Chapter 7

Investment in developing countries' food and agriculture: assessing agricultural capital stocks and their impact on productivity

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Between 1975 and 2005, global dietary energy supplies grew faster than the world population, which itself more than doubled. At the global average, food availability per person increased from 2 400 to nearly 2 800 kcal per day over those 30 years. In the developing countries the increase was even steeper, from 2 200 to 2 600 kcal per person per day. This was a remarkable achievement for the global food and agriculture system, and resulted from significant investment and technical progress. As a result, the share of the world's population with adequate access to food grew markedly. Most of the increases in consumption in developing countries were met by their domestic production, but food imports also expanded strongly.

Unfortunately, the growth in global per capita food supplies was not accompanied by a reduction in the number of undernourished people. Although the prevalence of undernourishment in developing countries declined from 20 to 16 percent between 1990/1992 and 2003/2005, the absolute number of undernourished individuals increased from 840 million to nearly 850 million. According to preliminary estimates by FAO, the high food prices in 2007 and 2008 may have driven this number up by a further 100 million. This rising trend could continue, as a result of the global financial crisis.

As has been confirmed by research results and numerous high-level intergovernmental bodies, there is no lack of knowledge about how to increase progress towards the reduction of hunger and poverty (World Bank, 2008). Rapid progress in cutting the incidence of chronic hunger in developing countries is possible if political will is mobilized. Nearly three-quarters of the poor in developing countries live in rural areas. They depend on agriculture for their earnings, either directly or indirectly. According to FAO (2003), a twin-track approach is required, combining the promotion of quick-response agricultural growth led by small farmers, with targeted programmes to ensure that the neediest people, who have neither the capacity to produce their own food nor the means to buy it, have access to adequate supplies. The two tracks are mutually reinforcing, as programmes to enhance direct and immediate access to food offer new outlets for expanded production.

Countries that have followed this approach have been comparatively successful in reducing the prevalence of undernourishment and achieving rapid and sustainable economic growth. A common feature of countries that have been successful in reducing hunger and poverty is that they have had higher overall rates of economic growth than the less successful countries, which they have achieved through a relatively higher growth in agriculture. These successful countries have also typically shared some other common features: absence of conflict, good governance, functioning markets, public investment in rural infrastructure, and greater integration into world markets. Such success stories can be found in all regions (FAO, 2008).

The vital role of income-earning opportunities in the rural areas of developing countries for success in improving the living conditions of the majority of the poor and hungry highlights the importance of investments in agriculture and rural development. In the World Food Summit Plan of Action of 1996, the members of FAO expressed their commitment: "to promote optimal allocation and use of public and private investments to foster human resources, sustainable food, agriculture, fisheries and forestry systems, and rural development, in high and low potential areas" (FAO, 1996: Preamble). According to the plan, many developing countries needed:

…to reverse the recent neglect of investment in agriculture and rural development and mobilize sufficient investment resources to support sustainable food security and diversified rural development. A sound policy environment, in which such food-related investment can fulfil its potential, is essential. Most of the resources required for investment will be generated from domestic private and public sources. Governments should provide an economic and legal framework which promotes efficient markets that encourage private sector mobilization of savings, investment and capital formation. They should also devote an appropriate proportion of their expenditure to investments which enhance sustainable food security. (FAO, 1996: Commitment Six)

Five years after the World Food Summit, FAO (2002) presented estimates of agricultural investments and capital stocks in developing countries since 1975, and concluded that additional resources for promoting agricultural growth are especially needed in countries where undernourishment is most prevalent. Many of the problems recognized in 2002 are still not resolved today. In addition, the pressures on world agriculture resulting from population growth, urbanization and growing demand for diversity, food quality and safety have grown, while new challenges have been added: climate change and variability, financial crisis, reduced availability of national and international finance, reduced public stockholding, fluctuating energy prices, and uncertain prospects for trade policy reforms.

Using various analytical tools, this chapter presents an update of earlier capital stock and investment estimates. It seeks to contribute information for assessing the extent to which developing countries have followed up on the commitments made more than a decade ago, and whether they are on track to achieve food security in the future. The following section provides an overview of possible approaches to measuring investment and agricultural capital stock (ACS). This is followed by a section that presents and discusses the results of the estimates made. In the next section, the capital stock estimates are used to produce new estimates of total factor productivity (TFP) changes in agriculture in different regions of the world, contrasting these with earlier TFP estimates. This section also explores the role that public expenditure on agriculture plays in encouraging both ACS and TFP growth. The final section closes the chapter with a summary and outlook.

Approaches to measuring investment and agricultural capital stock

Comprehensive analysis of the ACS and investment needs in agriculture requires data on fixed and human capital on farm, data on fixed capital in infrastructure, research and technology dissemination, and data on the industries up- and downstream from agriculture (input supply and agricultural processing) that have significant impacts on agricultural production. In addition to changes in physical and human capital, changes in natural capital can also have major effects on agricultural performance. Sustainable land-use practices such as conservation farming and integrated plant nutrition systems have contributed to considerable success in soil fertility management in many countries.

These are demanding requirements, which no existing source or compilation of data comes close to satisfying. Even if comprehensive data on all the components of ACS were readily available for all countries, or at least for a representative sample, difficult issues of allocation/attribution would remain. For example, machinery might be used for farm and non-farm purposes (e.g., transportation); apparently unrelated upstream investments in flood and erosion control can have far-reaching impacts on farming downstream; and investments in telecommunications infrastructure can have an important influence on market efficiency, production and welfare (Jensen, 2007). Measuring ACS necessarily involves finding a compromise between comprehensive coverage of countries/geographic entities over time – which is possible only for a relatively narrow definition of ACS – and comprehensive coverage of the relevant components of ACS, which involves exhaustive work on a country-by-country basis.

To date, two main approaches to measuring ACS and investments in agriculture have been employed: one based on national accounts, which captures a relatively broad set of ACS components, but only for a relatively narrow set of countries; and the other based on physical inventories contained in the FAOSTAT database, which are available for essentially all countries over several decades, but which cover only a relatively narrow set of fixed assets in farming. Both approaches are employed in this chapter. The following subsections first review earlier estimates of investment in developing country agriculture, before describing these two approaches and their strengths and weaknesses.

Earlier estimates of investment in developing country agriculture

Various attempts have been made to take stock of ACS formation in developing countries. FAO's last estimates of fixed capital in primary agriculture (FAO, 2002) covered the period 1975 to 1999 and revealed significant differences among countries. Specifically, the regions with the lowest prevalence of chronic undernourishment, particularly Latin America and the Near East and North Africa, were found to have a much higher ACS per agricultural worker ratio than the other developing regions. Not only was the level of capital intensity highest in regions with low prevalence of hunger, but these same regions had also realized a significant increase in the ACS-to-labour ratio, whereas other developing regions displayed stagnating or, in the case of sub-Saharan Africa, even declining capital intensities.

The same FAO publication also presented calculations of average labour productivity, measured as agricultural value added per agricultural worker. Not surprisingly, countries with low capital intensity in agriculture showed low productivity per agricultural worker. The divergence of gross domestic product (GDP) per agricultural worker in country groups of different capital-to-labour ratios, and hence of different rates of hunger prevalence, seemed to be very large and widening over time. Throughout the 1990s, the value added per worker in the group of countries with less than 2.5 percent of their populations' undernourished was about 20 times higher than that in the group with more than 35 percent undernourished.

Although equally relevant for the performance of the food and agriculture sector, capital formation in upstream and downstream sectors and in rural infrastructure has been far less frequently and completely documented. According to a tentative estimate published by FAO at the time of the World Food Summit in 1996, annual gross investments in primary agriculture of developing countries amounted to approximately USD 77 billion during the preceding ten to 15 years (with net investments of USD 26 billion). Over the same period, annual gross investments in post-harvest activities amounted to USD 34 billion, and public gross investments in rural infrastructure, agricultural research and extension to USD 29 billion. According to these estimates, therefore, capital formation in up- and downstream sectors and in rural infrastructure added up to almost the same total as investments in primary agriculture. By far the largest share of this off-farm investment (60 percent) took place in Asia during this period, while Latin America and the Caribbean accounted for 20 percent, and the Near East and North Africa and sub-Saharan Africa for 10 percent each. Unfortunately, the estimates published at that time did not allow a breakdown by country, nor have they been regularly updated. However, available evidence from various research projects shows that rural infrastructure is inadequate in many low-income countries, particularly in much of sub-Saharan Africa.

While changes in natural agricultural capital cannot be inferred at the global level, progress has been made towards including the cost of natural capital depletion in national accounts. Based on these efforts, the World Bank (2005a) estimated the value of natural resources, and concluded that in low-income countries, excluding the oil states, the share of natural capital in total wealth is greater than the share of produced capital. To account for the value of depletion of this natural capital, so-called adjusted net national savings were calculated as indicators of the real growth potential of a country. The results show that "net savings per person are negative in the world's most impoverished countries, particularly in sub-Saharan Africa" (World Bank, 2005a). Depletion of soil quality is found to be a major loss in this context. It is alarming that this trend is identified in precisely those countries where agricultural development matters most for poverty and hunger reduction.

Estimating the agricultural capital stock from national accounts data

Crego *et al.* (1998) first used information on gross fixed capital formation in national accounts to generate ACS estimates for 57 countries between 1967 and 1992. This chapter draws on an expanded version of their database, produced by Anriquez and Daidone (2008), which contains more than 100 countries, of which only 76 have agricultural gross fixed capital formation series long enough to allow reasonable estimates of physical capital stocks. This expanded database has been updated to cover the period up to 2002. As in Crego *et al.* (1998), data are not available in all years for all countries, but inter- and extrapolation enable a balanced panel from 1967 to 2003 to be generated for all 76 countries. Exceptions are the transition countries of Central and Eastern Europe, for which the series begin in 1990.

The data set was generated based on the assumption that agricultural capital is composed of three components: i) physical capital; ii) livestock; and iii) tree stocks, which represent the value of planted permanent crops. The physical capital series was constructed using time series of gross fixed capital formation in agriculture as published in national accounts statistics and, in a few instances, using case studies attempting to calculate these same series. The method used to estimate physical capital stocks is a variation of the perpetual inventory method, which estimates current capital stocks by adding suitably depreciated investments from previous periods. Because capital stocks depreciate, only a finite history of investments in previous periods has to be considered to determine current capital stocks.

This study assumes a hyperbolic depreciation function (details in Crego *et al.*, 1998) and that the lifetime of each investment is normally distributed with a mean of 20 years and a standard error of eight years. This means that with 95 percent probability, each agricultural investment has a service lifetime of between four and 36 years. When applying this methodology, a long time series on gross investment is required. Where such a series was not available, previous gross investment levels were predicted (back-casted), using both agricultural value added (either available or predicted using simple log trend) and the observed gross investment-to-agricultural value added ratio. All national capital stock series were estimated in constant national currency, and converted to current United States dollars using national deflators (to convert to series in current local currency) and current exchange rates. The final comparable series in 1995 dollars were created by deflating the current dollars series using the United States agricultural value added deflator.

The value of livestock was calculated using the stock numbers reported by FAOSTAT for different types of animal. Heads of livestock were valued using United States dollar prices, which were estimated as regional weighted (by quantity) averages of implicit unit export prices, also obtained from FAOSTAT. Current dollar series were converted to constant 1995 dollars by deflating with the United States agricultural GDP deflator.

Tree stocks were valued as the present value of discounted future net revenues. First, net revenues were assumed to equal 80 percent of gross revenues, which were themselves calculated per permanent crop as the product of yield and price. Yields were calculated using area and total output data from FAOSTAT, while prices were five-year moving averages of actual producer prices reported by FAOSTAT for each country. Two simplifying assumptions were made: first, that all permanent crops were at half of their productive life spans; and second, that the life span of all permanent crops was 26 years. Future revenues were discounted using a "real" rate of return defined as the difference between the yields of ten ten-year United States bonds and the inflation of the United States GDP deflator for each period. The value of tree stocks was converted to real 1995 dollars first by converting the series to current dollars using the period's exchange rate, and then by deflating this series with the United States agricultural GDP deflator.

Estimating the agricultural capital stock using physical inventories in FAOSTAT

For many countries, national accounts data on gross fixed capital formation in agriculture are not available. As an alternative, in 1995, the FAO Statistics Division first compiled estimates of ACS based on the physical stocks of various types of agricultural asset. For each asset, physical stocks were multiplied by a constant base year unit price to produce a series of asset values over time. These values were subsequently aggregated over all assets to produce an estimate of total ACS at constant prices.

Estimates of ACS based on this method were first prepared at the regional level in 1995, as part of the World Agriculture Towards 2010 exercise (Alexandratos, 1995). These estimates were for the period 1975 to 1995 and used 1990 United States dollar prices. They were subsequently updated in 2001 for the period 1975 to 1999, using a broader set of assets and 1995 dollar prices, and covering individual developing countries rather than only regional aggregates (FAO, 2002). These are the estimates of ACS referred to in the subsection on earlier estimates. A further update to include the years to 2002 was prepared by Barre in 2006 (FAO, 2006).

For this chapter, the 1975 to 1999 estimates produced in 2001 were updated and extended to 2007.[1] The assets covered fall into four categories, as outlined in Table 7.1, and are available for 223 countries and geographic entities.[2] To convert physical inventories into asset values, the 1995 unit asset prices compiled by FAO (2002) were used. These were drawn from a number of sources, including country investment project reports prepared by and for FAO, FAOSTAT data on purchase prices of means of production such as tractors, and unit trade values. Details on

1. For some assets, FAOSTAT data were available only until 2005 or 2006. In these cases, the remaining years to 2007 were extrapolated.

2. The number of countries changes over time, for example, owing to the break-up of the Soviet Union. FAOSTAT data include entities such as Gaza and Greenland, which are not independent countries.

these unit prices and other aspects of the estimation are given in FAO, 2001b. Key issues include the following:

- No data on physical stocks of hand tools were available, so the stock of these tools was estimated by multiplying the number of individuals active in agriculture in each country and year by a uniform estimate of USD 25-worth of hand tools.
- Unit land prices were estimated as the incremental values of development to make land suitable for crop production, plant it to permanent crops, or provide it with irrigation services.
- No data on physical stocks of structures were available, so these were estimated as a function of the number of animals/poultry in each country and year.

Table 7.1
Agricultural assets covered in the FAOSTAT measure of ACS

Land development	*Livestock*	*Machinery*	*Structures*
Arable land	Cattle	Tractors	For animals
Permanent crops	Buffaloes	Harvesters	For poultry
Irrigation	Sheep	Milking machines	
	Goats	Hand tools	
	Pigs		
	Horses		
	Camels		
	Mules and donkeys		
	Poultry		

Source: FAOSTAT.

Strengths and weaknesses of the national accounts and FAOSTAT approaches

National accounts-based estimates of ACS have the important advantage of providing a considerably broader coverage of fixed capital in agriculture than the estimates based on FAOSTAT physical inventories do. The use of the permanent inventory method coupled with consistent national accounts data on investments also provides theoretically much sounder estimates of the value of ACS in each year than the FAOSTAT approach does. The use of constant prices in the FAOSTAT approach means that it essentially produces a volume index that does not account for the age of assets or for quality improvements in assets over time (e.g., the average tractor made in 2005 can do more than the average tractor made in 1975, and there have been genetic improvements in livestock over the same period).

The main disadvantage of the national accounts-based estimates is that they are only available for some countries. As might be expected, Organisation for Economic Co-operation and Development (OECD) and other industrialized countries are well represented in the national accounts database, but this is not the case for developing countries (Table 7.2). For example, China is not included in the national accounts estimates, and only ten countries in sub-Saharan Africa are, compared with 51 in the FAOSTAT physical inventory estimates.

Table 7.2
Numbers of countries/geographic entities in the national accounts and FAOSTAT physical inventory databases

	Number of countries covered	
Region	National accounts estimates	FAOSTAT estimates
East Asia and Pacific	4	42
Europe and Central Asia	6	25
Latin America and Caribbean	15	45
Near East and North Africa	7	22
South Asia	3	7
Sub-Saharan Africa	10	51
High-income OECD	24	24
High-income non-OECD	6	7
Total	75	223

Source: FAOSTAT.

This would not be of major concern if the national accounts database included a representative sample of all developing countries. However, there are indications that this is not the case. As demonstrated in the following section, there appears to be some selection bias in the sample of countries covered by the national accounts approach; countries that are able to provide the required national accounts data appear to perform better on average in terms of investment in ACS. Hence, analysis based exclusively on the national accounts method might paint an overly positive picture of ACS levels and investments over time.

Results: development of the agricultural capital stock since 1975

In the following subsections, estimates of ACS and its growth are presented for various groups and sub-groups of countries. In most cases, the FAOSTAT physical inventories estimates are presented, because the generation of consistent aggregates over time is possible only with these estimates.

Development of the agricultural capital stock by region

Figure 7.1 displays the development of total ACS between 1975 and 2007, worldwide and broken down into developed and developing countries. The worldwide rate of ACS growth (net investment in ACS) slowed around 1990; calculations confirm that the average annual rate of worldwide ACS growth fell from 1.1 percent between 1975 and 1990 to 0.5 percent between 1991 and 2007 (Table 7.3). This slowdown was caused primarily by stagnating and then falling levels of ACS in developed countries, although rates of ACS growth also fell in developing countries over time. However, rates of ACS growth did not become negative in developing countries, as they did for developed countries after 1990.

Table 7.3
Average annual rates of ACS growth before and after 1990 (percentages)

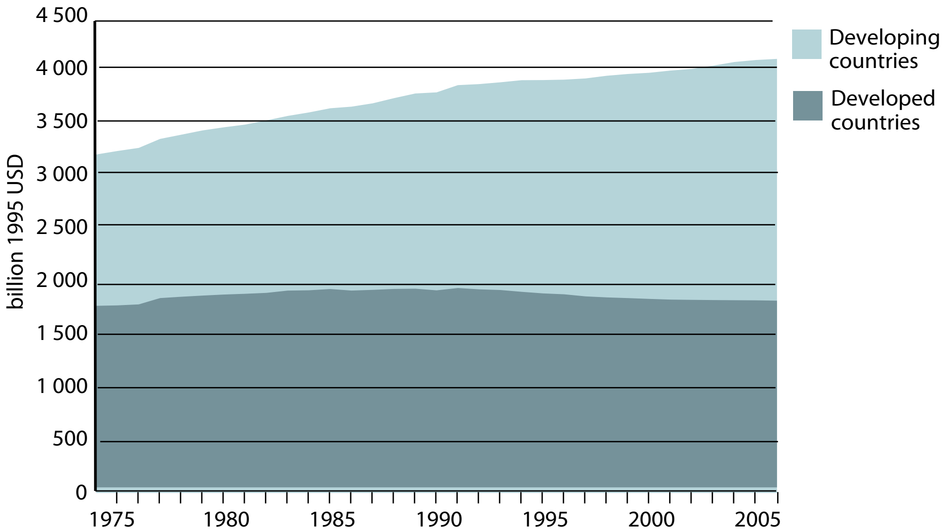
	1975-1990	1991-2007
World	1.11	0.50
Developed countries	0.60	-0.34
Developing countries	1.66	1.23

Source: Authors' calculations.

Further disaggregating these average annual growth rates reveals several interesting patterns. First, the reduction in the rate of ACS accumulation was sharpest in the second half of the 1990s, with ACS growth becoming strongly negative in developed countries and falling notably in developing countries (Figure 7.2). Since the beginning of the 2000s, the worldwide rate of ACS growth has increased again (from 0.32 to 0.52 percent per year), as the rate of ACS shrinkage in developed countries has slowed. At the same time, rates of ACS growth in developing countries have remained positive, but continued to fall. Hence, the gap between rates of ACS growth in developing and developed countries has closed from a high of slightly more than 2 percent (1.27 versus -0.76 percent) in 1995/1999 to slightly more than 1 percent (1.01 versus -0.11 percent) in 2005/2007.

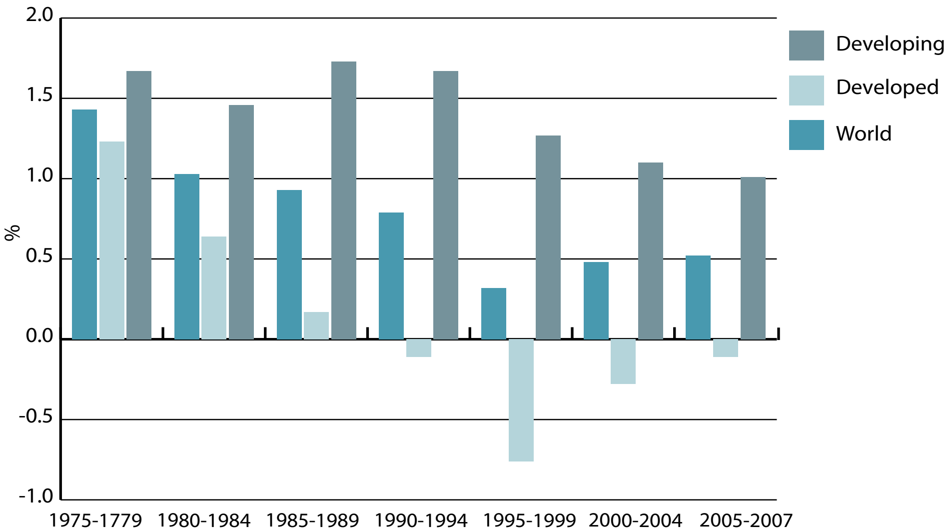
The rapid reduction in rates of ACS growth in developed countries over the 1980s and 1990s was driven by episodes of significant disinvestment in different regions. In the 1980s, North America saw negative rates of ACS growth, and in the 1990s rates of ACS growth in Western Europe became negative, presumably in part owing to the effect of the 1993 so-called MacSharry reforms of the European Union's (EU's) Common Agricultural Policy. In the second half of the 1990s and into the 2000s, ACS in the transition economies of Central and Eastern Europe

Figure 7.1
Development of ACS



Sources: Authors' calculations with FAOSTAT physical inventories estimates.

Figure 7.2
Average annual ACS growth rates in developed and developing countries



Sources: Authors' calculations with FAOSTAT physical inventories estimates.

shrank especially dramatically.[3] In developing countries, rates of ACS growth have been consistently positive across regions and sub-periods, with South Asia recording a sustained reduction in growth rate since the early 1990s.

Table 7.4
Average annual rates of ACS growth (percentages)

Region	1975/ 1979	1980/ 1984	1985/ 1989	1990/ 1994	1995/ 1999	2000/ 2004	2005/ 2007	1975/ 2007
World	1.43	1.03	0.93	0.79	0.32	0.48	0.52	0.78
Developed	1.23	0.64	0.17	-0.11	-0.76	-0.28	-0.11	0.09
North America	1.00	-0.16	-0.23	0.05	0.14	-0.12	0.02	0.08
Western Europe	0.93	0.74	0.06	-0.50	-0.27	-0.14	-0.10	0.09
Oceania	-0.84	0.24	0.51	-0.17	-0.54	0.49	0.42	0.02
Transition	2.03	1.55	0.62	0.07	-2.77	-0.71	-0.31	0.02
Developing	1.67	1.46	1.73	1.67	1.27	1.10	1.01	1.43
Latin America and Caribbean	2.15	1.40	1.76	1.40	0.39	1.16	0.22	1.24
Near East and North Africa	0.93	1.76	1.99	1.87	0.71	0.93	0.99	1.34
Sub-Saharan Africa	1.68	1.42	1.23	1.86	1.65	1.64	0.96	1.52
East and Southeast Asia	1.75	1.37	2.04	1.80	1.86	1.35	1.73	1.70
South Asia	1.61	1.49	1.19	1.42	1.22	0.34	0.32	1.11

Source: Authors' calculations.

Table 7.5
Average annual rates of ACS growth per worker in agriculture, developing country regions

	1975-2007 annual rate of growth *(%)*		
Region	ACS	Population active in agriculture	ACS/person active in agriculture
Latin America and Caribbean	1.24	-0.08	1.33
Near East and North Africa	1.34	0.83	0.51
Sub-Saharan Africa	1.52	1.97	-0.44
East and Southeast Asia	1.70	0.97	0.72
South Asia	1.11	1.38	-0.26

Source: Authors' calculations.

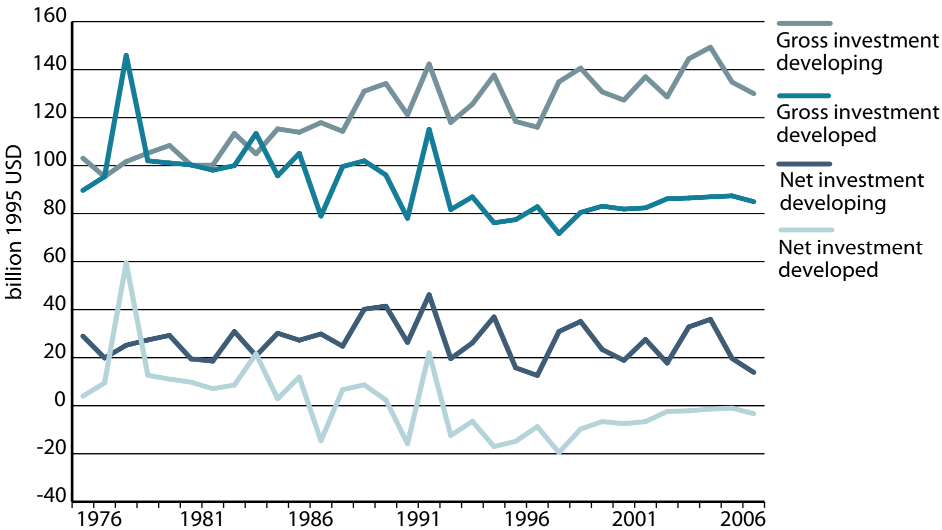
The consistently positive rates of ACS growth in developing country regions in Table 7.4 mask important changes in the availability of ACS per worker. In sub-Saharan Africa and South Asia, the growth of the population active in agriculture

3. The drop in the rate of ACS accumulation in developed countries is also at least partly due to improvements in input quality, which the FAOSTAT-based estimates do not pick up. See subsection on Comparing the national accounts and FAOSTAT approaches.

has outstripped the rate of ACS growth, leading to average annual reductions in ACS per agricultural worker of 0.44 percent per year in sub-Saharan Africa and 0.26 percent per year in South Asia, from 1975 to 2007 (Table 7.5). In the Near East and North Africa and in East and Southeast Asia, population growth has eroded but not completely outweighed growth in ACS. In Latin America and the Caribbean, the population active in agriculture has fallen at an average of almost 0.1 percent per year since 1975, contributing to an overall increase in ACS per agricultural worker over this period.

Figure 7.3 presents information on gross and net investments in ACS for developing and developed countries. Net investment is calculated as the simple difference between ACS in year t + 1 and year t. Gross investment is calculated assuming that in addition to net investment, 5 percent of the ACS in year t depreciated and was replaced.

Figure 7.3
Gross and net investments in ACS, developing and developed countries

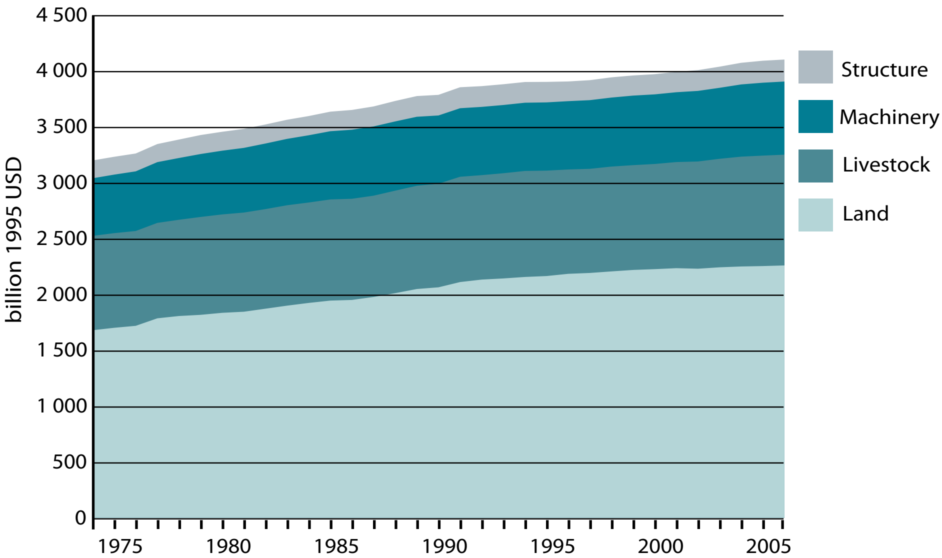


Source: Authors' calculations with FAOSTAT physical inventories estimates.

Components of agricultural capital stock

Of the four categories of agricultural capital in the FAOSTAT physical inventories estimates, land is clearly the most important, with a value share that is consistently between 52 and 55 percent of total ACS (Figure 7.4). Livestock comes next, with a share of 24 to 26 percent, followed by machinery, with 16 to 17 percent, and structures, with 5 percent.

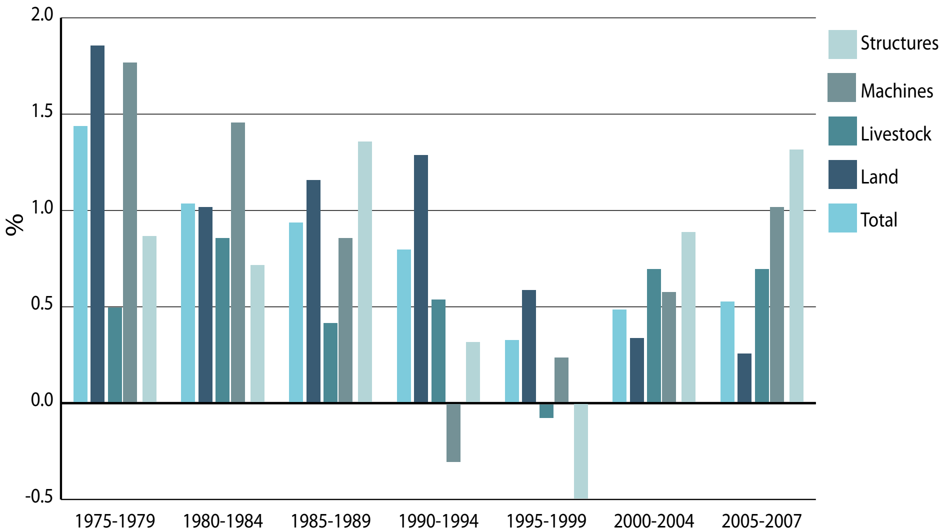
Figure 7.4
Composition of global ACS



Source: Authors' calculations with FAOSTAT physical inventories estimates.

All four components of ACS increased between 1975 and 2007. Expressed in average annual rates of growth, the land component increased by 0.93 percent per annum over this period, while livestock increased by 0.50 percent, machinery by 0.75 percent, and structures by 0.66 percent. However, the individual components evolved differently over time. The rates of growth in the livestock, machinery and structures components of ACS fell during the 1980s, reaching low negative rates in the first (machinery) or second (livestock, structures) half of the 1990s (Figure 7.5). Since 2000, these components have again displayed positive rates of growth. Land has followed a different pattern. Average annual rates of growth in land stock were never negative between 1975 and 2007 (Figure 7.5). However, they declined steadily over the entire period, and have not recovered since 2000. As the land component of ACS measures the value of land improvements (investments in permanent crops, irrigation and arable land) this sustained slowdown in land growth is not necessarily due to increased scarcity of agricultural land alone. It can also reflect a reduction in the willingness to invest in improving the productivity of land.

Figure 7.5
Average annual rates of growth in global ACS components



Source: Own calculations with FAOSTAT physical inventories estimates.

Agricultural capital stock and the prevalence and depth of hunger

The fact that population growth has outstripped ACS growth in sub-Saharan Africa and South Asia is cause for concern, because many countries with severe hunger problems are located in these regions. To cast more light on this issue, the study explored the relationship between ACS growth and the prevalence and depth of hunger as defined by FAO (2008). Hunger prevalence is defined according to the proportion of the population that is undernourished, and the depth of hunger according to the gap between actual calorie consumption by the undernourished and minimum dietary energy requirements (MDERs).

The estimates in Tables 7.6 and 7.7 indicate that the ACS per person active in agriculture has grown least in those countries with the highest prevalence and depth of hunger. In the countries in hunger prevalence categories 4 and 5 (more than 20 percent undernourished), growth in ACS has been outstripped by population growth, resulting in a reduction in the ACS per person active in agriculture. The same is true of countries in depth of hunger category 4 (where the average undernourished individual consumes less than 88 percent of his/her MDER). In both tables, China is listed separately because it would obscure the other countries in its hunger prevalence and depth of hunger categories.

Table 7.6
Average annual rates of growth in ACS per worker in agriculture, developing countries, by hunger prevalence category

	1975–2007 annual rate of growth *(%)*		
Hunger prevalence category	ACS	Population active in agriculture	ACS/person active in agriculture
1 < 5% undernourished	1.21	0.27	0.93
2 5–9% undernourished	1.88	-0.11	2.00
3 10–19% undernourished	1.83	1.55	0.28
4 20–35% undernourished	1.22	1.48	-0.25
5 > 35% undernourished	1.29	2.16	-0.85
China 9% undernourished	1.71	0.96	0.74

Hunger prevalence categories based on 2003/2005 data from FAO, 2008.

Source: Authors' calculations.

Table 7.7
Average annual rates of growth in ACS per worker in agriculture, developing countries, by depth of hunger category

	1975–2007 annual rate of growth *(%)*		
Depth of hunger category	ACS	Population active in agriculture	ACS/person active in agriculture
1 gap < 7% of MDER	0.73	-1.98	2.76
2 gap 7–9% of MDER	1.53	0.83	0.69
3 gap 10–12% of MDER	1.53	0.94	0.59
4 gap >12% of MDER	1.47	1.77	-0.30
China gap 12.6% of MDER	1.71	0.96	0.74

Depth of hunger categories based on 2003/2005 data from FAO, 2008.

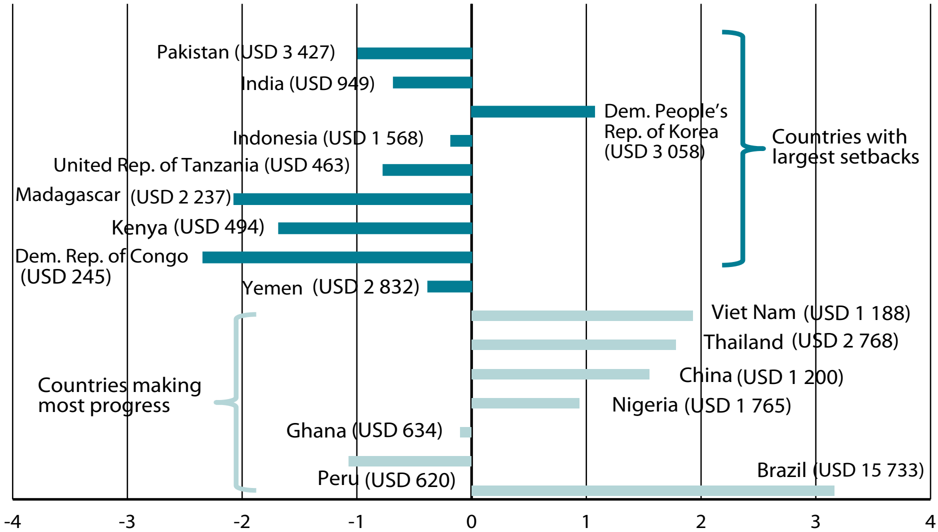
Source: Authors' calculations.

Agricultural capital stock in countries with success in hunger reduction

If countries with high prevalence and depth of hunger are characterized by lower levels of investment in ACS, is there also evidence that countries that have been successful in reducing hunger are characterized by higher investments? Figure 7.6 presents information on annual rates of ACS growth between 1990 and 2005 for the developing countries that FAO (2008: 16) identifies as having made the most progress or having experienced the largest setbacks in achieving the 1996 World Food Summit target of halving the number of hungry people by 2015. With the exception of the Democratic People's Republic of Korea, all the developing countries that suffered notable setbacks had negative rates of ACS growth between

1990 and 2005, and with the exception of Peru (and slight exception of Ghana), all countries that made notable progress had positive rates of ACS growth.

Figure 7.6
Annual rates of ACS growth in countries making the most progress or suffering the largest setbacks towards the 1996 World Food Summit targets



The 2005 ACS per worker is given in parentheses.

Sources: Authors' calculations with FAOSTAT physical inventories estimates; FAO, 2008.

The relatively high rate of ACS growth recorded for the Democratic People's Republic of Korea must be interpreted with caution because it is difficult to confirm official statistics in this country; Peru's progress towards the World Food Summit target, despite negative ACS growth, may be due to the resolution of internal conflicts and unrest during the 1990s. Note that according to the national accounts-based ACS estimates, Peru is one of the better-performing countries, with positive accumulation of ACS per worker for the same period. Ghana has made good progress towards the World Food Summit target and is on track for Millennium Development Goal (MDG) 1, but has witnessed slightly negative ACS growth. This suggests that the determinants of success have been outside the farm sector. A recent OECD study (Dewbre and De Battisti, 2008) concludes that Ghana's success in poverty reduction may have less to do with on-farm investments than with public investments in research, technology and infrastructure, leading to strong growth and income diversification in the rural non-farm economy.

Comparing the national accounts and FAOSTAT approaches

The results discussed so far have been drawn from the FAOSTAT physical inventories estimates of ACS. As these estimates cover essentially all countries, they lend themselves to calculation of the regional and global aggregates presented in previous subsections. However, these estimates suffer from methodological weaknesses. A comparison with estimates of ACS based on the national accounts method can cast some light on the robustness of the FAOSTAT estimates and the advantages and disadvantages of the two approaches.

Both the national accounts and FAOSTAT estimates cover almost the same set of developed countries (30 in the national accounts estimates, 31 in the FAOSTAT estimates; Table 7.2). Hence, an almost direct comparison of levels and changes is possible for these countries. Although the focus of this chapter is developing countries, the study began by comparing the national accounts and FAOSTAT estimates for developed countries. This revealed important discrepancies (Figure 7.7). First, the national accounts method produces a higher overall estimate of ACS. This is presumably owing to its more comprehensive coverage of ACS; the gross capital formation data on which the national accounts estimates are based capture investments that are not included in the limited set of assets covered by FAOSTAT.

Second, the national accounts estimates are more volatile than the FAOSTAT ones. This reflects a fundamental difference between the two. FAOSTAT estimates are calculated using a constant set of 1995 prices, while the use of changing prices, deflators and exchange rates in calculation of the national accounts-based estimates means that they capture not only changes in the volume of ACS, but also changes in the valuation. For example, the drop in the national accounts-based ACS estimates in developed countries during the first half of the 1980s (Figure 7.7) is presumably due to the strength of the United States dollar over this period, which reduced the dollar value of the ACS in other developed countries, such as in Europe. Examination of the national accounts-based data set for other regions (not shown) reveals that this drop was even more marked in Latin America, where currencies depreciated heavily against the dollar as a consequence of the debt crisis in the early 1980s; similar evidence of a fall in ACS at this time is also revealed for Asia and, to a lesser extent, Africa. There are no up-to-date numbers on the evolution of ACS in 2008/2009, but the experience of past global debt crises suggests that they can provoke large and protracted dents in the evolution of ACS.

A final discrepancy is that the national accounts estimates for developed countries trend strongly upwards over the entire period since 1975, while the FAOSTAT estimates show only a very slight increase overall, and a sustained downwards trend in the 1990s. This difference is at least partly due to the use of constant prices in the FAOSTAT approach, which means that the FAOSTAT estimates fail to capture increases in the quality of many components of ACS over time. However, Table 7.8 shows that the national accounts estimates do not trend upwards for all regions. Seven of the nine sub-Saharan African countries in the national accounts database, and all three of the South Asian countries display negative ACS trends between 1975 and 2003, while eight of the nine and the same three, respectively, display positive trends in the FAOSTAT database. It appears that the two approaches for estimating ACS produce substantially different results.

Table 7.8
Trends in the development of ACS by region, comparison of the national accounts estimates and FAOSTAT physical inventories estimates

	National accounts estimates			FAOSTAT estimates		
Region	Positive trend	Negative trend	No significant trend	Positive trend	Negative trend	No significant trend
North America (2)	0	2	0	1	1	0
Western Europe (16)	3	8	5	5	8	3
Oceania (2)	2	0	0	0	0	2
Other developed (3)	1	0	2	2	0	1
Transition economies (10)	4	4	2	4	0	6
Latin America and Caribbean (17)	3	9	5	13	2	2
Near East and North Africa (9)	6	2	1	9	0	0
Sub-Saharan Africa (9)	0	7	2	8	0	1
East and Southeast Asia (4)	4	0	0	4	0	0
South Asia (3)	0	3	0	3	0	0
Other developing (1)	1	0	0	1	0	0
Total (76)	39	24	13	50	11	15

The number of countries in the region is given in parentheses.

Sources: Authors' calculations with FAOSTAT physical inventories estimates; Anriquez and Daidone, 2008.

The comparisons in Table 7.8 are based on the 76 countries in the national accounts database. Comparisons for the many, especially developing, countries that are not included in this database are clearly not possible. Given the theoretical advantages of the national accounts approach to measuring ACS, the entire discussion in this chapter could be based on results produced from this method, if it was clear that these results were based on a representative sample of countries. However, this does not appear to be the case. Table 7.9 presents estimates of the ACS per person employed in agriculture for groups of developing countries in different hunger prevalence categories. One set of estimates is based on the national accounts approach and two on the FAOSTAT approach, using first the full sample of countries and second only the countries in the national accounts database. The estimates based on the national accounts approach are uniformly higher than those based on the FAOSTAT physical inventories approach, mirroring the result found for the aggregate of developed countries (Figure 7.7). In addition, the result that the ACS per person employed in agriculture is declining in the countries with the highest prevalence of hunger (Table 7.6) is confirmed with the national accounts-based estimates.

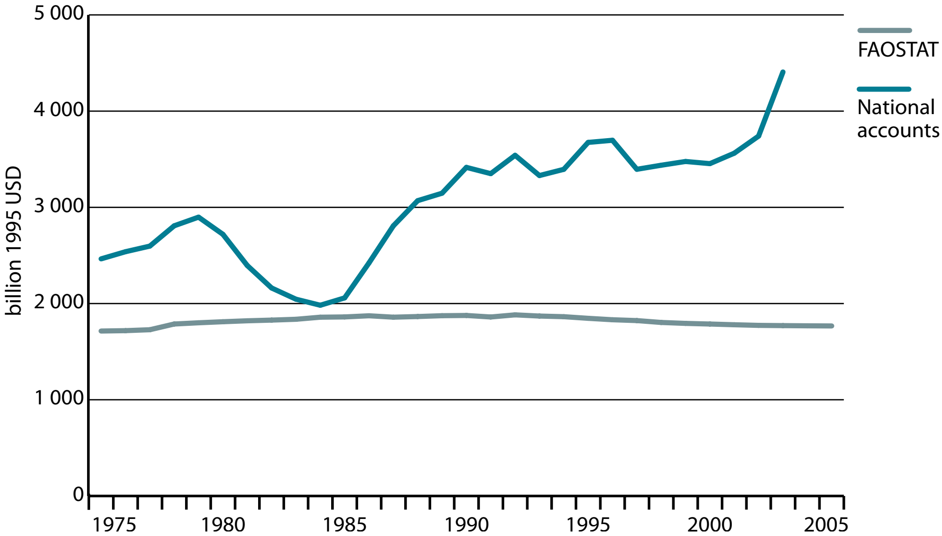
Table 7.9
ACS per person active in agriculture, by hunger prevalence category, comparisons across different approaches and samples of countries

Hunger prevalence category	1975–1979	1980–1984	1985–1990	1991–1994	1995–1999	2000–2003	Countries in sample
	(USD/capita)						*(No.)*
National accounts approach							
2	10 404	8 445	9 053	12 719	15 671	15 404	3
3	16 128	12 897	9 341	8 857	9 492	9 660	11
4	6 833	5 139	3 780	3 476	3 848	3 796	9
5	3 027	2 086	1 613	1 368	1 026	940	3
FAOSTAT physical inventories approach (full sample)							
2	3 660	4 122	4 535	5 104	5 315	5 820	20
3	1 636	1 668	1 675	1 906	2 070	2 076	28
4	1 391	1 389	1 371	1 398	1 397	1 353	24
5	891	880	854	820	773	724	18
FAOSTAT physical inventories approach (same sample as national accounts approach)							
2	3 524	3 860	4 430	5 283	5 863	6 569	3
3	4 192	4 409	4 343	5 084	5 644	5 862	11
4	2 338	2 322	2 246	3 001	3 692	3 888	9
5	1 470	1 493	1 480	1 434	1 355	1 266	3

Sources: Authors' calculations with FAOSTAT physical inventories estimates; Anriquez and Daidone, 2008.

However, the national accounts estimates are based on fewer developing countries than the FAOSTAT results. For example, there are nine countries in hunger prevalence category 4 in the national accounts database, compared with 24 in the FAOSTAT database (Table 9.9). If the FAOSTAT results are recalculated for only those countries that are included in the national accounts database, evidence of selection bias becomes apparent. Specifically, with the exception of hunger prevalence category 2 in the 1970s and 1980s, the FAOSTAT estimates increase, often considerably, when only the restricted sample of countries in the national accounts database is considered. In hunger prevalence category 4, for example, the estimate of the ACS per worker in agriculture is USD 1 353 in the full FAOSTAT sample of 24 countries, but increases to USD 3 888 if only the nine countries included in the national accounts data are considered.

Figure 7.7
Total ACS in developed countries, comparison of national accounts estimates and FAO physical inventories estimates



Sources: Authors' calculations with FAOSTAT physical inventories estimates; Anriquez and Daidone, 2008.

A comparison of the lists of countries in hunger prevalence category 4 included in the two databases confirms that selection bias may be playing a role. In addition to the nine countries in the national accounts database, the FAOSTAT database includes a number of countries (Bangladesh, Cambodia, Cameroon, the Democratic Republic of the Congo and Senegal) that have considerably lower levels of ACS per worker in agriculture (Table 7.10). It could be conjectured that a developing country's level of ACS per worker in agriculture is correlated with its ability to provide the detailed national accounts information required for the calculation of national accounts-based ACS estimates. If this is true, the national accounts method will tend to overestimate ACS levels at the aggregate level of groups of developing countries.

Altogether, the results of the comparisons presented in this subsection are sobering. They reveal important differences between the two sets of estimates. While both approaches point to a reduction in ACS per person employed in agriculture in the countries with the greatest prevalence of hunger, in other respects (e.g., the development of ACS in developed countries) there are large discrepancies. The inescapable conclusion is that too little is known about ACS, despite its obvious importance for efforts to combat hunger.

Table 7.10
Countries in hunger prevalence category 4 in the national accounts and FAOSTAT physical inventories databases

Countries in both databases	*Countries in only the FAOSTAT database*	
Botswana	Bangladesh	Grenada
Dominican Republic	Cambodia	Guinea-Bissau
India	Cameroon	Mongolia
Kenya	Democratic People's Republic of Korea	Nicaragua
Malawi	Democratic Republic of the Congo	Senegal
Niger	Djibouti	Sudan
Pakistan	Gambia	Timor-Leste
Plurinational State of Bolivia		Yemen
Sri Lanka		

Each of the approaches to estimating ACS suffers from important weaknesses that limit its usefulness as a basis for deriving robust conclusions and policy implications. The FAOSTAT-based estimates cover only certain components of ACS. The national accounts-based estimates cover only a (probably non-representative) sample of developing countries. However, each approach also has important advantages. The FAOSTAT approach provides global coverage over a long period; if the assets that it includes are representative of overall ACS, it provides a robust basis for comparisons across countries/regions and time. The national accounts estimates provide additional information on the value, as opposed to only the volume, of ACS.

For the moment, the only option is to work with both sets of estimates, interpreting them carefully. In the future, priority must be given to improving these estimates and resolving the differences between them. A first step would be to update the constant 1995 prices used to generate the FAOSTAT estimates, for example to 2000 and 2005. Efforts should also be made to expand the set of countries included in the national accounts database, with a special emphasis on developing countries characterized by high prevalence and depth of hunger. Producing robust ACS estimates that combine the coverage of the FAOSTAT approach with the greater conceptual consistency of the national accounts approach will require significant commitment of resources, but the effort must be made.

Agricultural capital stock and public expenditure on agriculture

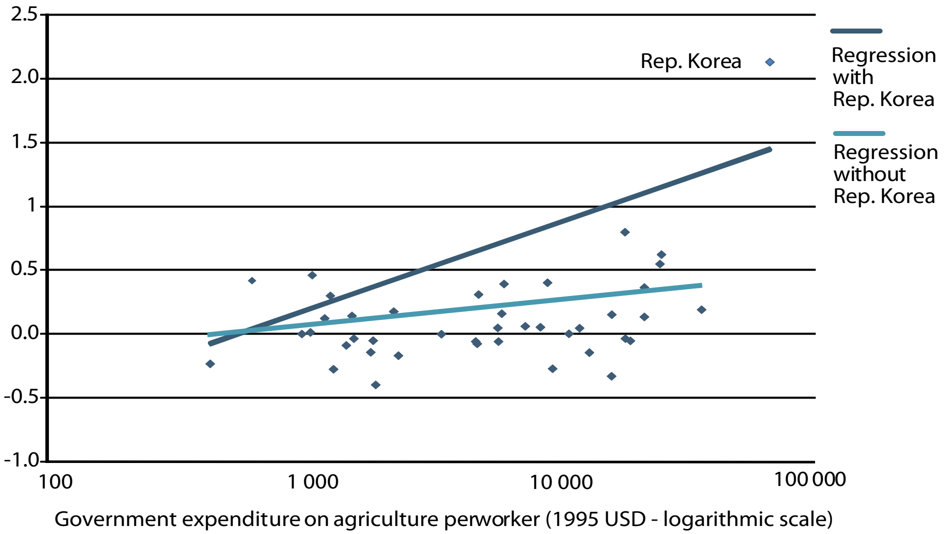
To what extent does public expenditure in agriculture support investment in ACS? Two types of public expenditure are relevant in this regard: national government expenditure, and international expenditure in the form of official development assistance (ODA). Although these types of public expenditure are discussed separately in the following paragraphs, the available statistics do not always distinguish clearly between them, so double counting may occur. It should also be noted that not all the public expenditure that supports the production capacity of the food and agriculture sectors or, more generally, benefits the rural population is included in official agricultural budgets.

National public spending: Several studies have shown that the level of public national spending on agriculture and rural areas has fallen during the 1990s and early 2000s. In its 2001 report, FAO noted "...that in countries with a very high incidence of undernourishment, public expenditure on agriculture does not reflect the importance of the sector in overall income or its potential contribution to the alleviation of undernourishment" (FAO, 2001a). While some of the earlier decline was the result of structural adjustment programmes and has even led to more efficient resource allocation, the main effect of low public expenditure has been inadequate provision of public services, lacking infrastructure, and hence missing incentives for investment in rural areas by farmers and other private investors.

Country panel data on national government expenditure and ODA that match the ACS data presented here over time and in cross-section are not available. Fan and Rao (2003) describe the compilation of a panel on national government expenditure for a set of 43 developing countries from Asia, Africa and Latin America for 1980 to 1998. This data set has since been expanded to 44 countries, and was updated to 2005 (data from Shenggen Fan, personal communication). It points to increasing real levels of government expenditure for the aggregate of all 44 countries over time. Figure 7.8 provides evidence of a robust positive relationship between government expenditure on agriculture and growth in ACS in these countries over the period 1980 to 2005.

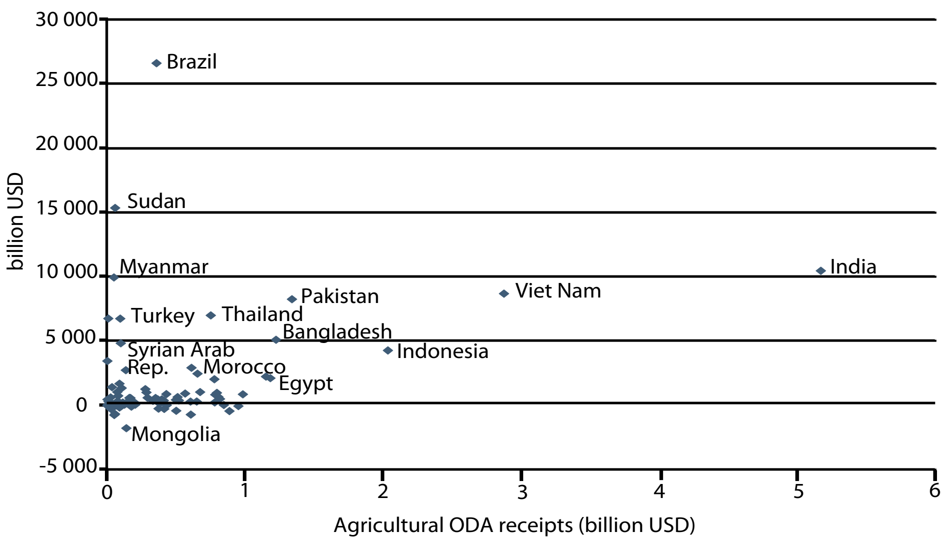
International assistance: External assistance to agriculture in developing countries has declined since the late 1980s. At the country level, the relationship between agricultural ODA and ACS growth (Figure 7.9) is not as clear-cut as is that between government agricultural expenditure and ACS growth. Between 1995 and 2005, the correlation coefficient between agricultural ODA receipts and growth in ACS for 118 developing countries in the ODA database is 0.48. However, the relationship between ACS and ODA is weakened by the fact that several countries (e.g., Brazil, the Sudan, Myanmar, Turkey and the Syrian Arab

Figure 7.8
Government expenditure on agriculture per worker, and ACS growth in 44 developing countries, 1980 to 2005



Sources: Authors' calculations with FAOSTAT physical inventories estimates; Fan and Rao, 2003.

Figure 7.9
Agricultural ODA and ACS growth in 118 developing countries, 1995 to 2005



Source: Authors' calculations with FAOSTAT physical inventories estimates.

Republic) recorded large increases in their ACS despite receiving comparatively low amounts of agricultural ODA (Figure 7.9). (Of course, it is not surprising that a country such as Brazil does not depend on agricultural ODA.) Furthermore, if a few countries that received large amounts of ODA (e.g., India, Viet Nam, Indonesia, Pakistan, Bangladesh and Thailand) are omitted, there appears to be no significant relationship between agricultural ODA receipts and growth in national ACS for the remaining countries.

Besides direct public investment, favourable market prospects and other components of the overall investment climate – such as stability and security, regulation and taxation, finance and infrastructure, and a functioning labour market – play a decisive role in determining the rate of ACS growth. In its *World Development Report 2005*, the World Bank (2005b: xiii) observed that "more governments are recognizing that their policies and behaviours play a critical role in shaping the investment climate of their societies and they are making changes". However, the report also underlines the need for far more progress, especially in rural areas.

Agricultural capital stock and productivity

The updated estimates of ACS presented in the previous section provide a basis for generating estimates of changes in TFP in individual countries and regions. TFP analysis can cast light on the extent to which countries have translated investment in agriculture into productivity gains. The starting point for this was a study in which Rao, Coelli and Alauddin (2004) estimate TFP changes in agriculture using panel data on agricultural inputs and output in 111 countries between 1970 and 2001. Data made available by these authors were then analysed to determine whether TFP estimates change when updated and expanded estimates of ACS are used. Rao, Coelli and Alauddin (2004) used land, tractors and an aggregate of five types of livestock as capital inputs; the analysis was also able to consider four types of machinery, nine types of livestock and structures from the FAOSTAT physical inventories data.

Methods

Rao, Coelli and Alauddin (2004) employed data envelopment analysis (DEA) to estimate the technical efficiency of agriculture for each country in their data set, and to derive shadow prices for agricultural inputs and outputs. They then used the Malmquist productivity index to measure growth in TFP and to decompose this TFP growth into its two main components: technical change (shifts in the production frontier over time); and efficiency change (a production unit's ability to move closer to the production frontier). Both methods are well-established in the literature (e.g., Coelli *et al.*, 2005). The application of these methods to panel data of countries over time treats each country in its entirety as an individual production unit and assumes that all countries have access to the same technology that underlies the frontier.

These methods were applied using the FEAR package in the programming language R (Wilson, 2008). The first series of estimates presented are those reported in Rao, Coelli and Alauddin (2004), which are replicated to confirm that there are no computational discrepancies (Model I). These are followed by a series of estimates in which different aspects of the data, model and/or estimation technique are modified to produce alternative results. Modifications account for the following factors:

- The data in Rao, Coelli and Alauddin (2004) contain a minor miscoding that leads livestock output to be listed as crop output, and vice versa, for North and Central America. This is rectified in Model II.
- Zelenyuk (2006) introduces a weighted TFP estimation technique that produces consistently aggregated regional averages. He demonstrates that this technique is superior to the standard approach of calculating output-weighted aggregates of individual country TFP estimates. Model III employs Zelenyuk's method.
- The updated FAOSTAT ACS data presented earlier in this chapter begin in 1975 and extend to 2007, while Rao, Coelli and Alauddin (2004) use data from 1970 to 2001. To make subsequent comparisons possible, this chapter first presents average TFP growth rates for 1970 to 2001 that account for both the output data miscoding and the aggregation method changes (Model IVa = Model II + Model III). It then presents the results of this model for only 1975 to 2001 (Model IVb).
- Maintaining the same two-output, five-input model estimated by Rao, Coelli and Alauddin (2004), the land, tractor and livestock input data are replaced by the more comprehensive land, machinery and livestock estimates in FAOSTAT ACS data for the period 1975 to 2001 (Model V).
- In DEA estimation, the so-called "curse of dimensionality" can influence results (Daraio and Simar, 2007). Essentially, as more inputs and outputs are included in the estimation procedure, the best practice frontier becomes increasingly flexible in higher-dimensional space. This permits it to accommodate individual observations better, creating the impression that they are all close to the frontier, and distorting subsequent TFP estimates. To reduce this problem, Model V was re-estimated with the data aggregated to one output and four inputs (as opposed to two and five). The

reduced 1-by-4 dimension was chosen based on recommendations from Park, Simar and Weiner (2000) and Daraio and Simar (2007: 153–154). Results are presented for 1975 to 2001 (Model VIa) and for 1975 to 2007 (Model VIb), to take advantage of the longer time period covered by the FAOSTAT ACS data.

- As an alternative means of dealing with dimensionality, partial or so-called robust frontiers can be estimated based on the m-order expected maximum output frontier proposed by Cazals, Florens and Simar (2002). The basic idea of this method is to estimate a more "taut" frontier, which does not envelop all the data points by repeated local re-sampling from the set of available observations. The advantages of the m-order method are summarized by Daraio and Simar (2007), and include robustness to outliers in the data, and less susceptibility to the curse of dimensionality. This method is employed in Model VII, which uses two outputs and all six available inputs (land and labour as in Rao, Coelli and Alauddin, 2004, and the four capital inputs in FAOSTAT ACS data).

In all estimations, labour, land and fertilizer (as a proxy for working capital) are included as inputs, along with the various measures and aggregations of capital input as outlined.

Results

A comparison of the different estimates of TFP change for the regions and the world reveals a number of results that are robust to the data, model and estimation technique alternatives outlined in Table 7.11. At the global level, estimates of annual TFP growth are quite consistent across models, ranging from 1.2 to 1.8 percent per year. Comparison of Models IVa and IVb reveals that omitting estimates for the first half of the 1970s leads to increased estimates of TFP growth in all regions except Latin America. The increase is especially large for China. This suggests that the first years of the 1970s were characterized by below-average TFP growth in most of the world. Comparison of Models VIa and VIb reveals that increasing the coverage to include 2002 to 2007 has no major impact on results.

North America and Oceania, Europe, the transition countries and China exhibit above-average rates of TFP growth that are relatively robust to the estimation method used. The Near East and North Africa, sub-Saharan Africa, Latin America and Asia (without China) exhibit below-average levels that are less robust, with estimates ranging from 0.3 to 1.8 percent for sub-Saharan Africa, and from 0.2 to 1.5 percent for Asia (without China). This is probably because the quality of the underlying data for the countries in these regions is comparatively low; DEA estimation is known to be highly sensitive to aggregation and data quality (Fuglie, 2008: 433; Daraio and Simar, 2007). This might also explain why, when Models I and II are compared, correcting the miscoded North and Central American output data has little impact on TFP growth rates for most regions, but a large impact on sub-Saharan Africa, where estimated TFP growth rates increase from 0.3 to 1.5 percent.

With this evidence of sensitivity in mind, the m-order estimates presented in Table 7.11 might be considered the most reliable, as the m-order method is far less sensitive to outliers. Because of this, the decomposition of TFP growth rates into efficiency change and technical change components in Table 7.12 is based on the m-order estimates. The results of this decomposition reveal that efficiency improvements have made relatively large contributions to TFP growth in the Near East and North Africa, China and the transition countries. In all other regions, TFP change has been largely determined by technical change. High rates of efficiency improvement in the transition countries and China are expected, as the restrictions and inefficiencies of central planning were removed over the study period.

Comparing TFP change and ACS accumulation between 1975 and 2007 reveals some interesting patterns. The industrialized countries (Europe, North America, Oceania and the transition countries) are characterized by low rates of ACS growth and relatively high rates of TFP growth (Figure 7.10). Their TFP growth over the study period is largely due to technical change (except in the transition countries, where efficiency improvements have also played a role). This is presumably a reflection of increases in input quality that are not captured by the FAOSTAT ACS estimates; TFP estimates based on the national accounts estimates of capital inputs would likely point to lower rates of TFP growth. The developing countries are characterized by much higher rates of ACS growth, but lower rates of TFP growth in Latin America and, especially, sub-Saharan Africa. China stands out as having the highest rates of both ACS and TFP growth. These results underline that high ACS growth does not necessarily lead to higher TFP growth.

All the TFP estimates in Tables 7.11 and 7.12 are based on non-parametric techniques and data on capital inputs derived from FAOSTAT. Ongoing work is looking into parametric estimation using stochastic frontier methods on the same data, and non-parametric and parametric estimates using national accounts-based capital input data. Of course, any use of national accounts-based data will have to deal with the issue of selection bias identified in the subsection on Comparing the national accounts and FAOSTAT approaches.

Table 7.11
TFP growth according to different specifications and estimation techniques

Model	Time period[a]	Specification (n = outputs; m inputs)	Near East and North Africa	Sub-Saharan Africa	North America and Pacific	Latin America	Asia without China	China	Europe	Transition	World
	Average annual rate of TFP growth *(%)*										
I = Rao, Coelli and Alauddin, 2004: 2 outputs (crop and livestock); 5 inputs (labour, fertilizer, land, tractors and livestock)	1970–2001	DEA n = 2, m = 5	0.6	0.3	2.2	0.7	0.3	3.0	1.9	1.4	1.5
II = I + corrected output data[b]	1970–2001	DEA n = 2, m = 5	0.8	1.5	2.3	0.7	0.5	2.8	2.1	1.9	1.4
III = I + corrected aggregation[c]	1970–2001	DEA n = 2, m = 5	0.7	0.6	1.9	0.9	0.2	2.5	1.9	2.2	1.2
IVa = II + III	1970–2001	DEA n = 2, m = 5	0.6	0.4	2.3	0.4	0.2	2.5	2.1	1.9	1.4
IVb = IVa beginning in 1975	1975–2001	DEA n = 2, m = 5	0.8	1.2	2.5	0.3	0.4	4.6	2.3	2.4	1.8
V = IVb + new FAOSTAT estimates for land, machinery (in lieu of tractors) and livestock inputs	1975–2001	DEA n = 2, m = 5	1.6	1.5	2.5	1.2	0.8	2.7	1.9	2.1	1.6
VIa = V with 1 aggregate output[d] and 4 inputs (labour, fertilizer, land and capital = structures, machinery and livestock)	1975–2001	DEA n = 1, m = 4	0.9	1.6	2.3	0.2	1.3	2.2	1.8	1.8	1.5
VIb = VIa extended to 2007	1975–2007	DEA n = 1, m = 4	0.9	1.8	2.2	0.6	1.5	2.1	1.5	1.8	1.5
VII = VI with 2 outputs (crop and livestock) and 6 inputs (labour, fertilizer, land, structures, machinery and livestock)	1975–2007	m-order n = 2, m = 6	1.5	0.9	2.0	1.0	1.4	2.1	1.4	1.7	1.7

[a] All results exclude 1992 and 1993, as these produce highly variable estimates owing to the impact that the break-up of the Soviet Union, the Socialist Federal Republic of Yugoslavia and Czechoslovakia had on input and output statistics.

[b] In the original Rao, Coelli and Alauddin (2004) data set (made available by the authors), crop output values are listed as livestock output values, and vice versa, for North America and Central American countries. This is corrected here.

[c] Zelenyuk (2006) introduces a weighted TFP estimation technique that produces consistently aggregated regional averages, and demonstrates that this is superior to the standard approach of calculating output-weighted aggregates of individual country TFP estimates.

[d] Output series are aggregated using 1999/2001 average international prices.

Source: Authors' calculations.

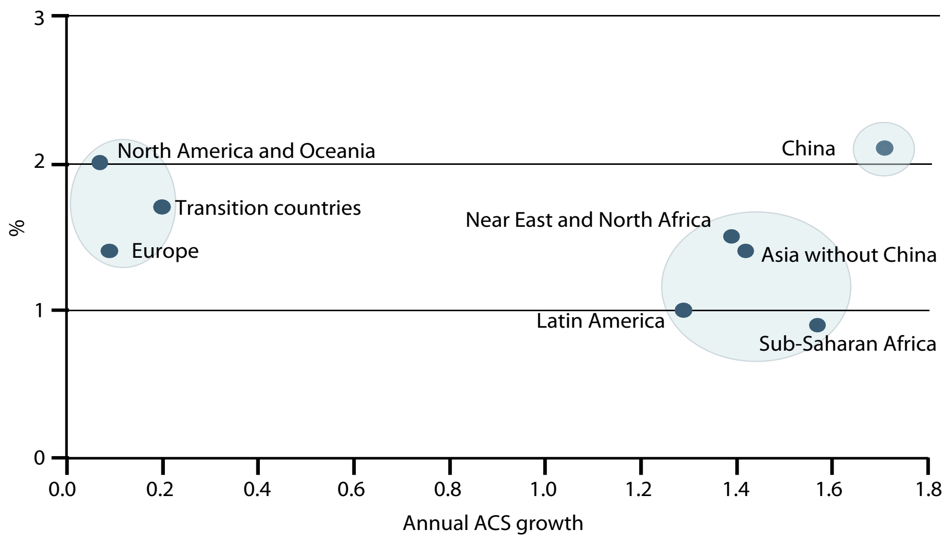
Table 7.12
Estimated changes in TFP and its components by region, 1975 to 2007 (percentages)

Region	Efficiency change	Technical change	TFP change
Near East and North Africa	1.4	0.1	1.5
Sub-Saharan Africa	0.3	0.6	0.9
North America and Pacific	-0.7	2.7	2.0
Latin America	0.3	0.7	1.0
Asia, without China	-0.9	2.3	1.4
China	0.9	1.3	2.1
Europe	0.3	1.1	1.4
Transition countries	0.7	1.0	1.7
World	0.7	1.0	1.7

Results based on m-order estimates in Table 7.11. Results exclude 1992 and 1993, as these produce highly variable estimates owing to the impact that the break-up of the Soviet Union, the Socialist Federal Republic of Yugoslavia and Czechoslovakia had on input and output statistics.

Source: Authors' calculations.

Figure 7.10
Annual rates of agricultural capital stock growth and TFP growth by region, 1975 to 2001



Sources: Authors' calculations with FAOSTAT physical inventories estimates; authors' TFP estimates based on data in Rao, Coelli and Alauddin, 2004, and FAOSTAT physical inventories estimates.

Factors that influence TFP growth

In a series of regressions, Rao, Coelli and Alauddin (2004) study factors that explain TFP levels across countries, such as land quality, irrigation, government expenditure, literacy rate and trade openness. They find that results are sensitive to the period that is studied and to whether or not the transition economies are included in the analysis, the latter probably being due to questionable data for these countries and to their unique circumstances. Two robust results are that both reducing illiteracy and reducing the incidence of malaria have positive impacts on TFP in agriculture. Foreign direct investment (FDI) as a share of GDP is found to have a uniformly positive impact on agricultural TFP, satisfying the expectation that FDI will be associated with improved technologies and expertise in implementing them. A surprising result of the analysis presented by Rao, Coelli and Alauddin (2004) is that both gross domestic investment as a share of GDP, and government consumption as a share of GDP have negative effects on agricultural TFP. The authors suggest that the latter result may be due to urban biases in government expenditure, so that much government consumption may actually be discriminating against agriculture in many countries. For this chapter, the issue of government expenditure and TFP was revisited using the Fan and Rao (2003) data on government expenditure on agriculture in developing countries. Although these data on government expenditure are available for only 44 countries, they have the advantage of measuring government expenditure specifically on agriculture. Hence, unlike the general government consumption data employed by Rao, Coelli and Alauddin (2004), they should be free of any urban bias.

The regression analysis is based on panel data for 37 of the 44 developing countries in the Fan and Rao (2003) database from 1980 to 2005. A lack of data for some of the independent variables described in the following leads to complete omission of seven countries in the Fan and Rao (2003) data, and omission of individual observations for some of the remaining 37 countries. The result is an unbalanced panel with a total of 761 observations. The dependent variable is the logarithm of TFP levels for country i in year j, calculated using base period TFP levels (relative to the United States of America) extrapolated with the m-order TFP estimates (for details, see Rao, Coelli and Alauddin, 2004: 29). Two base periods are used to account for the transition countries' entrance into the TFP estimation.

Drawing on Rao, Coelli and Alauddin (2004) and theoretical considerations, the following series of possible covariates is identified (descriptive statistics are given in Table 7.13):

- A dummy variable that equals 0 prior to 1994 and 1 thereafter is added to account for the transition countries' entry into the TFP estimation in 1994. Although there are no transition countries among the 37 countries included in this regression analysis, these countries affect TFP levels for all countries when they enter the TFP estimation.
- The rural population as a share of total population is included as a measure of labour abundance in agriculture, where a high share might point to surplus labour with a very low marginal product (World Bank World Development Indicators).
- The ratio of imports plus exports to GDP is a measure of economic openness that can capture access to foreign technology as well as the overall policy climate in a country (World Bank World Development Indicators).
- The share of irrigated land in total agricultural land is a proxy for land quality (FAOSTAT).
- An indicator of institutional quality that combines the quality of bureaucracy, the rule of law and the lack of corruption is added to measure the quality of government. This variable is standardized to ease interpretation (PRS Group's IRIS dataset).[4]
- A political regime index, defined as a country's degree of democracy less its degree of autocracy, is included to capture governance. This index is also standardized (POLITY IV Project).[5]
- Net FDI flows as a share of GDP are included to capture inflows of technology and expertise that might be expected to boost TFP (World Bank World Development Indicators).
- Gross fixed capital formation as a share of GDP might capture technology that is embodied in fixed capital (World Bank World Development Indicators).
- The logarithm of government expenditure on agriculture is included, in the expectation that higher levels of expenditure will be associated with improved availability of productivity-enhancing infrastructure, research and education (Fan and Rao, 2003).

4. www.prsgroup.com.
5. www.systemicpeace.org/inscr/inscr.htm.

Table 7.13
Results of panel regression analysis to explain differences in national TFP growth (dependent variable is *log*[TFP level] in country *i* and year *j*)

	Regression results		Descriptive statistics			
Covariate	Coefficient	Standard error	Mean	Minimum	Maximum	Standard error
Dummy1994–2005	-0.308[c]	0.023	0.47	0.00	1.00	0.50
Rural population as % of total	-0.031[c]	0.003	54.7	6.60	93.6	23.3
Exports + imports as % of GDP	0.002[a]	0.001	55.2	1.53	228.9	30.2
Share of irrigated land in total agricultural land	0.111	0.292	0.10	0.00	1.00	0.19
Institutional quality index	-0.109[c]	0.031	0.00	-2.61	2.31	1.00
Political regime index	0.032	0.040	0.00	-1.55	1.30	1.00
Institutional quality[a] political regime	-0.020[a]	0.011	0.16	-2.26	2.87	0.94
FDI inflows as % of GDP	-0.016[c]	0.006	1.58	-2.76	12.2	1.83
FDI[a] institutional quality	0.032[c]	0.006	0.53	-6.91	20.9	2.06
FDI[a] political regime	0.020[c]	0.005	0.49	10,3	14.1	2.31
Fixed capital formation as % of GDP	-0.007[c]	0.002	20.3	3.53	43.6	6.23
Fixed capital[a] institutional quality	0.003[a]	0.002	2.23	58.8	86.4	21.8
Fixed capital[a] political regime	-0.004[b]	0.002	0.21	52.2	47.3	20.8
Log [government expenditure on agriculture]	0.034[b]	0.014	1.01	-2.20	3.77	1.09
Period	1981-2005					
Number of observations	761					
R^2	0.32					

Significance levels: [a] 10 percent; [b] 5 percent; [c] 1 percent.

Several interaction terms involving the institutional quality and political regime indicators are included in the final specification, which also includes country fixed effects that are found to be jointly significant at the 1 percent level. The regression model was estimated using the *plm* package in R (Croissant and Millo, 2008) and results are presented in Table 7.13.

The overall fit of the regression (R^2 = 32 percent) is good for a panel estimate with annual country data. Most of the estimated coefficients are significant and have the expected signs. A 10 percent increase in the share of the rural population reduces agricultural TFP by 0.31 percent, all other things being equal, while a 10 percent increase in the share of trade in GDP increases agricultural TFP by 0.02 percent. The share of irrigated land has the expected positive impact on TFP, but this effect is not significant. This analysis finds a surprising negative relationship between institutional quality and TFP levels, as Rao, Coelli and Alauddin (2004) do. The impact of the political regime index (increasing democracy) on agricultural TFP is positive but not significant, while the interaction between institutional quality and the political regime has a negative impact.

FDI alone has a significant negative impact on agricultural TFP, but the interactions between FDI and the institutional quality and political regime variables are significantly positive and larger in magnitude. Hence, the impact of a 10 percent increase in net FDI inflows as a share of GDP is a 0.16 percent reduction in TFP, at mean values of the institutional quality and political regime covariates. However, for a country that is 1 standard deviation above the mean in terms of its institutional quality and political regime this turns into a net 0.36 percent increase. This result suggests that the institutional and governance environment within which FDI takes place is of crucial importance. An appropriate environment can ensure that the potential productivity-enhancing impacts of FDI are realized, while under conditions of poor governance and institutional quality, FDI will be more short-term and perhaps more focused on rent extraction than on establishing capacities for adding value. Fixed capital formation has a weak negative impact on agricultural TFP, which is only partially compensated for by the interaction between fixed capital formation and institutional quality, and somewhat strengthened by its interaction with the political regime variable. The overall negative effect of capital formation on agricultural TFP may be partly due to an urban/rural bias in the economy-wide measure of capital formation employed. However, it should be recalled that no positive relationship between ACS growth and TFP growth for regional aggregates was found (Figure 7.10).

The coefficient on the logarithm of government expenditure on agriculture is positive and significant. This coefficient indicates that a 10 percent increase in government expenditure on agriculture, all other things being equal, will lead to a 0.34 percent increase in the country's agricultural TFP. This underscores the importance of national government expenditure on agriculture as a means of not only increasing rates of ACS growth as identified in Figure 7.8, but also of contributing to increased productivity through technical change and more efficient use of inputs. Of course, even a specific measure of government expenditure on agriculture such as that employed here does not take the composition of this expenditure into account. In a study of ten Latin American countries, López (2005: 18) presents econometric evidence that "while government expenditures have a positive and highly significant effect on agriculture per capita income, the structure or composition of such expenditures is quantitatively much more important and also of great statistical significance. […] According to the estimates, a reallocation of just 10 percent of the subsidy expenditures to supplying public goods instead may cause an increase in per capita agriculture income of about

2.3 percent." Hence, a variable that isolates the public good aspect of government expenditures on agriculture, if available, could be expected to have an even higher estimated impact on agricultural TFP growth than that measured here.

Conclusions

The fixed capital stock (ACS) in primary agriculture has been growing steadily at the global level over the last three decades, although at declining rates for most of this period. Using a volume approach with country-specific constant values per asset to measure ACS, the average annual rate of worldwide ACS growth fell from 1.1 percent for the 1975 to 1990 period, to 0.5 percent for 1991 to 2007. Reductions were recorded in both developed and developing countries, although the rates of ACS growth were considerably stronger in developing than developed countries, in both sub-periods. In the latter group, some growth rates have been negative since the mid-1990s. Recently, this trend seems to have been reversed. Since reaching a point close to stagnation in the mid-1990s, global ACS growth rates have started to increase gradually, reaching 0.5 percent per year in 2005 to 2007. The reasons for this slight acceleration of capital growth need to be examined further, including whether the new demand for bioenergy has played a role. If ACS growth rates continue to improve, this may signal improving prospects for the world's aggregate capacity to meet future demand. As the data for 2007 are based on projections, and data for 2008/2009 are not yet available, it is not possible to determine the impact that the food price crisis of 2007/2008 had on rates of ACS accumulation worldwide or in developing as opposed to developed countries.

A shift in the relative shares of capital formation among regions and country groups appears to be taking place. The gap between higher rates of ACS growth in developing and lower rates in developed countries is closing. Whereas ACS shrinkage in developed countries has slowed, rates of ACS growth in developing countries have remained positive but continued to fall. As future demand growth is expected mainly in the developing countries, this shift could lead to increasing supply bottlenecks in import-dependent developing countries, unless action is taken to increase investments in these countries.

Annual rates of growth in the stock of improved agricultural land have been declining at the global level. As a consequence, the share of land, including land equipped for irrigation, in total ACS at the global level (currently about 50 percent) is gradually declining. This may in part reflect reduced willingness to invest in improving the productivity of the existing stock of land, which would be cause for concern, especially in many marginal areas where the ongoing depletion of natural capital through declining soil fertility is not accounted for.

ACS has grown the least in countries with the highest prevalence and depth of hunger. The majority of poor and hungry people live in rural areas and depend directly or indirectly on agriculture for their livelihood. Therefore, increasing the ACS per person active in agriculture has been an important factor in reducing undernourishment. However, in several of the least developed countries, particularly in sub-Saharan Africa and South Asia, the growth of the population active in agriculture has outstripped the rate of ACS growth. This development is particularly worrying because it severely limits these countries' ability to increase labour productivity in rural areas, and hence to reduce poverty and undernourishment. This result is obtained irrespective of the method used to estimate capital stock. By contrast, with few exceptions, the countries making the most progress towards the World Food Summit target of halving the number of undernourished by 2015 have realized relatively high rates of growth in ACS per worker in agriculture.

Government expenditure on agriculture is correlated with capital formation in a sample of developing countries. This correlation between national government expenditure on agriculture and growth in national ACS confirms the decisive role of public expenditure in creating an enabling environment in terms of the infrastructure and sustainable access to natural resources that provide adequate incentives for the private sector, particularly farmers, to invest in productive assets. This should be a strong signal for governments in developing countries to change priorities in budget allocations, to avoid or at least reduce any existing discrimination against agriculture. Public expenditure on agriculture can be an important ingredient in an investment climate conducive to agricultural development and the reduction of hunger.

Between 1975 and 2007, annual TFP growth in world agriculture was roughly 1.7 percent. This average masks important differences among regions, ranging from 2.1 percent in China and 1.7 percent in transition countries, to 1.4 percent in the rest of Asia, 1 percent in Latin America, and 0.9 percent in sub-Saharan Africa. These differences among regions point to substantial scope for further productivity growth. The breakdown of TFP growth into efficiency gains and technical change also varies widely among regions. Efficiency gains have contributed relatively little to overall total TFP in developing countries, but have played a significant role in transition countries. This has implications for the entry points of productivity-enhancing policies in developing countries.

Government expenditure on agriculture has a significant positive impact on TFP in a sample of developing countries. All other things being equal, increasing government expenditure on agriculture by 10 percent leads to a 0.34 percent increase in the country's agricultural TFP. FDI is also found to have a positive impact on productivity growth, but only when combined with an institutional environment characterized by efficient bureaucracy, a lack of corruption, and democratic political structures. This suggests that the investment climate in a country – including its institutional and governance structures – has an important influence on the type of FDI that it can attract and on the impact of this investment on the agricultural economy.

The estimates of ACS levels and growth presented in this chapter are based on two different approaches, which differ in many respects. Each of these approaches is characterized by important strengths and weaknesses, and the approaches do not always produce the same results. International organizations such as FAO should engage in a concerted and sustained effort to refine and reconcile estimates of fixed capital formation, including upstream and downstream sectors and rural infrastructure in developing countries. Efforts should also be made to combine the advantages of existing methodologies, and to improve the collection and processing of consistent data.

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