Expert Meeting on How to feed the World in 2050
Food and Agriculture Organization of the United Nations
Economic and Social Development Department

INVESTMENT IN DEVELOPING COUNTRIES' FOOD AND AGRICULTURE: ASSESSING AGRICULTURAL CAPITAL STOCKS AND THEIR IMPACT ON PRODUCTIVITY

Stephan von Cramon-Taubadel*, Gustavo Anriquez†, Hartwig de Haen* and Oleg Nivyevskiy*

CONTENTS

* University of Göttingen, Germany
† FAO, Rome

The authors wish to thank Mostafa Badr and Tayab Tahir for excellent research assistance.

TABLES

FIGURES

EXECUTIVE SUMMARY

(1) The agricultural capital stock (ACS), measured as fixed assets in primary agriculture, has been growing steadily at the global level over the last three decades, although for most of this period at declining rates. Using a volume approach with country-specific constant values per asset to measure the ACS, 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. This reduction was recorded in both developed and developing countries.

(2) A shift in the relative shares of capital formation between different 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 falling. While the ACS shrinkage observed in the developed countries since the early 1990s countries has slowed, rates of ACS growth in the developing countries have remained positive but continued to fall.

(3) Annual rates of growth in the stock of improved agricultural land have been declining at global level. This may reflect at least in part a reduction in the willingness to invest in improving the productivity of the existing stock of land.

(4) The ACS has grown the least in countries with the highest prevalence and depth of hunger. In several of the least developed countries, in particular in sub-Saharan Africa and South Asia, the growth of the population active in agriculture has outstripped the rate of ACS growth.

(5) Government expenditure on agriculture is correlated with capital formation in a sample of developing countries. This correlation confirms the decisive role of public expenditure in creating an enabling environment in terms of infrastructure and sustainable access to natural resources. Public expenditure on agriculture can be an important ingredient in an investment climate conducive to agricultural development and the reduction of hunger.

(6) Between 1975 and 2007, annual total factor productivity growth in world agriculture was roughly 1.7 percent. This average masks important differences between 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-Sahara-Africa. These differences between regions point to a substantial scope for further productivity growth.

(7) Government expenditure on agriculture has a significant positive impact on productivity 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 a country's agricultural TFP. Foreign direct investment is also found to have a positive impact on productivity growth, but only in combination with efficient bureaucracy, a lack of corruption, and democratic political structures.

(8) The estimates of ACS levels and growth presented in this paper are based on two approaches which do not always produce the same results. Each of these approaches is characterised by important strengths and weaknesses. International Organizations such as the FAO should engage in a concerted and sustained effort to refine and reconcile estimates of ACS formation, including upstream and downstream sectors and rural infrastructure in developing countries.

1. INTRODUCTION

Between 1975 and 2005, global dietary energy supplies grew faster than the world population, which itself more than doubled. On global average, the food availability per person increased from 2400 to nearly 2800 kcal/person/day over those 30 years. In the developing countries the increase was even slightly steeper, from 2200 to 2600 kcal/person/day. This was a remarkable achievement of the global food and agriculture system, which was the result of significant investment and technical progress. As a result, the share of the world 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 caput food supplies was not accompanied by a reduction in the number of the under-nourished. Although the prevalence of under-nourishment in the developing countries declined from 20 to 16 percent between 1990/92 and 2003/05, the absolute number of under-nourished individuals increased from 840 to nearly 850 million people. According to preliminary estimates by FAO, the high food prices in 2007 and 2008 may have driven up this number 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 make more progress towards the reduction of hunger and poverty (World Bank, 2008). Rapid progress in cutting the incidence of chronic hunger in developing countries is quite 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, since 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. In fact, a common feature of countries which were successful in reducing hunger and poverty is that they not only had higher overall rates of economic growth than the less successful countries, but that they achieved this higher growth through a relatively higher growth in agriculture. Moreover, these successful countries typically shared some other common features, namely absence of conflict and good governance, functioning markets, public investment in rural infrastructure and greater degree of integration in world markets than the less successful countries. Such success stories can be found in all regions (FAO, 2008).

This 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 stock in developing countries since 1975 and concluded that additional resources for promoting agricultural growth were especially needed in countries where undernourishment is more prevalent. Today, many of the problems recognized in 2002 are still not resolved. However, the pressures on world agriculture resulting from population growth, urbanization and growing demand for diversity, food quality and safety have grown, and new challenges for global agriculture have been added: climate change and variability, financial crisis, reduced availability of national and international finance, reduced public stock-holding, fluctuating energy prices and uncertain prospects for trade policy reforms.

Using various analytical tools, the following paper presents an update of earlier capital stock and investment estimates. We seek to contribute information needed to assess the extent to which developing countries have followed up on the commitments made more than a decade ago, and whether they are prepared to achieve food security for the future. We begin in section 2 with an overview of possible approaches to measuring investment and the agricultural capital stock. In section 3 the results of our estimates are presented and discussed. In section 4 we use our capital stock estimates to produce new estimates of total factor productivity (TFP) changes in agriculture in different regions of the world, contrasting these with earlier TFP estimates, and we explore the role that public expenditure on agriculture plays in both encouraging agricultural capital stock growth and TFP growth. Section 5 closes with a summary and outlook.

2. APPROACHES TO MEASURING INVESTMENT AND THE AGRICULTURAL CAPITAL STOCK

Comprehensive analysis of the agricultural capital stock (ACS) and investment needs in agriculture requires data on fixed and human capital on farm, as well as on fixed capital in infrastructure, in research and technology dissemination, and in the industries up- and down-stream 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 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 above-mentioned components of the ACS were readily available for all countries or at least a representative sample, difficult issues of allocation/attribution would remain to be solved. 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; investments in telecommunications infrastructure can have an important influence on market efficiency, production and welfare (Jensen, 2007). Measuring the ACS necessarily involves finding a compromise between a comprehensive coverage of countries over time – which is only possible for a relatively narrow definition of the ACS – and a comprehensive coverage of the relevant components of the ACS – which involves exhaustive work on a country-by-country basis.

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

2.1 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, in particular 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, these same regions had also realized a significant increase in the ACS-labour ratio, whereas the other developing regions had stagnating or, in the case of Sub-Sahara-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 a low productivity per agricultural worker. In fact, the divergence of GDP per agricultural worker in country groups of different capital-labour ratios and hence 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 the population under-nourished was about 20 times higher than in the group with more than 35 percent undernourished.

Although equally relevant for the performance of the food and agricultural sector, capital formation in upstream and downstream sectors and in rural infrastructure has been much 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 had amounted to approximately US$ 77 billion during the preceding ten to fifteen years (net investments: US$ 26 billion). Over the same period, annual gross investments in post harvest activities amounted to US$ 34 billion and public gross investments in rural infrastructure, agricultural research and extension US$ 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 this 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-Sahara Africa.

Although changes in natural agricultural capital cannot be inferred at the global level, some progress towards including the cost of natural capital depletion in national accounts has been made. Based on these efforts, the World Bank (2005a) has estimated the value of natural resources and concluded that in low-income countries, excluding the oil states, the share of the natural capital in total wealth is greater than the share of produced capital. Accounting for the value of depletion of this natural capital, so-called adjusted net national savings have been calculated as an indicator of 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". 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.

2.2. Estimating the agricultural capital stock with 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. We draw on an expanded version of this database produced by Anriquez and Daidone (2008) that contains more than 100 countries, but of which only 76 have agricultural gross fixed capital formation series long enough to allow for a reasonable estimate of physical capital stocks. This expanded database has been updated to cover up to 2002. As in Crego et al. (1998), data is not available in all years for all countries, but with some inter- and extrapolation a balanced panel from 1967 to 2003 can be generated for all 76 countries. Exceptions are the transition countries of Central and Eastern Europe, for which the series begin in 1990.

This dataset is generated based on the assumption that agricultural capital is composed of three components: 1) physical capital, 2) livestock, and 3) treestocks, which represent the value of the planted permanent crops. The physical capital series is constructed using time series of gross fixed capital formation in agriculture as published in national account statistics, and in a few instances using case studies that attempt to calculate these same series. The method used to estimate physical capital stocks is a variation of the perpetual inventory method (PIM). The PIM estimates current capital stocks by adding suitably depreciated investments from previous periods. Since capital stocks depreciate, only a finite history of investments in previous periods must be considered to determine current capital stocks.

In this study we assume a hyperbolic depreciation function (details in Crego et al. 1998), and also that the lifetime of each investment is normally distributed with a mean of 20 years and a standard error of 8 years. This means that with 95 percent probability each agricultural investment has a service lifetime between 4 and 36 years. To apply this methodology a long time series on gross investment is required. Where this was not available, previous gross investment levels where predicted (back-casted) using both agricultural value added (either that available or predicted using simple log trend), and the observed gross investment to agricultural value added ratio. All national capital stock series where estimated in constant national currency, and converted to current dollars using national deflators (to convert to series in current local currency) and the current exchange rates. The final comparable series in 1995 dollars were created by deflating the current dollars series using the US agricultural value added deflator.

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

Treestocks are valued as the present value of discounted future net revenues. First, net revenues are assumed to equal 80 percent of gross revenues which, in turn, are calculated per permanent crop as the product of yields and prices. Yields are calculated using area and total output data from FAOSTAT, while prices are 5-year moving averages of actual producer prices reported by FAOSTAT for each country. Two simplifying assumptions are made: first, that all permanent crops are at half of their productive life-spans; and second, that the lifespan of all permanent crops is 26 years. Future revenues are discounted using a 'real' rate of returns defined as the difference between the yields of ten 10-year US bonds and the inflation of the US GDP deflator for each period. The value of treestocks is 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 US agricultural GDP deflator.

2.3. Estimating the agricultural capital stock using physical inventories in FAOSTAT

For many countries, national accounts data on gross fixed capital formation in agriculture is not available. As an alternative, the FAO Statistics Division in 1995 first compiled estimates of the 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 the total ACS at constant prices.

Estimates of the ACS based on this method were first prepared at the regional level in 1995 as part of the World Agriculture Towards 2010 exercise (FAO 1995) for the period 1975 to 1995 and using 1990 US$ prices. These were subsequently updated in 2001 for the period 1975 to 1999, using a broader set of assets and 1995 US$ prices, and covering individual developing countries rather than only regional aggregates (FAO, 2002). These are the estimates of the ACS referred to in section 2.1 above. A further update to include the years to 2002 was prepared for FAO in 2006 (Barre, 2006).

We have updated the 1975-1999 estimates produced in 2001, and extended them to 2007.[1] The assets covered fall into four categories as outlined in Table 1 and are available for 223 countries and geographic entities.[2] To convert physical inventories into asset values, we use the 1995 unit asset prices that were compiled by the FAO (2002). These were drawn from a number of sources such as 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. For details on these unit prices and other aspects of the estimation, the reader is referred to FAO (2001a). Key issues include:

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

[1] For some assets, FAOSTAT data is only available until 2005 or 2006. In these cases, the remaining years until 2007 have been extrapolated.
[2] The number of countries changes over time, for example due to the breakup of the Soviet Union. The FAOSTAT data includes entities such as Gaza and Greenland that are not independent countries.

Table 1: Agricultural assets covered in the FAOSTAT measure of the ACS

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

2.4 Strengths and weaknesses of the national accounts and FAOSTAT approaches

The national accounts-based estimates of the ACS have the important advantage of providing a considerably broader coverage of fixed capital in agriculture than the estimates based on FAOSTAT physical inventories. Furthermore, the use of the permanent inventory method coupled with consistent national accounts data on investments provides theoretically much sounder estimates of the value of the ACS in each year than the FAOSTAT approach. 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 quality improvements in assets over time (e.g. the fact that the average tractor made in 2005 can do more than the average tractor made in 1975, or that 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, the OECD and other industrialised countries are well represented in the national accounts database, but this is not the case for developing countries (Table 2). For example, China is not included in the national account estimates, and only 10 countries in sub-Saharan Africa are, compared with 51 in the FAOSTAT physical inventories estimates.

Table 2: Countries in the national accounts and FAOSTAT physical inventories databases by region

Region	Number of countries covered by...	
	National accounts estimates	FAOSTAT estimates
East Asia & Pacific	4	42
Europe & Central Asia	6	25
Latin America & Caribbean	15	45
Near East & 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

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 is demonstrated below, there appears to be some selection bias in the sample of countries covered by the national accounts approach; the 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.

3. RESULTS: THE DEVELOPMENT OF THE AGRICULTURAL CAPITAL STOCK SINCE 1975

In the following sections, estimates of the 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 it is only possible to generate consistent aggregates over time with these estimates.

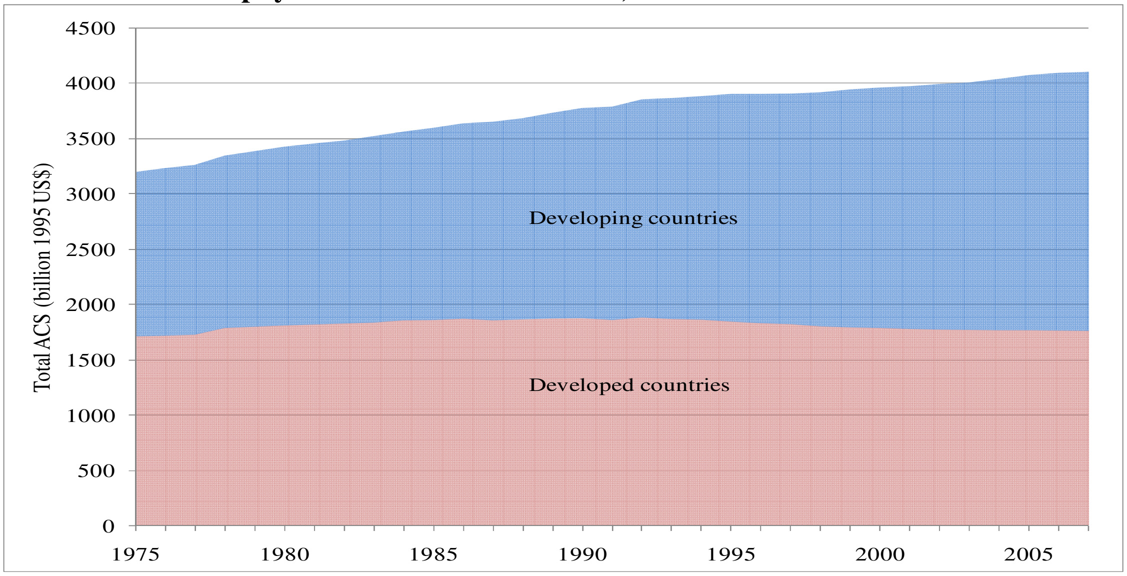
3.1. The development of the agricultural capital stock by region

Figure 1 displays the development of the total ACS between 1975 and 2007, worldwide and broken down into developed and developing countries. The worldwide rate of ACS growth (in other words net investment in the 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 (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 2). Since the beginning of the 2000s, the worldwide rate of ACS growth has increased again somewhat (from 0.32 to 0.52 percent per year), as the rate of ACS shrinkage in the developed countries has slowed. At the same time, rates of ACS growth in the developing countries have remained positive but continued to fall. Hence, the gap between rates of ACS growth in developing and developed countries has fallen from a high of just over 2 percent (1.27 percent vs. -0.76 percent) in 1995-99 to just over 1 percent (1.01 percent vs. -0.11 percent) in 2005-07 (see also 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 (**Error! Not a valid bookmark self-reference.**). In the 1980s, North America saw negative rates of ACS growth, and in the 1990s rates of growth in the ACS in Western Europe became negative, presumably due to in part to the effect of the 1993 so-called MacSharry reforms of the EU's Common Agricultural Policy. In the second half of the 1990s and into the 2000s, the ACS in the transition economies of Central and Eastern Europe shrank especially dramatically. In the developing countries, rates of ACS growth have been consistently positive across regions and sub-periods, with South Asia recording a sustained reduction in growth rates since the early 1990s.

Table 4). Since the data for 2007 are based on projections and data for 2008-09 are not yet available, it is not possible to determine what impact the food price crisis of 2007-08 had on rates of ACS accumulation in developing and developed countries.

Table 3). This slowdown was caused primarily by stagnating and then falling levels of ACS in the developed countries, although rates of ACS growth also fell in the developing countries over time. However, rates of ACS growth did not become negative in developing countries as they did for developed countries after 1990.

Figure 1: The development of the agricultural capital stock (1975-2007, in billion 1995 US$ - FAOSTAT physical inventories estimates)



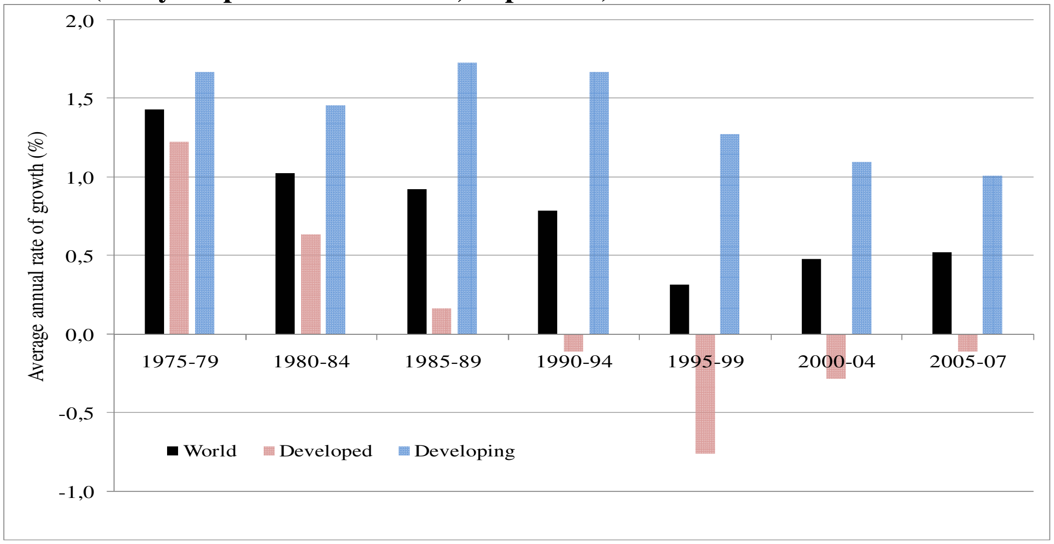
Further disaggregating these average annual growth rates reveals several interesting patterns. First, the reduction in the rate of ACS accumulation was sharpest in the second half of the 1990s, with ACS growth becoming strongly negative in developed countries and falling notably in developing countries (Figure 2). Since the beginning of the 2000s, the worldwide rate of ACS growth has increased again somewhat (from 0.32 to 0.52 percent per year), as the rate of ACS shrinkage in the developed countries has slowed. At the same time, rates of ACS growth in the developing countries have remained positive but continued to fall. Hence, the gap between rates of ACS growth in developing and developed countries has fallen from a high of just over 2 percent (1.27 percent vs. -0.76 percent) in 1995-99 to just over 1 percent (1.01 percent vs. -0.11 percent) in 2005-07 (see also 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 (**Error! Not a valid bookmark self-reference.**). In the 1980s, North America saw negative rates of ACS growth, and in the 1990s rates of growth in the ACS in Western Europe became negative, presumably due to in part to the effect of the 1993 so-called MacSharry reforms of the EU's Common Agricultural Policy. In the second half of the 1990s and into the 2000s, the ACS in the transition economies of Central and Eastern Europe shrank especially dramatically. In the developing countries, rates of ACS growth have been consistently positive across regions and sub-periods, with South Asia recording a sustained reduction in growth rates since the early 1990s.

Table 4). Since the data for 2007 are based on projections and data for 2008-09 are not yet available, it is not possible to determine what impact the food price crisis of 2007-08 had on rates of ACS accumulation in developing and developed countries.

Table 3: Average annual rates of ACS growth before and after 1990 (percent)

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

Figure 2: Average annual rates of growth in the ACS in developed and developing countries (five-year periods since 1975, in percent)



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 (**Error! Not a valid bookmark self-reference.**). In the 1980s, North America saw negative rates of ACS growth, and in the 1990s rates of growth in the ACS in Western Europe became negative, presumably due to in part to the effect of the 1993 so-called MacSharry reforms of the EU's Common Agricultural Policy. In the second half of the 1990s and into the 2000s, the ACS in the transition economies of Central and Eastern Europe shrank especially dramatically.[3] In the developing countries, rates of ACS growth have been consistently positive across regions and sub-periods, with South Asia recording a sustained reduction in growth rates since the early 1990s.

Table 4: Average annual rates of growth in the ACS in regions of the world (five-year periods since 1975, in percent)

Region	1975-79	1980-84	1985-89	1990-94	1995-99	2000-04	2005-07	1975-07
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*
N. America	1.00	-0.16	-0.23	0.05	0.14	-0.12	0.02	*0.08*
W. 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 A. & Caribbean	2.15	1.40	1.76	1.40	0.39	1.16	0.22	*1.24*
Near East & N. 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 & 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*

The consistently positive rates of ACS growth by developing country region in 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 (**Error! Not a valid bookmark self-reference.**). In the 1980s, North America saw negative rates of ACS growth, and in the 1990s rates of growth in the ACS in Western Europe became negative, presumably due to in part to the effect of the 1993 so-called MacSharry reforms of the EU's Common Agricultural Policy. In the second half of the 1990s and into the 2000s, the ACS in the transition economies of Central and Eastern Europe shrank especially dramatically. In the developing

[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 section 3.5.

countries, rates of ACS growth have been consistently positive across regions and sub-periods, with South Asia recording a sustained reduction in growth rates since the early 1990s.

Table 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 has outstripped the rate of ACS growth, leading to average annual reductions in the ACS per worker in agriculture of 0.44 percent and 0.26 percent per year between 1975 and 2007 (Table 5). In the Near East and North Africa as well as in East and Southeast Asia, population growth has eroded but not completely outweighed growth in the ACS. In Latin America and the Caribbean, the population active in agriculture has fallen at an average rate of almost 0.1 percent per year since 1975, contributing slightly to an overall increase in the ACS per worker in agriculture over this period.

Table 5: Average annual rates of growth in ACS per worker in agriculture by developing country region (1975-2007, in percent)

Region	1975-2007 annual rate of growth of...		
	...capital stock in agriculture	...population active in agriculture	...capital stock per person active in agriculture
Latin America & Caribbean	1.24%	-0.08%	1.33%
Near East & North Africa	1.34%	0.83%	0.51%
Sub-Saharan Africa	1.52%	1.97%	-0.44%
East & Southeast Asia	1.70%	0.97%	0.72%
South Asia	1.11%	1.38%	-0.26%

Figure 3 presents information on gross and net investments in the ACS for the developing and the developed countries. Net investment is calculated as the simple difference between the 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.

3.2. Components of the 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 the total agricultural capital stock (Figure 4). Livestock is next with a share of 24 to 26 percent, followed by machinery (16 to 17 percent) and structures (5 percent).

Figure 3: Gross and net investments in the agricultural capital stock – developing and developed countries (1976-2007, in billion 1995 US$)

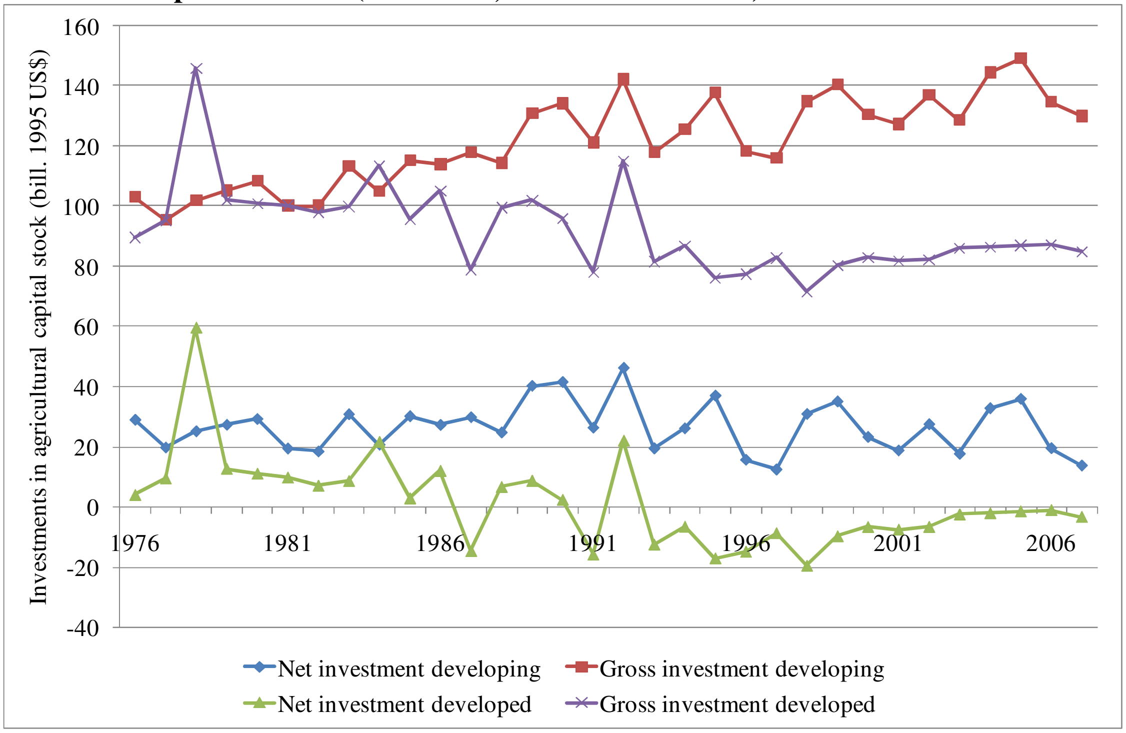
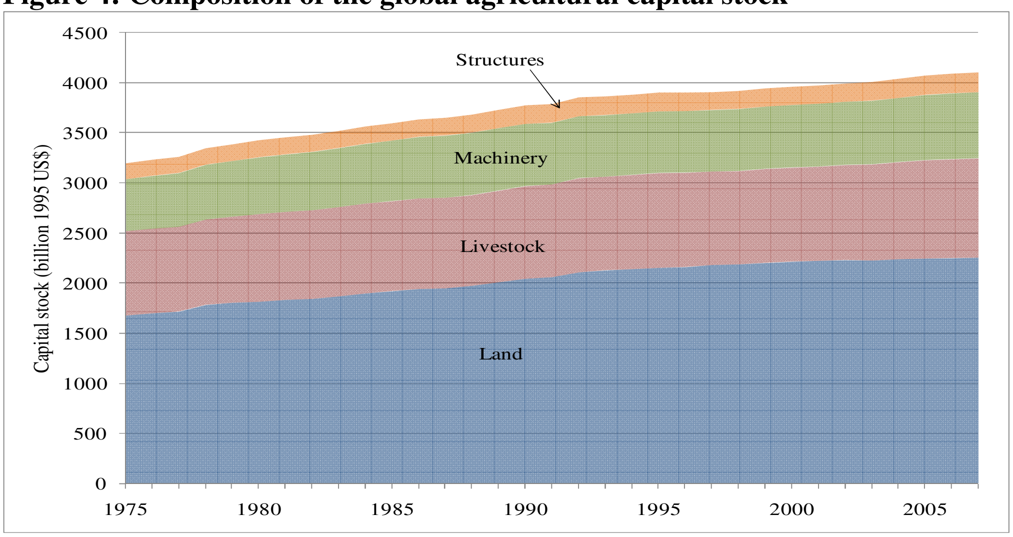
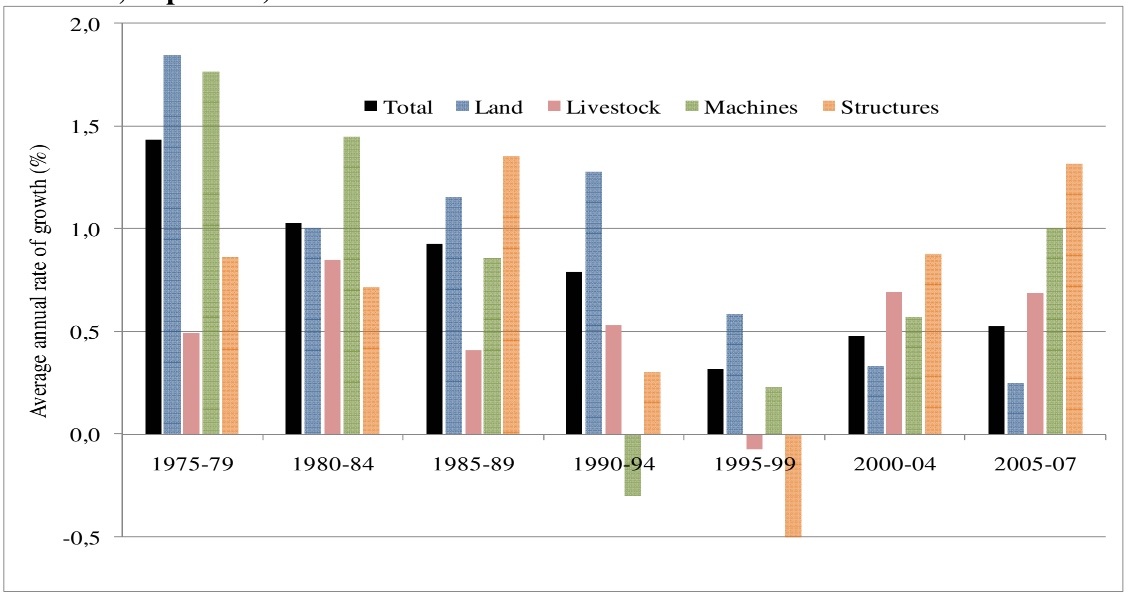


Figure 4: Composition of the global agricultural capital stock



All four components of the ACS increased between 1975 and 2007. Expressed in average annual rates of growth, the land component of the ACS 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 the ACS fell in the course of the 1980s, reaching low, negative rates in the first (machinery) or second (livestock, structures) half of the 1990s (Figure 5). Since 2000, the livestock, machinery and structures components of the ACS have once again displayed positive rates of growth. Land however has followed a different pattern. Average annual rates of growth in the land stock were never negative between 1975 and 2007 (Figure 5). However, they steadily declined over the entire period and have not recovered since 2000. Since the land component of the 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. Instead, it can also reflect in part a reduction in the willingness to invest in improving the productivity of land.

Figure 5: Average annual rates of growth in global ACS components (five-year periods since 1975, in percent)



3.3. The agricultural capital stock and the prevalence and depth of hunger

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

The estimates in Table 6 and Table 7 indicate that the ACS per person active in agriculture has indeed grown least in those countries with the highest prevalence and depth of hunger. In the countries in hunger prevalence categories 4 and 5 (>20 percent undernourished), growth in the ACS has been outstripped by population growth, resulting in a reduction in the level of ACS per person active in agriculture. The same is true for those 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 otherwise obscure the other countries in its respective hunger prevalence and depth of hunger categories.

Table 6: Average annual rates of growth in ACS per worker in agriculture by hunger prevalence category* (1975-2007, in percent)

Hunger prevalence category (only developing countries)	1975-2007 annual rate of growth of...		
	...capital stock in agriculture	...population active in agriculture	...capital stock per 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%

** Note: Hunger prevalence categories based on 2003-2005 data from FAO (2008).*

Table 7: Average annual rates of growth in ACS per worker in agriculture by depth of hunger category* (1975-2007, in percent)

Depth of hunger category (only developing countries)	1975-2007 annual rate of growth of...		
	...capital stock in agriculture	...population active in agriculture	...capital stock per 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%)	1.71%	0.96%	0.74%

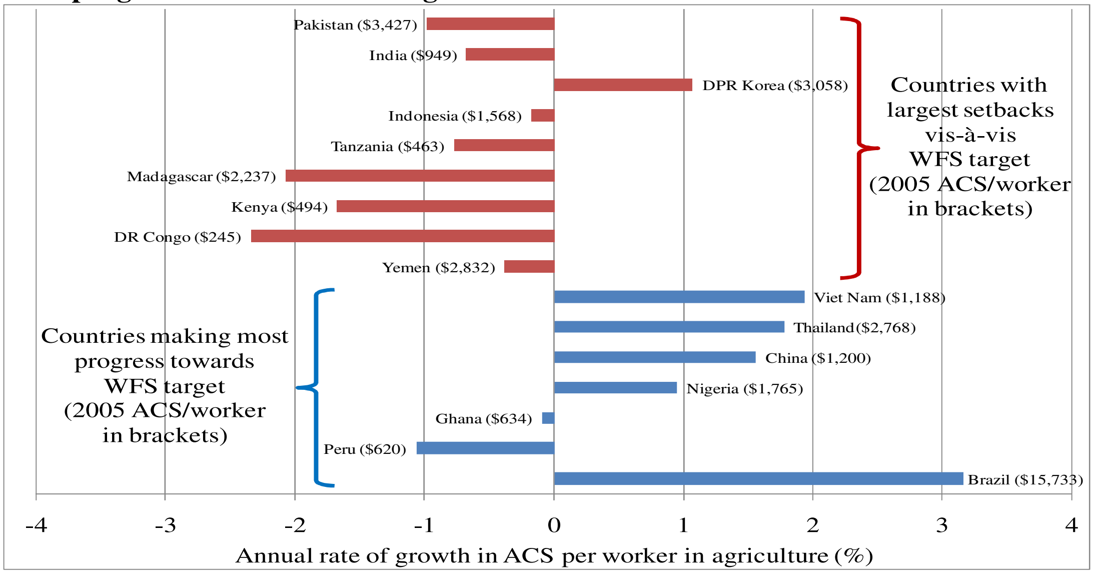
** Note: Depth of hunger categories based on 2003-2005 data from FAO (2008).*

3.4. The agricultural capital stock in countries with success in hunger reduction

If it is true that countries with high prevalence and depth of hunger are characterised by lower levels of investment in ACS, is there also evidence that countries that have been successful in reducing hunger are characterised by higher rates? Figure 6 presents information on annual rates of ACS growth between 1990 and 2005 for developing countries that the FAO (2008, p. 16) identifies as having made the most progress or as having experienced the largest setbacks with respect to the 1996 World Food Summit (WFS) target of halving the number of hungry by 2015. With the exception of the Democratic People's Republic of Korea, all of the developing countries that have 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.

The relatively high rate of ACS growth recorded for the DPR Korea must be interpreted with caution because it is difficult to confirm official statistics in this country; Peru's progress toward the WFS target despite a negative rate of ACS growth may be due the resolution of internal conflicts and unrest in the course of the 1990s. Note that according to the national accounts-based ACS estimates, Peru is actually one of the better performing countries, with positive accumulation of ACS per worker for the same period. Ghana has made good progress towards the WFS target and is on track for MDG1, but has witnessed slightly negative ACS growth. This suggests that the determinants of success have been outside the farm sector itself. In fact, a recent OECD study (Dewbre and Debattisti, no date) concludes that Ghana's success in poverty reduction may have been caused less by on-farm investments than by public investments in research, technology and infrastructure leading to strong growth and income diversification in the rural non-farm economy.

Figure 6: Annual rates of ACS growth (1990-2005) in countries that have made the most progress or suffered the largest setback towards the 1996 World Food Summit targets



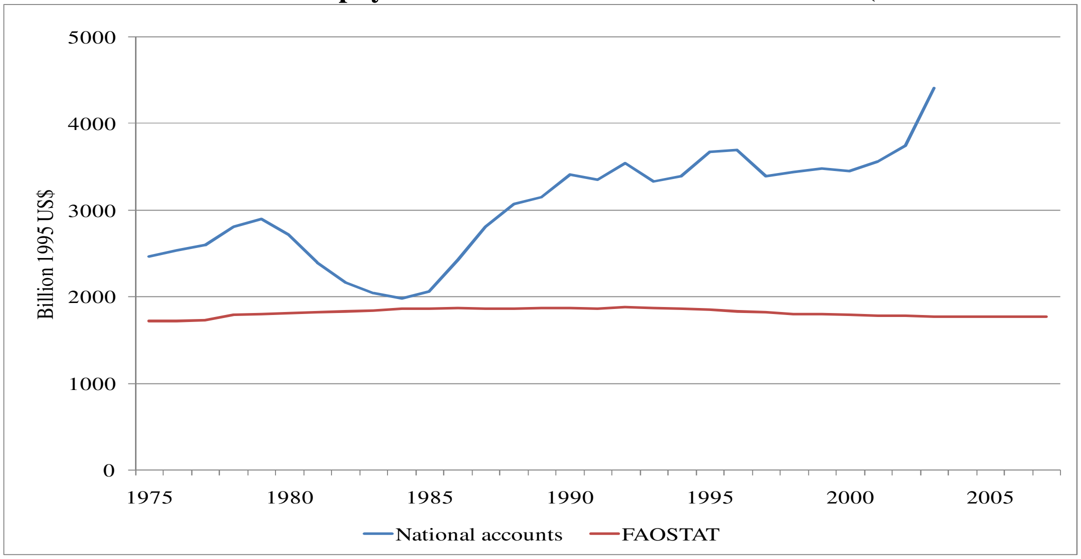
3.5. Comparing the national account and FAOSTAT approaches

The results discussed so far have been drawn from the FAOSTAT physical inventories estimates of the ACS. Since these estimates cover essentially all countries, they lend themselves to the calculation of the regional and global aggregates presented above. However, these estimates do suffer from methodological weaknesses. A comparison with estimates of the ACS based on the national accounts methods 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 the FAOSTAT estimates cover almost the same set of developed countries (30 in the case of the national accounts estimates, 31 in the FAOSTAT estimates – see Table 2). Hence, an almost direct comparison of levels and changes is possible for these countries. Although the focus of this paper is developing countries, we therefore begin by comparing the national accounts and FAOSTAT estimates for developing countries. This comparison reveals important discrepancies (Figure 7). First, the national accounts method produces a higher overall estimate of the ACS. This is presumably due to its more comprehensive coverage of the ACS; the gross capital formation data on which the national accounts estimates are based will capture investments that are not included in the limited set of assets that are covered by FAOSTAT.

Second, the national accounts estimates are more volatile than the FAOSTAT estimates. This reflects a fundamental difference between the estimates. The FAOSTAT estimates are calculated using a constant set of 1995 prices. The use of changing prices, deflators and exchange rates in the calculation of the national accounts-based estimates means that they capture not only changes in the volume of the ACS, but also changes in its valuation. For example, the drop in the national accounts-based ACS estimates in developed countries displayed in the first half of the 1980s (Figure 7) is presumably due to the strength of the US-dollar over this period, which reduced the US-dollar value of the ACS in other developed countries for example in Europe. Examination of the national accounts-based dataset 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 is also revealed for Asia and to a lesser extent Africa at this time. We do not have up-to-date numbers on the evolution of the ACS in 2008-09, but the experience of past global debt crises suggests that they can provoke large and protracted dents in the evolution of agricultural capital.

Figure 7: Total agricultural capital stock in developed countries – comparing national accounts and FAO physical inventories estimates since 1975 (billion 1995 US$)



Finally, the national accounts estimate for developed countries trends strongly upward over the entire period since 1975, while the FAOSTAT estimate show only a very slight increase overall, and a sustained downward trend in the 1990s. This difference is at least partly due to the use of constant prices in the FAOSTAT approach, as a result of which the FAOSTAT estimates fail to capture increases in the quality of many components of the ACS over time. However, Table 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 same nine and three of three, respectively, display positive ACS trends in the FAOSTAT database. It appears that the two approaches to estimating the ACS are producing substantially different results.

Table 8: Trends in the development of the agricultural capital stock by region – a comparison of the national accounts and FAOSTAT physical inventories estimates (1975-2003)

Region (number of countries)	National accounts estimates			FAOSTAT estimates		
	Positive trend	Negative trend	No sig. trend	Positive trend	Negative trend	No sig. 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 & Caribbean (17)	3	9	5	13	2	2
Near East & North Africa (9)	6	2	1	9	0	0
Sub-Saharan Africa (9)	0	7	2	8	0	1
East & 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 comparison in Table 8 is based on the 76 countries in the national accounts database. Comparison for the many especially developing countries that are not included in this database is clearly not possible. Given the theoretical advantages of the national accounts approach to measuring the ACS, we could base our entire discussion on results produced using this method, if we could be sure that these results are based on a representative sample of countries. However, this does not appear to be the case. Table 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 are based 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, a result which mirrors that found for the aggregate of developed countries (see Figure 7). Furthermore, the result that the ACS per person employed in agriculture is declining in the countries with the highest prevalence of hunger (see Table 6) is confirmed with the national accounts-based estimates.

However, the national accounts based estimates are based on fewer developing countries than the FAOSTAT results. For example there are 9 countries in hunger prevalence category 4 in the national accounts database, compared with 24 in the FAOSTAT database (Table 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, if 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 1,353 US$ in the full FAOSTAT sample of 24 countries, but increases to 3,888 US$ if only the 9 hunger prevalence category 2 countries included in the national accounts data are considered.

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 9 countries in the national accounts database, the FAOSTAT database includes a number of countries (e.g., Bangladesh, Cambodia, Cameroon, Democratic Republic of Congo and Senegal) that have considerably lower levels of ACS per worker in agriculture (Table 10). One might conjecture 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 in groups of developing countries.

Table 9: The agricultural capital stock per individual active in agriculture by hunger prevalence category – different approaches and samples of countries (US$/capita)

Hunger prevalence category	1975-79	1980-84	1985-90	1991-94	1995-99	2000-03	*# of countries in sample*
National accounts approach							
2	10404	8445	9053	12719	15671	15404	*3*
3	16128	12897	9341	8857	9492	9660	*11*
4	6833	5139	3780	3476	3848	3796	*9*
5	3027	2086	1613	1368	1026	940	*3*
FAOSTAT physical inventories approach (full sample)							
2	3660	4122	4535	5104	5315	5820	*20*
3	1636	1668	1675	1906	2070	2076	*28*
4	1391	1389	1371	1398	1397	1353	*24*
5	891	880	854	820	773	724	*18*
FAOSTAT physical inventories approach (same sample as national accounts approach)							
2	3524	3860	4430	5283	5863	6569	*3*
3	4192	4409	4343	5084	5644	5862	*11*
4	2338	2322	2246	3001	3692	3888	*9*
5	1470	1493	1480	1434	1355	1266	*3*

Table 10: Comparison of countries in hunger prevalence category four in the national accounts and FAOSTAT physical inventories databases

Countries in both databases	Countries only in the FAOSTAT database	
1. Bolivia	10. Grenada	19. Sudan
2. Botswana	11. Nicaragua	20. Cambodia
3. Dominican Republic	12. Yemen	21. Timor-Leste
4. India	13. Cameroon	22. DPR Korea
5. Kenya	14. DR Congo	23. Mongolia
6. Malawi	15. Djibouti	24. Bangladesh
7. Niger	16. Gambia	
8. Pakistan	17. Guinea-Bissau	
9. Sri Lanka	18. Senegal	

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

Each of the approaches to estimating the ACS suffers from important weaknesses which limit its usefulness as a basis for deriving robust conclusions and policy implications. The FAOSTAT-based estimates only cover certain components of the ACS. The national accounts-based estimates only cover 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 the 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 the ACS.

For the moment, all that can be done is to work carefully with both sets of estimates and to interpret them carefully. For 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 that are characterised by high prevalence and depth of hunger. Producing robust estimates of the ACS that combine the coverage of the FAOSTAT approach with the greater conceptual consistency of the national accounts approach will require a significant commitment of resources, but the effort must be made.

3.6. The agricultural capital stock and public expenditure on agriculture

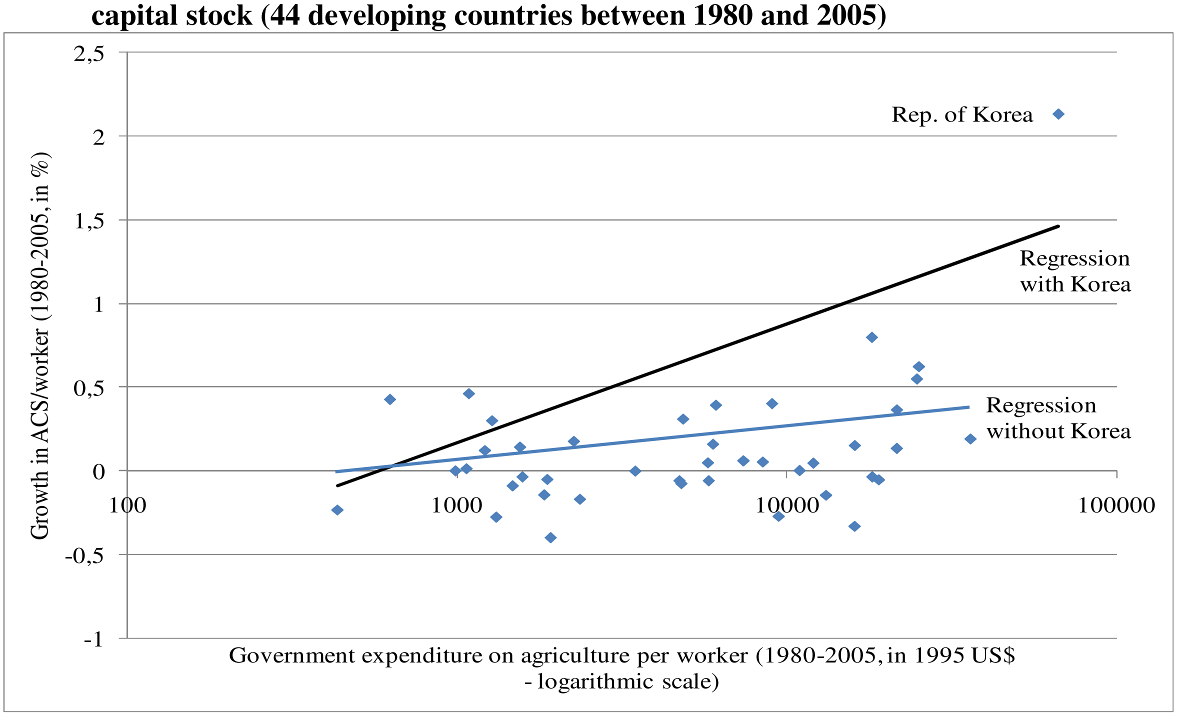
To what extent does public expenditure in agriculture supports investment in the ACS? Two types of public expenditure are relevant in this regard; national government expenditure and international expenditure in the form of official development assistance (ODA). Although we discuss these types of public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

a) 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 2001b). While some of the earlier decline was the result of structural adjustment programmes and has even led to a more efficient resource allocation, the main effect of low public expenditure was an inadequate provision of public services and lacking infrastructure and hence missing incentives for investment by the farms and other private investors in rural areas.

Country panel data on national government expenditure and ODA which matches the ACS data presented here over time and in cross section is not available. Fan and Rao (2003) describe the compilation of a panel on national government expenditure for a set of 43 developing countries from across Asia, Africa, and Latin America from 1980 to 1998. This dataset has since been expanded to 44 countries and updated to 2005.[4] It points to increasing real levels of government expenditure for the aggregate of all 44 countries over time. Figure 8 provides evidence of a robust positive relationship between government expenditure on agriculture and growth in the ACS in these countries over the period 1980 to 2005.

b) International assistance. As has been documented elsewhere, external assistance to agriculture in developing countries has declined since the late 1980s. At the country level, the relationship between agricultural ODA and the ACS growth (Figure 9) is not as clear-cut as in the case of government agricultural expenditure and ACS growth. The correlation coefficient between agricultural ODA receipts between 1995 and 2005 and growth in the ACS over the same period for 118 developing countries in the ODA database equals 0.48. However, the relation is weakened by the fact that several countries (e.g. Brazil, Sudan, Myanmar, Turkey and Syria) have recorded large increases in their ACS despite receiving comparatively low amounts of agricultural ODA (Figure 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 have received large amounts of ODA are omitted (e.g. India, Vietnam, Indonesia, Pakistan, Bangladesh and Thailand) there appears to be no significant relationship between agricultural ODA receipts and growth in the national ACS for the remaining countries.

Figure 8: Government expenditure on agriculture per worker and growth in the agricultural capital stock (44 developing countries between 1980 and 2005)



** Data on government expenditure on agriculture kindly provided by Shenggen Fan (see Fan and Rao, 2003).*

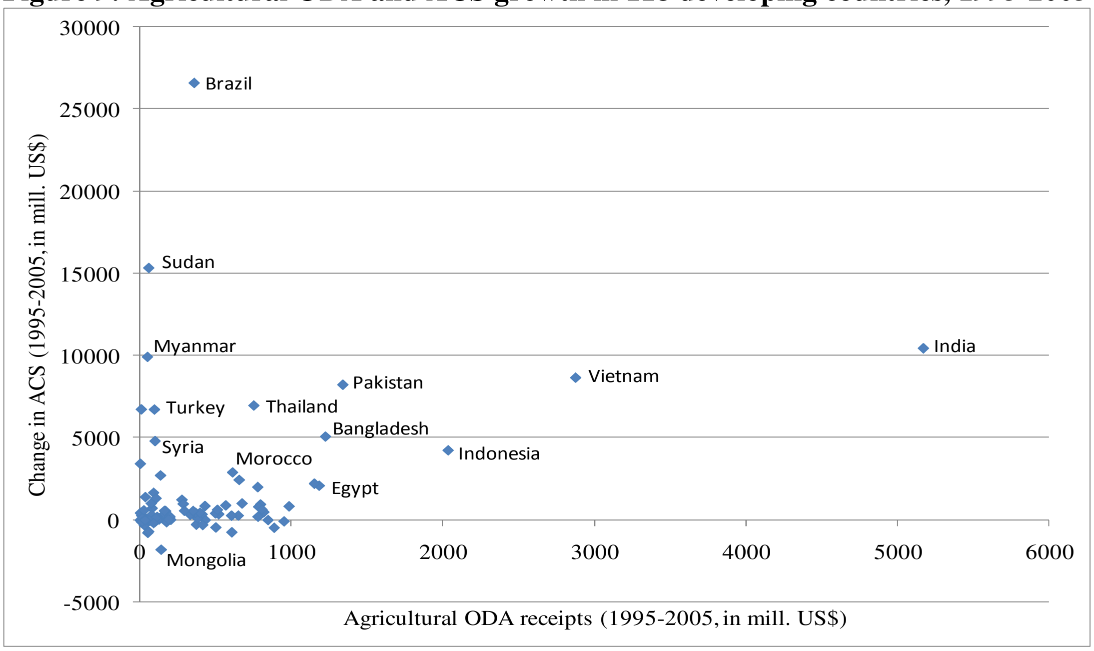
Besides direct public investment, favourable market prospects and other components of the overall investment climate such as stability and security, regulation and taxation, finance and infrastructure and a functioning labour market play a decisive role in determining the rate of ACS growth. In its World Development Report 2005, the World Bank (2005b, p. 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 much more progress, especially in rural areas.

[4] We are grateful to Shenggen Fan for making this data available to us.

4. THE AGRICULTURAL CAPITAL STOCK AND PRODUCTIVITY

The updated estimates of the ACS presented above provide a basis for generating estimates of changes in total factor productivity (TFP) in individual countries and regions. TFP analysis can cast light on the extent to which countries have succeeded in translating investment in agriculture into productivity gains. To this end, we take as a starting point a study in which Rao et al. (2004) estimate TFP changes in agriculture using panel data on agricultural inputs and output in 111 countries between 1970 and 2001.[5] The main aim of our analysis is to determine whether TFP estimates change when our updated and expanded estimates of the ACS are used. Rao et al. (2004) used land, tractors and an aggregate of five types of livestock as capital inputs; besides land we are able to consider four types of machinery, nine types of livestock and structures using our FAOSTAT physical inventories data.

Figure 9: Agricultural ODA and ACS growth in 118 developing countries, 1995-2005



4.1. Methods

Rao et al. (2004) employ data envelopment analysis (DEA) to estimate the technical efficiency of agriculture for each country in their dataset, and to derive shadow prices for agricultural inputs and outputs. They then use the Malmquist productivity index to measure growth in TFP and to decompose TFP growth into its two main components: technical change (i.e. shifts in the production frontier over time) and efficiency change (i.e. a production unit's ability to move closer to the production frontier). Both methods are well-established in the literature, so no review is provided here (see for example 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.

We apply these methods using the FEAR package in the programming language R (Wilson, 2008). We present a series of estimates beginning with those reported in Rao et al. (2004), which we replicate 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:

a) Rao et al.'s (2004) data contains a minor mis-coding of data which leads livestock output to be listed as crop output and *vice versa* for North and Central America. This is rectified in Model II.

[5] We are grateful to Prasada Rao and Tim Coelli for making their data available to us.

b) 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 (2006) method.

c) The updated FAOSTAT ACS data presented earlier in this paper begin in 1975 and extend to 2007, while Rao et al. (2004) use data from 1970 to 2001. To make subsequent comparisons possible, we first present average TFP growth rates for the 1970-2001 period that account for both the output data mis-coding and aggregation method changes mentioned above (Model IVa = Model II + Model III). We then present the results of this model for only 1975-2001 (Model IVb).

d) Maintaining the same 2-output, 5-input model estimated by Rao et al. (2004), we replace their land, tractor and livestock input data with the more comprehensive land, machinery and livestock estimates in our FAOSTAT ACS data for the period 1975-2001 (Model V).

e) 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-dimension 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, we re-estimate Model V but with the data aggregated to 1 output and 4 inputs (as opposed to 2 and 5). The reduced 1-by-4 dimension is chosen based on recommendations provided by Park et al. (2000) and Daraio and Simar (2007, pp. 153-154). We present results for 1975-2001 (Model VIa) and then for 1975-2007 (Model VIb) to take advantage of the longer time period covered by our FAOSTAT ACS data.

f) 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 et al. (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); they include robustness to outliers in the data, and less susceptibility to the curse of dimensionality. We employ this method in Model VII which uses 2 outputs and all 6 available inputs (land and labour as in Rao et al. (2004), and the 4 capital inputs in our FAOSTAT ACS data).

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

Table 11: TFP growth in different regions of the world according to different specifications and estimation techniques (average annual rate of TFP growth in percent)

Model	Time period*	Specification (outputs = n, inputs = m)	North Africa & the Middle East	Sub-Sahara Africa	North Am. & Pacific	Latin Am.	Asia w/o China	China	Europe	Trans-ition	World
I = Rao et al. (2004), 2 outputs (crop & livestock) & 5 inputs (labour, fertiliser, land, tractors & livestock)	1970-01	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†	1970-01	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‡	1970-01	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	1970-01	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	1975-01	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) & livestock inputs	1975-01	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° & 4 inputs (labour, fertiliser, land & capital = structures, machinery & livestock)	1975-01	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	1975-07	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 & livestock) & 6 inputs (labour, fertiliser, land, structures, machinery & livestock)	1975-07	m-order n = 2, m = 6	1.5	0.9	2.0	1.0	1.4	2.1	1.4	1.7	1.7

* All results exclude 1992 and 1993 as these produce highly variable estimates due to the impact of the breakup of the Soviet Union, the Yugoslav SFR and Czechoslovakia on input and output statistics.

† In the original Rao et al. (2004) data set (kindly 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.

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

° Output series are aggregated using 1999-2001 average international prices.

4.2. Results

A comparison of the different estimates of TFP change by region of the world reveals a number of results that are robust to the data, model and estimation technique alternatives outlined above (Table 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. Comparing Models IVa and IVb reveals that omitting the first half of the 1970 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 characterised by below average TFP growth in most of the world. Comparing Models VIa and VIb reveals that increasing the coverage to include 2002-2007 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. North Africa and the Middle East, sub-Saharan Africa, Latin America and Asia (without China) exhibit below-average levels that are less robust, with estimates for sub-Saharan Africa, for example, ranging from 0.3 to 1.8 percent, and estimates for Asia (without China) ranging from 0.2 to 1.5 percent. This probably reflects the fact that 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, p. 433; Daraio and Simar, 2007). This might also explain why, when Models I and II are compared, correcting the mis-coded 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 11 might be considered the most reliable, as the m-order method is much less sensitive to outliers. For this reason, the decomposition of TFP growth rates into efficiency change and technical change components in Table 12 is based on the m-order estimates. The results of this decomposition reveal that in North Africa and the Middle East, China and the Transition countries efficiency improvements have made relatively large contributions to TFP growth. 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 have been removed over the study period.

Table 12: Estimated changes in TFP and its components by region (1975-2007, in percent)

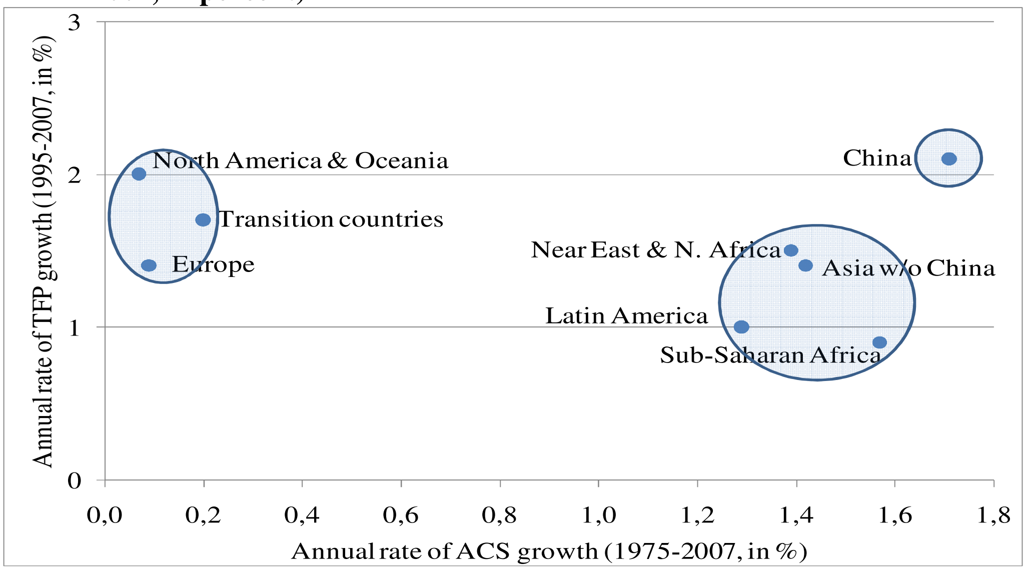
Time period	**Efficiency change**	**Technical change**	**TFP change**
North Africa & Middle East	1.4	0.1	1.5
Sub-Saharan Africa	0.3	0.6	0.9
North America and Pacific	-0.7	2.7	2.0
Latin America	0.3	0.7	1.0
Asia without China	-0.9	2.3	1.4
China	0.9	1.3	2.1
Europe	0.3	1.1	1.4
Transition countries	0.7	1.0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

Note: Results based on m-order estimates in Table 11. Results exclude 1992 and 1993 as these produce highly variable estimates due to the impact of the breakup of the Soviet Union, the Yugoslav SFR and Czechoslovakia on input and output statistics.

Comparing TFP change and ACS accumulation over the period between 1975 and 2007 period reveals some interesting patterns. The industrialised countries (Europe, North America, Oceania and the Transition countries) are characterised by low rates of ACS growth and relatively high rates of TFP growth (Figure 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 characterised by much higher rates of ACS growth but, in Latin America and especially sub-Saharan Africa, lower rates of TFP growth. China stands out as having both the highest rates of ACS and TFP growth. These results underline that high ACS growth does not necessarily lead to higher TFP growth.

All of the TFP estimates in Table 11 and Table 12 are based on non-parametric techniques and data on capital inputs that is derived from FAOSTAT. Ongoing work is looking into parametric estimation using stochastic frontier methods on the same data, and into both non-parametric and parametric estimates using national accounts-based capital input data. Of course, any use of the national accounts-based data will have to deal with the issue of selection bias identified above in section 3.5.

Figure 10: Annual rates of agricultural capital stock growth and TFP growth by region (1975-2001, in percent)



4.3. Factors that influence TFP growth

In a series of regressions, Rao et al. (2004) study factors which explain TFP levels across countries, such as land quality, irrigation, government expenditure, literacy rates and trade openness. They find that results are sensitive to the period that is studied and whether or not the transition economies are included in the analysis, the latter point probably being due to questionable data for these countries and the unique circumstances in which they find themselves. Two robust results are that both reducing illiteracy and reducing the incidence of malaria have positive impacts on TFP in agriculture. Furthermore, foreign direct investment (FDI) as a share of GDP is found to have a uniformly positive impact on agricultural TFP, confirming the expectation that FDI will be associated with improved technologies and know-how to implement them. A surprising result of the analysis presented by Rao et al. (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. Rao et al. (2004) 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. We revisit the issue of government expenditure and TFP using the Fan and Rao (2003) data on government expenditure on agriculture in developing countries. While this data on government expenditure is only available for 44 countries, it has the advantage of measuring government expenditure specifically on agriculture. Hence, unlike the general government consumption data employed by Rao et al. (2004), it 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. Missing data for some of the independent variables described below leads to complete omission of 7 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 (see Rao et al., 2004, p. 29 for details). We use two based periods to account for the entrance of the Transition countries into the TFP estimation.

Drawing on Rao et al. (2004) and theoretical considerations, the following series of possible covariates is identified (descriptive statistics in Table 13):

a) A dummy variable that equals 0 prior to 1994 and 1 thereafter is added to account for the fact that in 1994 the Transition countries enter the TFP estimation described above. 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.

b) The rural population as a share of the 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 (source: *World Development Indicators*).

c) The ratio of imports + 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 (source: *World Development Indicators*).

d) The share of irrigated land in total agricultural land is a proxy for land quality (source: *FAOSTAT*).

e) 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 standardised to ease interpretation (source: PRS Group's *IRIS dataset* – www.prsgroup.com).

f) 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 standardised (source: *POLITY IV Project* – http://www.systemicpeace.org/inscr/inscr.htm).

g) Net foreign direct investment (FDI) flows as a share of GDP are included to capture inflows of technology and know-how that might be expected to boost TFP (source: *World Development Indicators*).

h) Gross fixed capital formation as a share of GDP might capture technology that is embodied in fixed capital (source: *World Development Indicators*).

i) The logarithm of government expenditure on agriculture is included in the expectation that higher levels of this expenditure will be associated with improved availability of productivity enhancing infrastructure, research and education (source: Fan and Rao, 2003).

Several interaction terms involving the institutional quality and political regime indicators are included in the final specification. The final specification includes country fixed effects which are found to be jointly significant at the 1 percent level. The regression model is estimated using the *plm* package in R (Croissant and Millo, 2008) and results are presented in Table 13.

Table 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*)

Covariate	Regression results		Descriptive statistics			
	Coefficient	Standard error	Mean	Min.	Max.	Std. error
Dummy1994-2005	-0.308***	0.023	0.47	0.00	1.00	0.50
Rural population as % of total pop.	-0.031***	0.003	54.7	6.60	93.6	23.3
Exports + imports as % of GDP	0.002*	0.001	55.2	1.53	228.9	30.2
Share of irrigated land in total ag. land	0.111	0.292	0.10	0.00	1.00	0.19
Institutional quality index	-0.109***	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 * Political regime	-0.020*	0.011	0.16	-2.26	2.87	0.94
FDI inflows as % of GDP	-0.016***	0.006	1.58	-2.76	12.2	1.83
FDI * Institutional quality	0.032***	0.006	0.53	-6.91	20.9	2.06
FDI * Political regime	0.020***	0.005	0.49	10,3	14.1	2.31
Fixed capital formation as % of GDP	-0.007***	0.002	20.3	3.53	43.6	6.23
Fixed capital * Institutional quality	0.003*	0.002	2.23	58.8	86.4	21.8
Fixed capital * Political regime	-0.004**	0.002	0.21	52.2	47.3	20.8
log[Government expenditure on ag.]	0.034**	0.014	1.01	-2.20	3.77	1.09
Period	*1981-2005*					
Number of observations	*761*					
R^2	*0.32*					
Significance levels	** (10%), ** (5%), *** (1%)*					

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. Like Rao et al. (2004) we find a surprising negative relationship between institutional quality and TFP levels. 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 of 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 value and political regime covariates. But for a country that is one 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 take place is of crucial importance. An appropriate environment can ensure that the potential productivity enhancing impacts of FDI are realised, while under conditions of poor governance and institutional quality, FDI will be more short term and perhaps more focused on rent extraction rather than establishing capacities for adding value. Fixed capital formation has a weak negative impact on agricultural TFP which is only partially compensated 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 that we employ. Recall, however, that we also found no positive relationship between ACS growth and TFP growth for regional aggregates (Figure 10).

Finally, 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 a country's agricultural TFP. This underscores the importance of national government expenditure on agriculture, not only as a means of increasing rates of ACS growth as identified above (Figure 8), but also as a means of contributing to increased productivity *via* 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, p. 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.

5. CONCLUSIONS

(1) The fixed capital stock (ACS) in primary agriculture has been growing steadily at the global level over the last three decades, although for most of this period at declining rates. Using a volume approach with country-specific constant values per asset to measure the ACS, 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. This reduction was recorded in both developed and developing countries, although the rates of ACS growth were considerably stronger in developing countries than in developed countries in both sub-periods. In the latter group, growth rates have even been negative since the mid-1990s. Most recently, this trend seems to have been reversed. Since reaching a point close to stagnation in the mid-nineties, global ACS growth rates have started to gradually increase, reaching 0.5 percent annually in 2005-07. The reasons for this slight acceleration of capital growth need to be further examined (e.g. has new demand for bio-energy 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. Since the data for 2007 are based on projections and data for 2008-09 are not yet available, it is not possible to determine what impact the food price crisis of 2007-08 had on rates of ACS accumulation worldwide or in developing as opposed to developed countries.

(2) A shift in the relative shares of capital formation between different 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 falling. Whereas ACS shrinkage in the developed countries has slowed, rates of

ACS growth in the developing countries have remained positive but continued to fall. In view of the fact future demand growth is mainly expected in the developing countries, this shift could lead to increasing supply bottlenecks in the import dependent developing countries, unless action is taken to increase investments in these countries.

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

(4) The ACS has grown the least in countries with the highest prevalence and depth of hunger. The majority of the poor and hungry 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 of success in reducing undernourishment. However, in several of the least developed countries, in particular 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 under-nourishment. 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 reaching the WFS target of halving the number of under-nourished by 2015 have realized relatively high rates of growth in ACS per worker in agriculture.

(5) 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 infrastructure and sustainable access to natural resources that can provide adequate incentives for the private sector, in particular farmers, to invest in productive assets. This should be a strong signal for governments in developing countries to change priorities in budget allocations so as 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.

(6) Between 1975 and 2007, annual total factor productivity growth in world agriculture was roughly 1.7 percent. This average masks important differences between 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-Sahara-Africa. These differences between regions point to a substantial scope for further productivity growth. The breakdown of TFP growth into efficiency gains and technical change also varies widely between regions. Overall, efficiency gains have contributed relatively little to overall total TFP in the developing countries, although they have played a significant role in the transition countries. This has implications for the entry points of productivity enhancing policies in developing countries.

(7) Government expenditure on agriculture has a significant positive impact on total factor productivity 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 a country's agricultural TFP. Foreign direct investment is also found to have a positive impact on productivity growth, but only in combination with an institutional environment characterised by efficient bureaucracy, a lack of corruption, and democratic political structures. This suggests that the investment climate in a country – among other things its institutional and governance structures – has an important influence on the type of foreign direct investment that it can attract, and the impact of this investment on the agricultural economy.

(8) The estimates of ACS levels and growth presented in this paper are based on two different approaches which differ in many respects. Each of these approaches to estimating the ACS is characterised by important strengths and weaknesses, and they do not always produce the same results. International Organizations such as the 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 be made to combine the advantages of existing methodologies, and to improve the collection and processing of consistent data.

8. REFERENCES

Anriquez, G. and S. Daidone (2008): *An Expanded Cross-Country Database for Agricultural Investment and Capital*. Presentation, FAO-ESA, Rome.

Barre, M. (2006): *Investment as a Means to Agricultural and Rural Development in Africa: A Study on the Investment Needs for Agriculture and Rural Development*. Prepared for the FAO. Rome.

Cazals, C., J.P. Florens and L. Simar (2002): Nonparametric frontier estimation: A robust approach. *Journal of Econometrics,* Vol. 106: 1-25.

Coelli, T.J., G.E. Batteses, C.J. O'Donnell and D.S. Prasada Rao (2005): *Introduction to Efficiency and Productivity Analysis*. Berlin, Springer.

Crego, A., D. Larson, R. Butzer and Y. Mundlak (1998): *A new database on investment and capital for agriculture and manufacturing*. Policy Research Working Paper Series 2013, The World Bank, Washington, DC.

Croissant Y., and G. Millo (2008): Panel Data Econometrics in R. *Journal of Statistical Software*, Vol. 27(2).

Daraio, C. and L. Simar, L. (2007): *Advanced Robust and Nonparametric Methods in Efficiency Analysis: Methodology and Applications*. Springer, New York.

Dewbre, J. and A. D. Debattisti (no date): *Agricultural Progress in Cameroon, Mali and Ghana, why it happened and how to sustain it*. OECD, Paris.

Fan, S. and N. Rao (2003): *Public spending in developing countries: Trends, determination and impact*. EPTD Discussion Paper No. 99, IFPRI, Washington DC.

FAO (1995): *World Agriculture: Towards 2010*. Rome.

FAO (1996): *World Food Summit – Rome Declaration on Food Security*. Rome.

FAO (2001a): *Note on the Revision of the Estimates of Capital Stock Prepared by the FAO Statistics Division*. Rome.

FAO (2001b): *Mobilizing Resources to Fight Hunger*. 27th Session of the Committee on World Food Security. Rome.

FAO (2002): *The World Food Summit: Five Years Later. Mobilising the political will and resources to banish world hunger.* Technical Background Documents. Rome.

FAO (2003): *Anti-Hunger Programme. A twin-track approach to hunger reduction: priorities for national and international action*. Rome.

FAO (2008): *The State of Food Insecurity in the World. 2008: High Food Prices and Food Security – Threats and Opportunities*. Rome. http://www.fao.org/docrep/011/i0291e/i0291e00.htm.

Fuglie, K. (2008): Is a Slowdown in Agricultural Productivity Growth Contributing to the Rise in Commodity Prices? *Agricultural Economics*, Vol. 39(3 – supplement): 431-441.

Jensen, R. (2007): The Digital Provide: Information (Technology), Market Performance and Welfare in the South Indian Fisheries Sector. *Quarterly Journal of Economics*, Vol. CXXII(3): 879-924.

López, R. (2005): *Why Governments Should Stop Non-Social Subsidies: Measuring Their Consequences for Rural Latin America*. Department of Agricultural and Resource Economics, University of Maryland at College Park.

Park, B.U., L. Simar and C. Weiner (2000): The FDH Estimator for Productivity Efficiency Scores: Asymptotic Properties. *Econometric Theory*, Vol. 16: 855-877.

Rao, D.S.P., T.J. Coelli and M. Alauddin (2004): *Agricultural productivity growth, employment and poverty in developing countries, 1970-2000*. ILO Employment Strategy Paper 2004/9, Geneva.

Wilson, P.W. (2008): FEAR 1.0: A Package for Frontier Efficiency Analysis with R. *Socio-Economic Planning Sciences*, Vol. 42: 247-254.

World Bank (2005a): *Beyond GDP, World Bank Releases New Measure of Wealth.* http://web.worldbank.org/WBSITE/EXTERNAL/NEWS/0,,contentMDK:20648103~pagePK:34370~piPK:34424~theSitePK:4607,00.html.

World Bank (2005b): *World Development Report 2008:A Better Investment Climate for Everyone*. Washington DC.

World Bank (2008): *World Development Report 2008: Agriculture for Development*. Washington DC.

Zelenyuk, V. (2006): Aggregation of Malmquist Productivity Indexes. *European Journal of Operational Research*, Vol. 174(2): 1076-1086.