productivity, measured as the value of aggregate agricultural output per hectare of agricultural land, in 1970 and 1995; Table V.7 captures in more detail

the growth rates over the 1967–1995 period. Land productivity, measured as the value of aggregate agricultural output per hectare of agricultural land, increased by an average of 3.3 percent per year from 1967 to 1995 in Asian developing countries. Growth in land productivity was highest in the Republic of Korea (4 percent per year), followed by the PRC, Indonesia, Pakistan, and Viet Nam, all at or above 3.4 percent annually. In Nepal, on the other hand, growth was comparatively low, at 1.2 percent per year. In Indonesia, Republic of Korea, Malaysia, Myanmar, the Philippines, Sri Lanka, and Thailand, growth was highest during the green revolution. In the South Asian countries of Bangladesh, India, Nepal, and Pakistan, on the other hand, growth accelerated during 1982–95. In Viet Nam, growth was also higher during the 1980s, when the country entered its agricultural liberalization phase.

Figure V.2: Land Productivity in Asian Agriculture  
(International 89-91 \$/hectare)



Note: Net Agricultural Production is gross production minus feed and seed.

Source: FAO FAOSTAT, 1998 (Agricultural Production Indices, Land Use Domain).

Table V.7: Land productivity in Asian Agriculture (International 89-91 \$/Hectare)

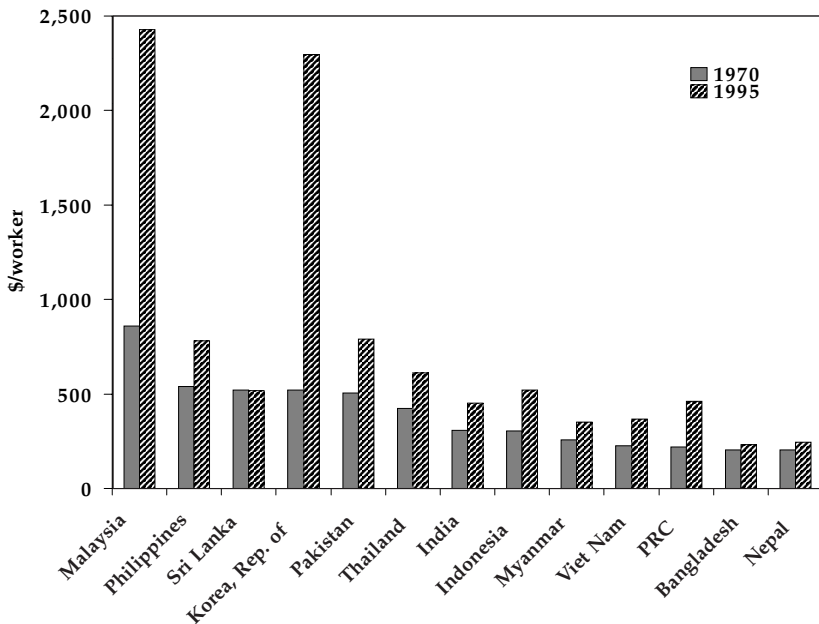
Year/Period	1970	1995	1967-82	1982-95	1982-89	1989-95	1967-95
	(\$/ha)		(percent per year)				
Bangladesh	617.3	931.3	1.39	2.12	1.61	2.86	1.73
PRC	720.4	1733.6	3.40	3.44	3.60	5.62	3.42
India	327.7	664.5	2.78	3.34	2.06	3.03	3.04
Indonesia	353.0	812.3	3.95	2.93	3.23	3.96	3.48
Korea, Rep. of	1270.1	3399.9	4.57	3.37	0.60	3.53	4.01
Malaysia	389.6	586.8	3.55	0.66	0.60	0.73	2.20
Myanmar	264.7	588.7	4.48	1.95	0.01	4.27	3.30
Nepal	564.4	764.8	0.80	1.60	4.24	-1.39	1.17
Pakistan	382.9	898.4	2.92	4.15	4.33	3.94	3.49
Philippines	631.8	977.2	2.04	1.65	1.00	2.42	1.86
Sri Lanka	661.0	968.3	2.18	0.76	-0.25	1.95	1.52
Thailand	425.1	617.9	1.56	1.57	1.14	2.07	1.56
Viet Nam	582.4	1426.3	2.72	4.40	4.64	4.12	3.49
AVERAGE	469.7	1058.6	3.03	3.55	2.81	4.43	3.27

Note: Net Agricultural Production is gross production minus feed and seed. Growth rates are 3-year centered moving averages.

Source: FAO FAOSTAT, 1998 (Agricultural Production Indices, Land Use Domain).

Figure V.3 shows the value for labor productivity, measured as aggregate agricultural output per worker, in 1970 and 1995; Table V.8 shows the rate of growth in labor productivity. During 1967–1995, labor productivity increased by 2.2 percent annually. The slower growth of labor productivity compared to growth in land productivity indicates that the Asian developing economies have generally adopted land-saving agricultural technologies. East Asian countries clearly outperformed South Asian countries in labor-productivity growth during the last 30 years. Annual growth averaged 2.7 percent in the PRC, 2.3 percent in Indonesia, 5.8 percent in the Republic of Korea, and 4.6 percent in Malaysia and a lower 2.0 percent in Viet Nam, 1.4 percent in the Philippines, and 1.5 percent in Thailand.

Figure V.3: Labor Productivity in Asian Agriculture  
(International 89-91 \$/worker)



Source: FAO FAOSTAT, 1998 (Agricultural Production Indices, Population Domain).

**Table V.8: Labor Productivity in Asian Agriculture  
(International 89-91\$ /Agricultural Worker)**

Year/Period	1970	1995	1967-82	1982-95	1982-89	1989-95	1967-95
	(\$/ha)		(percent per year)				
Bangladesh	204.3	231.9	0.37	0.79	1.29	0.21	0.57
PRC	220.1	461.9	1.48	4.04	2.90	5.39	2.66
India	306.9	452.1	1.37	2.16	2.62	1.62	1.74
Indonesia	303.3	520.3	2.51	2.13	2.32	1.92	2.33
Korea, Rep. of	520.7	2,297.1	4.26	7.64	8.17	7.01	5.81
Malaysia	859.5	2,427.7	4.03	5.17	6.00	4.20	4.55
Myanmar	258.0	351.6	2.29	0.22	-1.84	2.68	1.32
Nepal	203.1	243.9	0.53	0.99	2.21	-0.41	0.74
Pakistan	505.1	790.1	0.84	2.84	3.44	2.14	1.76
Philippines	541.0	781.1	1.86	0.96	0.16	1.89	1.44
Sri Lanka	521.0	516.3	0.43	-0.58	-1.53	0.55	-0.04
Thailand	424.2	611.5	1.91	1.03	0.69	1.44	1.50
Viet Nam	225.4	368.5	1.66	2.37	1.59	3.29	1.99
AVERAGE	268.0	472.3	1.53	2.98	2.48	3.57	2.20

Note: Growth rates are 3-year centered moving averages.

Source: FAOSTAT. (Agricultural Production Indices, Population Domain) 1998.

In South Asia, on the other hand, annual growth trailed at 0.6 percent in Bangladesh, 1.7 percent in India, 0.7 percent in Nepal, 1.8 percent in Pakistan, and negative 0.04 percent in Sri Lanka. The relatively better performance in India and Pakistan was a response to the adoption of new (second- and third-generation) green-revolution technologies. The productivity performance of both countries slipped in the 1990s, however.

Labor productivity increased more rapidly after the green revolution and accelerated again at the beginning of the 1990s, particularly in the PRC, Sri Lanka, Thailand, and Viet Nam. Labor-productivity growth in the PRC and Viet Nam can be attributed mainly to the adoption of economic and institutional reforms during the late 1970s for the PRC and late 1980s for Viet Nam. Especially in the PRC, movement of labor between rural and urban areas was prohibited prior to reforms. As population continued to increase and agricultural labor productivity improved, a huge pool of surplus and underemployed labor developed throughout rural areas of the PRC. Following the reforms, rural workers were finally permitted to leave primary production and seek employment in various rural enterprises and even in urban-based industries. As a result, labor use in agriculture declined dramatically while agricultural output continued to rise. These dual developments led to a rapid growth in labor productivity in agriculture.

## **PATTERNS OF PUBLIC SPENDING ON AGRICULTURE**

Government expenditures in agriculture have been estimated by Fan and Pardey (1998) and Pardey, Roseboom, and Fan (1998) using purchasing power parities (PPPs) as the basis for converting local currencies into U.S. dollars to make international comparisons. PPPs compare currency values by measuring the relative cost in local currencies of a detailed basket of traded and nontraded goods and services. These have the major advantage that they suffer less from distortions than market

exchange rates, which are more susceptible to changes from policy-induced variations in currency values or sudden swings in financial transactions. PPP measures also capture the price of nontradables such as the labor, land, and facilities components that constitute a large share of government expenditures on agriculture; exchange rates are based only on a basket of traded goods and services (Craig, Pardey, and Roseboom 1991).

To convert expenditures denominated in current local currencies into international dollar aggregates expressed in base-year (1985) prices, current local currency expenditures were deflated to a set of base-year prices using each country's implicit GDP deflator. Then the 1985 PPPs reported by the World Bank (1997) were used to convert local currency expenditures measured in terms of 1985 prices into a value aggregate expressed in terms of 1985 international dollars. The results are shown in Tables V.9-V.12 and in Figure V.4, which summarize data presented in Fan and Pardey (1998).

## Size and Trends in Public Expenditures

In 1993, India, at 35.9 billion public international dollars, ranked first in public expenditures on agriculture based on 1985 PPP values (Table V.9). Its expenditures were 16 percent higher than those of the PRC at \$31 billion, the second biggest spender. Indonesia, Thailand, and the Republic of Korea spent between \$4 and \$6 billion on agriculture. The levels of public expenditures on agriculture in Bangladesh, Malaysia, Pakistan, and the Philippines were similar despite the dramatically different sizes of their agricultural economies. Public expenditures on agriculture were lowest in Myanmar, Nepal, and Sri Lanka.

Public expenditures on agriculture increased at 4.6 percent per year, on average. Growth in expenditures varied widely by period and country. It was highest during the 1970s, at 9.5 percent per year, slowed down during the 1980s, and was lowest at the beginning of the 1990s, at 0.6 percent annually, a period when almost half the countries experienced a real reduction in public spending on agriculture.

Table V.9: Government Expenditures on Agriculture in Asian Countries, 1985 US dollars (Purchasing Power Parity)

Year	1972	1975	1980	1985	1990	1993	1972-79	1980-89	1990-93	1972-93
	(million dollars)						(percent per year)			
Bangladesh	2,358	528	1,187	1,749	1,269	1,773	-3.56	-1.30	11.81	1.29
PRC	11,595	17,843	24,542	21,113	28,229	31,061	14.20	1.16	3.24	4.80
India	15,491	13,680	22,877	30,549	39,109	35,918	6.18	5.46	-2.80	4.09
Indonesia	1,436	3,020	5,026	4,351	6,157	5,958	15.68	1.36	-1.09	7.01
Korea, Rep. of	537	993	1,129	2,244	4,332	4,160	21.48	15.03	-1.34	10.24
Malaysia	348	458	1,264	1,851	1,830	1,693	11.43	3.00	-2.57	7.83
Myanmar	272	219	655	874	296	181	8.53	-8.13	-15.22	-1.93
Nepal	107	136	257	541	254	359	15.15	1.79	12.24	5.96
Pakistan	740	1,031	1,168	971	1,312	1,669	2.96	1.97	8.36	3.95
Philippines	416	1,145	729	604	1,409	1,694	12.68	7.19	6.32	6.92
Sri Lanka	627	449	589	2,124	614	596	-2.83	4.02	-0.97	-0.24
Thailand	902	767	1,850	3,181	3,190	4,513	8.26	3.54	12.26	7.97
AVERAGE	34,828	40,269	61,273	70,151	88,001	89,574	9.46	3.46	0.59	4.60

Note: Government expenditures in PPP US dollars was calculated in two steps: Government expenditures in constant (1985) local currency for each year was calculated, and then 1985 PPP exchange rates were used to convert local currency to PPP US dollars.

Source: Fan and Pardey 1998

Most East, Southeast and South Asian countries followed this pattern of slowing growth in public expenditures on agriculture over the last 20 years. There was a recovery in expenditures during the beginning of the 1990s, however, in the PRC and the South Asian countries of Bangladesh, Nepal, and Pakistan. Growth was largest in the East and Southeast Asian countries of Republic of Korea (10.2 percent), Thailand (8.0 percent), Malaysia (7.8 percent), and Indonesia (7.0 percent). The Republic of Korea's growth in public agricultural expenditures during the 1980s was mainly due to the rapid increase in government investments in rural development projects aimed at improving the quality of life of rural residents (APO 1991).

The size of national economies and their agriculture sectors varies widely throughout Asia. The PRC and India alone account for nearly three fourths of total agricultural GDP and government spending on agriculture in the latter part of the period examined. Thus, comparing expenditures in relative terms provides an alternative and, for many purposes, more meaningful perspective on public commitment to agriculture.

Government expenditure on agriculture expressed as a percentage of agricultural GDP is a useful comparative indicator of the size of the public commitment to agriculture (Table V.10). After increasing slightly in 1980, this ratio declined to 8.1 percent, on average, in 1993. In 1993, Thailand and the Republic of Korea had the highest public investment intensities, spending the equivalent of almost 20 percent of agricultural GDP on the agriculture sector. The governments of India, Indonesia, Malaysia, Sri Lanka, and the Philippines spent between 7 and 12 percent of agricultural GDP on the sector.

Malaysia had one of the highest agriculture intensity ratios during the 1980s but since the mid-1980s its spending intensity on agriculture has declined to below 10 percent. The Indian government has spent more intensively on agriculture than the PRC government during the past several decades. Especially in recent years, India's public spending on agriculture per dollar of agricultural output has been almost twice the amount spent in the PRC. Sri Lanka spent almost one third of its agricultural

**Table V.10: Government Expenditures on Agriculture as a Percentage of Agricultural GDP**

Year	1972	1975	1980	1985	1990	1993
	<i>(percent)</i>					
Bangladesh	6.8	1.3	2.7	3.6	2.3	3.2
PRC	5.7	7.9	9.1	6.0	6.5	6.3
India	10.4	8.0	12.3	13	13.9	11.7
Indonesia	4.1	7.9	10.4	7.3	8.2	7.2
Korea, Rep. of	3.7	5.6	6.5	10.6	19.9	18.7
Malaysia	5.7	6.1	13.5	14.7	10.7	8.1
Myanmar	4.6	3.5	8.6	8.3	3.3	1.7
Nepal	2.1	2.4	4.3	7.8	2.7	3.7
Pakistan	3.5	4.6	4.3	2.9	3.1	3.6
Philippines	3.1	6.8	3.6	3.0	5.9	7.0
Sri Lanka	10.7	7.1	7.7	26.9	8.1	8.1
Thailand	8.0	5.5	10.9	15.4	15.2	19.7
AVERAGE	6.9	7.0	9.3	8.5	8.9	8.1

Source: Fan and Pardey 1998.

GDP on the sector in 1985, but expenditure levels have declined since. Myanmar has drastically reduced its government spending on agriculture relative to the size of the sector, while the level of public resources Bangladesh has committed to agriculture has persistently been small when compared with the size of the country's agricultural economy.

The percentage of public expenditures on agriculture in total public expenditures provides some indication of the public priority afforded by the agricultural sector. As the Asian economies have become more industrialized, the relative importance of agriculture in the economy has declined. One might expect this to cause the share of overall government expenditures directed toward agriculture to shrink. However, this rule cannot be generally applied to Asian developing countries. Indeed, the rapidly growing economies like Indonesia, Malaysia, and the Republic of Korea have earmarked a reasonably stable share of their total government spending for agriculture over the past decade or so. In the Philippines and Thailand, the share of public agricultural expenditures in total government expenditures even increased during the 1980s.

On the other hand, the slower-growing economies of Bangladesh, Myanmar, Nepal, Pakistan, and Sri Lanka have dramatically reduced the shares of public expenditures going to agriculture. Between 1975 and 1980, the PRC and India committed similar proportions of public expenditures to agriculture, but the PRC's share has declined more than India's share in recent years (Table V.11).

**Table V.11: Percentage of Government Agricultural Expenditures in Total Government Expenditures**

Year	1972	1975	1980	1985	1990	1993
	<i>(percent)</i>					
Bangladesh	23.2	11	12.3	15.7	5.4	6.9
PRC	8.5	12.1	12.4	8.3	8.9	8.3
India	22.1	9.7	14.6	12.6	11.5	9.6
Indonesia	7.6	9.8	9.6	6.8	7.6	6.6
Korea, Rep. of	3.8	6.3	4.1	5.8	6.9	5.2
Malaysia	4	4.2	7.2	7.9	5.7	4.8
Myanmar	12.5	13.3	23.6	24.5	9.3	7.5
Nepal	13.7	15.5	16.4	22	8.5	10.5
Pakistan	5.7	6.7	5.4	2.9	2.6	2.6
Philippines	4.5	9	5.3	5.7	6	7.3
Sri Lanka	12.3	9	5.7	20	5.8	5.1
Thailand	7.8	5.9	8.1	11.7	10.4	10.4
AVERAGE	15.4	10.5	12.4	10.9	9.6	8.4

*Note:* Expenditures include those at both central and local government levels.

*Source:* Fan and Pardey 1998.

## Public Expenditures on Subsidies and Investments

Public expenditures on agriculture can be allocated to current expenditures such as input subsidies or to investments such as research and development, irrigation, and rural infrastructure. The limited available data show that input subsidies often account for 20 to 60 percent of total Asian government spending on agriculture. Asian governments have intervened in the setting of fertilizer prices in support of a number

of broad-based policy goals, for example. Many countries have protected domestic fertilizer production by restricting imports or maintaining import tariffs. In the Philippines, for example, domestic fertilizer prices were maintained well above world prices through the mid-1980s by a combination of import controls and subsidies to domestic fertilizer plants. More commonly, governments have subsidized farm-level fertilizer prices in support of several objectives, including income support for farmers and provision of incentives to increase the rate of adoption and level of fertilizer use, to increase crop production, and to balance other taxes against agriculture.

Fertilizer subsidies can become extremely costly to government treasuries. In Indonesia, subsidies have been maintained both for farmers and for the domestic fertilizer industry. The total fiscal costs for the two types of fertilizer subsidy were about Rupiah 670 billion (US\$407 million) in 1986/87, representing nearly one sixth of total government development expenditures for agriculture and irrigation. Since 1986, Indonesia has been slowly phasing out fertilizer subsidies, but they remain large. Fertilizer subsidies in Bangladesh in 1983/84 accounted for about 14 percent of its budget allocation for agriculture. The economic costs can be even greater, as subsidies soak up funds that could be used for alternative investments and can induce the overuse of fertilizers above socially optimal levels. To the extent that subsidies are not fully funded to provide enough fertilizer to meet demand at the subsidized price, excess demand will be created, which can contribute to nonprice rationing, nonavailability of fertilizer, black markets, poor logistics, and untimely delivery of fertilizer.

Given the negative effects of subsidies, are there appropriate uses for them? Fertilizer subsidies to farmers may be cost-effective in stimulating farmers to adopt and utilize fertilizer appropriately together with new production technology. Temporary subsidies during the early stage of fertilizer adoption may be effective in overcoming the fixed costs related to adoption of new technology and in inducing farmer experimentation and learning during periods of rapidly changing technological potential. Such temporary subsidies

should be phased out as adoption and appropriate use of fertilizer become widespread, however, as they actually have been in many Asian countries. At high levels of fertilizer use, the budgetary cost of the fertilizer subsidy becomes prohibitively expensive and the subsidy induces inefficient use of fertilizer beyond appropriate levels. Reallocation of expenditures on subsidies to more productive investments could have large payoffs (see Box V.1).

**Box V.1: Subsidies versus Investments: Indonesian Food Crops**

Fertilizer subsidies have been a cornerstone of Indonesian food production policy. In the late 1980s and early 1990s, the annual fiscal cost of fertilizer subsidies was over Rp 750 billion, (\$455.5 million) almost the same as expenditures on irrigation development and seven times as much as expenditures on agricultural research and extension. An analysis of the dynamic food-crop supply response in Indonesia during 1969–1990, however, shows that the contribution of investment in technology to long-run output growth was far higher than the contribution of fertilizer subsidies. An examination of the historical sources of growth based on the model clearly shows the primary importance of technology in explaining growth in production of rice, corn, cassava, and soybeans. The share of output growth accounted for by public investment in research, extension, and irrigation is more than 70 percent for all four crops. Changes in relative prices due to fertilizer subsidies and output price supports also contributed to output growth, but the impact was minor compared to the contribution of technology. These results show that the fertilizer subsidies in Indonesia represent a serious misallocation of public resources. Given the high output response to public investment in technology, combined with the very low output response to fertilizer prices, the elimination of fertilizer subsidies and transfer of the resulting fiscal savings into investments in research, extension, and irrigation would have large benefits.

Source: Rosegrant, Kasryno, and Perez 1998.

As will be seen below and can be seen in the Indonesian example in Box V.1, public investment—in particular agricultural research expenditure—has been the driving force behind productivity growth in Asian agriculture. In the past several decades, a number of Asian governments have increased government spending on agricultural research by more than 5 percent per annum (Table V.12). In India, Malaysia, and Thailand government expenditures on agricultural research increased at more than 7 percent annually during 1972–93. The Philippines was the only country in which public spending on agricultural research declined in real terms during this period.

Nonetheless, the share of public agricultural research in total public expenditures on agriculture declined in several East Asian countries, in particular Indonesia, the Republic of Korea, Malaysia, and the Philippines (Figure V.4). In the largest countries, the PRC and India, the share has been fairly constant or slightly increasing. The expenditure share also declined significantly in Nepal. In the PRC and India, the share has been fairly constant or slightly increasing. Whereas Pakistan and Thailand invested about 11 percent of agricultural expenditures on research in agriculture in 1993, the level was 6 to 8 percent in Bangladesh, the PRC, and Sri Lanka, and only 3 to 5 percent in India, Indonesia, Republic of Korea, Nepal, and the Philippines.

## SOURCES OF GROWTH IN ASIAN AGRICULTURE

Compared to the analysis of overall economic growth (see Chapter I), studies assessing the breakdown of agricultural output growth into factor accumulation and total factor productivity growth for Asian economies using comparable data sets across countries have been few. Fan and Pardey (1998) estimate the contribution of TFP to agricultural output growth, using comparable data available from international sources (Figure V.5).

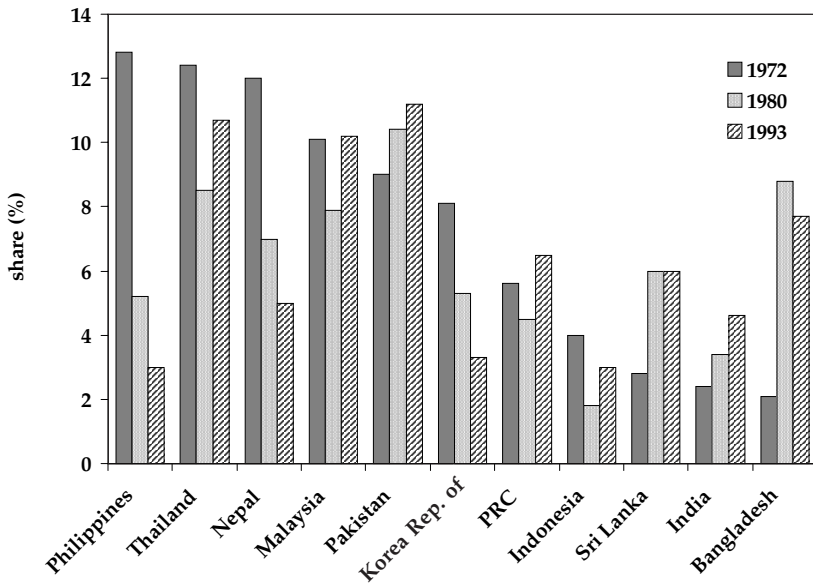
The South Asian countries of Bangladesh, Nepal, and Sri Lanka, as well as Thailand in Southeast Asia, experienced

Table V.12: Public Investments in Agricultural Research in Asia, 1985 International Dollars

Year/Period	1972	1975	1980	1985	1990	1993	1972-79	1980-89	1990-93	1972-93
	(million dollars)						(percent per year)			
Bangladesh	50.2	58.3	104.7	122.7	143.9	136.7	9.53	2.68	-1.69	4.89
PRC	650.5	736.7	1,092.5	1,480.7	1,528.3	2,027.7	7.52	5.58	9.88	5.56
India	374.7	463.8	775.7	921.8	1,561.9	1,649.7	9.79	7.04	1.84	7.31
Indonesia	57.8	69.3	89.6	148.7	208.2	181.6	9.66	10.71	-4.45	5.61
Korea, Rep. of	43.2	44.2	59.8	79.3	108.7	135.3	4.49	5.74	7.59	5.58
Malaysia	35.2	60.9	99.5	147.3	145.9	173.3	14.87	4.26	5.90	7.88
Nepal	13.1	14.6	17.6	28.7	13.5	19.0	6.06	-1.04	12.24	1.79
Pakistan	66.7	90.3	121.8	194.1	205.4	187.6	8.48	5.95	-2.98	5.05
Philippines	53.2	45.7	37.6	28.7	57.9	51.6	-4.67	0.11	-3.75	-0.15
Sri Lanka	17.5	24.4	35.5	34.9	31.7	35.5	10.46	-2.33	3.89	3.42
Thailand	112.1	132.5	156.8	217.1	316.9	480.7	3.61	4.87	14.90	7.18

Source: Fan and Pardey 1998.

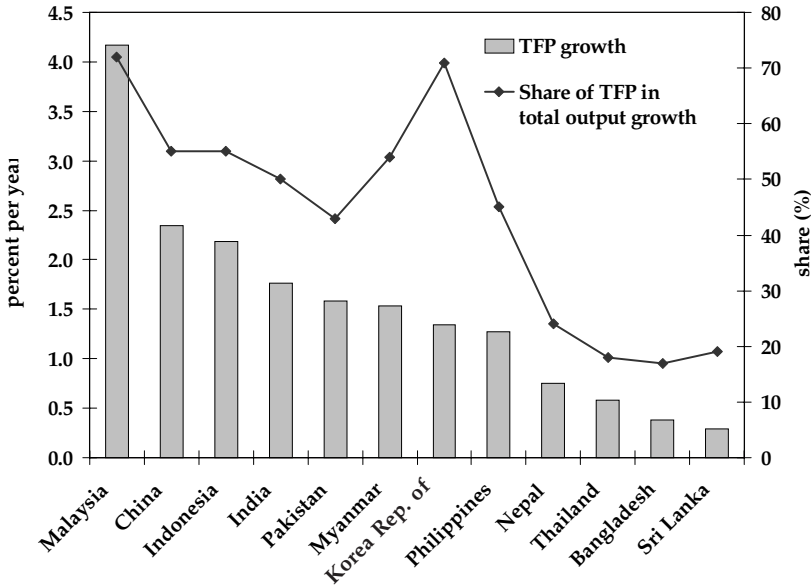
Figure V.4: Percentage of Agricultural Research Expenditures in Total Government Expenditures on Agriculture, 1972, 1980, and 1993



Sources: Pardey, Roseboom, and Fan 1998; Fan and Pardey 1998.

relatively low TFP growth during 1972–93, both absolutely and in proportion to agricultural output growth. It is noteworthy that the South Asian countries had low or negative rates of growth in agricultural research expenditures during the 1980s (Table V.12). In Bangladesh, agricultural TFP growth was slowed by relatively low investment in research, rural infrastructure, extension, and irrigation in the 1970s and dislocations arising from the civil war and separation of Bangladesh from Pakistan (Dey and Evenson 1991). In Sri Lanka, stagnation in TFP growth was also caused by intensifying civil war. Nepal is characterized by a difficult agroclimatic environment; moreover, the limited funding available for research was misallocated, with a heavy emphasis on crops that contributed relatively little to total area or value of production, like tobacco and sugarcane (Thapa and Rosegrant 1995). Thailand, on the other hand, experienced low TFP growth because it relied mainly on expansion of area to promote

Figure V.5: Total Factor Productivity Growth in Asian Agriculture, 1972-93



Source: Fan and Pardey 1998.

agricultural growth during this period rather than on technological change driven by research. There was also little adoption of modern rice varieties because of their perceived relatively poor eating quality (Setboonsarng and Evenson 1991).

Explicit analysis of the sources of TFP growth in agriculture from country-specific studies bears out the importance of agricultural research and extension as a source of growth and illuminates additional important growth factors. In addition to being a primary source of TFP growth, the economic rates of return on agricultural research have been very high in Asian agriculture (see Box V.2).

The sources of growth in total factor productivity in agriculture can be understood through TFP decomposition analysis. TFP is estimated as a function of variables representing investments in research, extension, human capital, infrastructure, and other factors. Comparison of the sources of TFP growth in India and Pakistan is instructive.

**Box V.2: Economic Rates of Return to Agricultural Research**

In addition to being a primary source of TFP growth, investment in agricultural research has high economic rates of return. A ranking of country-level analyses on the estimated marginal internal rates of return to agricultural research for Asia shows that returns exceed 50 percent in 41 out of 65 studies and lie between 20 and 50 percent for 20 studies. Returns in Asian agriculture are considerably higher than in other developing and developed regions. For India, rates of return to agricultural research range from 40 percent (Evenson and Jha 1973) to 100 percent (Evenson 1987). Evenson, Pray, and Rosegrant (1999) find marginal internal rates of return diminishing over time: 59 percent during 1966–76 and 57 percent during 1977–87. For Pakistan, Pray (1978) estimates rates of return to agricultural research of 34–44 percent in 1906–56 and 23–37 percent in 1948–63. Azam, Bloom, and Evenson (1991) find a rate of 58 percent (1956–85) for Pakistan, and Nagy (1985) estimates a rate of 64 percent (1959–79) for Pakistan.

These high rates of return on agricultural research indicate that governments are underinvesting in agricultural research and that additional large investments in agricultural research would also have high payoffs. Although these past trends of economic returns to research cannot be simply extrapolated into the future, there is no evidence of diminishing rates of return over time. Some caution should be used in evaluating rates of return on research because of a host of potential errors in measurement and compilation that might inflate them. In particular, costs may be understated and benefits overstated; the use of truncated lags on the benefit stream in analyzing rates of return could bias rates of return upward (Alston, Craig, and Pardey 1998; Alston and Pardey 1996; Evenson, Pray, and Rosegrant 1999).

Even with a substantial downward revision in estimated economic rates of return to agricultural research, however, these rates would compare favorably with returns on other investments.

In India, public research and extension and private inventions have been the most important sources of TFP growth. For the period 1956–87, public research and extension account for 70 percent of TFP growth (Evenson, Pray, and Rosegrant 1999). In addition, expansion of roads has had a strong impact on TFP growth in India (Fan, Hazell, and Thorat 1998, see also Box II.1. in Chapter 2). The estimated effect of irrigation on TFP is also strongly positive, indicating that irrigation has a large impact on productivity, in addition to its value as an input. Moreover, the estimated effects of literacy are positive, showing the important impact of human capital development on productivity growth. For Pakistan, the factors with the highest positive impacts on productivity growth are research, share of modern varieties, rural literacy, and overall share of irrigation (Rosegrant and Evenson 1993).

A key result of the TFP decomposition analysis for both India and Pakistan is an understanding of the underpinnings of the substantial total productivity growth during 1955/56–65, before the rapid spread of modern varieties. For India, this was a period of rapid growth in investment in research and extension, strong growth in literacy, and very rapid growth in inventions in agricultural implements and inputs generated by private research and investment. Similarly, for Pakistan, heavy investment in research and rapid improvements in human capital, as shown by improvements in literacy and share of graduate personnel in research, induced strong growth in agricultural productivity even before the rapid adoption of modern crop varieties. These results show that strong productivity growth generated by research is feasible even when productivity is not embodied in the spread of modern varieties (Evenson, Pray, and Rosegrant 1999; Rosegrant and Evenson 1993).

In the early green-revolution phase (1965–75), TFP growth in India was sustained by rapid adoption of modern varieties and sharp increases in irrigation investment, despite somewhat lower rates of growth in investment in extension and public and private research. In Pakistan, TFP growth accelerated during 1965–75, due to sustained growth in irrigation development and explosive growth in the use of modern varieties, which more than offset the decline in growth of investment in research and

human capital development (the latter reflected in a slowdown in the growth of literacy).

However, as the adoption of modern varieties slowed during the 1975–85 period, putting downward pressure on productivity growth, the patterns of productivity-enhancing public investment diverged in India and Pakistan. As a result, TFP growth during 1975–85 slowed only slightly in India, but turned negative in Pakistan. In India, investment in irrigation infrastructure dropped moderately, but was sufficient to sustain growth in the proportion of area irrigated, while expansion of the proportion of area irrigated in Pakistan virtually stopped. Growth in investment in public research, extension, and literacy in India actually increased relative to the previous decade. By contrast, the rate of growth in investment in research, technology, irrigation, and human capital development in Pakistan declined sharply relative to the previous decade.

Other factors contributing to the decline in TFP in Pakistan during 1975–85 were government policies taxing agriculture and increasingly serious waterlogging and soil salinity (Rosegrant and Evenson 1993; Azam, Bloom, and Evenson 1991). After 1985 there was a significant recovery in TFP growth in Pakistan as a whole and in the important Punjab region (Fan and Pardey 1998; Ali and Byerlee 1998). TFP growth in this latter period appears to be mainly due to labor-saving tractorization, at least in the Punjab, but sustainability of this growth appears questionable, because of the severe and growing negative impacts of resource degradation, particularly declining soil and water quality (Ali and Byerlee 1998).

More recently, TFP growth has slowed in India. Kalirajan and Shand (1997) show that both the level and contribution of TFP growth to overall output growth declined sharply between 1980–87 and 1988–90 in each of the 15 states that they analyzed. At the national level, TFP growth in Indian agriculture during 1975–80 was 1.71 percent per year and contributed 42 percent of agricultural output growth, but during 1986–90 slowed to 1.33 percent per year accounting for 30 percent of agricultural output growth (Desai 1994; Desai and Namboodiri 1997).

The decline in agricultural productivity growth was due in significant part to the relative neglect of investment in agricultural research during the 1980s, continuing into the 1990s (as shown in Table V.12), in favor of massive fertilizer and other input subsidies. Input subsidies grew from an already substantial 53 percent of agricultural plan expenditures in 1982/83 to 131 percent in 1992/93 (Ranade and Dev 1997). While the resulting growth in input use fueled fairly strong agricultural output growth during 1982–89, this input-led growth slowed after 1989 (see Tables V.1 and V.5). Given the importance of investment in research and extension, roads, and irrigation to agricultural output and growth in TFP, long-term prospects for productivity growth in India would be greatly enhanced by a shift of resources currently spent on input subsidies into these more productive investments. Input-led growth will not be sufficient without technological change (Kalirajan and Shand 1997; Kumar and Rosegrant 1994, 1997; Desai and Namboodiri 1997).

India also must deal with environmental problems that appear to have exerted a long-term downward pressure on TFP growth. Evenson, Pray, and Rosegrant (1999) estimate a negative coefficient for the time-trend variable in their analysis of sources of growth in TFP. They suggest that the negative sign could reflect negative effects from soil degradation (Antle and Pingali 1994) or cultivation intensity (Rosegrant and Pingali 1994), as well as other institutional or infrastructural factors. A lack of detailed environmental time-series data prevents a direct attribution of the negative trend to environmental degradation, but other evidence indicates that degradation is likely to be a significant contributor to the negative trend term. In areas of India (and elsewhere in Asia) where intensive rice monoculture has been practiced over the past two to three decades, there is considerable evidence of stagnant yields and/or declining trends in partial factor productivities, especially for fertilizers, and declining growth rates in total factor productivities (Cassman and Pingali 1995). In addition to these trends with respect to intensive monoculture rice, a similar slowing in partial factor productivity trends for the rice-wheat zone in India is

reported by Kumar and Mruthyunjaya (1992) and Hobbs and Morris (1996) (see also Chapter VI).

The PRC's growth in both agricultural production and TFP has been extraordinary since the mid-1970s. Fan (1997) estimates TFP growth of 3.45 percent per year during 1972–1995, accounting for two thirds of agricultural output growth in the PRC. Productivity growth was particularly rapid immediately following economic reform, at 5.10 percent per year during 1979–84. The series of agricultural reforms resulted in sharply improved efficiency in agriculture as opportunities for off-farm activities became available, permitting a large transfer of inefficient labor out of agriculture; the growth in use of traditional inputs began to decline while total output continued to increase rapidly (Fan 1991). A range of analyses has documented the importance of economic reform in boosting agricultural productivity growth. Lin (1992) estimates that decollectivization accounted for about one half of total output growth in 1978–84. Fan (1991) finds that institutional changes accounted for two thirds of agricultural productivity growth during this period, and McMillan et al. (1989) estimate the contribution of reforms to productivity growth at 78 percent during 1978–84.

Huang, Rozelle, and Rosegrant (1995) estimate the simultaneous effects on growth in output of public investment in agricultural research, technology and irrigation, institutional innovations, pricing policies, and environmental factors, within a comprehensive dynamic analysis of sources of growth of agricultural production in the PRC during 1975–92. The results confirm that the economic reforms initiated during the establishment of the household responsibility system were an important source of agricultural growth, particularly during the reform period of 1978–84, but show that the one-time effects of those institutional innovations were largely exhausted after 1984.

Even after the efficiency gains from agricultural reform were mostly reaped, the PRC maintained remarkably high growth in agricultural output (5.54 percent per year) and TFP (3.91 percent per year) from 1985 to 1995 (Fan 1997). Huang, Rozelle, and Rosegrant (1995) show that most of this agricultural

output growth since the mid-1980s has been the result of the expansion of agricultural research and investment in irrigation. Provincial-level analysis confirms that most of the growth in agricultural productivity in the PRC during 1984–93 was due to technological change, with relatively little continued contribution from efficiency changes induced by reform (Mao and Koo 1997). After a period of slower growth in the early to mid-1980s, investment in agricultural research and irrigation in the PRC has rebounded strongly, improving the prospects for continued productivity growth (Tables V.3 and V.12).

As with the case for India and Pakistan, however, Huang, Rozelle, and Rosegrant (1995) find that environmental degradation, including salinization, erosion, and natural disasters caused by the breakdown of the local environment, significantly reduced growth rates in production of rice, other grains, and cash crops in the PRC during 1975–90. Negative effects were largest for wheat, corn, and soybeans. These crops are much more likely to be grown in hilly and more ecologically fragile areas than paddy rice, which is grown more in plains areas and on terraces. These results suggest that increased attention should be given by policymakers to the adverse consequences of environmental stresses.

Private investment in agriculture consists mainly of investments by farmers aimed at increasing their long-term production capacity and private-sector investments in the crop research, input supply, processing, and marketing subsectors. The rapid growth in Asian agriculture has led to rapid income growth in rural areas and consequently to rapid growth in personal savings. This has created considerable capacity for increases in private agricultural investment within the rural sector. Private investments in agriculture have been relatively small in many Asian countries, however (Fan and Pardey 1998). At the same time, private investment can play an important role in agricultural productivity growth when government policies provide appropriate incentives (see Box V.3). The massive expansion of private-sector tubewell irrigation in India, Pakistan, and Bangladesh is the most successful example of private-sector irrigation development in the developing world

### **Box V.3: Private-Sector Research in Indian Agriculture**

The private sector in India engages in considerable research and development (R&D) relevant to agriculture and has increased its investment quite rapidly over time. By the early 1990s, private-sector agricultural R&D was approximately one half the level of public-sector agricultural R&D. Private agricultural research accounted for more than 10 percent of TFP growth in India during 1956–87. The contribution of private research was highest during 1965–75, when it accounted for 22 percent of TFP growth. The contribution of private-sector industrial research declined, however, as India's trade and industrial policy turned inward and foreign technology was downplayed.

Many of the inventions produced in the private machinery, fertilizer, seed, and chemical industries have been embodied in inputs sold to farmers. The private firms undertaking R&D capture part, but not all, of the actual productive value of this technology in the form of higher prices. This partial capture of value means that private inventions will also provide social benefits in terms of productivity growth that are not directly appropriated by the private firms.

Policymakers need to be more aware of the expanding role of private-sector R&D in India, as well as of foreign suppliers of technology; Indian public policy toward private-sector R&D has to better recognize their favorable role in overall growth. Industrial policy and technology policy, including intellectual property-rights policy, will require careful evaluation and reform in order to encourage private investment in agriculture. Moreover, barriers to technology transfer should be removed in order to stimulate technology transfer and growth.

Source: Evenson, Pray, and Rosegrant 1999.

(tubewells are wells bored from the ground surface to the aquifer, from which water is pumped through a tubular casing using motor-driven or manually-operated pumps). A "groundwater

revolution" in Bangladesh beginning in the 1980s was a key stimulant to rapid agricultural growth in the 1980s and early 1990s. Nearly 1.5 million hectares of land were newly irrigated after 1980, in large part from private installation of shallow tubewells spurred by deregulation of tubewell imports.

Public investments have been an important facilitator of private irrigation investment. Private tubewells in South Asia have grown most rapidly in areas with reasonably good roads, research and extension systems, and accessibility to credit and to electric or diesel energy; they have been concentrated in and around the command areas of large, publicly developed surface irrigation systems. Seckler (1990) notes three reasons for the complementarity between public and private irrigation investment in South Asia: deep percolation losses from the surface systems recharge the aquifers for tubewells; tubewells are often used together with surface irrigation water, which lowers pumping costs and concentrates these costs in periods of the highest marginal returns; and the tubewells ride piggyback on the infrastructure created for the surface systems.

It is likely that the share of private investment in Asian agriculture will increase in the future. As economies in the region continue to grow rapidly, the demand for agriculturally related technologies will increasingly move off-farm. Further increases in the use of inputs such as fertilizers, pesticides, and machinery will stimulate increased demand for new technologies and knowledge aimed at the input-supply sector. Rising incomes are leading to a rapid increase in the demand for processed agricultural products that in turn stimulates demand for post-harvest technologies related to the storage, processing, packaging, and marketing of agricultural produce (Fan and Pardey 1998). As shown in the case of expansion of private tubewells in South Asia, government policy plays a key role in stimulating private investment. Strengthening of property rights and removal of restrictions, regulations, and tax biases that penalize private investment will encourage the expansion of private investment in agriculture. In addition, properly targeted public investments can mobilize private investment.

While private investment in Asian agriculture is likely to grow, an important role for public investment in the sector will remain, because of incentive problems that discourage private investment in agricultural research and because of government desire to pursue equity or poverty-alleviation objectives. Agricultural research is in many cases long-term, large-scale, and risky, which means that most firms cannot carry out effective research and institutions may have to be set up on a collective (industry-wide or government) basis to achieve an economically efficient size and scale. The returns on new technologies are often high, but the firm responsible for developing the technology may not be able to appropriate the benefits accruing to the innovation—as in the case of improved open-pollinated rice and wheat varieties. The benefits of agricultural research often accrue to consumers (through reduction in commodity prices resulting from increased supply), rather than to the adopters of the new technology, so social returns may be greater than private returns to research. Appropriate government investments and policy interventions are therefore warranted, especially in areas with relatively low private incentives and relatively high social payoffs (Alston and Pardey 1996; Fan and Pardey 1998).

A number of developments could increase the role of the private sector in agricultural research in Asia. The appropriability of research results has increased, with hybrids being increasingly used and policy barriers to private-sector appropriation being reduced. Biotechnology innovations are likely to further the scope for private-sector involvement. In several countries the private seed sector has emerged as the dominant supplier of finished varieties for a number of crops. Policies to further increase private-sector involvement require continued attention; while many research activities require the long-term continuity of a public or semipublic institution, the potential for contracting for research should be explored more vigorously. Private-sector research, however, has generally shown little interest in solving the critical issues involved in increasing basic yield potential in wheat or rice varieties adapted to Asian agroclimatic zones or in developing hybridization

procedures for additional crops. Moreover, there are some “orphan” commodities, usually tropical crops, fruits and vegetables, where the private sector makes no investments. Contracting of entire long-term research agendas to the private sector is therefore probably impossible and a significant and sustained public role in funding agricultural research will remain necessary (Binswanger 1994; Lipton 1994).

## CONCLUSIONS

Strong agricultural growth in most Asian countries has been based both on rapid growth in input use and on productivity growth. The main sources of productivity growth have been public agricultural research and extension, expansion of irrigated area and rural infrastructure, and improvement in human capital. The rates of return to public research are high, showing the continued profitability of public investment in agricultural research, and strongly indicating that governments are underinvesting in research. The importance of productivity-driven growth is likely to increase relative to input-driven growth, because the growth rates in input use are declining as many regions in Asia reach high levels of input use. The public benefits from private research can be substantial, indicating that private firms capture only part of the real value of improved inputs through higher prices. Private investment in agriculture is likely to increase in importance, if policy reforms continue to create and improve the incentives for private investments by eliminating price distortions and strengthening property rights. However, continuing difficulties for private firms in recouping investments—particularly in research on many important crops—together with social objectives for public investment in agriculture, will continue to call for an important role for public investment in agriculture.