CHAPTER 11

The Changing Pattern and Sources of Agricultural Growth in India

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1. INTRODUCTION

The Indian economy has moved decisively to a higher path of growth in recent years, making it one of the fastest-growing economies in the world. The rate of economic growth measured in real per capita gross domestic product (GDP) (1999-2000 prices) averaged less than 5% per year during the 1980s and 1990s, increasing to more than 7% per year during the period 2003-07 (Planning Commission 2008). The economy is now poised to sustain these more rapid rates of expansion, with the potential to bring significant improvements to the lives of millions of the country's poor.

In contrast, the country's agricultural economy has performed erratically during the past several decades. Indian agricultural output, especially that of rice and wheat in irrigated areas, recorded a quantum jump in growth during the 1970s and 1980s in response to the widespread adoption of new seed- and fertilizer-based technologies. This was accompanied by substantial growth in rural infrastructure, mainly through public investments. The growth stimulus spread into rain-fed agricultural production beginning in the 1980s with the rapid adoption of high-yielding varieties of coarse cereals, oilseeds, pulses, and cotton. Rising yield growth and cropping intensities greatly contributed to buoyant agricultural growth, despite frequent instability due to weather events. The livestock sector, the second-largest component of India's agricultural GDP, also

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has had exemplary growth since the 1980s. However, this impressive overall growth performance obscures very different growth rates across different sectors, states, and social groups.

In recent years, agricultural growth has slowed, with wide year-to-year fluctuations. Beginning in the early 1990s, agricultural growth was substantially below that of the non-agricultural sector, and the gap is widening. The comparatively slow growth of agriculture would perhaps have been of less concern if there had been a commensurate decline in the percentage of the population dependent on agriculture. But this has not been the case; in fact, the official statistics showed that the agricultural population has continued to increase. This widening gap may seriously jeopardize the national goal of inclusive economic growth, as two-thirds of India's population still depends on agriculture and allied sectors for gainful employment and a secure livelihood.

The difficulty of improving agricultural productivity on a sustainable basis is further compounded by increasing pressure on natural resources and the environment, the vulnerability of agriculture to external shocks like climate change, and the fragmentation and small scale of Indian farms. Given these natural resource and structural constraints, agricultural growth must increasingly rely on sustained and improving productivity growth through continued technological and institutional innovations. There are some positive developments on these fronts that have helped maintain agricultural growth at a reasonable level and have thereby insulated the country from the recent global food crisis. In this chapter we examine the broad pattern of agricultural growth in the country, its sources and regional dimensions. We particularly underscore the recent success stories, diversification patterns, and binding constraints.

In the next section we present the main characteristics of Indian agriculture and its changing contribution to India's national economy. This is followed by a detailed discussion of the pattern of growth in agriculture, and the regional and commodity dimensions of that growth. Trends in total factor productivity are also reviewed at length in Section 3. An in-depth analysis of sources of growth in Indian agriculture—particularly recent trends in public investment such as irrigation, research, and infrastructure development—is provided in Section 4. In Section 5, we address challenges faced by Indian agriculture and the possible strategies for dealing with them. We conclude the chapter with some observations about options for accelerating India's agricultural growth.

2. AGRICULTURE IN THE INDIAN ECONOMY

The Indian economy has grown at an impressive rate in recent times. This sharp uptrend in growth can be attributed in (perhaps significant) part to a series of economic reforms initiated by the government in the early 1990s. The composition of growth has also changed substantially. In earlier times, agricultural and manufacturing sectors fueled much of the country's economic growth. Since the 1990s, a newly emerging services sector has been the main driver of growth, along with manufacturing, while the relative contribution of agriculture to current economic growth has shrunk significantly. Agriculture's share of Indian GDP fell from 37.9% during the early 1980s to less than half of that share (17%) during 2008-09. However, in real terms, Indian agriculture has continued to grow, albeit at varying rates, owing to several factors. Agriculture has an impressive long-run record, from delivering the country from serious food shortages, to becoming food self-reliant, to growing a food-surplus economy. Agriculture still contributes significantly to export earnings and is an important source of raw materials and demand for the booming non-agricultural sector. The country is increasingly taking its place in the global production marketplace as a leading producer of many agricultural commodities, including milk, wheat, rice, and cotton.

The shifting contribution of agriculture and other sectors of the economy is quite consistent with the evolution of economic growth witnessed in the developed countries. In contrast to the slowdown in the rate of growth of agricultural output, non-agricultural GDP shows a robust and rising growth trend. And while agriculture's share of total employment has declined, it is still a dominant source of employment, from employing 73.9% of the economically active population in 1973-74 down to 56.5% in 2004-05. A comparison of agriculture's share of domestic output and employment shows that the decline in agriculture's share of the labor force is slower than the decline in its share of output (Table 11.1). This clearly indicates the increasing gap between average incomes of workers engaged in agricultural and non-agricultural occupations and also highlights the inability of the non-agricultural sector to provide gainful employment to the masses.

Agricultural GDP grew by 3.5% per year during the 1980s (characterized by wider technology dissemination), which was substantially slower than the rate of growth of either the non-agricultural sector or the overall economy (Table 11.1). The 1980s pace of growth carried through to the middle of the 1990s, but thereafter agricultural growth slowed to 2.5% for the following decade against a target

Table 11.1. Share of agriculture in India's gross domestic product and employment

Period	Agriculture and Allied Sector's Share[a]		Real Average Annual Growth Rate		
	Total GDP at Factor Cost	Share in Employment[b]	Total GDP	GDP Agriculture and Allied Sector	GDP Non-agriculture
	(percentage)		(percent per year)		
1981-82 to 1990-91	31.4	61.0	5.4	3.5	6.4
1991-92 to 1996-97	27.8	56.6	5.7	3.7	6.6
1997-98 to 2006-07	18.5	52.1	6.6	2.5	7.9

Source: MoF (*Economic Survey, 2007-08*).
Note: Nominal values deflated to 1999-2000 prices.
[a]The share was computed only for the terminal years.
[b]Data pertain to 1993-94, 1999-00, and 2004-05, respectively.

growth of 4% per year[1] (Planning Commission 2008). The main challenge to India's agricultural sector continues to be the failure to meet growth targets, along with degraded natural resources, the predominance of rain-fed agriculture, and a preponderance of small farmers.

2.1. Structural Changes in Agriculture

Though the relative contribution of agriculture to the national economy has changed, the basic characteristics of Indian agriculture have not. Indian agriculture continues to be dominated by smallholders; in fact, their number has risen much faster in the recent period. As a result, there has been a significant reduction in the average size of a farm holding—close to one hectare at present (Table 11.2). Net cultivated area remains at around 140 million hectares, and more than half of this area is rain-fed. Much of the agricultural production is for domestic consumption, and only about one-tenth of the total value of production is exported. The output of food grains has registered a two-fold increase since the early green revolution period (1970), and output has jumped again in recent years. One significant shift in the growth process has been its source, with much of the more recent (post-1980) increase in output attributable to yield growth, followed by changes in cropping patterns, with a minimal contribution of area growth.

[1]The Government of India envisaged annual growth of 4% per year in the agriculture sector in its National Agricultural Policy, 2000, and Eleventh Five Year Plan (2007-2012).

Table 11.2. Major trends in Indian agriculture

Indicator	1971	1981	1991	2001	2006
Average size of holding (ha)	2.30	1.84	1.57	1.33	n.a.
Net cultivated area (mha)	139.72	141.93	141.63	141.45	141.89
Total cropped area (mha)	165.19	176.75	182.24	189.75	192.80
Total irrigated area (mha)	38.43	51.41	65.68	78.73	82.63
Share of rural population (%)	80.1	76.7	74.3	72.2	n.a.
Share of exports in AgGDP (%)	2.7	3.9	4.4	6.1	9.1
Share of agriculture in national GDP (%)	40.6	34.4	29.6	23.2	18.2
Total food grain production (million tons)	105.17	133.30	168.38	212.85	217.28
Food grain yield (metric tons/ha)	0.85	1.03	1.38	1.73	1.76

Sources: Compiled from MoA (various years) and CSO (various years).

The crop sector continued to be a principal component of overall agricultural output, accounting for more than two-thirds of the value of agricultural output in 2008, with the livestock sector accounting for about one-quarter of total output (Table 11.3). Since the early 1980s there has been a modest decline in the crop sector's share of agricultural output while the livestock and fisheries sectors increased their respective market shares. The increasing share of output coming from the livestock sector—17.5% in the triennium ending (TE) 1981 to 24.5% in 2006 (Table 11.3)—reflects both supply-side and demand-side factors. Livestock production is considered to be remunerative and labor intensive, and thus it suits the needs of smallholders. At the same time, Indian farmers are responding well to opportunities in commercial agriculture and diversifying to meet the rising demand for livestock products. Milk and milk products now make a major contribution to livestock output, such that India is now the largest milk producer in the world. The livestock sector has also diversified, with more production of poultry meat and eggs over recent years. The fishery sector still accounts for less than 5% of agricultural GDP, albeit with a steadily increasing share over the past several decades. However, the sector saw a considerable shift from marine to inland production, with inland production becoming increasingly important of late.

The crop sector is dominated by food grains production, which accounted for about 64.5% of the total cropped area during 2005-06. Food grains production increased markedly, to total 230 million metric tons in 2008, through

Table 11.3. Production shares and amounts by category, and selected crop yields

Indicator	TE 1981	TE 1991	2008
Share in the total value of production (%)			
Crop	75.5	70.6	67.1
Livestock	17.5	22.0	24.5
Forestry	5.2	4.7	3.6
Fishery	1.7	2.7	4.8
Agricultural production			
Food grains production (mt)	124.20	172.45	230.67
Milk production (mt)	31.60	51.23	100.87
Fish production (mt)	2.44	3.55	6.87
Egg production (billion, number)	10.06	20.10	50.66
Crop yields (t/ha)			
Rice	1.25	1.72	2.20
Wheat	1.71	2.33	2.79
Coarse cereals	0.69	0.88	1.42
Pulses	0.46	0.58	0.64
Cotton	0.16	0.23	0.47
Groundnut	0.84	0.88	1.46

Sources: Share of value of production from CSO (various years) and remaining data from MoA (various years).
Note: TE indicates triennial ending.

tripling the average yield of principal crops since the early 1950s. The share of cereals production decreased from 39% in TE 1981 to 30% in TE 2006, while that of fruits and vegetables increased from 16% to 25% during the same period. Oilseeds peaked in terms of their market share in TE 1991 and then lost ground thereafter. These trends show that the crop sector is diversifying toward non-food grains and high-value commodities such as fruits and vegetables. The share of overall output coming from pulses and fibers changed little over the years, while sugar marginally increased its share of total crop output (Table 11.4). The changing composition of agricultural output is well reflected in the growth of value of agricultural output, which has shown a significant increase since the early 1990s (Figure 11.1). On the input front, the share of purchased inputs in value of output from agriculture including livestock hovered around 22% during the same period. Gains in rice yields were higher than those of wheat during the period. More significant is the marked increase in the yields of cotton and coarse cereals, indicating rapid diffusion of new technologies even in rain-fed areas. (Table 11.3).

Table 11.4. Compositional changes within crop sectors

Crop Group	TE 1981	TE 1991	TE 2001	TE 2006
		(percentage)		
Cereals	38.7	35.9	33.8	30.1
Pulses	6.1	6.4	4.9	5.2
Oilseeds	8.6	12.0	7.9	8.5
Fruits and vegetables	16.3	17.2	24.1	25.0
Sugar	5.1	4.9	6.4	7.3
Fibers	4.4	4.3	3.3	4.0

Sources : CSO (various years), NAAS (2009).
Notes: TE indicates triennial ending. Data are percent shares of value of crop productions.

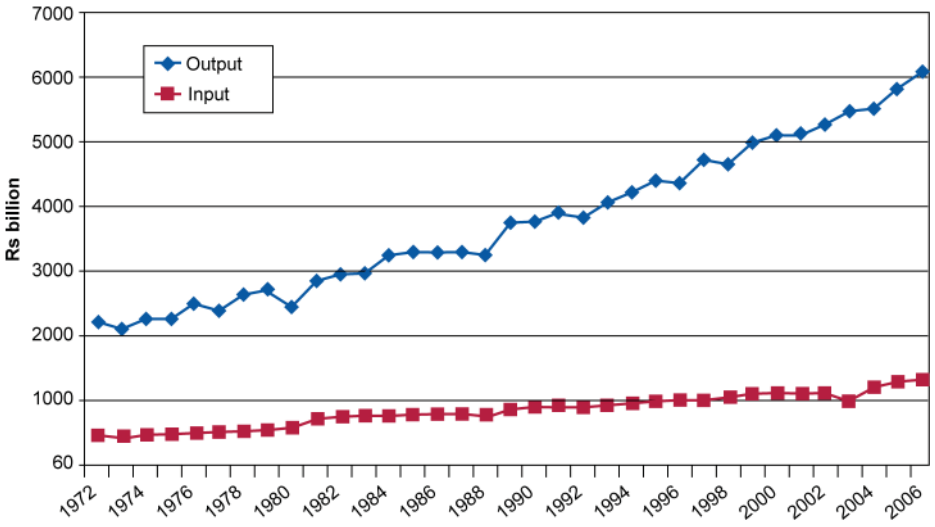

Figure 11.1. Value of agricultural output and input (1999-2000 prices)
Source: Period from CSO (various years, www.mospi.gov.in).
Note: Nominal values deflated to 1999-2000 prices.

2.2. Agricultural Trade

India's agricultural trade is diverse, ranging from raw products to processed and ready-to-eat items. The share of India's agricultural exports in total exports has varied between 11% and 15% since 2000. During 2007-08, the value of agricultural exports totaled more than U.S.$7 billion, of which marine products and oil meal were among the largest contributors. The composition of agricultural trade has changed significantly in the recent period. The proportion of Indian agricultural exports coming from fruits and vegetables, flowers, cotton, sugar

and molasses, and livestock products has increased considerably. Cereals (mostly basmati and non-basmati rice), tea, coffee, cashews, and spices are other prominent products, each accounting for between 5% and 10% of the country's total agriculture exports. India's agricultural imports, on the other hand, have constituted only a small portion of the country's total imports (less than 5%) during the current decade. The country imports mainly vegetable oil and pulses, which alone account for about 70% of total agricultural imports.

3. AGRICULTURAL GROWTH PATTERN

Agricultural growth was significant during the 1980s and early 1990s, as evidenced by the performance of the crops, livestock, and fisheries sectors (Table 11.5). The crop sector showed modest (but still substantial) growth during the early 1990s, but it consistently slowed down thereafter. The rate of growth in livestock production also began to slow in the mid-1990s but has remained higher than the corresponding rate of growth in food grains and oilseeds. There is a noticeable decline in growth rates after the mid-1990s across all agricultural sectors, with growth in some sectors (including pulses and oilseeds, livestock, and fisheries) rebounding in recent years. A substantial cause for concern has been the ratcheting down in the pace of growth of cereals output in recent decades, given the fact that the substantial share of agricultural output still derives from this sector and is the mainstay of India's food security. Consequently, the

Table 11.5. Period average growth of real agricultural output by sector

	Crops						
Period	Cereals	Pulses and Oilseeds	Fruits and Vegetables	Other Crops	All Crops	Livestock	Fishery
	(percent per year)						
1981-82 to 1990-91	3.52	5.41	2.84	1.71	2.97	4.78	5.74
1991-92 to 1996-97	2.36	2.92	6.07	2.18	3.09	4.00	7.05
1997-98 to 2001-02	1.49	-1.43	4.11	3.82	2.25	3.53	2.63
2002-03 to 2006-07	1.28	4.29	2.97	2.25	2.46	3.69	3.23

Source: Planning Commission (2008).
Note: Respective nominal totals deflated to 1999-2000 prices.

overall rate of growth of agricultural GDP has been well below a target rate of 4% per year. The annual data suggest that the rate of growth of crop output peaked by the mid-1990s and has slowed afterward. In contrast, the horticulture sector exhibited impressive output growth throughout the entire 1990s. Although it, too, slowed thereafter, it has sustained a rate of output growth that is more than twice as fast as the corresponding growth in cereals output. However, food grain production spiked in 2008 as global commodity prices soared, while the high-value livestock, fisheries, and fruits and vegetables sectors sustained growth rates of at least 3% per year.

One fact concealed in these period averages is the wide year-to-year fluctuations in growth performance. In some years, growth rates increased by as much as 10% (between 2002-03 and 2003-04) compared with the average growth of 4.5% between 2002-03 and 2006-07. Unfavorable weather conditions corresponded with low-growth years, and these lowered the overall growth rate. However, excluding the abnormally poor years of 2002-03 and 2004-05, the average growth of GDP from agriculture and allied sectors (1999-2000 prices) during the 1997-98 to 2008-09 period was estimated at 3.7% per year.

3.1. Agricultural Diversification

Indian agricultural production began to diversify gradually in the 1980s, as reflected by changes in sectoral and crop contributions to the total value of agricultural output, and this trend began to accelerate during the 1990s. This pattern is visible in the distinctly different growth patterns between food grains and non-food grains. The share of area under food grains has declined since the early 1980s, with a small decline in the share of area under rice and wheat, compounded by a marked decline in the area under coarse cereals (Table 11.6). Notwithstanding these shifting area shares, the yields of coarse cereals grew at markedly higher rates than yields for other grains such as rice and wheat, especially during the 1990s (Table 11.6). The official statistics show that about 60% of the cropped area for coarse cereals in the late 1990s was planted to high-yielding varieties, even though the coverage of irrigation was much lower for coarse grains. Among the food grains, the growth scenario is completely different for pulses, as shown by the crop's declining growth in output, area, and yield, especially during the 1990s. However, during the last decade, there was appreciable acceleration in the growth of pulse production, owing to growth in both area and yield. The growth performance of oilseeds as a group surpassed that all of

Table 11.6. Area, production, and yield growth rates of principal crops in India

Crop Group	1980-81 to 1990-91			1990-91 to 1999-2000			2000-01 to 2006-07		
	Area	Production	Yield	Area	Production	Yield	Area	Production	Yield
	(percent per year)								
Food grains	-0.23	2.85	2.74	-0.07	2.02	1.52	0.48	2.09	2.82
Cereals	-0.26	3.03	2.90	0.04	-0.02	1.59	0.16	1.95	3.10
Coarse cereals	-1.34	0.40	1.62	-2.12	-0.02	1.82	-0.41	3.25	4.25
Pulses	-0.09	1.52	1.61	-0.60	0.59	0.93	1.91	3.42	1.65
Non-food grains	1.12	3.77	2.31	1.18	2.69	1.09	2.46	5.09	3.87
Oilseeds	1.51	5.20	2.43	-0.86	1.63	1.15	2.71	6.69	4.91
Cotton	-1.25	2.80	4.10	2.71	2.29	-0.41	1.45	17.48	15.79
All principal crops	0.10	3.19	2.56	0.27	2.29	1.33	1.06	3.17	3.80

Source: MoA (2008).

Notes: Area represents planted area of each crop category. Area, production, and yield growth rates calculated as annual average growth of respective area, output, and yield indexes (base: triennium ending 1981-82=100).

other crop groups during the 2001-07 period and was distinctly superior to its past rates of growth. Both area and, particularly, yield components contributed significantly to this dramatic expansion in output. More importantly, unlike the slowdown in output growth of cereals and pulses during the 1990s, oilseed output continued to expand. Of India's major cash crops, cotton merits special mention because of its strong growth performance, especially in recent years. This was made possible mainly through significant advances in seed technology, especially Bt cotton and the resulting high growth in yield per hectare (Qaim et al. 2006; Gandhi et al. 2006).

The livestock sector is also noteworthy, as its overall growth performance outpaced that of the crop sector by a wide margin, enabling the country to enjoy higher per capita availability of milk and other livestock products. However, the pace of growth dropped steadily, from 4.8% in the 1980s to 3.7% during 2002-06 (Table 11.5). Milk and milk products constitute around two-thirds of all livestock output (by value) and thus heavily influence the overall trend for the sector. However, considerable diversification toward production of poultry meat and eggs has occurred, as evident from the spectacular growth of these commodities since the 1980s. The share of meat and meat products in total agricultural output has remained fairly stable over the last three decades (Chand and Raju 2008).

What are the major drivers of agricultural diversification toward high-value commodities? There are a number of factors responsible for this shift. The most important among these is greater demand for high-value commodities such as fruits, vegetables, and livestock products as per capita incomes increase. As incomes rise, people consume more higher-value commodities and less traditional food items such as cereals. This effect has been more pronounced in the recent past because of the spectacular growth in the Indian economy. Demographic changes are also at play, including increased urbanization, increased female literacy, and increased participation of women in the workforce, especially in urban areas and small towns. These demand-side factors were matched by positive developments on the supply side. Farmers responded to the incentives offered by high-value commodities, both for domestic and international markets. This was particularly true for the fruits and vegetables, poultry, and fisheries sectors, in which new farming opportunities and technologies emerged. Imports of improved seed varieties and planting materials were permitted under a new seed policy introduced during the late 1980s. Because these commodities provided comparatively high and regular returns to smallholders in a short period,

farmers directed resources to these areas. Finally, the participation of the private sector in retail marketing and input supply and other production-enhancing undertakings, including new forms of contractual arrangements with growers, provided further impetus to the growth of high-value commodities (Joshi, Gulati, and Cummings 2007).

3.2. Regional Patterns of Agricultural Growth

The structure and regional distribution of agricultural production varies markedly among regions and states. At the national level, the rate of growth in net state domestic product (NSDP)[2] from agriculture slowed significantly when comparing the period 1984-85 to 1995-96 with the period 1995-96 to 2004-05 (Table 11.7). Almost all the major states of India, except Bihar and Orissa, the two poorest states, exhibited impressive rates of growth during the earlier period. This period is in fact a turning point in Indian agriculture, as the sector witnessed not only impressive growth rates but also better distribution of growth among different states of the country. Notable was the growth performance of the rain-fed states of Madhya Pradesh and Rajasthan, primarily because of large shifts from coarse cereals to oilseed production. The shift toward oilseeds reflected the commodity's relative profitability fueled by an appreciable increase in administered prices coupled with a faster rate of yield growth compared with coarse cereals. Both these effects were realized through concerted government efforts under the Oilseed Mission.[3] Another important development was the impressive growth performance of West Bengal, especially in rice production. The spread of modern seed varieties and an increase in area cultivated under summer (*boro*) paddy with improved irrigation and input management contributed to this performance. Gujarat also deserves special mention, as it has attained 9.6% growth per year in agricultural state domestic product since 1999-2000. The main sources of its growth are a massive boom in cotton production, growth in high-value commodity groups like livestock, and fruits and vegetables, and wheat production (Gulati, Shah, and Shreedhar 2009).

The national slowdown in agricultural output growth during the post-1995-96 period was evident in all states except Bihar. The slowdown even affected

[2]NSDP is one of the important indicators for measuring economic growth in states and union territories of the country.

[3]The Oilseed Mission was launched by the Indian government in 1986 to increase oilseed production and achieve self-sufficiency in edible oils. Subsequently, pulses, oil palm, and corn were also brought within the purview of the Mission in the early 1990s.

Table 11.7. Measures of state agricultural and economy-wide activity

State	Growth of Net State Domestic Product in Agriculture		Net State Domestic Product	Yield of Food Grains	Rural Population Below the National Poverty Line
	1984-85 to 1995-96	1995-96 to 2004-05	2007-08	2006-07	2004-05
	(percent per year)		(Rs/ha, 1000s)	(t/ha)	(percent)
Punjab	4.00	2.16	53.4	4.02	9.10
Haryana	4.60	1.98	48.5	3.39	13.60
Uttar Pradesh	2.82	1.87	37.4	2.06	33.40
Tamil Nadu	4.95	-1.36	64.2	2.61	22.80
West Bengal	4.63	2.67	69.0	2.51	28.60
Bihar	-1.71	3.51	35.2	1.66	42.10
Andhra Pradesh	3.18	2.69	56.4	2.23	11.20
Gujarat	5.09	0.48	34.1	1.42	19.10
Rajasthan	5.52	0.30	19.1	1.12	18.70
Orissa	-1.18	0.11	27.7	1.36	46.80
Madhya Pradesh	3.63	-0.23	17.7	1.17	36.90
Maharashtra	6.66	0.10	34.1	0.94	29.60
Karnataka	3.92	0.03	28.4	1.29	20.80
Kerala	3.60	-3.54	74.6	n.a.	13.20
Assam	1.65	0.95	47.3	1.29	22.30
All India	3.62	1.85	40.6	1.76	28.30

Sources: State domestic product from CSO (various years); yield from MoA (2008); poverty indicator from Planning Commission.

the comparatively well developed northwestern region of the country, including states such as Punjab and Haryana. Many other states in rain-fed regions of the country, which account for 60% of the total cultivated area, also saw significantly poorer growth performances during this period. These rain-fed areas are characterized by relatively higher incidences of poverty, more limited (off-farm) employment opportunities, higher production risks, and high rates of out-migration, and thus the slowdown in these areas is particularly problematic.

Although growth in agricultural output has slowed in recent years, there are some significant exceptions to this general trend. For example, corn production has increased rapidly (5% per year from 1997 to 2007) as the intro-

duction of winter corn and use of modern hybrids has spread rapidly. The area under corn also continues to expand, even in the states that typically have grown little if any corn such as Karnataka and Andhra Pradesh in southern India. Much of the crop was used as feed in the flourishing poultry sector in these southern states. Beginning in the 1980s, the production of *boro* rice also increased markedly, especially in the eastern part of the country. This was further enhanced by the spread of hybrid rice, which offers significant yield advantages (up to two metric tons per hectare) over conventionally bred varieties. The northern states have had no significant spurt in productivity growth, but they have maintained their comparatively high yields, with impressive improvement in the grain quality of rice. Yields have not improved in the pulses at the aggregate level but crop duration has been reduced, particularly in pigeon peas and chick peas, which has extended their reach into several non-traditional areas. The spread of Bt hybrids has improved yields in cotton. Similarly, farmers' access to improved varieties of vegetable seeds has led to increased production in the eastern, southern, and hill states characterized by predominantly small farms. All of these developments, among others, have contributed to the growth of Indian agriculture.

3.3. Partial and Total Factor Productivity Trends

Crop growth performances clearly show that the relative roles of area expansion and yield growth varied among crops. As a general rule, yield growth contributed more than area expansion to the growth in output for most crops, with the exception of cotton during the 1990s when yield growth was negative (Table 11.6). However, yield growth for all principal crops taken together slowed from an average of 2.56% per year during the 1980s to 1.33% per year during the 1990s, and the same pattern held true for most of the crops. The growth in crop yield, especially of coarse cereals and non-food grains, showed signs of recovery in more recent years. Cotton yields continued to decline during the 1990s, but development of hybrid cotton varieties, better pest management practices, and the introduction and rapid adoption of Bt cotton led to a rapid turnaround, with double-digit growth in yield and production after 2000.

Although yields have tended to increase over time in most of the states, and for all of India, there remains large spatial (state) variation in crop yields. The states with the highest productivity measured in terms of net state domestic product (measured in rupees [Rs] per hectare of total cropped area in the state in

the year 2007-08) are Kerala (Rs 74,600/ha), West Bengal (Rs 69,000/ha), Tamil Nadu (Rs 64,200/ha) and Andhra Pradesh (Rs 56,400/ha).

A number of studies on total factor productivity (TFP) growth in Indian agriculture, and an assessment of the factors explaining those changes, have been carried out (Table 11.8). They clearly show evidence of robust growth in partial factor productivity and TFP as major drivers of output growth in the crop sector during the 1980s. Estimates of various studies show that the average rates of growth in TFP in the agricultural sector, including livestock, ranged from 0.90% to 2.29% per year during the 1980s and 1990s (Table 11.8). However, the reported rates of growth in TFP vary considerably in terms of the methodologies, time periods, and data series used. None of the studies reports TFP growth for India after the latter half of the 1990s. In addition, little research explores whether the source of growth is technical change or purely gains in efficiency. However, the study by Kalirajan and Shand (1997), following a frontier production function approach, found that during the 1980s much of the slowdown in the TFP con-

Table 11.8. Summary of total factor productivity studies of Indian agriculture

			Total Factor Productivity	
Author(s)	Commodity	Period	Annual Growth	Share of TFP Growth[a]
			(percent per year)	(percent)
Evenson, Pray, and Rosegrant 1999	Crops	1966-76	1.40	50.2
		1977-87	1.05	48.8
Fan, Hazell, and Thorat 1999	Crops and livestock	1980-89	2.52	66.5
		1990-94	2.29	72.2
Coelli and Rao 2003	Crops and livestock	1980-2000	0.9	-
Kumar, Kumar, and Shiji 2004	Aquaculture	1992-98	4.4	71.7
	Marine	1987-98	2.0	48.8
Birthal et al. 1999	Livestock	1951-70	-0.04	-
		1970-80	0.93	33.2
		1980-95	1.79	45.0
Joshi et al. 2003	Rice (IGP)	1980-90	3.5	-
		1990-99	2.1	-
	Wheat (IGP)	1980-90	2.4	-
		1990-99	2.1	-

Source: Compiled from NAAS (2009).

[a]Indicates share of respective output growth attributable to growth in TFP.

tribution to output growth could be attributed to low rates of technological progress, together with gradual improvements in technical efficiency, but the output growth in the sector had become increasingly dependent on input growth.

As with crop yields, the measured rates of growth of TFP varied markedly throughout the country. For example, the Indo-Gangetic Plains witnessed impressive TFP growth in rice (3.5% per year) and wheat (2.4% per year) during the 1980s, thus underscoring the key role of technology in making the country food secure (Joshi et al. 2003). However, the study showed deceleration in TFP growth, especially for rice, during the 1990s, thus raising concerns about the sustainability of the rice-wheat cropping system. Kumar, Kumar, and Mittal (2004) also found that TFP grew more rapidly in the agricultural sector during the 1980s relative to the 1990s in the Indo-Gangetic Plains. By way of contrast, TFP in the livestock sector grew little before the 1970s. The sector saw the pace of productivity growth picking up during the 1980s when TFP growth reached nearly 1.8% per year, contributing 45% to total output growth (Birthal et al. 1999). In the fisheries sector, TFP growth was much higher in aquaculture as compared to marine production during the 1990s. The TFP index for aquaculture grew by 4.4% annually and accounted for more than 70% of the growth in aquaculture production (Kumar, Kumar, and Shiji 2004).

In an effort to explain the rate of productivity growth, Kumar, Kumar, and Mittal (2004) identified research, extension, literacy, and infrastructure as the most important sources of TFP growth in the Indo-Gangetic Plains. Extension accounted for about 45% of the TFP growth, followed by public research (36%) and literacy (10%). Investment in agricultural research and development (R&D) also made a significant contribution to Indian productivity growth according to Evenson, Pray, and Rosegrant (1999) and Fan, Hazell, and Thorat (1999).

4. SOURCES OF AGRICULTURAL GROWTH

4.1. Public Investment in Agriculture

Public investment in agriculture targeted to infrastructure and the provision of farm services has been an important element of agricultural policy in India. The experiences of the green revolution showed that a strategy of strong public support for agriculture has paid rich dividends. Initially most public investment in India was directed toward irrigation infrastructure, particularly surface irrigation. Investment eventually extended to such areas as R&D, public provision of critical inputs like seed and fertilizer, rural electrification, animal health, and agricultural prod-

uct markets. Empirical evidence supports a positive correlation between public and private investment (Roy and Pal 2002). This positive correlation could be seen in the development of groundwater irrigation in India, whereby public investment in rural electrification encouraged farmers to invest in tubewell installation. This led to rapid growth in the adoption of groundwater irrigation, beginning especially in northwest India and then spreading to other parts of the country.

The broad trends in public investment constitute three phases during the post-independence period. First, although investment has increased significantly over the years since independence, it rose rapidly during the food crisis of the 1960s and 1970s. Second, driven by the objective of food security, the government invested heavily in agriculture during the early 1970s, and this level was sustained during the subsequent period. Third, spurred by a slowdown in agricultural growth beginning in the mid-1990s, the government once again stepped up its investment in agriculture, leading to a spike in investments during the first decade of this millennium (Figure 11.2). An upward trend in private investment commenced in the mid-1970s and a sharper rise was further witnessed in the 1990s.

The pattern of public investment has changed significantly over time. It became more broad based (spatial coverage and items of investment), and the share of centrally funded and state-operated schemes also rose over time. The rising

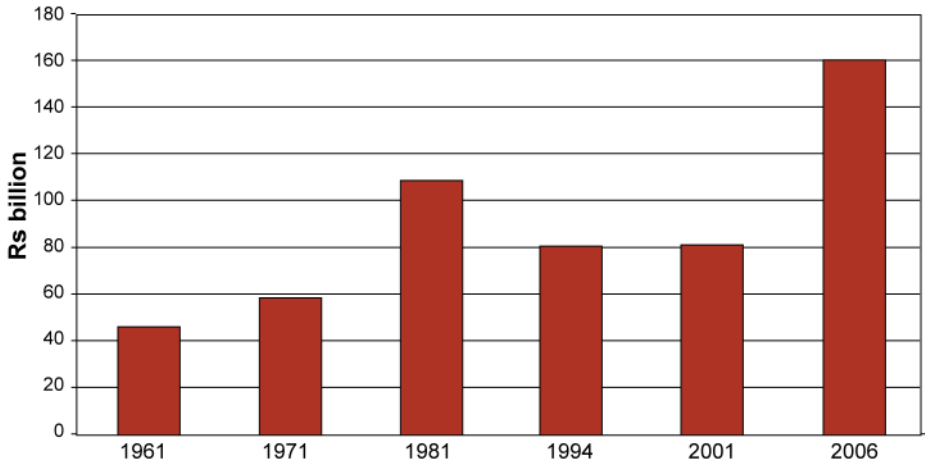

Figure 11.2. Gross capital formation in agriculture from the public sector, 1999-2000 prices

Source: CSO (various years).

burden of subsidies eroded the government's ability to invest in agriculture, and there is an emerging consensus that these subsidies should be rationalized and the resulting savings diverted to public investments in the sector.

4.2. Irrigation

Most of the public investment in agriculture has been for development of irrigation infrastructure, mainly surface irrigation. But investment in rural electrification has also expanded and in turn stimulated investments into tube-well technologies, thereby affecting crop productivity. Studies indicate that the increased use of irrigation and the spread of high-yielding crop varieties have been major sources of growth in Indian agriculture. This trend has continued, but a number of issues have emerged requiring immediate attention. Per capita demand for water is projected to increase markedly, but without commensurate increases in its availability. It is estimated that the latent demand for water for various purposes will far exceed availability by 2050, and other sectors (urban domestic, industries, etc.) will compete with agriculture for water (NAAS 2009).

The first major issue for agriculture is the optimal use of surface irrigation (canal and tank irrigation) and increased technical efficiency in water use, which is currently estimated at about 25% to 35% in most irrigation systems (Planning Commission 2008). Substantial investment is needed for upgrades in irrigation infrastructure to reduce water losses. In addition, better distribution of irrigation water and recovery of irrigation charges are envisaged through participation of farmers in water user associations. These associations, in partnership with irrigation departments, can effectively maintain irrigation channels, manage water distribution at the farm level, and recover costs from member farmers. Successful joint management has yet to materialize, especially in terms of cost recovery.

The second major issue is improvement of water use efficiency through water-saving technologies like drip and sprinkler irrigation and conservation agricultural practices (zero tillage and aerobic rice). These technologies can reduce pressure on groundwater irrigation. Technological advancements are also needed to address poor quality water. A large part of India (northwest plains and coasts) is facing the problem of salt-affected water, and any technological advancement to reclaim and use this and other poor quality water will help sustain crop productivity in these regions. Besides technological options, policy and institutional options are needed to control groundwater depletion. The state of Punjab has enacted a ban on summer paddy, a crop that is transplanted in May, while Haryana

has withdrawn price supports for summer paddy. There is also a move to shift to volumetric pricing of electricity for tubewell irrigation to control water extraction.

4.3. Agricultural R&D

The creation of a strong R&D system for agriculture has been an important policy goal of the Government of India. As a result, India is one of the few developing countries to sustain a positive rate of growth in real public investment in agricultural research. Research funding increased from 0.3% of agricultural GDP in 1971 to more than 0.5% in 2004 for both agricultural research and education, and all signs point to a continuation of this uptrend. India has seen two structural changes in funding and the use of this investment. First, the central government's share of funding has risen over time and now accounts for nearly half of total funding. Second, allocation to the dryland regions, for such things as natural resource management research and livestock development, has been increasing. The only region that continues to receive low investment is the eastern region, where funding by state governments is very low. Another noteworthy trend is that an increasing amount of funding is being allocated competitively, thus opening up access to funding to a broader set of public institutions (Pal and Byerlee 2003).

Besides raising the amount of public investment, the government, through the Indian Council of Agricultural Research (ICAR), has addressed organizational issues to enhance research effectiveness. The government has made a number of policy reforms recently, and the focus is now on accelerating the pace of implementation of these reforms. Highlights of these institutional reforms are

- strengthening the monitoring and evaluation of institutes and their programs and the use of information communication technology in research management;
- strengthening the research and development continuum through stronger linkages between research, technology transfer, and end-users; and
- managing intellectual property for rapid transfer of technology and fostering partnership among actors in R&D, especially between the public and private sectors.

Management of intellectual property rights (IPRs) represents a major shift in R&D, and these measures warrant further elaboration. India has put in place legislation to comply with the agreements related to IPRs under the World Trade Organization. Among these, protection of plant varieties, farmers' rights, and other innovations are of great significance to agriculture. ICAR has established a

unit for IPRs management and has developed IPRs policy and guidelines for their implementation. The main elements of the policy are as follows:

- ICAR will seek and maintain ownership rights for all intellectual properties, such as plant varieties, process and product innovations, research data, computer programs, designs, and publications, generated by its institutes.
- ICAR will encourage its institutes to use IPR policy to accelerate technology flow to farmers, promote competitive markets for innovations/ technologies, especially in the private domain, and promote inclusive and sustainable agricultural growth.
- ICAR will offer incentives for innovation by sharing the benefits of research with researchers, entrepreneurs, and farmers.

With the establishment of the Protection of Plant Varieties and Farmers' Rights Act, a large number of extant and new varieties have been registered for protection. These varieties are being commercialized through partnership with state and private seed agencies. In addition, efforts are being made to conserve and protect genetic resources through in situ and ex situ measures. ICAR also encourages conservation of animal and fish genetic resources by registering species.

Networking and partnership for pooling of resources, expertise, and skills are important for generating synergies in research. This concept is promoted through a number of network projects involving ICAR institutes and other institutions. These projects are in high-priority research areas and complement the network of coordinated research projects in India.

The private sector role in many facets of agriculture has expanded, from supplying inputs (seeds, fertilizers, pesticides, animal feed, etc.), to product marketing and value chain development, to commercialization of technologies. For instance, the private sector provides 58% of total commercial seeds (Planning Commission 2008). The non-profit private sector, such as research foundations and civil society organizations, is also active in agricultural development, including R&D. All of these organizations will increasingly depend on public R&D organizations for a variety of support. ICAR has instituted initiatives to foster partnerships with private and civil society organizations. These efforts have been accelerated to promote partnership with the private sector under externally funded projects of the World Bank. An emphasis on commercialization of technologies is also encouraging partnership with the private sector, whereby public research institutions license their technologies to the private sector on a non-exclusive basis.

4.4. Use of Inputs

Table 11.9 illustrates the rapid uptake of new seed and fertilizer technology during the green revolution. Average per hectare use of fertilizer doubled in every decade from 1971 to 1991. Subsequently the rate of increase was not as high but was still impressive; in fact, in absolute terms the increase in the application rate of fertilizer during the 1990s equaled that of the 1970s. Currently, the average rate of fertilizer application is 113 kg/ha, which is still much below the recommended level. Another notable feature of fertilizer use is that there is considerable interregional variation, especially in irrigated areas. For example, in the Punjab, average fertilizer use is as high as 209 kg/ha. Nitrogen fertilizer is most commonly used by farmers, with a high imbalance in the use of other plant nutrients (e.g., phosphorus and potassium). Recently, the government has provided price subsidies to encourage a more balanced use of plant nutrients. Similar trends are echoed in the use of other purchased inputs, and this is somewhat reflected by the growth in institutional credit to agriculture.

Private investment in farm mechanization and tubewell irrigation has been another major driver of economic growth. There were only 148,000 tractors in India in 1971 (Table 11.9). The number rose to more than two million tractors by 2006. Similarly, the share of cropped area irrigated by tubewells increased from 16.6% in 1971 to 26% in 1981, and rose further to 44% in 2006. This investment in farm mechanization and irrigation has not only contributed to an increase in crop productivity but also has helped raise the intensity of cropping. Another advantage of the expansion of tubewell irrigation has been a greater

Table 11.9. Inputs use in Indian agriculture, 1971-2006

	1971	1981	1991	2001	2006
Fertilizer use (kg/ha)	16.5	34.24	69.84	91.13	113.26
Number of tractors (000)[a]	148.2	275.9	738.4	1,221.8	2,361.2
Share of tubewells in irrigated area (%)	16.63	26.2	38.42	40.84	43.86
Quality seed distribution (000 tons)	n.a.	450	575	918	1,550
Institutional credit (Rs/ha)	53.58	232.42	631.39	3,261.40	10,544.45

Source: MoA (various issues).
[a]Data pertain to 1972, 1977, 1987, 1992, and 2003, respectively.

stability in crop yields, thereby reducing the size of government interventions to maintain buffer stock. However, as with fertilizer use, the most disquieting feature of farm mechanization and irrigation is that these developments have been mostly concentrated in the northwestern region of the country (in states such as Punjab and Haryana). This has led to charges of over-investment in mechanization (which results in a higher cost of production and lower farm income), and overuse of irrigation water in this region has led to questions about the long-term sustainability of the rice-wheat production system in this part of India.

One recent development concerning input use and crop establishment practices has been the adoption of resource conservation agriculture, mainly in the rice-wheat system. The most widely adopted technology is direct sowing of wheat after paddy in untilled fields, which is known as zero tillage. Estimates place more than three million hectares under zero-till wheat in 2005. The main advantages of this technology are (a) tractor fuel savings and a reduction in carbon emissions; (b) savings in the use of irrigation water, mainly groundwater; (c) carbon sequestration and low or delayed carbon dioxide emissions; and (d) a reduction in herbicide use (Laxmi, Erenstein, and Gupta 2007).

4.5. Price Support and Terms of Trade

Government interventions in providing price support to farmers and improving the physical and economic access of poor consumers to food have been important elements of agricultural price policy in India since 1965 when the Commission for Agricultural Costs and Prices (CACP, formerly the Agricultural Price Commission) was established. The government procures food grains at a predetermined price called the Minimum Support Price announced by the government on the recommendation of the CACP. Although the price is announced for two dozen commodities, there is procurement of only a few select commodities (rice and wheat). The commodities are distributed to the public at a price lower than market price through fair price shops managed by the state governments. Part of the stock is used as a buffer to reduce temporal variations in availability of food grains.

These government interventions have been successful in improving food access and ensuring a fairly stable price environment. This in turn has encouraged farmers to adopt new technology and use modern inputs and crop practices and thereby helps improve crop productivity, which in turn strengthens national food security, which is a significant impact of agricultural price policy (Acharya

1997). This, coupled with other interventions, such as development of market infrastructure and regulation of markets to control exploitative practices of traders, has helped in providing incentives to farmers and reducing margins in the market. This effect has been so significant that some observers have charged that the government has discouraged private corporate participation in food grain markets (Chand 2003). However, because government operations are confined to so few food grain surplus states, there is tremendous opportunity for the corporate sector to participate in food grain trade.

With the demand side of the Indian food economy developing rapidly, a number of initiatives have been enacted recently to attract corporate investment in agricultural marketing. An act prohibiting direct purchase of produce from farmers by traders was relaxed, and model legislation was prepared in 2003 to allow participation of the corporate sector. Since then, most states have adopted this legislation, and some private firms are directly procuring produce from farmers. Some firms have established terminal markets,[4] mainly for high-value commodities like fruits and vegetables, while others are procuring produce from farmers through dissemination of market information using informational technology (for example, the e-Choupal program of ITC Limited). Another related development has been the practice of contract farming, in which a processing or agricultural company enters into a contract with farmers to purchase produce at a pre-agreed price. The company also provides crop information, inputs on credit, and other support for better yields and produce quality. Although there have been some instances of both companies and farmers failing to comply with contracts, the arrangements have worked well, especially for high-value commodities (Joshi, Gulati, and Cummings 2007).

In addition to these major policy changes, several other market reforms initiated by the government have improved the discovery and stability of agricultural prices. These reforms relate to relaxation of control over movement and storage of food grains and of futures markets, attracting investment in market infrastructure and agro-processing, and liberalization of trade. Although the impact of these reforms will not be clear for some time, all signs point to improvement in incentives for farmers. The domestic terms of trade (i.e., farm output to input prices) did not favor agriculture during the 1980s but started to improve in the early 1990s. Also,

[4]These are professionally managed enterprises that provide complete market services to farmers at their door step and operate in hub-and-spoke format.

domestic agricultural commodity prices have remained much more stable than international prices, which have shown a high degree of volatility. A stable price environment and better incentives will encourage farmers to invest in productivity-enhancing inputs and practices and thereby contribute to agricultural growth.

5. FUTURE CHALLENGES AND STRATEGY

Notwithstanding the impressive performance of Indian agriculture in the past, there are a number of challenges which, if not addressed, in time may hold back not only the agricultural sector but also the entire Indian economy. We have seen this in the recent past when impressive economic growth but moderate agricultural growth puts upward pressure on food prices and exacerbates rural-urban income disparities. The first and foremost challenge is to attain and sustain a target growth of 4% per year in agricultural output as envisaged by the Planning Commission. This growth should be inclusive and geographically widespread in terms of participation of smallholders and those in marginal production environments. Most of this growth will be realized through higher productivity through the application of modern technology. However, participation of smallholders will also entail institutional innovations to enable aggregation of their production and to link them with markets.

The second most important challenge is to address the vulnerability of Indian agricultural production. Currently, two-thirds of agricultural lands are rain-fed and subject to the vagaries of weather and other vulnerabilities. This vulnerability is further accentuated by the degradation and depletion of natural resources, which are also seen in irrigated production environments (NAAS 2009). A two-pronged strategy is needed. First, the severity and long-term implications of these challenges are not well understood by farmers. Therefore, a national program should be created to educate farmers about long-term sustainability issues. Second, farmers should be empowered with the appropriate technologies to address sustainability and vulnerability concerns. This should be backed with policy interventions to manage risk and strengthen social safety nets.

Climate change is a recent challenge, and its likely impacts are becoming better understood and local responses are evolving. Responses include a continued partnership with the international community to assess the challenge as the events unfold and further work on adaptation and mitigation strategies consistent with local realities. A considerable amount of resources will be needed for technological solutions and their adaptation by farmers and other stakeholders.

Finally, development of human capital is the key to innovation and acceleration of agricultural growth. The government should invest more in building this capacity within various government departments, development agencies, and with farmers. Efforts to accelerate the flow of technologies to farmers and improve their skills and ability to innovate will go a long way toward strengthening the long-term productive capacity of Indian agriculture. But this requires the mobilization of resources in the public and private sector, ensuring the participation of farmers, and encouraging technology-led solutions.

6. CONCLUSION

Despite the impressive performance of Indian agriculture during the period of the green revolution supported by significant public investments and associated institutional developments, agriculture has failed to meet its growth target over the last decade. However, if we exclude some years of abnormally adverse weather (specifically the years 2002-03 and 2004-05), an adjusted annual growth rate of more than 3% per year was sustained over the period 1997-98 to 2008-09. This is a notable achievement, especially considering India's severe resource and production environment constraints. The trend toward commercialization and diversification of agriculture is increasing, and most of the growth in output in recent years was realized through productivity growth. Given the increasing demand for high-value commodities, as well as the need to produce more food grains to feed a still growing population, the goals of food security and diversification for high-value agriculture should be pursued through technological interventions. An increase in the productivity of food grains would enable land to be used to grow high-value crops like fruits and vegetables without compromising domestic food production. Continued government support for agricultural R&D and higher public investment in infrastructure are welcome steps in increasing productivity. Encouraging business interests in food and agriculture and fostering institutional innovations to improve smallholders' access to technology are current policy thrusts. A supportive policy environment with well-structured incentives can be a major driving force to promote innovation in agriculture, and lessons from any localized successes in this regard also need to be well understood and replicated. Enhanced efforts to sustain India's natural resources, provide productive infrastructure through better technological and institutional solutions, and develop human capital capacity will help accelerate the country's agricultural growth.

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