Chapter 9

Setting meaningful investment targets in agricultural research and development: challenges, opportunities and fiscal realities

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This chapter is aimed at the policy-makers who ask "Is there enough investment in agricultural research and development (R&D)?" They are constantly being reminded of declarations, commitments and targets asserting that they must do more or better. To provide some analytical structure and limits to the discussion, this chapter examines underinvestment separately from the demand and supply sides, before moving on to the investments, policy actions and institutional arrangements that are needed to bring supply and demand into balance.

The chapter has four sections in addition to this introduction. The next section sets the scene by providing historical trends in human and financial investments in agricultural R&D. This is followed by a section looking at underinvestment in three ways (two technical and one political): first, evidence of a continuing high rate of return relative to the social rate of discount is a formal definition of underinvestment, as additional investment would add more to social gains than to social costs; second, failure to maintain on-farm productivity growth at its historical trend and potential level is a sign of underinvestment; and third, if there are large gaps between the resources required to attain political commitments, such as the Millennium Development Goals (MDGs) with respect to poverty and hunger, there is underinvestment with respect to political commitments. At this point, nothing is said about how quickly the gaps must be eliminated to avoid waste.

Turning to the supply side, the chapter's fourth section questions whether countries' national efforts are commensurate with their financial and human resource capacities for doing more to deliver on commitments and investment targets set in various international fora. This section examines several public finance issues on the taxation and expenditure sides (which are not independent of each other), identifies the agricultural research intensity ratio, analyses the four components that determine the ratio's value, and comments on what could be done to increase investment in R&D. On the human resources side, it identifies gaps in research and higher education that affect research institutions' ability to ramp up their efforts in response to emerging challenges. Financial resource needs cut across all scales, from the global to the local.

The final section deals with new challenges that imply the need for not only reinvestment in agricultural R&D, but also investment in other parts of the knowledge system, to ensure balanced growth. The need for more highly trained researchers to deal with climate change, price volatility in global markets or water scarcity puts demands on the university system to expand M.Sc. and Ph.D. training. Such an expanded cadre provides valuable research support to existing scientists, while learning the advanced skills needed to become senior researchers.

New challenges demand new approaches, new skills and new institutional arrangements for collaborative research. The time and process by which these new arrangements come about are necessary investments.

Trends in agricultural R&D investments[1]

Public agricultural R&D spending

Global spending on public agricultural R&D (including the government, non-profit and higher education sectors) totalled USD 24 billion in 2005 purchasing power parity (PPP) dollars in 2000,[2] the latest year for which comparable global data are available (and excluding Eastern Europe and the former Soviet Union, for which no time series data were available).[3] Total public investment had increased

1. This section draws on Beintema and Stads (2008; 2010), Stads and Beintema (2009) and underlying data sets of the Agricultural Science and Technology Indicators (ASTI) initiative (www.asti.cgiar).

2. Financial data in this chapter are reported in real values using gross domestic product (GDP) deflators with the benchmark year 2005 and PPP indices from the World Bank (2008a). PPPs are synthetic exchange rates used to reflect the purchasing power of currencies, typically by comparing prices among a broader range of goods and services than conventional exchange rates (see also Beintema and Stads, 2011b). These global trends differ from those reported in Pardey *et al.* (2006). These revisions were in response to the World Bank's adjustments to its comparative pricing of goods and services across countries (using PPP indices), reclassification of non-Organisation for Economic Co-operation and Development (OECD) high-income countries, and new estimates for Latin American and a number of other countries (Beintema and Stads, 2008).

3. If Eastern European and former Soviet Union countries are included, total public spending on agricultural R&D totalled USD 25.1 billion (in 2005 international prices) in 2000 (Beintema and Stads, 2010).

considerably from the USD 16 billion reported in 1981 (Table 9.1). However, this increase did not take place equally across all regions. Spending in Asia and the Pacific more than doubled during the period, increasing at an average of 4.2 percent per year (Figure 9.1).[4] This was largely a result of high growth in agricultural R&D spending in the two largest countries, China and India (with annual growth of 4.4 and 5.8 percent, respectively). In contrast, spending in sub-Saharan Africa grew by an average of only 0.6 percent per year from 1981 to 2000. More worrisome is that the spending for the region as a whole contracted slightly during the 1990s, with more than half of the sub-Saharan African countries for which time series data were available spending less in 2000 than they did in 1991.

Table 9.1
Total public agricultural R&D expenditures, by income class and region

	Public spending	Public agricultural R&D spending		Regional share of global total		
	1981	1991	2000	1981	1991	2000
Country category	*(million 2005 PPP dollars)*			*(%)*		
Country grouping by income class						
Low-income (46)	1 410	2 010	2 566	9	10	11
Middle-income (62)	4 670	6 453	7 953	29	30	33
High-income (32)	9 951	12 806	13 456	62	60	56
Total (140)	16 032	21 268	23 975	100	100	100
Low- and middle-income countries by region						
Sub-Saharan Africa (45)	1 084	1 253	1 239	7	6	5
China	773	1 350	2 244	5	6	9
India	400	748	1 301	3	4	5
Asia and Pacific (26)	2 032	3 460	5 114	13	16	21
Brazil	1 005	1 414	1 247	6	7	5
Latin America and Caribbean (25)	2 245	2 676	2 755	14	13	12
Near East and North Africa (12)	720	1 074	1 0412	5	5	6
Subtotal (108)	6 081	8 463	10 519	36	40	43

Estimates exclude Eastern Europe and the former Soviet Union. Estimation procedures and methodology are described in Beintema and Stads, 2011b and various ASTI regional reports available at www.asti.cgiar.org. Number of countries indicated in parentheses.

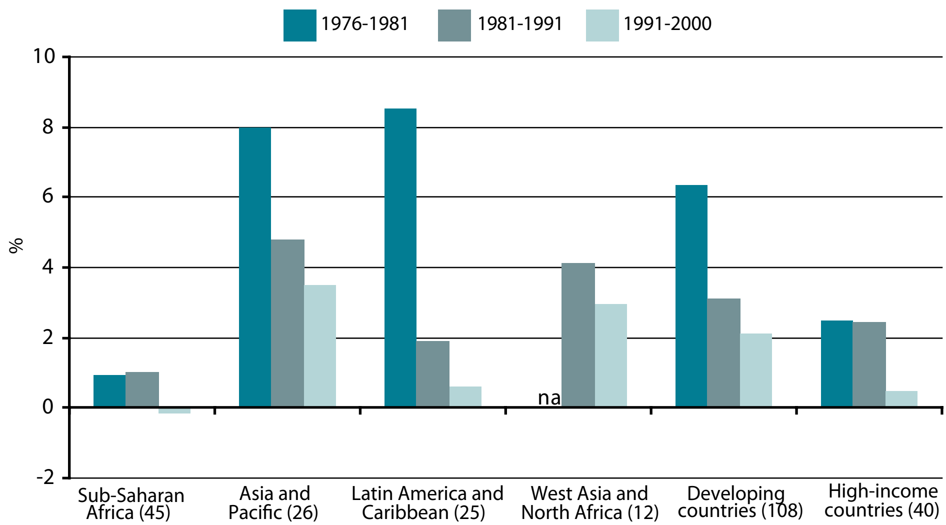
Sources: ASTI datasets and other secondary sources prepared for Beintema and Stads, 2010.

As a result of these different regional growth patterns, the distribution of agricultural R&D spending changed over the two decades. Due to the high

4. The regional totals refer to developing countries (defined as low- and middle-income countries) only, and exclude high-income countries such as the Republic of Korea in the Asia and the Pacific region and Israel and Kuwait in the Near East and North Africa region.

increase in total spending in Asia and the Pacific, its share in the global total increased from 13 percent in 1981 to 21 percent in 2000. As a result, the shares of sub-Saharan Africa and Latin America declined to 5 and 11 percent of the total, respectively. Total agricultural R&D spending in sub-Saharan Africa was about the same as total spending in Brazil, the largest public investor in Latin America, and considerably lower than the spending levels in India and China. Although spending in high-income countries as a whole continued to grow in absolute terms, their share of total global spending declined from 62 to 56 percent. The shares of spending by low- and middle-income countries increased from 9 to 11 percent and from 23 to 32 percent, respectively.

Figure 9.1
Annual growth rates in agricultural R&D spending



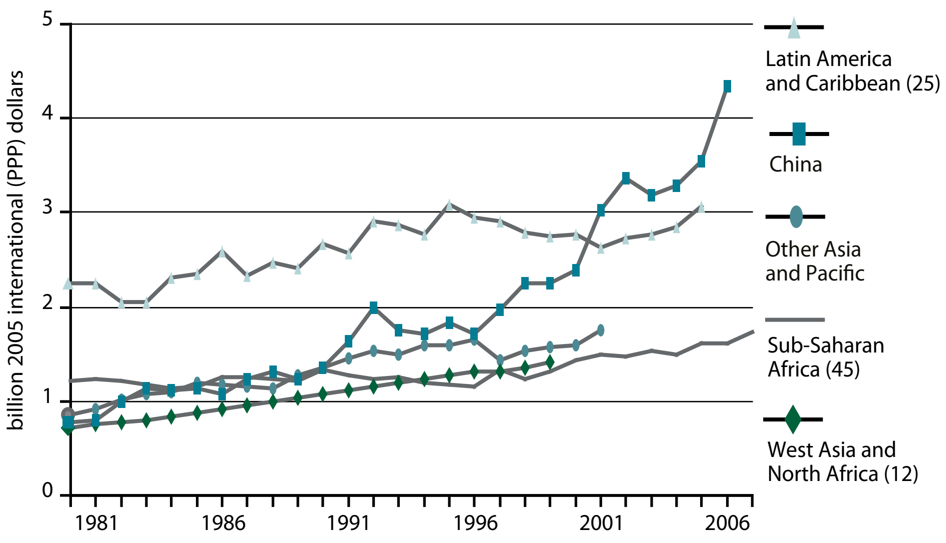
Estimates exclude Eastern Europe and the former Soviet Union. Estimation procedures and methodology are described in Beintema and Stads, 2011b and various ASTI regional reports available at www.asti.cgiar.org. Number of countries indicated in parentheses.
Sources: ASTI datasets and other secondary sources prepared for Beintema and Stads, 2010.

Although data on global public investment patterns since 2000 are still unavailable,[5] more recent data collected by the ASTI initiative show that investments continued to grow in China and India (Figure 9.2). Agricultural R&D

5. Data collection efforts by the ASTI initiative are under way in sub-Saharan Africa and a few other countries to ensure a new global update for 2008.

expenditures in Latin America and the Caribbean rebounded in recent years, following a period of contraction during the late 1990s, which was mostly due to financial crisis in a number of Southern Cone countries. Public agricultural R&D investment also increased in sub-Saharan Africa, by about one-fifth during 2001 to 2008. This was the result of increased government commitments in some of the larger countries, such as Ghana, Nigeria, the Sudan, the United Republic of Tanzania and Uganda. However, many other countries experienced declining agricultural spending, and even in the countries that experienced growth, the additional funds were mostly used for salary increases or augmentation of (often poorly maintained) infrastructure, and not for research. In addition, increased funding, such as in Nigeria and the Sudan, often followed many years of underinvestment, and levels are still below those needed to sustain these countries' agricultural R&D needs (Beintema and Stads, 2011a).

Figure 9.2
Public agricultural R&D investment trends in developing countries



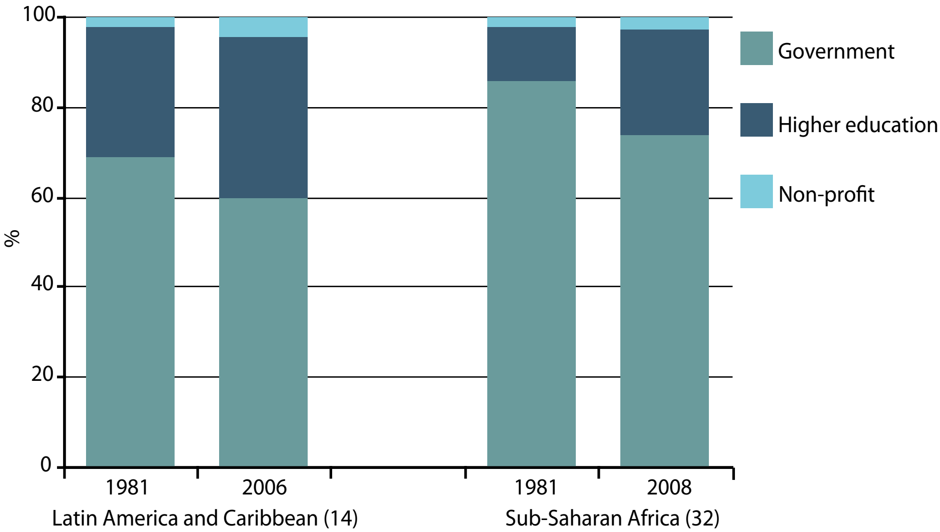
Number of countries indicated in parentheses.
Sources: Beintema and Stads 2008; 2011a; Stads and Beintema, 2009, based on ASTI data sets.

However, public agricultural R&D has become increasingly concentrated in a handful of countries (Pardey *et al.*, 2006). The top five countries in terms of agricultural R&D spending – the United States of America, Japan, China, India and Brazil – accounted for 48 percent of total global public agricultural R&D in 2000, up from 41 percent in 1991. Meanwhile, only 6 percent of agricultural R&D

investments worldwide were made in 80 (mostly low-income) countries, which had a combined population of more than 600 million people and accounted for 14 percent of the world's agricultural land area. In Latin America, about three-quarters of total public investments in agricultural R&D were spent by only three countries: Brazil, Mexico and Argentina. Since the mid-1990s, the investment gap between the region's low- and middle-income countries has widened, in part as a result of sharp cuts in research expenditures in some of the poorer, more agriculture-dependent countries, such as Guatemala and El Salvador. Asia has a similar, but less pronounced, knowledge divide between its rich and poor countries, and the gap between the scientific "haves" and "have-nots" is becoming increasingly visible. From 1981 to 2002, especially in the latter decade, both China and India intensified their agricultural research spending, while some smaller countries, such as Malaysia and Viet Nam, also realized impressive agricultural R&D spending growth. However, other countries, such as Pakistan, Indonesia and Lao People's Democratic Republic, proved sluggish and at times negative, largely owing to the Asian financial crisis, the completion of large donor-financed projects, or high rates of inflation. In Africa, agricultural research has historically been better funded in some countries, such as Kenya and South Africa, than in a large number of the very poorest countries, especially in Western Africa. There is no evidence that this divide has increased over the past few decades, partly because of the donor dependency of many countries and the erratic nature of government and donor support to agricultural research over the years.

The government sector is still the main player in public agricultural R&D, in terms of execution as well as funding. The government sector accounted for 60 percent of total full-time equivalent (FTE) R&D staff in Latin America in 2006, and for 74 percent in sub-Saharan Africa in 2008 (Figure 9.3). Despite this leading role of the government sector, the higher education sector has gained prominence in several countries, and accounted for 36 percent of total public agricultural R&D in Latin America in 2006, compared with 29 percent in 1981. The higher education share in sub-Saharan Africa increased from 12 percent in 1981 to 24 percent in 2000. In absolute terms, the total number of FTE researchers employed in the higher education sector almost doubled in Latin America and tripled in sub-Saharan Africa. In some countries, such as Argentina and Mexico, higher education's capacity approaches that of the government sector. In India, higher education has surpassed the government sector in terms of FTE agricultural research staff; this results from the integration of research, extension and education in the Indian system. Despite the increasing share of the higher education sector as a whole, the individual capacity of each faculty/school is often very small, and the agricultural higher education system is often fragmented, such as in the Sudan, the Philippines and Nigeria.

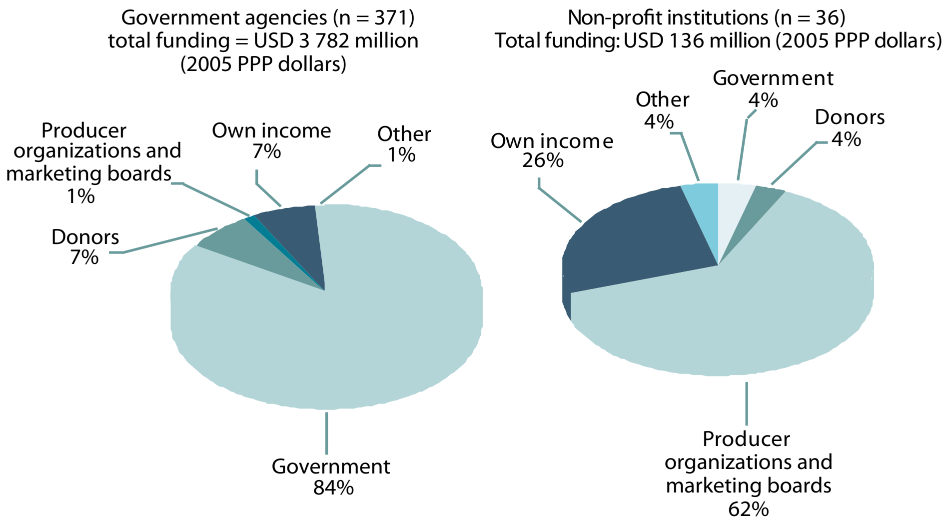
Figure 9.3
Shares of institutions in agricultural R&D, Latin America and the Caribbean and sub-Saharan Africa



Shares measured in terms of FTE researchers. Number of countries indicated in parentheses.
Sources: Stads and Beintema, 2009; Beintema and Stads, 2011a, based on ASTI data sets.

The government sector is also still the largest contributor to public agricultural research (Figure 9.4). Government allocations accounted for an average of 81 percent of total funding received by a sample of more than 400 government agencies and non-profit institutions in 53 developing countries. Only 7 percent of total funding was received from donor contributions, in the form of loans or grants. This share was driven mostly by the high donor dependency of government agencies in sub-Saharan Africa. In 2000/2001, among the main government agencies in 23 countries for which data were available, 35 percent of funding came from donor loans and grants. Internally generated funds, including contractual arrangements with private and public enterprises, accounted for an average of 7 percent of total funding. The 36 non-profit organizations in the sample received close to two-thirds of their funding contributions from producer organizations and marketing boards. These contributions were collected mainly through taxes on the export or production of commercial crops. The non-profit organizations were also more active than the government agencies in raising income from internally generated resources, which accounted for 26 percent of their total funding and included contracts with private and public enterprises.

Figure 9.4
Composition of funding sources since 2000

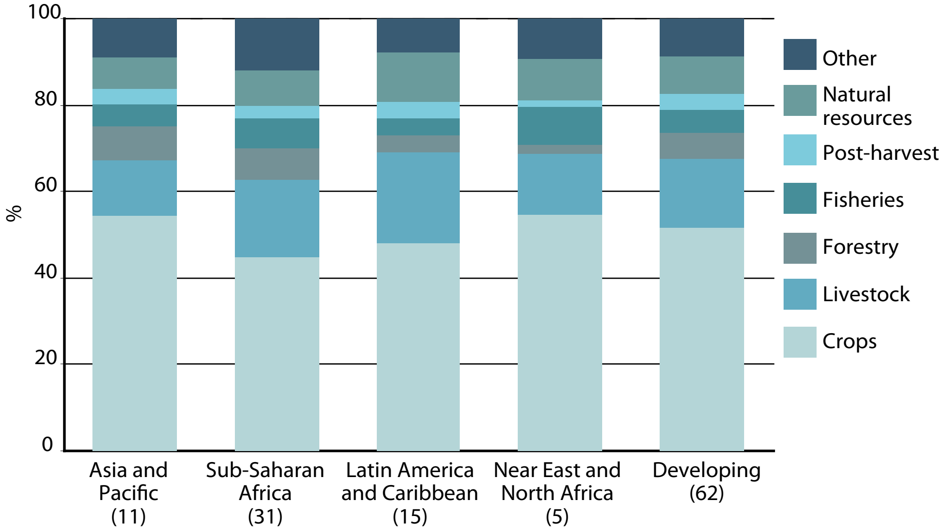


Own income includes contracts with private and public enterprises. Data are for 53 developing countries; they exclude China, Nigeria and South Africa, which have large agricultural R&D investments.
Source: Echeverria and Beintema, 2009, based on ASTI data sets.

Although government allocations still represent the main source of funding, there are again considerable differences among countries. A number of developing countries depend on non-governmental sources of funding. This is mostly the result of high donor dependency, but some countries have increased the diversity of their funding sources and include considerable income from the sale of products or services, contractual arrangements with public and private enterprises, or contributions from producer organizations through taxation of exports or production.

In a sample of 62 developing countries, more than half of total FTE researchers in agricultural R&D were involved in crop research, while 16 percent focused on livestock (Figure 9.5). The remaining one-third of the researchers focused on forestry (6 percent), fisheries (5 percent), natural resources (9 percent), post-harvest (4 percent) and other agricultural disciplines. Researchers in sub-Saharan Africa and Latin America and the Caribbean spent relatively more time on livestock research than staff in Asia and the Pacific and the Near East and North Africa.

Figure 9.5
Research focus of agricultural research staff, by main subsector (shares of FTE staff)

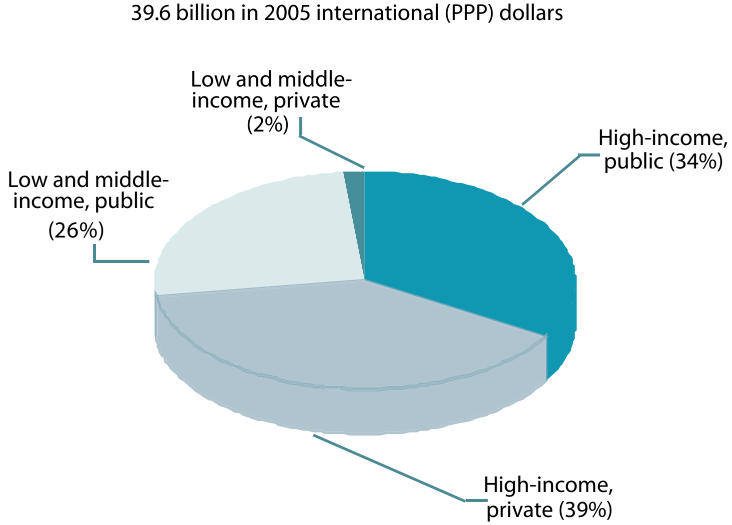


Sub-Saharan Africa data are for 2008; Asia and the Pacific for 2002; Latin America and the Caribbean for 2006; and the Near East and North Africa for 2002/2003. The "other" category includes subsectors such as forestry, fisheries, natural resources, post-harvest and socio-economics. Number of countries indicated in parentheses.
Source: Authors' calculations based on ASTI data sets.

Private agricultural R&D spending

Data on private sector investments in agricultural R&D remain very limited. In 2000 (the only year for which global estimates are available), the private sector spent an estimated USD 16 billion in 2005 PPP dollars (Figure 9.6), 41 percent of the global total. Almost all of these private sector investments were made by private companies performing agricultural R&D in high-income countries. Private sector investments in the developing world accounted for only 2 percent of total public and private agricultural R&D investments in 2000, with most being made by Asian private companies (Beintema and Stads, 2008). The private sector plays a stronger role in funding agricultural research, as many private companies contract research to government and higher education agencies, but its role in most developing countries is and will remain small, given the limited funding opportunities and incentives for private research. Most private sector research in developing countries focuses on the provision of input technologies or technical services for agricultural production, and most of these technologies are produced in high-income countries (Pardey *et al.*, 2006).

Figure 9.6
Shares of public and private agricultural research investments, circa 2000



Source: Beintema and Stads, 2008, based on ASTI data sets.

There is only limited information on the level of private sector involvement over time or on the type of research that private companies are conducting. Alston *et al.* (1999) found that only 12 percent of private research in Australia, the Netherlands, New Zealand, the United Kingdom and the United States of America focused on farm-oriented technologies in 1992; the corresponding share for the public sector in these countries was 80 percent. Food and other post-harvest activities accounted for 30 to 90 percent in Australia, the Netherlands and New Zealand; and chemical research for between 40 and 50 percent in the United Kingdom and the United States of America. Pray and Fuglie (2001) found that the share of private sector investments in total agricultural R&D investments grew between the mid-1980s and the mid-1990s in China, India and Indonesia (from a sample of seven Asian countries), and that private investments grew more than public ones. However, growth in private sector investments was uneven across subsectors, with investments in the agricultural chemical and, to a lesser extent, the livestock subsectors increasing substantially, while growth in other subsectors, such as plantation crops and machinery, was slower.

International agricultural R&D investment

The majority of research is carried out by the Consultative Group on International Agricultural Research (CGIAR), which currently consists of 15 centres. The first four centres were established in the late 1950s and the 1960s, with considerable financial support from the Rockefeller and Ford Foundations. During the 1970s, the number of centres increased to 12, and the funding per centre increased over the decade. This led to a tenfold increase (in nominal terms) in total CGIAR investments. Total funding continued to increase during the 1980s, but at a slower pace. During the 1990s, however, total funding grew less than the number of centres, and per-centre spending levels could not be maintained. Since 2000, overall funding to CGIAR has increased, but a larger proportion is directed to specific research projects and programmes that also involve non-CGIAR research organizations (Beintema *et al.*, 2008; Pardey *et al.*, 2006).

There are a number of other international research providers, mostly with a regional or subregional focus. For example, the two largest non-CGIAR agencies conducting research in Africa are the International Cooperation Centre of Agricultural Research for Development (CIRAD, based in France) and the Institute of Research for Development (IRD). In Asia, the Australian Centre for International Agricultural Research (ACIAR) develops international agricultural research partnerships, but does not conduct research in the region's developing countries itself. The mandate of the Japan International Research Center for Agricultural Sciences (JIRCAS) covers all developing countries, and most JIRCAS agricultural research is in Asia. Two important regional agencies conducting agricultural research in Latin America and the Caribbean are the Tropical Agricultural Research and Higher Education Center (CATIE) and the Caribbean Agricultural Research and Development Institute (CARDI). Other agricultural research agencies are also active in these three regions (Beintema and Stads, 2006; 2008; Stads and Beintema, 2009).

Three definitions of underinvestment in agricultural R&D

As argued in the introduction, underinvestment in research can occur when: i) the rate of return on research is consistently higher than the social rate of return on alternative investments; ii) the nature of investment has changed so that the country is failing to maintain historical growth in on-farm productivity; and iii) there are gaps between current investments and the resources needed to attain goals.

Evidence from rates of return analysis

The underinvestment hypothesis is a straightforward application of marginalist economic theory: if, through policy decision or budget constraints, the social value of the last unit of product consumed (or input employed) is greater than the social cost, there is underconsumption or underuse of the product (or input) because it would pay to borrow until the social gain and social cost are equal. If projects are ranked in descending order by their expected rates of return (the marginal efficiency of investment), and the return of the last project undertaken is higher than the social (opportunity) cost (of capital), this is prima facie evidence of underinvestment.

Hundreds of studies of the social rate of return on research consistently show that the rate of return on public investment in agricultural research is higher than either the social rate of return on capital or the other opportunities for public investment. In general, the return on public investment is higher than the private rate of return, even when allowing for the marginal excess tax burden of the tax collection system and the returns accruing to farmers. This is because it is impossible to appropriate many of the benefits associated with research by private firms (Widmer, Fox and Brinkman, 1988; Evenson and Westphal, 1995).

There is no tendency for the rate of return to decline over time, and it appears that rates of return may be higher when the research is conducted in more developed countries (Alston *et al.*, 2000).

Roseboom (2002) defines the "underinvestment gap" as the difference between the economic rate of return of a marginal R&D project and the social rate of return. Based on the distribution of projects studied, he concluded that:

Under the assumption of full information and rationality, developed countries could have invested about 40 percent more in public agricultural R&D and developing countries about 137 percent more. In terms of agricultural R&D intensity (i.e. expenditures as a percentage of agricultural GDP), developed countries could have invested 2.8 rather than 2.0 percent and developing countries 1.0 rather than 0.4 percent in the period 1980 to 1985.

Fuglie and Heisey (2007) analysed the economic returns of public agricultural R&D in the United States of America and summarized their findings as follows:

- *There appear to be significant social returns to private agricultural research. The private sector is able to capture only a share of the productivity benefits from its technology.*
- *Agricultural research generates long-term benefits. Public research undertaken today will begin to noticeably influence agricultural research productivity in as little as two years and its impact could be felt for as long as 30 years.*
- *Agricultural knowledge or research "spill-overs" across state and national boundaries are significant.*

It is important to note that the rate of return concept measures the economic benefits of agricultural investments, but not the non-economic impacts, such as environmental, social, health and cultural benefits and costs. These are important when investment decisions are being made, but are not included as they are difficult to quantify and validate (Beintema *et al.*, 2008). Furthermore, spill-overs of agricultural technologies among countries and regions account for a large share of the total social benefits of public agricultural research. When spill-overs occur, rate of return studies will overestimate the total benefits of the research investment in the receiving country, while underestimating the total benefits in the country where the technology originated (Alston, 2002; Beintema *et al.*, 2008). Pardey *at al.* (2006) state that the supply and demand for spill-over technologies are changing. Agricultural research in high-income countries is focusing increasingly on technology types that are less relevant for the agriculture sector in developing countries (especially the poorest ones). In addition, technologies have become less mobile because of stricter intellectual property rights and other regulatory policies.

Failure to maintain historical levels of productivity growth

It is sometimes necessary to reiterate the importance of productivity. Nobel Prize winner, Sir W. Arthur Lewis (1996) stated unequivocally that "an increase in agricultural productivity is fundamental to the solution of the problem of distribution since it makes possible simultaneous increases in mass consumption, saving and taxation". Although agricultural research has proved good for increasing on-farm productivity and providing spill-overs to other social goals, it is a blunt instrument for addressing these other goals directly. Other authors have underlined the importance of productivity growth. Cereal output in developing countries has grown by 2.8 percent per year for three decades, and yields, not area, were responsible for this growth. Total factor productivity has grown along with yields (Pingali, 2009). Today's investment in research drives tomorrow's growth of productivity (Fuglie and Heisey, 2007).

Recent studies point out that underinvestment in research that enhances productivity at the farm level explains the significant decline in the rate of agricultural productivity growth in developed countries. The greater share of agricultural innovations can be traced to organized, scientific and industrial R&D efforts funded by government and the private sector, but such investment has not only slowed but has also changed its focus.

Pardey (2009) notes that productivity growth in the United States of America was slower in the 1990 to 2005 period than between 1961 and 1989, and suggests several possible causes of this: bad weather, a changing regulatory environment, degradation of the natural resource base, slower growth of investment, the changing composition of agricultural research, changing private sector roles, and reduced spill-over from other countries and CGIAR. He argues that this decrease in productivity growth is partly the result of a slowdown in spending and the redirection of agricultural R&D away from maintaining or enhancing productivity.

Alston, Pardey and James (2009) point out that public investments in California's agriculture have shown benefit-to-cost ratios of 10:1, indicating substantial underinvestment in agricultural research according to the first definition. In addition to the slowing and increased variability of funding, these authors point to recent trends indicating that the extent of underinvestment in productivity-enhancing agricultural science may be worsening:

Public-sector research has drifted away from on-farm productivity enhancements toward investments emphasizing food safety and quality, human health and nutrition, and natural resources and the environment. Much of this research could have social payoffs comparable to those from farm-productivity enhancing research; but a slower rate of growth in total spending and the drift of research emphasis will result in slower rates of farm productivity growth and a decline in global competitiveness.

For developing countries, the decline in productivity-enhancing research in developed countries means that the spill-over benefits will be reduced, at the same time as climate change and economic conditions become worse. Alston, Pardey and James (2009) note that the situation will become even worse for developing countries, given the long lag before spill-over benefits occur.

This chapter identifies a "productivity growth failure", which is the difference between the historical growth rate of on-farm productivity (approximately 2 percent) and the current rate (approximately 1 percent). This situation is characterized as underinvestment when the level and composition of investment keep on-farm productivity growth below its historical trend and presumed potential.

The incremental investment needed to achieve goals and commitments

There are many prescriptive targets for investment in agricultural R&D. While they all perform useful functions in defining what should be done, their original purpose and value are often forgotten. Table 9.2 summarizes some of the most common targets and the investment needed to achieve them.

For countries with adequate policies and institutions, what are the additional needs for reducing income poverty to the desired level, and what do these imply in terms of research and other support to the agriculture sector? For countries without adequate policies, what studies and activities are needed to improve policies and institutions? If the focus is exclusively on MDG 1, the additional costs of attaining health, education and environmental goals that do not come as spill-overs from meeting MDG 1 would have to be estimated.

Table 9.2
Common prescriptive targets

Target	*Underlying concept*	*Qualifications*	*Formulation*[a]
Agricultural research intensity ratio (ARI)	There should be a norm for relating reinvestment in the agriculture sector to the size of the sector	Its components are more instructive than its level; there are different norms for different classes of country	ARE/AGDP from 0.2 to 2.5
Maputo Declaration: Commitment to Agriculture	Public expenditure in agriculture needs to double to achieve MDG 1	Determinants of investment needs and growth possibilities are country-specific	AE/BUD = 10%
Fiscal effort	Even low-income countries can raise the government share in the economy to 20%	Fiscal will/drag is country-specific	BUD/GDP ≈ 20%
Growth rates to achieve MDG 1: e.g., ASARECA (Omamo *et al.*, 2006)	Overall growth must be accelerated to achieve reduction in poverty and hunger	Needs to identify and prioritize sectors that can produce this growth or economy	ΔGDP/GDP = 6%
	GDP growth of 6% produces GDP per capita growth of 3% (except for in the Democratic Republic of the Congo, which starts from negative growth)	Implies threefold increase in agriculture sector and subsector growth rates. Differential growth may lead to geographic concentration	ΔAGDP/AGDP from 4.3% to 6.6%
Climate change adaptation: e.g., Oxfam, World Bank	Urgent adaptation and mitigation; net addition to current aid	Research includes more robust estimates of the economics of adaptation, study of best practices, and an intensive action-learning phase	Annual requirements of USD 10–40 billion (World Bank) and USD 50 billion (Oxfam International 2007)

[a] The formulations are discussed in detail in the next section.
ARE = agricultural research expenditure.
AGDP = agricultural GDP.
BUD = government budget (public expenditure).
AE = public expenditure on agriculture.
Δ = change in variable since the previous period.

An important target that has been elevated to a political commitment is the Commitment to Agriculture expressed in the Maputo Declaration (2003), which has been adopted by the New Partnership for Africa's Development (NEPAD) Comprehensive Africa Agriculture Development Programme (CAADP).[6] CAADP's strategy restates MDG 1 – to reduce poverty and hunger by half by 2015 – and postulates that it would require the economy to grow at 6 percent annum. As one of the largest sectors, agriculture must strive for a growth rate approaching this level (with the possibilities for growth varying widely by region and commodity subsector). The Maputo Declaration called on governments to raise their expenditures on agriculture to 10 percent of their national budgets. The simplicity of the stated target of raising the GDP growth rate to 6 percent belies the complexity of the task, and raising expenditure on agriculture to 10 percent of national budgets is not sufficient. The critical question is: If the necessary changes in policies and institutions are forthcoming, how much in additional financial resources will be needed to achieve the 2015 goals?

CAADP calls for increasing investment in four pillars:

- extended area under sustainable land management and reliable water control (USD 37 billion);
- rural infrastructure and trade-related capacity for market access (USD 37 billion);
- increased food supply through policy, technology and farm services (USD 7.5 billion) and disaster and emergency relief and safety nets (USD 42 billion);
- agricultural research, technology dissemination and adoption (USD 4.6 billion).

Under CAADP, African countries would commit themselves to:

- increasing their domestic contributions progressively, from 35 to 55 percent by 2015;
- increasing private sector contributions;
- doubling current annual spending on agricultural research within ten years; Beintema and Stads (2006) calculated that this means an average increase of 10 percent per year, which is substantially higher than the average annual growth rate of 1 percent that occurred during the 1990s;
- investing 10 percent of government budgets in agriculture.

A pioneering example of the use of CAADP targets is the strategic priorities study carried out by the Association for Strengthening Agricultural Research in

6. NEPAD/CAADP has become an operational programme of the African Union.

Eastern and Central Africa (ASARECA) in association with the International Food Policy Research Institute (IFPRI). This study assessed the possibility of creating a regional strategy for ASARECA's ten member countries to meet MDG 1 with respect to hunger (Omamo *et al.*, 2006).

The ASARECEA study had the beneficial effect of focusing attention on the supply side, and highlighted the information gaps for planning. In the absence of field data on the various agro-ecological zones (and lacking the time to generate them), IFPRI used crop models that predicted the expected performance of different commodities according to soil, topography and rainfall. Looking at the drivers of demand in the region, IFPRI's multi-market model helped demonstrate that regional staples, livestock products, fruit and vegetables would have the greatest impact on poverty reduction. Milk and cassava were seen as having the greatest potential for GDP growth, but such growth would be concentrated in a small number of countries. The study underlined that agricultural productivity growth alone would not be sufficient to meet poverty reduction targets; the region would also require growth in non-agricultural sectors and improvement in market conditions. This would follow identification of the best development domains for strategic investment.[7] The exercise prioritized areas of high potential, low population density and low market access, i.e., areas that require significant investment in infrastructure, markets, adaptive research and scaling up of technology.

The study concluded that under the default "business as usual" scenario, none of the ten ASARECA countries would achieve the 6 percent growth in GDP that is needed to achieve MDG 1. It was estimated that most countries would produce less than 3 percent growth in agriculture (based on historical trends and allowing for rapid growth in some countries recovering from civil war). Other development goals, such as food and nutrition security, would remain out of reach. Meeting the goals would demand a trebling of current growth rates. Not all commodities and all regions have the potential to contribute equally.

Analysing the agricultural research intensity ratio

Placing a country's agricultural R&D efforts in an internationally comparable context requires measures other than absolute levels of expenditures. The most common research intensity indicator is the agricultural research intensity ratio (ARI). This is the ratio formed by the sum of agricultural R&D investments over agricultural GDP. For two decades, the ARI was held up as an instrument of

7. A development domain is an area with homogenous production potential, access to markets and population density. Investment requirements differ among different development domains.

coercive comparison: if a country's neighbour with similar characteristics had a higher ARI, the presumption was that the country was not trying hard enough to support agricultural research.

The ARI first appeared in a World Bank sector paper on agricultural research in 1981. The authors were looking for a target figure for establishing a norm to which National Agricultural Research Systems (NARS) could aspire.[8] Lacking an empirical basis from the developing world, they borrowed the estimated investment in science and technology in developed countries (about 2 percent of GDP) and made this the target figure. However, this target proved to be unrealistic for low-income developing countries, largely owing to competing claims on low fiscal capacity and the large weight of the agriculture sector in the economy. Moreover, the target did not account for the more limited opportunities for innovation in developing countries (Roseboom, 2004). In addition, the expectation that agricultural R&D investments would continue to grow at the high rates of the 1980s was not met. A more realistic research intensity target of 1 percent has been recommended[9] in more recent literature (e.g., Pardey and Alston, 1995; Roseboom, 2004; Casas, Solh and Hafez, 1999).

Trends in the ratio of agricultural research intensity to GDP

The average intensity ratios for developing countries fluctuated slightly around 0.56 percent during 1981 to 2000 (Figure 9.7). This is often attributed to the fact that the denominator, agricultural output, grew at the same pace as total public agricultural research spending. In contrast, the average intensity for high-income countries increased considerably during this period. For every USD 100 of agricultural output, high-income countries spent USD 2.35 on public agricultural R&D in 2000, compared with USD 1.51 in 1981. More than half of the industrialized countries for which data are available had higher research intensity ratios in 2000 than in 1991. Most countries in the samples for Asia and the Pacific and Latin America and the Caribbean also increased their intensity ratios (Beintema and Stads, 2008; Stads and Beintema, 2009). In sub-Saharan Africa however, only six of 26 countries reported higher intensity ratios in 2000 than in 1991 (Beintema and Stads, 2006).

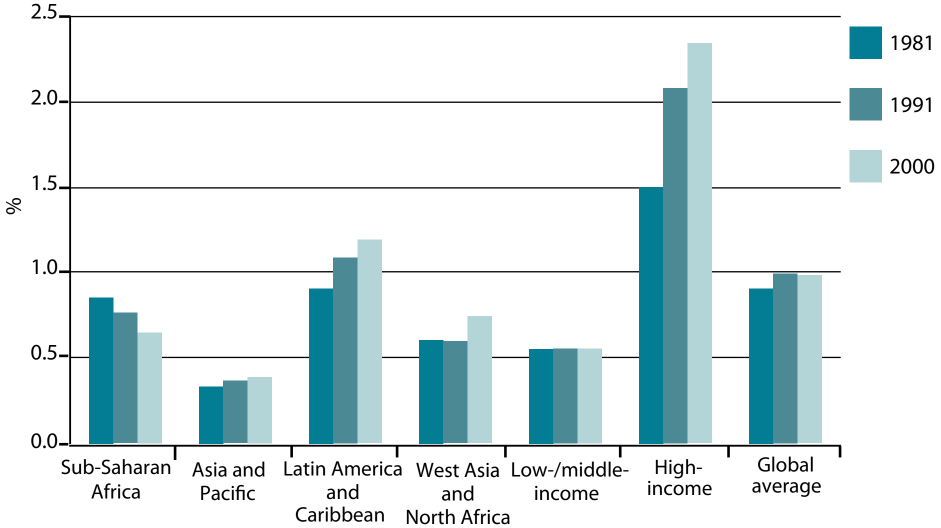
The use of intensity ratios is not always appropriate because they do not take into account the policy and institutional environment in which agricultural

8. For many observers, the 1980s was the "decade of NARS", which saw the creation of new national institutes and consolidated national systems in Africa, experiments with *fundaciones* in Latin America, and second-generation council models in Asia.

9. "Recommended" in the sense that a 1 percent target could be attained by even poor countries, if all the priority and institutional factors are functioning as desired.

research occurs, or the broader size and structure of a country's agriculture sector and economy. Human and capital investments have a basic fixed component, regardless of the size of a country's population, especially when facilities and services are dispersed across broad areas. Furthermore, a number of countries conduct research in areas related to the agribusiness sector, whose production value is counted as manufacturing not agriculture (and hence is not included in agricultural GDP). More important in this context, an increase in the research intensity could mean a decrease in agricultural output, rather than a higher level of investment, as was the case for a number of OECD countries during the 1990s (OECD, various years).

Figure 9.7
Intensity ratios of agricultural R&D spending (shares of agricultural GDP)



Estimates exclude Eastern Europe and the former Soviet Union. Estimation procedures and methodology are described in Beintema and Stads, 2011b and various ASTI regional reports available at www.asti.cgiar.org.
Source: Beintema and Stads, 2010, based on ASTI datasets and other secondary sources.

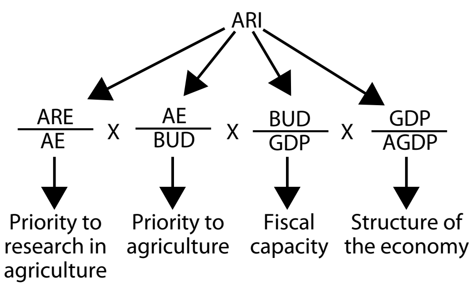
A number of countries, such as China and India, continue to have relatively low intensity ratios (Beintema and Stads, 2008). Nevertheless, both of these countries have increased their agricultural R&D investments significantly over the past decade or so, such that their agricultural research systems are well equipped in terms of both infrastructure and human resources. However, specific areas may require further investment. Research intensity ratios should be interpreted within the appropriate context of investment growth, human resource capacity and infrastructure.

While it is clear in cross-section that rich countries have higher ARIs than poor countries, it is necessary to examine budget details country by country to understand what drives this difference and what it implies for the contribution of research to growth and poverty reduction (Elliott, 1995).

Trends in agricultural research intensity and the research effort

The ARI alone can only be the starting point for discussion: it is necessary to create a new identity for the ARI, by decomposing it into four components, as shown in Figure 9.8.

Figure 9.8
Components of the agricultural research intensity ratio



ARE = agricultural research expenditure.
AE = public expenditure on agriculture.
BUD = government budget (public expenditure).
AGDP = agricultural GDP.

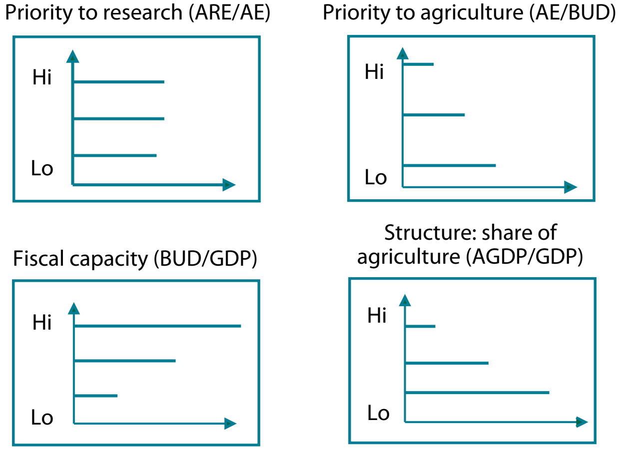
Source: Adapted from Elliott, 1995.

The four components are:

- *priority for agricultural research:* the share of agricultural research in total agricultural expenditure;
- *priority for public agricultural expenditure:* the share of public expenditure on agriculture in total public expenditure;
- *fiscal effort (or fiscal capacity):* the share of public (government) revenue and expenditure in GDP;
- *structure of the economy:* the inverse of agriculture's share in GDP.

Each of the elements in the identity is a ratio, so the ARI itself is independent of the unit of measurement for each element. Each element has its own drivers, which are analysed as determinants of a country's efforts in agricultural research (Pardey, Kang and Elliott, 1989).

Figure 9.9
Determinants of ARI, by country income group



Y axis = level of country income per capita; x axis = ratio as defined.
Source: ASTI.

Figure 9.9 represents each of the elements in the ARI identity by country income group (low, middle and high).

The following stylized facts are illustrated in Figure 9.9:

- The share of expenditure on agricultural research in total agricultural expenditure is fairly similar across income levels (upper-left quadrant).
- Although total expenditures on agriculture are low in absolute terms, in low-income agriculture-based economies they represent a higher share of total public expenditure than in wealthier countries (upper-right quadrant).
- The fiscal capacity (tax collections, public budgets) accounts for a far smaller share of GDP in low-income than in higher-income countries (lower-left quadrant).
- The agriculture sector's share in the economy declines as the country's income rises (lower-right quadrant).

Changes in the ARI at the country level require very country-specific analysis of the drivers of each ARI element. Policy-makers' commitments to invest more in agricultural R&D can be measured against the realism of their targets, the coherence of their strategies and priorities, their political and fiscal capacity, and the weight of the sector they are trying to move. In the most developed countries, agricultural research intensity is rising. As the growth of higher education expenditures also rises as income rises, it could be asked whether this investment is all productive or includes an element of income-elastic consumption of research made possible by rising fiscal resources and a declining share of agriculture in the economy. Countries in the middle-income group, where non-agriculture is growing, have an opportunity to shift tax burdens away from agriculture, invest in infrastructure and other public goods, and improve incentives that reinforce agricultural development. These become easier as the share of agriculture in the economy falls. In low-income, agriculture-based economies, it is difficult to raise the ARI where the fiscal base is small, the agriculture sector is large and the relative cost of a researcher is high.

The following subsections highlight issues concerning underinvestment in research that originate in each of the four components of the ARI. As yet, there is no structured, cross-country information that can "unpack" each of the drivers of the ARI. This has to be done at the country level, by policy-makers seeking to understand the points of intervention that will improve investments in agriculture.

Priority for research – the share of agricultural research in public agricultural expenditure: The first determinant of the ARI is the priority given to agricultural research within the overall effort to develop agriculture.

Studies by IFPRI have suggested that agricultural research in low-income economies continues to be the most productive investment in support of the agriculture sector, followed by education, infrastructure and input credits. "Disaggregating total agricultural expenditures into research and non-research spending reveals that research had a much larger impact on productivity than non-research spending" (Fan and Rao, 2003).

Donor programmes, especially in Africa, can have an important impact on the allocation of resources. Programmes for highly indebted poor countries aim at social goals, and public expenditure reviews point out that this has affected the selection of projects within sectors, including agriculture (Bevan, 2001).

The domestic political economy of budget allocations needs to be better understood. For example, in India, overall public expenditure on agriculture has remained at approximately 11 percent of the budget, while the share of subsidies for fertilizer and electricity, and support prices for cereals, water and credit have steadily risen at the expense of investment in R&D, irrigation and rural roads (World Bank, 2008b; Beintema Stads, 2008).

In some more scientifically advanced middle-income countries, the higher education sector has become a major player in agricultural research. In Argentina, Costa Rica, Honduras, Mexico and Uruguay, for example, higher education accounted for more than 40 percent of agricultural research, with government funding coming mostly from ministries of education. In South Africa, funding for the Agricultural Research Council comes through the Council of Science and Technology (with input from the National Department of Agriculture).

In North America, the changing composition of agricultural research expenditure is a recent concern: the share of research directed to farm-level productivity enhancement has fallen to as low as 60 percent (Pardey, 2009; Alston, Pardey and James, 2009; Fuglie and Heisey, 2007).

While research investment undoubtedly has value beyond the farm-gate, the long-term slowdown in research into productivity growth at the farm level is cause for concern, for three reasons: i) cumulative loss in productivity growth translates into a significant loss of future income; ii) there is an accompanying loss of potential spill-over to neighbouring states (which may have accounted for as much as 50 percent of measured research benefits); and iii) there is the risk of missing out on research discoveries that will be needed ten to 20 years from now, as the world confronts the impact of climate change:

Given research lags that may be as long as 10-20 years, the effect of this slow-down in developed countries will become apparent in the future when scarcity of land and water, the impact of climate change, and population pressure will become major problems for developing countries. The stream of research outputs which have travelled fairly freely will be reduced significantly. (Alston, Pardey and James, 2009)

Recent studies in Canada have also documented a slowdown in productivity growth, linked to declining public research investment and structural changes in the sector, which have led to calls for more public sector research expenditure:

- Veeman, Unterschultz and Stewart (2007) found that R&D expenditure for Canadian agricultural research has shown no growth since 1990 and that total factor productivity (TFP) growth in the prairie crop sector fell to an average of 0.51 percent per year for the 1990 to 2004 period, which is much lower than historic rates of close to 2 percent per year.
- Gray and Weseen (2008) argue that the slowdown in productivity growth highlights a need for more effective research expenditure.
- While noting that the private sector has filled the applied research gap in key crops, the Canadian Grains Council (CGC, 2008) argues that the private sector has concentrated on recombinant DNA technologies, which

reduces the possibilities for sharing and coordination. CGC emphasizes the importance of: i) sharing discoveries; ii) developing polices that protect plant breeders, small-scale seed producers and niche developers; and ii) facilitating greater collaboration among public and private sector research partners.

The composition of agricultural research expenditure is also changing in some middle-income countries, such as Argentina, where research into food safety, food technology and processing are budgeted to the national agricultural research institute. However, as the increase in GDP occurring further down the value chain is counted in the manufacturing sector, the apparent rise in ARI is partly an accounting phenomenon.

Priority for agriculture – the share of agricultural expenditure in total public expenditure: The second component in the ARI is the share of agriculture in total public expenditure. This ratio is subject to many different drivers, including the following:

- *The influence of the domestic political economy:* In their review of medium-term expenditure frameworks, Akroyd and Smith (2007) point out the difficulties of budgeting in a "neo-patrimonial political model" and cite Birner and Palaniswamy (2006) on political challenges to increased spending on agriculture. These challenges include farmers' low political voice, lack of knowledge about agriculture's potential for pro-poor growth, and, possibly, the negative experiences that donors and governments have had of prior agricultural programmes.
- *The impact of donor programmes:* Fan and Rao (2003) point out that structural adjustment programmes have increased the size of government spending, but not all sectors have received equal treatment. In Africa, expenditures on agriculture, education and infrastructure all declined as a result of structural adjustment programmes.

In sub-Saharan Africa, CAADP reports that seven countries have reached or exceeded the Maputo target of spending 10 percent of their budgets on agriculture. For agriculture-based economies, the difficulty lies in the next two components: fiscal capacity (the share of tax collections and expenditures); and the agriculture sector's importance in the economy. To transform an economy, one opportunity is to shift tax collection to a growth base in non-agriculture and to begin net reverse flows of public funds to agriculture. In transforming economies, fiscal policies can make or break a pro-agriculture strategy. This factor leads into consideration of the fiscal effort or fiscal capacity of a country.

Fiscal effort – the share of government revenue and expenditure in the economy: A government that can raise and spend 20 percent of GDP through tax collection can do more than a government that can raise and spend only 12 percent. This includes being able to spend more on agriculture and agricultural research. How a country raises its revenues and how it spends its budget are specialized fields. This subsection is concerned with policy decisions that should involve some input from agricultural policy advisers.

This starts with a look at the revenue side. The question of whether a country's fiscal effort and taxation of agriculture are appropriate can only be answered in the light of the specific constraints facing that country. Constraints could include the nature of the country's taxable bases, incentive structures, fiscal structure and fiscal culture. The following are common issues in designing fiscal policies with agricultural development in mind:

- *Taxable bases:* Countries with agriculture as their principal resource have historically overtaxed the sector through biased macroeconomic policies and export taxes and marketing board surpluses. Oil- or mineral-rich countries with large agricultural populations have an opportunity to free agriculture from poor terms of trade and local taxation that discourage production. Failure to do so is often the cause of countries suffering from the "curse of wealth".

- *Fiscal structure:* Decentralization of fiscal responsibility to the state/province and district levels may be a positive factor in raising revenue by bringing services and taxation together in the minds of the population. However, districts may also introduce levies on local agriculture and trade for revenue purposes that are unnecessary disincentives for development if they could be substituted by federal grants.

- *Fiscal culture:* Low revenue collection and low government services may result from a variety of circular problems and pathologies: low tax rates, excessive exemptions, lax tax administration, widespread non-compliance and corruption; or problems of central versus decentralized accountability. Turning the culture around may be a long-term effort.

- *Fiscal returns on public investment:* Easterly (2007) argues that planners have to be aware of the fiscal effects of public investment. Benefit-cost analysis focuses on social costs and benefits, but the fiscal returns and benefits of early pay-back from increased production and exports should also be kept in mind.

- *Impact of taxes on key sectors:* In the post-conflict Ugandan economy, the World Bank decided that raising Uganda's fiscal effort above its low 12 percent would have been counterproductive at a time when attracting private sector reinvestment in key agricultural activities was crucial for post-civil war recovery. Future tax collections would come from expanding the base, rather than raising the average rate of taxation. (Kreimer *et al.*, 2000).

The other aspect of the government's role is the efficiency of its expenditure. Do projects meet all the priority criteria? Does the budget process allocate funds in that direction, and is this the way the funds will be spent? The remainder of this subsection looks at the effectiveness of public expenditure in agriculture and its link back to underinvestment and proposals for dealing with it.

This discussion starts with a few general observations:

- It is easier to make progress on revenue reform than on expenditure. It only takes a handful of people to design a regulation or tax reform, but it is impossible to subject all activities to a benefit-cost analysis at the project level. Such detail is necessary because it is a mistake to lump all, for example, roads (or all agricultural projects) into one bundle and say "we do roads (or agriculture)" (Harberger, 2009).
- Agricultural research organizations have assimilated the tools of planning and priority setting, but they are largely absent from the budget discussions where trade-offs are made. Decision-makers rarely have the time or information to make informed choices among projects that have different fiscal and social profiles.
- Donor programmes, especially in sub-Saharan Africa, have had an impact on broad priorities, but have not necessarily been able to control expenditures.

The World Bank introduced medium-term expenditure frameworks as part of Poverty Reduction Strategy Programmes. They were supposed to ensure that expenditures were driven by policy priorities. Various reviews have highlighted their successes and failures:

- The medium-term expenditure framework in Uganda has been successful in shifting expenditure composition, most notably in favour of education, and protecting priority sectors against cuts. It has been less successful in ensuring that budget allocations translate reliably into actual expenditures (Bevan, 2001).

- The Nigeria Agriculture Public Expenditure Review pointed out seven areas of concern, including discrepancies between policies and expenditures, off-budget funds, lack of information about the functional areas of public spending in agriculture, and poor data quality for planning and impact analysis (Mogues *et al.*, 2008).
- The frameworks failed to link budgets with strategies and policies; spending patterns were not pro-growth or pro-poor; there was a high degree of centralization in spite of decentralization plans; there was low execution capacity; donor funding was not integrated; and there were poor tracking and monitoring (Fan, 2009).

As with any budgetary and control mechanism, there were loopholes in the process: ring-fencing of certain types of expenditure (e.g., drought relief), supplementary budgets, and donor support that bypassed the mechanism. In the final analysis, it was concluded that the reform of budgetary processes requires major cultural changes for some countries and development of the capacity for implementation.

Towards more effective financing of research – the interaction of revenue collection and allocation mechanisms: Before leaving this somewhat structuralist view of the ability to finance research, it is worth noting that the source of funding affects the nature of the research carried out. Partly in response to the problems mentioned in the previous subsection, donors have been searching for effective and innovative funding mechanisms that will result in more efficient and successful research agencies and systems. The "new" school of public administration argues that not all public goods need to be produced by the public sector itself, and that research deals with many cases of "impure" public goods. This opens up both investment in and delivery of quasi-public R&D results through many forms of partnership with interested producers and beneficiaries.

Echeverria and Beintema (2009) define effective financing as "one that increases the average returns of current levels of investment in agricultural research and that also attracts complementary investment from additional sources. An effective funding mechanism will then be the one that allows optimum use of research infrastructure to execute the research." Because of the underinvestment in agricultural R&D, policy-makers and research managers will find a right mix of various financing mechanisms in addition to the direct allocations from central and/or regional public budgets. As mentioned earlier, government support to agricultural R&D has stagnated or declined in many countries, especially when measured in inflation-adjusted terms. Governments have also hampered the performance of agricultural R&D agencies because actual disbursements have fallen behind earlier budget allocations.

Echeverria and Beintema (2009) list a number of alternative funding mechanisms that bring the sources of funding closer to the prospective beneficiaries of research, or that permit project-level control of expenditure:

- Competitive grants often complement direct government budget allocations, and have played an important role in mobilizing research actors around specific outputs and improving the efficiency and accountability of research outputs and actors. On the other hand, they may not be as effective as core funds in ensuring long-term capacity. Furthermore, competitive funding schemes mostly fund specific projects, and often cover only their operational costs and not salaries or maintenance of the institutional infrastructure.
- Producer check-offs and export levies are mostly collected through taxes raised on the export or production of commercial crops. One benefit is that farmers are more involved in setting the research priorities. They finance "club goods and services", which is a form of benefit restriction. Such para-fiscal levies come from the industry itself, but may not be available at the times of major crisis when they are most needed.
- A number of agencies and countries have been successful in commercializing their research outputs, often through partnerships with the private sector. One important downside is that in many countries the revenue from commercialization goes directly into the government treasury, so there is limited incentive for research agencies to sell research outputs and services.
- The debate about programme versus project funding continues (see also the paragraph on CGIAR investments in the subsection on International agricultural R&D investment). When donors talk about shifting financing from the supply side (institutional commitment) to financing results it is often a prelude to reducing the overall level of funding.

The structure of the economy – the inverse of the share of agriculture in GDP: The final element underlying movements in the ARI is the inverse of the share of agriculture in GDP.

In a successful transformation, the share of agriculture in GDP, the share of population in agriculture in the total population, and the dependence on agriculture as the source of development finance all drop. This is made possible by rising productivity in agriculture and the transfer of labour to other sectors.

In transforming economies, agricultural and fiscal policy should be able to make the breakthrough to more sustainable support for agricultural research:

i) better macro policies usually improve the opportunities for agriculture; ii) new tax bases outside the agriculture sector remove some of the fiscal drag caused by agricultural taxation; and iii) a large population in non-agriculture can make significant contributions to a declining population in agriculture.

The policy lesson for governments would be to maintain a macroeconomic balance and the positive environment for agriculture that it creates. Productivity increases will free both land and labour, and policies should facilitate the movement of people out of agriculture as they are no longer needed on farms to feed the country. The point is not to maintain millions of small farmers but to eliminate poverty, with recourse to safety nets where agricultural and overall growth are not enough (Valdés and Foster, 2005).

New analytical challenges coming from ReSAKSS

Recently, the Regional Strategic Analysis and Knowledge Support System (ReSAKSS) has synthesized much of the available information on investment in agricultural R&D, to link expenditure with performance in Africa. The complete report is available in Omilola *et al.* (2010), and the findings are consistent with issues raised in this chapter. Observations in the report that merit further analysis and explanation include the following:

- While some African countries have increased their budgetary allocations to the agriculture sector, the majority have generally stayed in the same budgetary allocation grouping, especially those countries with low spending rates.
- In West Africa, actual public expenditure on agriculture increased in most countries (with the exception of those in crisis or post-conflict situations).
- Regardless of the distribution of agricultural expenditures, there are two trends emerging in West Africa:
  - First, in the Sahelian countries, the majority of expenditures were directed towards investment, while in the coastal countries, a large share of agricultural expenditure was devoted to recurrent expenses.
  - Second, in the Sahelian countries where expenditures were largely spent on investments, agricultural spending was predominantly financed by official development assistance (ODA). Internal sources accounted for less than 25 percent of agricultural funding. The share of internal resources in agricultural investment was much higher in the coastal countries, reaching 67 percent in Ghana, 57 percent in Côte d'Ivoire, and 48 percent in Benin.

- There is a negative correlation between the share of agricultural expenditure devoted to investments and the share of agricultural investments financed from internal sources. This dependence on external sources for investments is attributed to the dismantling of programmes of public support to agriculture under structural adjustments.
- The capacity to disaggregate expenditure by subsector and function varies greatly. The available data point to a lack of congruence between expenditure on crops versus livestock and their relative shares in agricultural GDP. It was even more difficult to obtain data disaggregated by function: R&D, irrigation, inputs and equipment, extension and administration.

The focus then turns to the quality of expenditures. Looking in greater detail at Malawi, Nigeria and Zambia, the authors find that agricultural spending has increased in all three, largely from government sources. Adding Ghana to their observations, they note that countries all focus on one major programme: cocoa in Ghana, and input supply in the other three (raising questions about the sustainability and balance of agricultural spending).

With the resurgence in development assistance of recent years, the need for clear links between plans, budgets and outcomes calls for improved data and analysis on the issues raised in this chapter.

Challenges and essential investments

Investment options targeting special non-productivity objectives

This chapter has argued that research oriented towards enhancing farm-level productivity has being shown to have high rates of return and make generally positive contributions to environmental and social objectives. Other policy instruments can be designed (e.g., safety nets, facilitation of migration, and payments for the true value of resources and ecosystem services) to ensure that society gains.

The International Assessment of Agricultural Science and Technology for Development (IAASTD) (Gurib-Fakim *et al.*, 2008) identifies some of the directions in which new research can make a direct impact on sustainability and social goals (Table 9.3)

Investment in basic capacity for R&D

This section highlights three basic areas of underinvestment:

- the need for basic studies and methodologies – even a country considered too small to have a full-fledged NARS needs to invest in knowing: i) its own potential in terms of water resources, soils and climate; ii) where it can obtain knowledge, science and technology to realize this potential; and iii) sufficient advanced science to be a good negotiator of partnerships and purchaser of technology;

- the need to address capacity requirements in a systemic way that includes balanced growth of research institutes, universities and upstream and downstream partners;
- the need to integrate networks at the global, regional and subregional levels, while escaping high transactions costs and dispersion of effort.

Table 9.3
Investment options outlined in the IAASTD Global Report

Goal	*Investment required to*	*Examples and comments*
Environmental sustainability	1. Reduce the ecological impact of farming systems	Management practices; reduced use of fossil fuel, pesticides, fertilizer; biological substitutes for fossil fuels and chemicals
	2. Enhance systems that are known to be sustainable	Social science research on policies and institutions.
	3. Support traditional knowledge	Non-conventional crops and breeds; traditional management systems
Hunger and poverty reduction	1. Target institutional change in organizations	Planning with a pro-poor perspective
	2. Include equity in planning and pro-poor policies	Access to resources; sharing of benefits from environmental services
Improving nutrition and human health	1. Improve nutritional quality and safety of food	Coexistence of obesity and micronutrient deficiency; pesticide residues; sanitary and phytosanitary measures
	2. Control environmental externalities	Pollution; overuse of antibiotics, pesticides; on-farm diversification
	3. Ensure better diagnostic data and response to epidemic disease	Increasing zoonotic diseases and dangers of pandemics; prediction of disease and pest migration with climate change
Economically sustainable development	1. Enhance research on water use and control of pests and diseases	Both affected by population growth and climate change
	2. Carry out productivity-enhancing research to save land and water as limiting factors	TFP benefits from higher yields per hectare and more crop per drop; need to address the most limiting factors
	3. Establish prices and incentives that promote proper social use of resources	Pricing policies and payment for ecosystem services make land and water use more efficient
	4. Advance basic research in genomics, proteomics and nanotechnology	Historically high rates of return on basic research; applications may spill over to developing countries in the future

Source: Adapted from Gurib-Fakim *et al.*, 2008: 381-384, Table 6.2, and Chapter 8, Section 4.

Basic studies and methodologies: Decisions about investment are ultimately based on two judgements: What are the possibilities of advancing knowledge and technology? and What is the value to society of the new technology? (Ruttan, 1982). Processes for making decisions increasingly involve a combination of supply-led analysis of expected gains prepared by scientists, and a participatory (bottom-up) evaluation of the usefulness of the knowledge to clients and beneficiaries. Both the governance of the process and the nature of the evidence have to be appropriate to the level and nature of the decision to be made.

The need for basic studies is apparent in the three approaches being adopted to address priorities and strategies for global agricultural R&D (CGIAR, 2009):

- The trust in models approach includes definition and characterization of the systems that will form the building blocks for assessing agricultural, environmental and institutional/policy research challenges and opportunities; and evaluation of the nature and scale of potential R&D-induced impacts (by system), according to scenarios and parameter estimates established during the elicitation process.
- The trust in front-line researchers approach designs and implements a science-focused identification of appropriate technical, institutional and social variables to be used in assessing the potential impact of research-induced change.
- The trust in wisdom approach draws on consultation with highly recognized research and policy leaders as reviewers and on stakeholder and partner dialogues.

Modelling and spatial analysis tools can be used to identify homogeneous development domains. However, basic information needs to be collected and processed. In all areas, there is an urgent need for better information and tools on hydrology, meteorology and soil potential that goes beyond research strictly devoted to agriculture.

In some areas, the challenges are likely to grow with climate change, population growth and increasing resource scarcity. The current level of research can therefore be considered underinvestment even if it is congruent with the current importance of the issue. Given that agricultural and land-use practices contribute 32 percent of global greenhouse gas emissions (Stern, 2007), the need for better understanding is clear. In this respect, IAASTD highlights the need for strategic cross-disciplinary methodological research on environmental sustainability and poverty reduction:

The first important need for [agricultural knowledge, science and technology] *AKST investment is for social and ecological scientists working with other* *scientists to develop methodologies and to quantify the externalities of high and low external input systems from a monetary perspective as well as from other perspectives such as the concept of energy flows used in energy evaluations. Evidence on these externalities' potential implications on food security also needs to be analysed.* (Gurib-Fakim *et al*., 2008)

Both neoclassical economists and agro-ecologists agree that proper pricing of resources and the value of ecosystem services has been underexamined. While they may disagree on the need for markets versus the need for taxes and subsidies, their shared recognition of this continuing need argues for openness to all solutions.

Institutional capacity for agricultural research and higher education: More investment is needed to reverse the general underinvestment of the last decade, meet the various political targets, and prepare for the emerging challenges outlined in the previous two subsections. However, this presumes that there is either sufficient research capacity to address these targets or the commitment to invest in creating it. Moreover, the rate at which research capacity can grow is linked to the strength of the higher education system. In many countries, this system itself requires re-tooling. Plans that project annual growth of 10 percent or more in current research expenditures should therefore be reviewed carefully so that good intentions do not result in wasteful expenditures that put pressure on scarce human and institutional resources.

Several organizations and publications have expressed concern in this regard:

- An assessment of the national agricultural research and extension systems in Africa found many agencies with professional staff shortages, vacant staff positions and an ageing pool of professional research staff (FARA, 2006).
- A recent study by the ASTI initiative covering 14 countries showed that although the numbers engaged in agricultural research and higher education had increased by 20 percent from 2000/2001 to 2007/2008, two-thirds of this increased capacity was trained only to B.Sc. level (Beintema and Di Marcantonio, 2009).

This is a worrisome trend, especially in light of the increasing costs of postgraduate training abroad, and the diminishing relevance of these programmes to Africa. This calls for an expansion of postgraduate-level training in agricultural sciences (World Bank, 2007).

Although the number of agricultural science universities and faculties has grown substantially during the past three decades, many suffer from staff shortages, insufficient funding, declining student enrolments, outdated curricula, and a continuing focus on undergraduate studies (Beintema, Pardey and Roseboom, 1998; IAC, 2004; World Bank, 2007). Donor support for training programmes waned in the 1990s, and African governments have largely been unable to fund training themselves (Beintema, Pardey and Roseboom, 1998). Eicher (2006) has highlighted the sequential rather than balanced way in which agricultural research, extension and higher education have been addressed in sub-Saharan Africa. A more balanced development of the agricultural knowledge system is needed.

Some initiatives are already addressing this problem. The Rockefeller Foundation established a programme for training future teachers of biometrics so that African universities are able to meet the demand for this basic research skill, which has been neglected in recent years. A number of countries have recently established postgraduate training programmes, but these are generally small in terms of student enrolments. There is increasing recognition of the need to expand Africa's postgraduate training in agricultural sciences, at both the national and regional levels (World Bank, 2007).

Current discussions of capacity go beyond the usual discussion of scientific and technical skills. Reviews of agricultural education and training by the World Bank (2007) and research institutions mention three needs: i) scientific capacity; ii) "soft skills" for innovative work across institutional boundaries; and iii) institutional capacity to learn and change. For the first of these needs, M.Sc. and Ph.D. students are an essential part of the research infrastructure.

Among the soft skills needed are postgraduate education and building of the personal skills that facilitate work across ministerial and sectoral boundaries. Institutional policies that facilitate cross-institute and cross-sectoral collaboration are being put in place by research institutes and universities. Policies aimed at increasing women's participation should also be established; given the growing concern over declining agricultural research capacity, women's increased participation in agricultural R&D is important for not only gender balance, but also for tapping substantial additional human resources for agricultural R&D.

These processes are important because the training lags and transaction costs involved in adopting new agendas affect the rate at which the research system can grow without wasting resources.

Policy and the institutional architecture for research: Policies, institutional arrangements and governance of research all require investments for which they must compete with the actual performance of scientific and technical research. Attempts have been made to measure the productivity of social science and policy research, establish the value of institutional changes or management improvements, and examine the cost of governance. This is where the concept of the process being as important as the product comes up against the burden of high transaction costs.

As noted in the subsection on Basic studies and methodologies, the planning of investment requires a process in which the issues are properly framed, relevant information is collected and used, different perspectives are integrated, and some form of governance mechanism is used to oversee implementation. There is need for better basic information, methodologies and models to support decision-making.

The structure of global agricultural research is undergoing a period of important changes. The alliance of research centres supported by CGIAR is forming a consortium that will negotiate the core functions and mega-programmes to be supported by a consolidated donor fund. It is essential that this fund provide a guaranteed core on which a sustainable system can be built. In sub-Saharan Africa, bilateral and multilateral donors are promoting the creation of regional research programmes and subregional centres of excellence in areas that go beyond the previous research networks. The development of a more effective global system that meets stakeholder needs is receiving investment of time and resources.

Many emerging problems, such as climate change, migratory pests and pandemics, are transboundary in nature, and new mechanisms are needed for addressing them effectively.

Legal frameworks, particularly relating to intellectual property and biosafety are affecting both the concentration of research activity and access to strategic genes. New institutions such as the African Agricultural Technology Foundation have been set up to facilitate developing countries' access to proprietary technology. Recent attention to biosafety has resulted in regulations that may have the unintended consequences of either keeping certain potentially valuable technologies out of developing countries, or concentrating ownership further in the hands of large corporations able to bear the costs of the required processes and in countries with large enough markets to justify these costs. Research into proper frameworks for ensuring that developing countries benefit from new science and technology is a priority for investment.

Concluding remarks

The rate of growth in agricultural research investment has been declining globally, and a large number of developing countries experienced negative growth rates during the 1990s, especially in sub-Saharan Africa. Since the turn of the millennium, a number of mostly larger African countries have increased their commitments to agriculture and agricultural research, but many countries are still experiencing declines in agricultural spending, and even for those experiencing growth, levels are often still below those necessary to sustain national agricultural R&D needs. General underinvestment is evidenced by: i) the continuing high rates of return on research demonstrated in studies at the commodity level; and ii) macroeconomic studies showing that the relevant MDGs cannot be reached without a doubling or even tripling of research investment, given the estimated growth-poverty reduction elasticities, Also of concern is new evidence that a change in the composition of research away from farm-level productivity enhancement is statistically related to a decline in the growth of agricultural productivity to below historical levels in advanced economies. This trend may be considered another form of underinvestment that reduces potential spill-overs for the future. Policy-makers are reminded that growth in agricultural productivity provides the consumption, savings and taxes needed for development and the attainment of social goals.

Capacity in agricultural research is increasingly concentrated in a few leading countries in each region. While efforts are under way to create new structures and mechanisms for collaboration across the global, regional and national levels, policy-makers are reminded that no country is too poor or too small to support a national effort that is sufficient for it to gain from global knowledge. Various investment targets have been adopted over the years, such as CAADP's for making public expenditure on agriculture equal to 10 percent of the national budget. Seen from the results side, investment should be sufficient to produce 6 percent growth in agricultural production (or to meet MDG 1). However, such targets do not provide guidance on their own feasibility or on how rapidly the institutional and human capacity can be built up to achieve them.

One of the main indicators for comparing relative R&D investment levels is the ratio of agricultural research investment to agricultural output – the ARI. Many have suggested an ARI of 1 percent as being an appropriate target for low-income agriculturally based countries. However, the ARI is influenced by several factors that need to be studied in depth at the country level. The ARI can be decomposed into four components: i) priority for research in agricultural expenditure; ii) priority for agriculture in total public expenditure; iii) fiscal capacity measured as the ratio of public expenditure to GDP; and iv) the (inverse of the) share of agriculture in GDP. Analysis of each of these elements in a country's effort highlights the importance of strategy and priorities, institutions and incentives, public sector finance and public expenditure management, and the role of global partners.

Emerging challenges, such as adaptation to climate change and increasing variability of weather, water scarcity and price volatility in global markets, will confront many of the countries that are least able to adapt to existing stresses. This lends increasing importance to the development of human and institutional capacity in agricultural research at the national level, to enable interaction with regional and global efforts. A systemic approach to planning will bring universities and research institutes closer together.

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