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Mobilizing Financial Resources for Agricultural Research in Developing Countries, Trends and Mechanisms

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ABSTRACT

Purpose:
This paper, written by Ruben G. Echeverria and Nienke M. Beintema, gives a detailed explanation of past and current trends in funding of agricultural research and analyzes various agricultural research funding mechanisms that have been used in the past and should be explored today in order to increase agricultural research outputs in developing countries.

Summary of the Facts/Recommendations:
Despite recent increased international awareness of the importance of agriculture as a generator of income, employment, foreign exchange and tax revenues as well as its association with poverty reduction and the preservation of natural resources, there is still a need for increased awareness of the important role that agricultural research for development (AR4D) plays in the above issues.

The great potential of AR4D in issues of food security, poverty reduction, and preservation of natural resources must be emphasized in order to overcome the perpetual under-investment in public agricultural research in developing countries.

Because under-funding threatens the survival of AR4D systems in developing countries, policymakers and development assistance agencies must find "alternative institutional mechanisms for sustained financing of AR4D". Some such alternative mechanisms have been tried in many countries since the mid 1980s. They include: joint public-private sector ventures, sale of research products, competitive funds, research foundations, farmer managed levies on production, and greater involvement of universities and private sector research.

While exploring the potential of these alternative funding mechanisms is very important, another part of the solution is to create better managed and more flexible public sector systems, as the public sector is the greatest source of funding for agricultural research in developing countries. While government financing made up 81% of total funding for agricultural research in developing countries, the growth rate of public spending on agricultural research across the globe (developing and high income countries) has decreased from a growth rate of 2.7 % in the 1980's to 1.1% in the 1990's. Public spending on agricultural research in developing countries has become more concentrated, with China, India, and Brazil now accounting for 43 % of this total vs. 35% in the early 1980's.

Despite the dominance of the public sector both in the financing and implementation of agricultural research, other avenues can and should be explored. Universities in developing countries are an underutilized resource that could greatly increase research output with just slight increases in funding. Research foundations present another alternative to the public sector for providing funding and/or implementing agricultural research. Because the boards of directors of these research foundations usually consist of representatives from the private-sector they often base their research priorities on market demands and therefore provide an important link between the public and private sectors.

The private sector also contains huge potential in terms of increasing funding and efficiency of the global agricultural research system, however private sector involvement in AR4D in developing countries remains fairly small. 94 percent of private sector executed agricultural research is conducted in high income countries.

Donor support for agriculture began to decline in the 1980's as international attention began to be placed on health and education sectors in developing countries. Recently, however, donors are becoming interested in agriculture in general as well as agricultural research as a means of alleviating poverty, increasing food security, and attaining economic development in developing countries.

While government sector funds are the largest financing source of AR4D for developing countries, often there are large differences between budgeted allocations and actual disbursements which greatly affect the output of AR4D in these countries.

Other funding mechanisms should be explored in order to increase agricultural research output in developing countries. One such funding mechanism is the use of competitive funds which finance research through grants and can increase the accountability of research, lower costs, and help build a more demand-driven research system. The downside of competitive funds is that they are only sustainable in the long-term when endowment funds are used to ensure the continuation of funding. Endowment funds require large up-front investment, which makes their formation more difficult. Furthermore, most competitive funding schemes fund specific projects and often only their operating costs.

Research organizations can help fund their organizations by commercializing their research outputs. This commercialization can often be achieved through partnerships with the private sector therefore increasing private sector investment in AR4D as well as creating revenue directly from research outputs. The only downside of the commercialization of public sector research outputs is that in many cases revenue goes directly into the country's treasury instead of being re-invested in the organization itself, therefore creating little incentive to sell research output.

Funding for research can also be provided through levies on agricultural production. The benefits of this type of funding are that farmers are more involved in the setting of research priorities, and the farmers who pay more in levies also end up being the biggest beneficiaries of the research. Problems with funding research through levies on agricultural production include losses in production caused by price disincentives, and the high cost of collecting levies in some areas. This can be counterbalanced, however, by matching contributions from public revenues with those paid by farmers.

In addition to national funding mechanisms, sub-regional, regional, and global mechanisms can both finance and implement AR4D. A consensus has been reached that coordination of the funding and implementation of agricultural research as well as increased funding for agricultural research is needed in order to address global agricultural research concerns.

Mobilizing financial resources for agricultural research in developing countries: Trends and mechanisms

June 2009

Ruben G. Echeverría and Nienke M. Beintema[*]

This paper presents a comparative analysis of current agricultural research funding sources in developing countries and discusses several agricultural research funding mechanisms in an effort to promote dialogue and future analysis on key funding issues related to agricultural research for development (AR4D).

Background

The role of agriculture as a major source of income, employment, foreign exchange, and tax revenues is generally understood. However, agriculture's connection with food security, poverty reduction, and maintenance of the natural resource base has only recently received attention. As agriculture becomes better appreciated and these issues move higher on the agenda of national governments and international agencies, it is important to link them with the large potential contribution of AR4D, if the traditional trend in underinvestment in public AR4D in developing countries is to be overcome. Many developing countries have introduced financial, governance, and management reforms to improve public-sector effectiveness and efficiency and to achieve balance between the public and private sectors. They have also introduced specific reforms to stimulate growth in key sectors, such as agriculture. The effects of such reforms on public AR4D systems have been significant: they imply an agenda with greater client orientation; a more demand-driven approach to planning and considerable diversity in funding sources and institutional plurality in executing research; and readiness to network with partner institutions. Such collaborations are increasing at national, regional, and international levels and include the execution as well as the funding of joint research activities.

Paradoxically, despite the demonstrated high payoffs to investment in agricultural research, chronic underfunding threatens either the performance or the existence of many research systems in developing countries. Searching for alternative institutional mechanisms for sustained financing of AR4D is one of the major current concerns of national and international

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research systems, and it must be central to the agenda of policymakers and multilateral and bilateral development assistance agencies. While most countries are experiencing budget shortages, and the gap is growing between maintenance of and investment in the physical and human capital infrastructure for traditional AR4D, additional important demands are being added to the research agenda, such as poverty and environmental issues. Since the mid 1980s, many countries have responded by developing new mechanisms for funding and organizing research, such as joint public–private-sector ventures, sale of research products, competitive funds, research foundations, farmer-managed levies on production, and greater involvement of universities and the private sector in research. What elements have proven successful in this array of mechanisms? Are they comparable across regions?

Although several relatively new funding mechanisms such as the ones mentioned in this paper may play an important role in reversing funding trends, one should keep in mind that the government is still the main source of funding for agricultural research in developing countries and the main executor of research activities. Since funding trends may also reflect institutional stagnation and inflexibility in some national research organizations, institutional change to produce better managed and more flexible systems will also be part of the solution to the funding problem. Will future public research organizations be able to continue to produce public goods and at the same time take on characteristics of the private sector with respect to organization, management, and employment practices?

For how long will the argument that research is a public good justify public funding for research? When markets fail, the government is usually called upon to step in. The argument for publicly funded research is associated with the "public good" character of its outputs. If better knowledge, a new research technique, or an open-pollinated variety cannot be withheld from potential users, and its use by one does not preclude others from using it, it takes on the character of a public good. There will be persistent underinvestment in such goods by the private sector if it cannot appropriate the benefits through legal means or some market dominance.

This argument, although true under certain conditions and situations, is neither complete nor static. Traditionally the research process is thought to include basic, strategic, applied, and adaptive activities, continuing with product development. Basic research creates new scientific knowledge with no immediate commercial application, strategic research provides knowledge and techniques that increase the efficiency of applied and adaptive research, applied research creates new technologies, and adaptive research adjusts technologies to specific conditions. The conventional wisdom is that research at the basic end of the spectrum is a public responsibility, and private initiative increases in importance as we move toward applied research and product development. However, the nature of the technology is also an important criterion for determining the public–private boundary, as it affects the appropriability of research results. It is usually much easier to obtain intellectual property rights for technologies embodied in agricultural inputs (irrespective of whether they are biological, chemical, or mechanical); consequently, these technologies can attract private interest even for strategic research. In contrast, disembodied technological knowledge in the form of new information for crop management is, in most cases, only developed if there is public funding to support the required research.

While many seed-based technologies are evolving away from being public goods and could be further developed in the private sector (for example, the use of hybrid seed or protected plant varieties), the technological needs of small-scale farming and the need to maintain the natural resource base point in the opposite direction. Research for small-scale farmers may be less attractive to private-sector interests because it has higher market development costs, it is risky, the beneficiaries have little capacity to pay, and intellectual property rights are difficult to protect in a cost-effective manner. Besides, as priorities for research and technological development move beyond the search for productivity increases to such objectives as product quality and environmental protection, a new set of public goods will be in demand. Not only do "sustainable" production technologies depend for their development on improved information and management (non-appropriable technologies) but often, their successful implementation depends on group action and profound socio-organizational changes. Consequently, the private sector is unlikely to participate in, and finance much of, this research.

The definition of public-goods research is further influenced by the institutional environment. The development of biotechnology and information sciences, together with changes in the legal and institutional environments for intellectual property protection, is rapidly changing the relative positions of different types of research along the public–private spectrum. For instance, advances in molecular biology have brought much basic research closer to commercial applications and made private industry a major player in many fields of basic science. The same has happened with agronomic practices and management techniques where new information technologies have transformed de facto what used to be classic examples of the public-good nature of AR4D into embodied technologies (for example, "expert systems" in the form of computer software to improve farm-management decisions that can be legally protected, at least in the short run).

It seems too simplistic to classify the role of the public and private sectors in agricultural research by the type of producer served. Some research products that are appropriate for the small-scale sector, such as hybrid seed, can be most effectively produced in the private sector.

Similarly, some products intended for the commercial agricultural sector, such as integrated pest management, will require strong public-sector support. Moreover, research managers and policymakers must keep a broad perspective with respect to the role of research versus policy in solving poverty and environment problems. Agricultural technology definitely has a role to play in solving poverty and environmental problems, but policy and institutional change may, in some instances, be more important. In any event, policy and institutional change are often central to the successful adoption of technology targeted to the small-scale sector and natural resource management.

The new funding mechanisms have arisen in response to the acute shortage of operating budgets in many public research institutes, and so it is not surprising that they tend to address this issue. Since farmers' funds, competitive grants, and funds from commercialization of research products are largely allocated to operating costs, and government appropriations are largely spent on salaries, there is little left for maintenance of the research infrastructure and investment in new infrastructure and human capital and skills for new fields of agricultural science such as biotechnology. If research managers used full-cost accounting, the new funding mechanisms would earn sufficient overhead to cover infrastructure maintenance, but this rarely happens. This notwithstanding, investment in new infrastructure should come from public-sector appropriations and should constitute a priority for increased government allocations to research.

Agricultural research investment trends in developing countries[1]

Global patterns of AR4D investments are changing considerably. Spending on public agricultural research worldwide totaled $23 billion in 2000 (in 2005 PPP dollars), the latest year for which global aggregated data are available. [2,3] Total public spending increased, in inflation-adjusted terms, by almost one-half from the $16 billion spent in 1981. Although the share of developing countries has increased during 1981-2000—from 38 to 43 percent—it was still slightly below that of the high-income countries as a group in 2000 (Beintema and Stads 2008a).[4]

[1] This section draws on Beintema and Stads (2008a).

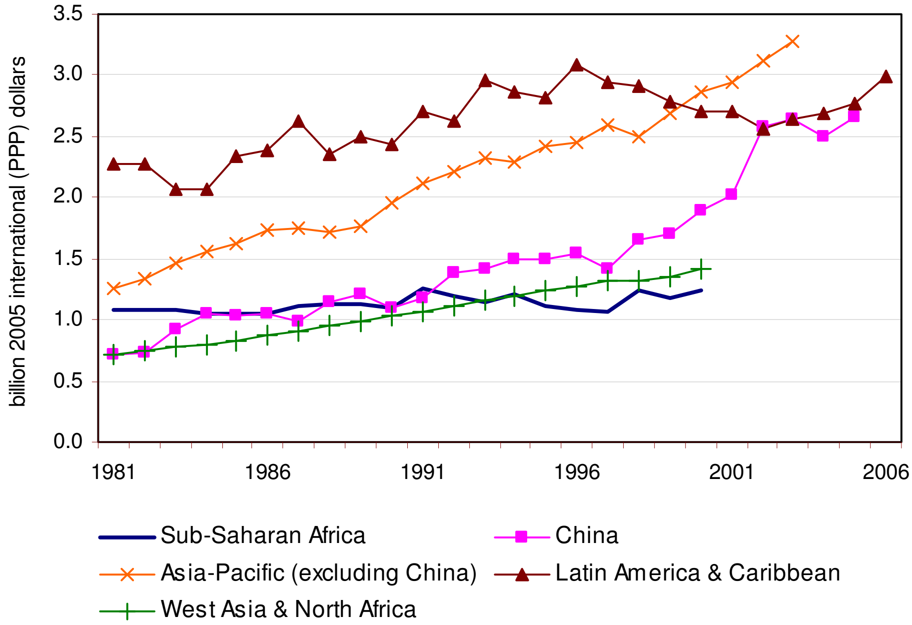
[2] Data collection efforts are underway to ensure a global update for 2007/08. These estimates exclude East Europe and former Soviet Union countries. Developing countries are defined as low- and middle-income countries. Public spending includes government, higher education, and nonprofit.

[3] Financial data in this paper are reported in real values using gross domestic product (GDP) deflators using the benchmark year 2005 and purchasing power parity (PPP) indexes taken from the World Bank (2008). PPPs are synthetic exchange rates used to reflect the purchasing power of currencies, typically comparing prices among a broader range of goods and services than conventional exchange rates. The global spending data differ from those published in Pardey et al. (2006) due to a major revision of PPP indexes for China, India, and many other developing countries released by the World Bank in early 2008.

[4] These global trends differ from those reported in Pardey et al. (2006). These revisions were in response to World Bank adjustments to its comparative pricing of goods and services across countries (using PPP indexes),

Of the 2000 global total, the developing countries in the Asia-Pacific region (APC) combined invested $4.8 billion in 2000, compared to $2.7 billion for Latin America and the Caribbean (LAC), $1.2 billion for West Asia and North Africa (WANA), and $1.2 billion for Sub-Saharan Africa (SSA) (Figure 1).[5] Agricultural R&D spending for China and APC as a whole has grown considerably since 2000. After a period of declining investments in public agricultural R&D, the LAC region also experienced an increase in total agricultural R&D spending in 2006, comparable to the mid-1990s level.

Figure 1—*Public agricultural R&D investment trends in developing countries, 1981–2006*



Source: Beintema and Stads (2008a), based on Agricultural Science and Technology Indicators (ASTI) initiative datasets.

Quantitative information on how agricultural research agencies are funded is collected through the Agricultural Science and Technology Indicators (ASTI) initiative.[6] Since the turn of the millennium, funding data have been collected for more than 400 agencies— mostly the main

reclassification of non-OECD high-income countries, and new estimates for Latin America and a number of other countries (Beintema and Stads 2008a).

[5] These regional totals refer to developing countries only and exclude high-income countries such as South Korea in APC and Israel and Kuwait in WANA.

[6] The ASTI initiative's, which is managed by the International Food Policy Research Institute (IFPRI), overriding objective is to inform and thereby improve research policy choices around the world by providing internationally comparable information on the investment, capacity, and institutional environment surrounding agricultural research and development (R&D).

agricultural research government agencies and nonprofit institutions—in 53 different developing countries.[7]

The government sector is still providing most of the funding to agricultural research in the developing world. Government allocations accounted on average for 81 percent of the $3.9 billion (in 2005 PPP dollars) of total funding received by the 407-agency sample, while 7 percent of this total was obtained from donor loans and contributions (Table 1 and Figure 2). This donor share was mainly driven by the high dependency on donor funding by SSA agricultural research organizations. In 2000/01 the main government agricultural research agencies in the 23 countries for which data were available obtained 35 percent of their funding through donor loans and contributions, which was considerably higher than the corresponding shares in the other regions.[8] Funding generated through internally generated funds, including contractual arrangements with private and public enterprises, accounted for an average of 7 percent of total funding. The share of funding by producer organizations was 3 percent, with 1 percent coming from other sources.

Table 1—*Composition of funding sources by region for various years since 2000*

Region (year of data availability)	Type of Institute	Countries[a]	Agencies	Government	Donor organizations	Producer organi-zations[b]	Own income and contracts[c]	Other
		(number)				*(percentage)*		
Sub-Saharan Africa (2000/01)	Government		45	55.9	34.8	1.3	6.9	1.1
	Nonprofit		5	0.7	4.7	80.5	14.2	—
	Total	23[d]	50	52.3	32.9	6.5	7.4	1.0
Asia-Pacific (2002/03)	Government		201	85.4	6.9	1.8	5.5	0.4
	Nonprofit		2	23.2	1.9	14.3	60.6	—
	Total	10[e]	203	84.6	6.8	2.0	6.2	0.4
Latin America (2006)	Government		42	88.0	2.8	1.1	7.0	1.2
	Nonprofit		24	1.9	3.6	68.4	20.1	5.9
	Total	15	66	83.4	2.8	4.7	7.7	1.5
West Asia and North Africa (2002/04)	Government		83	89.5	0.8	—	7.4	2.3
	Nonprofit		5	0.7	—	—	99.3	—
	Total	5	88	88.7	0.8	—	8.2	2.3
Total developing countries	Government		371	83.9	7.2	1.1	6.6	1.1
	Nonprofit		36	3.8	3.5	62.5	26.5	3.8
	Total		407	81.1	7.1	3.3	7.3	1.2
					(in million 2005 PPP dollars)			
Total developing countries	Government		371	3,173	272	43	251	43
	Nonprofit		36	5	5	85	35	5
	Total	53	407	3,178	277	128	287	48

Sources: Calculated by authors based on Agricultural Science and Technology Indicators (ASTI) initiative datasets.
Note: — indicates zero or almost zero (that is, funding from this source was almost negligent).

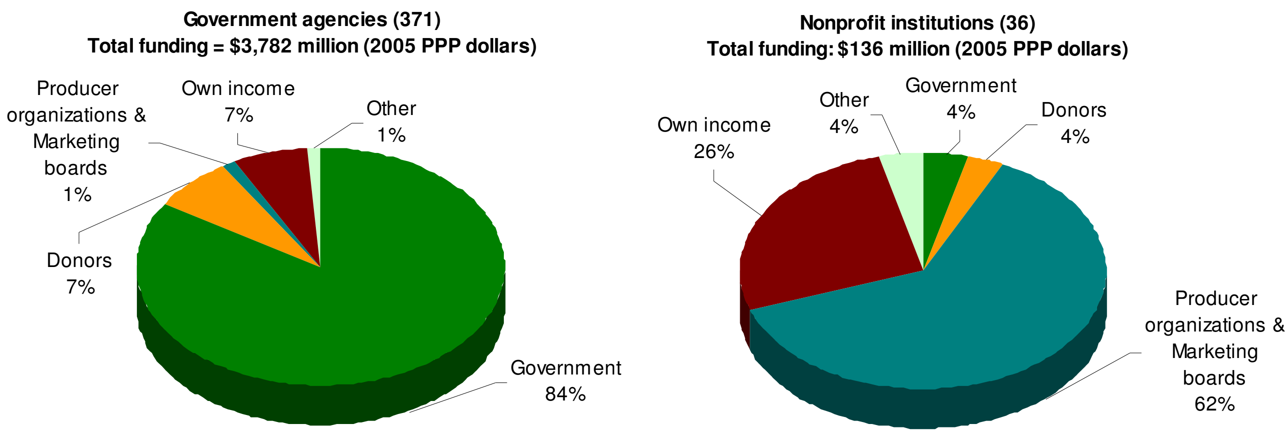
[7] For more details, see the various ASTI country reports and briefs, which are available online at http://www.asti.cgiar.org/publications.aspx. No or limited information was available on the funding sources for agricultural R&D performed by higher-education agencies.

[8] Donor contributions are not always directly channeled to research agencies, but in some cases they are made to the government itself. The share of donor contributions to agricultural research will probably be slightly higher, as it is not always possible to extract these donor contributions in overall government allocations in these cases.

[a] For a list of included countries, see Beintema and Stads (2006; 2008b); Stads and Beintema (2009).
[b] Includes marketing boards.
[c] Includes contracts with private and public enterprises.
[d] Excluding China.
[e] Excluding Nigeria and South Africa, the two largest countries in terms of agricultural R&D investments.

The nonprofit organizations combined received close to two-thirds of their total funding through contributions from producer organizations and marketing boards; these were mostly made in the form of levies raised on export or production of commercial crops. Interestingly, the nonprofit organizations received 26 percent of their total income from internally generated resources, including contracts with private and public enterprises. This was substantially higher than the average share for the government sector (7 percent). The nonprofit organizations received very limited funding from either government or donor organizations (4 percent each).

Figure 2—*Composition of funding sources for various years since 2000*



Source: Table 1.

Although government allocations represent the principal source of funding for public agricultural research, funding sources can differ tremendously at the country level. In 2002/03, for 6 of the 10 APC countries for which data were available, government contributions accounted for from about 67 percent (Malaysia and Sri Lanka) to more than 90 percent (India) of total funding by the main government and nonprofit organizations combined. In 2000/01, government contributions accounted for at least two-thirds of total agricultural R&D funding for 8 of the 23 sample countries in SSA, three of which (Botswana, Malawi, and Sudan) had shares of more than 90 percent. Three of the 14 sample countries in LAC (Argentina, El Salvador, and Panama) also reported shares of more than 90 percent during 2006, with three other countries reporting government allocation shares between 75 and 81 percent that same year. All of the five WANA countries received three-quarters or more of their funding from the government.

In contrast a large number of developing countries depended on nongovernmental sources of funding, resulting in shares of government allocations in total funding of 30 percent or less. This mostly reflected the high donor dependency of some national AR4D systems in countries such as Eritrea, Laos, Nepal, Nicaragua, and Tanzania. Exceptions are Belize and Honduras. In 2006, Belize's agricultural research activities were funded by an almost equal mix of government and donor allocations, producer contributions, and internally generated resources. That same year, internally generated resources accounted for 60 percent of total funding to government and nonprofit agencies in Honduras. Government and donor funding to AR4D has become increasingly scarce in the country and, as a result, nongovernmental institutions have come to the fore as leaders of the country's research agenda (Stads et al. 2008).

Public spending in agricultural research has become increasingly concentrated in just a handful of countries. In 2000, Brazil, China, and India accounted for 43 percent of all developing countries' expenditures, up from 35 percent in the early 1980s. The 44 SSA countries combined represented only 12 percent of the developing-world total in 2000 and a decline from their 18 percent share two decades earlier.

Although absolute expenditures (in inflation-adjusted terms) have continued to inch upward, the support for public agricultural research (including high-income countries) has decreased since the mid 1980s. Global public agricultural research spending increased with an annual growth rate of 1.1 percent during the 1990s, down from 2.7 percent during the 1980s. Most of the growth during the 1990s was due to the continued high growth rates in the APC region. Noteworthy is the fairly stagnant growth in SSA during the 1990s, which was less than the already low average annual growth of 1.0 percent of the 1980s. Public agricultural research spending in the high-income countries as a group remained fairly stagnant during the 1990s (Beintema and Stads 2008a).

The ***research intensity***—the measurement of AR4D expenditures expressed as a percentage of agricultural gross domestic product (AgGDP)—of developing countries was 0.55 percent in 2000, whereas the ratio for high-income countries was 2.35 percent. While the intensity ratio for the high-income countries combined has increased over the past two decades, the corresponding ratio for the group of developing countries remained fairly constant despite the fact that public AR4D spending grew much faster in the developing countries than in the high-income countries. This is the result of relatively higher growth in agricultural output in developing countries (Beintema and Stads 2008a).

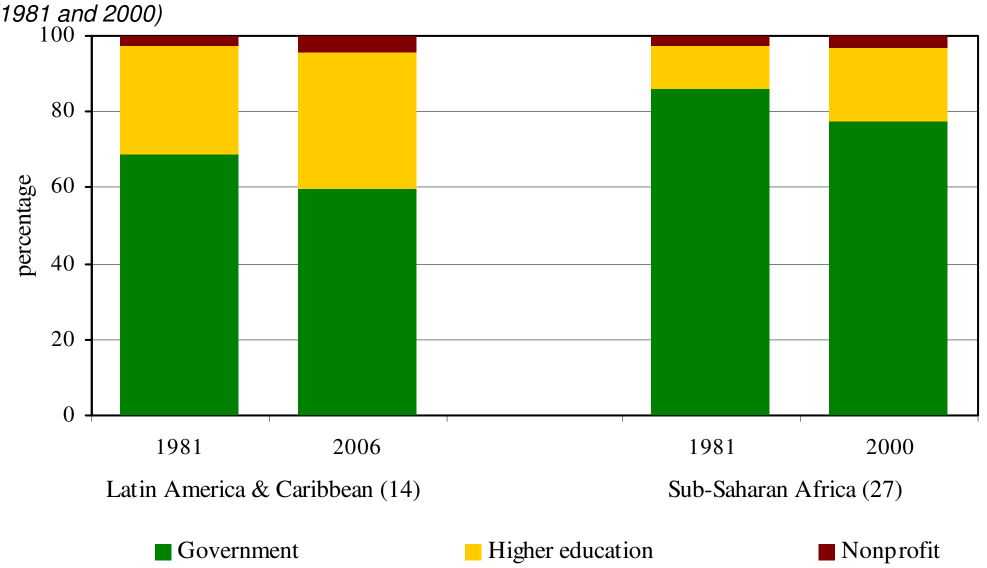
The rapid growth in the number of scientists in relation to growth of funding has resulted in downward pressure on real salaries of scientists and inadequate operating resources for professional satisfaction and productivity in many developing countries. Where priorities are not reexamined, this has led to a dispersion of remaining resources over fragmented and inadequately funded activities. This has particularly been a concern in SSA where overall spending per scientist declined by one-half during 1971–2000 (Beintema and Stads 2006).

Implementation of agricultural research in developing countries

Time series data on the institutional distribution of public agricultural research were available for the LAC and SSA regions. The public sector accounted for 60 percent of the total full-time equivalent (FTE) research staff in LAC (2006) and 70 percent in SSA (2000) (Figure 3). Although the government sector continues to dominate the execution of public agricultural research, the ***higher-education sector*** has gained prominence in a number of countries. In LAC, the higher-education sector represented 36 percent in 2006—up from 29 percent in 1981. The corresponding share in SSA increased from 11 percent in 1981 to 19 percent in 2000. In absolute terms, the number of FTE researchers in the higher education sector almost doubled in LAC and tripled in SSA over the respective periods. In a number of countries the capacity in the higher-education sector is closing in on that of the government sector. For example, in five LAC countries (Argentina, Costa Rica, Honduras, Mexico, and Uruguay) the higher-education sector accounted for 40 percent or more of the total public AR4D staff in 2006 (Stads and Beintema 2009). In India, the higher-education sector employs more FTE agricultural researchers than the government sector. This is the result of India's system that integrates research, extension, and education following the so-called land-grant system of the United States (Beintema and Stads 2008b). Despite the increasing share of the higher-education sector as a whole, the individual capacity of many individual higher-education agencies remains small. For example, about 65 percent of the identified agricultural higher-education agencies in Sudan and 75 percent in the Philippines employed fewer than 10 FTE researchers (Beintema and Stads 2006, 2008b).

Agricultural higher-education agencies have considerable potential to increase the resources available to research, especially human resources (students and professors). Although universities have been generally regarded as teaching institutions, there are a number of reasons why they may wish to be involved in research and indeed may have a comparative advantage in doing some types of AR4D. These include the complementary relationship between research and teaching, especially at the postgraduate level where all students are expected to undertake a significant research project; the international and national prestige often associated with scientific research; the desire by universities to contribute to increasing national welfare through scientific advances; and the recent interest by universities in potential revenues from sales of research products based on university research. Despite their interest in research, universities have historically accounted for only a small proportion of AR4D in developing countries, usually more basic research that has often been funded through a small annual appropriation from the government. One of the major reasons for this low profile in research has been the shortage of research funds for university scientists. When research funds have been made available, generally through a competitive grant system, universities have responded enthusiastically to the opportunity to conduct more research. Thus agricultural and nonagricultural universities represent an underutilized resource that can be tapped with modest levels of funding to increase the total research output of the country. Nonetheless, with heavy dependence on competitive funding, they may not be able to develop a coherent long-term research program due to the lack of funds for research infrastructure and the short-term nature of grants.

Figure 3—*Institutional orientation of agricultural research in LAC (1981 and 2006) and Sub-Saharan Africa (1981 and 2000)*



Source: Calculated by the authors based on Beintema and Stads 2006 and Stads and Beintema 2009 and underlying datasets of the Agricultural Science and Technology Indicators (ASTI) initiative.

Note: Shares are measured in terms of full-time equivalent (FTE) researchers. The number of countries is indicated in parentheses.

Nonprofit organizations such as producer organizations, marketing boards, foundations, and nongovernmental organizations (NGOs) are increasingly relevant elements of national and global AR4D. Although in absolute numbers—total FTE researchers more than doubled in LAC and SSA during their respective periods—they continue to account for a small share of public agricultural research: 3 percent in SSA (2000) and 4 percent in LAC (2006).

Research foundations are NGOs of various types that constitute an alternative mechanism for funding or conducting AR4D or both. There are foundations that both fund and execute research, those that act as intermediaries for research funds but are not involved in implementing research, and those that seek to link scientific and technological capabilities with research needs and investment projects. Some foundations execute research, usually under contract, while others transfer technology and promote the commercialization of research products. Most foundations focus on the commercial sector, especially export crops and agribusiness. Although some foundations have endowment funds, the endowments are usually only sufficient to support a small administrative secretariat but not to fund significant research projects. The foundation model has the potential to incorporate the demands from the private sector in several ways. Often, the boards of directors are made up of private-sector representatives; hence priorities for research activities are usually based on market opportunities and specific producer requirements. Foundations can thus play a catalytic role in bringing together public and private initiatives and so positively influence technology transfer and training of producers. Those foundations that enjoy national and local funding support and those that have endowments will probably continue to be important players in the research system. Others, especially those that are heavily dependent on outside sources of funds, may decrease in importance.

Although ***private-sector*** spending data are not easy to gather, the best global estimates indicate a total of about $16 billion in 2000, which is 41 percent of the total global (public and private) investments in AR4D. Only 2 of this 41 percent is spending by private companies that execute agricultural research in developing countries, less than $1 billion in absolute terms. Ninety-four percent of private investments occurred in high-income countries where 54 percent of total funding for AR4D is private. Seven percent of the total investment in agriculture in developing countries is private (Beintema and Stads 2008a). The private sector, however, plays a stronger role in funding, as opposed to conducting, agricultural research given that many private companies contract research out to government and higher education agencies (see the section on private-sector participation later in this report).

The growing diversity of funding mechanisms for public-sector research institutions is being complemented by increased participation of private companies in the direct funding and execution of research, especially where markets have been liberalized and intellectual property rights have been strengthened. Research in the private sector is increasing with the growing importance of the agricultural input and processing sectors; the rise of regional free-trade blocks, which increases market size; and the strengthening of intellectual property legislation. A more active private sector not only increases the total resources available for research but also provides many opportunities for increasing the efficiency of the entire research system by exploiting complementarities and interactions between the public and private sectors in funding and research implementation. Multinational firms with access to global markets are able to exploit economies of size and scope in research and operate somewhat independently of public-sector research institutions. National companies, with a few exceptions, will require greater interaction with and access to public-sector research in order to develop their own applied research capacity and compete effectively with the multinationals.

Bilateral and multilateral funding has been an important source for agricultural research for many developing countries, particularly in SSA. SSA, more than the other regions, has become dependent on donor contributions to its agricultural research agencies. As shown in Table 1, in 2000/01 donor contributions averaged 33 percent of total funding for the main AR4D agencies in 23 African countries for which data were available. For 7 countries, donor funding accounted for more than half of all agricultural research funding to the main government agencies (Beintema and Stads 2006). The World Bank in particular was an extremely important contributor to agricultural research activities in Africa through loan-supported projects during the 1990s. Projects variously focused on agricultural research and on agriculture in general with an agricultural research component. Some projects aimed to reshape a country's entire national AR4D system, whereas others focused on specific crops, agencies, or general research management and coordination.

After several decades of strong support, international funding for agriculture and for AR4D began to decline around the mid-1980s. Data on aggregate trends of donor funding for agriculture and agricultural research are unavailable, but information on agricultural R&D grants and loans from the World Bank and the United States Agency for International Development (USAID) is accessible. The amount of funding that USAID directed toward AR4D conducted by national agencies in less-industrialized countries declined by 75 percent in inflation-adjusted terms from the mid-1980s to 2004. APC experienced the largest losses, but funding to SSA and LAC was also cut severely. Over the past two decades, World Bank lending to the rural sector has been erratic, but after adjusting for inflation, the general trend has been downward as well (Pardey et al. 2006).

There appears to be no single cause for the decline in donor support for agriculture between1980 and 2003; Morrison, Bezermer, and Arnold (2004) list a number of causes that include declining donor confidence in agriculture and shifting priorities toward health and education sectors by donors and many developing-country governments. Eicher (2003) also reported changes in aid modalities away from the Green Revolution technologies of the 1960s to

1980s and the integrated rural development projects of the 1980s and 1990s toward the current sector-wide approaches. Support to poverty reduction strategies has also led to declining donor support to AR4D. Recently, however, there has been renewed donor interest in the importance of the role that the agricultural sector can play in achieving economic development, poverty reduction, and ensuring food security. Donors are also acknowledging the important role that R&D plays in agricultural development. Time will tell (especially in light of the current financial crisis) whether this renewed donor interest will translate into an increase in contributions toward agricultural research, not only by donors but by national governments as well.

Because of the limited availability of time series data on funding sources, no regional trends could be derived. But in general, national governments in developing countries, while publicly recognizing the need for rapid development of agriculture in order to reduce poverty, have not (as a group) increased allocations to AR4D in real terms. Moreover, donor support for agriculture and especially for research has been ambivalent and not sustained; it is not comparable, for instance, with the large amount of existing subsidies to developed country agriculture. Further, while the concept of collaboration in research is actively promoted by donors, most funding support is bilateral and often without the needed harmonization of a clear focus on a small set of research priorities. Mechanisms to financially support agricultural research that are transparent and adequate at various levels from national to global are also weak and often hinder the establishment of good partnering arrangements. How can efficient mechanisms to mobilize adequate financial support to agricultural research at the national, regional, and international levels be developed?

Assuming that public AR4D investments continue to grow and governments remain the main source of funding, does this imply that developing countries may have to become more dependent on one another for the funding and performance of public-good type agricultural research in the future? Do these trends also imply that more collaborative international research for development should be conducted to fill the apparent huge research gaps in developing-country agriculture? In addition, the question of who benefits from the research (whose agenda is being addressed), who finances the research, and who executes the research are related, but they do not have a one-to-one correspondence. The public sector can commission research by the private sector; the private sector may be left to take care of its own needs for certain types of research; and the private sector may find it cost-effective to contract with public-sector institutions for other types of research.

Examples of mechanisms for financing agricultural research at the national level[9]

Innovative funding mechanisms that reflect the opportunities offered by the various research-executing agents are critical for the development of more effective and efficient research systems. In searching for a diversified research funding base, we should go beyond a simplistic dichotomy between public and private funding and consider a number of combinations based on the source of funds and the research to be executed. For instance, research to produce a public-good type technology may be financed by the government sector, but the research could be subcontracted to a foundation, a university, or the private sector. But private companies may fund research that is executed at public institutes.

The criteria for selecting appropriate mechanisms for funding research may differ from those for selecting appropriate institutional forms for executing research. On the one hand, the responsibility for funding research is a distributional issue and should be determined on the basis of who benefits from the research; on the other hand, the execution of research activities could be defined on the basis of efficiency considerations.

For the purpose of this paper, ***effective financing is defined as one that increases the average returns of current levels of investment in agricultural research (efficiency criteria) and that also attracts complementary investment from additional sources (market).*** In the presence of scale economies, average returns may increase simply as a result of increasing AR4D investments. But in practice several actions must be taken: adding research projects to the portfolio with better-than-average returns and deleting projects from the portfolio with inferior expected returns. In short, more "successful projects" should be identified, designed, and implemented, which would serve to improve the overall quality, efficiency, and productivity of AR4D. The second key condition for effective financing is that contributions by one source should lever contributions from one or more additional sources.

An effective funding mechanism will then be one that allows optimum use of research infrastructure to execute the research. This is affected by economies of size and scope in research, market size, and existing institutional and management capabilities (including sunk costs), while providing fiscal instruments and the operational flexibility for those who benefit from the research to assume the financial burden of research investments. In most developing-country cases where public-good type technologies are the goal, this will mean that a large share of execution of research may remain in the public domain. This to benefit from economies of size and scope and a more efficient use of sunk costs (for example, research stations, highly trained

[9] For further reading on financing agricultural research, see Alston, Pardey, and Roseboom (1998); Echeverría, Trigo, and Byerlee (1996); Echeverría et al. (1995); and Janssen (1997).

human resources, and advanced laboratories and equipment), but financial resources will flow through a diverse array of alternatives.

A key ingredient for effective financing is the availability of a menu of financing arrangements and mechanisms that can be adapted to the particular circumstances of agricultural research and to the potential investors in specific research topics. Given the diversity of institutions performing agricultural research, an equally diverse array of sources and mechanisms of funding is needed to induce the participation of all potential investors. While it is tempting to search for new models for funding and executing research, each system will have to evolve its own model based on the existing research infrastructure, market size, and historical factors.

As mentioned earlier, ***direct institutional funding from a central or regional public budget*** (either related to agriculture or to science and technology) remains the most important funding source in developing countries. The overall level of support to national AR4D may be, among other factors, related to the stage of development of the research system and of the country, its fiscal capacity, and the demonstrated effectiveness and efficiency of use of financial resources. Government support to AR4D remained very strong in China and India—the two largest countries in terms of public agricultural R&D capacity— which is also reflected in the strong increases in total spending as evidenced earlier in this report. Recently, the government of Brazil announced a significant increase in its support to its national agricultural research organization EMBRAPA. But in many developing countries, government support to AR4D has stagnated or declined, especially in inflation-adjusted terms. In Chile, for example, total government contributions to the Institute for Agricultural Research (INIA) amounted to less than the institute's total salary bill. INIA is therefore forced to obtain supplementary funding resources to remain financially solvent. If researchers fail to secure funding for operational expenditures through other sources, they will have no funds to carry out their research. This has created a highly competitive environment (Stads and Covarrubias Zúñiga, 2008). The share of specific project funding in total government allocations for the Colombian Corporation for Agricultural Research (CORPORICA) has increased in recent years. This has caused financial difficulties for CORPOICA because project funds are not allowed to go toward the recovery of overhead costs or the salaries of permanent staff; project funds are allowed to pay for contract labor only (Stads and Romano 2008).

A problem of this traditional funding mechanism that has hampered the performance of AR4D in various developing countries, especially in SSA, is the discrepancies that have occurred between budget allocations and actual disbursements. The Nigerian government, for example, only released slightly more than half of the planned recurrent budget during 1992–99 while, on average, only 5 percent of the proposed capital allocation was disbursed (Beintema and Stads 2006). These discrepancies still occurred after 1999. Other SSA countries such as Tanzania and Uganda also experienced discrepancies between budget allocations and actual disbursements, but not at a level such as Nigeria's during the 1990s.

As greater institutional diversity and efficiency continues to be promoted, several agricultural research agencies are acquiring a greater share of their funding through ***competitive funds***. They finance research conducted by public institutes, universities, nonprofit organizations, and private firms through grants allocated to projects on the basis of their scientific merit and their congruence with broadly defined AR4D priorities. These funds complement annual appropriations from national budgets, while increasing the accountability of research and researchers. Competitive funding mechanisms at the national and regional levels can bring additional research resources while lowering execution costs and encouraging a more demand-driven research system. Such funds may have several contributors, including governments, multilateral development banks, bilateral donors, and private-sector organizations. In most cases, the funds operate on a depleting basis, usually over a period of four to six years, unless they are established as an endowment. By using only the proceeds of investments, endowment funds have the advantage of securing resources on a continuing basis. However, large up-front investments are needed to generate sufficient annual income to fund a significant research program.

Competitive research funds provide accountability and flexibility to national agricultural research systems in their effort to adjust to the changing priorities of AR4D. They can also be used to promote cooperation between different components of the agricultural research systems and thus improve the linkages between public-sector capabilities and private-sector and market initiatives. However, since these funds normally finance specific projects (and often only their operating costs), they should be considered as a complement to institution-based formula funding, such as annual appropriations from the state that are needed to maintain and build research infrastructure. Another concern is the long-term sustainability of the funds, since many of them are highly dependent on external funding. In the case of those financed by loans with a long repayment period from development banks, it is likely that funding will be reduced once the initial loan has run its course.

Chile was one of the first countries in Latin America to introduce competitive funding schemes for agricultural research, which started in the 1980s. Stads et al. (2008) argue that these schemes have helped to significantly increase the volume and quality of Chilean (agricultural and nonagricultural) research, as well as to introduce better-defined research agendas for both private and public research agencies. In 2006, for example, about 18 percent of the total funding resources of Chile's six government agencies involved in agricultural R&D were obtained through various competitive funds. Competitive funds have also become the most important mechanism to allocate public funds for scientific research in Mexico. In the case of AR4D, two main competitive programs were established: the Subprogram for Research and Technology Transfer, managed by the Produce Foundations and the Sector Fund for Agricultural Research. With the aim of increasing funding for Mexico's main government agency, the National Institute for Forestry, Agricultural, and Animal Husbandry Research, and to encourage research staff to be more responsive to farmers' needs, the federal administration created Produce Foundations in each of the 32 states in the mid-1990s. The foundations are controlled by the farmers; government representatives have only an advisory role. Both the federal and state governments contribute to foundations' core funding, while farmers and private companies pay a share of specific projects. The foundations are playing an increasingly important role in financing Mexican AR4D.

Quite a number of other LAC countries have established sizeable competitive funding schemes, as well as various Asian countries such as India, Indonesia, Malaysia, and Sri Lanka. In SSA the competitive funding mechanisms have been limited, with the exception of countries such as Kenya, Mali, Senegal, and Tanzania. These, however, were all created as part of broader World Bank-supported projects, which raises the question of whether such schemes are sustainable (Beintema and Stads 2006).

Income through sales and services are becoming more common. Most public-sector research organizations (government, nonprofit, and higher education agencies) now have mechanisms to commercialize research results through various types of alliances with the private sector, especially joint ventures for both funding and execution of research. However, commercialization is only relevant for technologies for which the benefits can be appropriated, and this source of funds will necessarily only account for a small share of the total budget of institutions that specialize in the production of public goods. The potential to commercialize research products depends on the degree of appropriability of the technology being produced. As the level of appropriability increases, private-sector contributions of funds should also increase, utilizing several mechanisms such as consortia, direct support, and franchising. Where there is a high level of appropriability, joint ventures with private organizations are useful instruments for sharing funding responsibilities. There are two major motives for such joint ventures. First, a private company may find it cheaper to contract certain types of research to the public sector, rather than establish or expand its own research facilities. Second, public-sector research organizations in general, and those in the agricultural sector in particular, usually lack the skills needed to mass produce and distribute the production inputs that embody the technologies that they have generated. The lack of these skills has been frequently recognized as one of the main limitations to technology diffusion. Joint ventures between public- and private-sector institutions that share the costs and benefits of research are being developed in many countries in fields such as genetic improvement, seed production, plant propagation, and veterinary products. While currently affecting only small segments of the overall research program, such schemes are bound to grow as market mechanisms become more prevalent in guiding AR4D. Although contract research and the sale of improved seeds and other research products can provide additional funding to public research institutes, more analysis may be needed to determine if this mechanism may have the potential to contradict the public-good character of the research output and, if so, to explore the possibility of an eventual privatization of much of such research.

Resources generated through the sale of research products and services (including contract work conducted for public and private enterprises) accounted on average for 7 percent of total funding for the main government agencies and nonprofit organizations in the developing world. Some agencies/countries, however, are further ahead in generating their own income than others. Internally generated resources, for example, have become an increasingly important component of funding AR4D in China and Indonesia. Since the mid-1980s the Chinese government has encouraged research institutes to generate income through the provision of research services and commercial activities, a proportion of which can be retained by the generating agencies (Fan, Qian, and Zhang 2006). Conducting contract research for public/private enterprises and the sale of plantation crops and technology inputs (such as seed stock) constituted the most important income source during 1994–2003 for the Indonesian Research Institute for Estate Crops (IRIEC)—Indonesia's largest government agency in terms of research expenditures (Beintema and Stads 2008b). In 2000/01, the principal government agencies involved in agricultural research in Benin, Côte d'Ivoire, and Ghana also generated significant shares of total funding from research contracts, commercialization of agricultural products, and dissemination of research results. In the case of Côte d'Ivoire, this was driven by a World Bank project that included an important commercialization component (Beintema and Stads 2006). Internally generated resources have also become an important funding source in a number of Latin American countries such as Chile's INIA. During 2004–06, about one-third of the institute's funding was derived through the sale of products, mainly seeds, but also through contract work for private companies and sale of laboratory services (Stads and Covarrubias Zúñiga 2008).

In a large number of countries internally generated income is generally channeled back to the treasury of the country. This does not provide incentives for generating income through sale of products or services.

Another promising source of funding is a ***levy on agricultural production***. Commodity associations can raise these funds in order to conduct their own research or to fund research in public and/or private research organizations. The leverage of these funds can be even greater if there is a legislated commitment by governments to match the funds provided by farmers. Farmer financing of research provides a means to foster a demand-driven research system—farmers' participation in funding research must be accompanied by farmers' participation in setting research priorities and monitoring impacts. Direct funding of research by farmers and other consumers of research products has additional benefits since those contributions may increase the total funds available for research. And, by linking funding to output, those who benefit most from research will pay more; therefore the system may be relatively more equitable.

Farmer-financed systems may be organized by commodity or geographic region. Most commonly, farmers pay a small levy on the output of a particular commodity to finance research on that commodity. An alternative is for farmers in a particular region to pay a small levy on the output of all agricultural produce so as to support research at a research station that serves that region.

Although farmer funding of research has many advantages, there are factors that can limit the implementation of these schemes. As with any levy or tax on output, a research levy induces price disincentives and, therefore, a loss in production. Also it is not always clear if the levy provides additional resources or if it substitutes for funds that would have been provided from general tax revenues in the absence of the levy. In the case of export crops or other commodities that pass through a limited number of collection points (for example, a port or a flour mill), levy collection can be quite efficient. However, for commodities and regions where most farm output is consumed on the farm or is sold in informal markets, the cost of collection is high. Government legislation is usually needed to initiate the scheme and make the levy compulsory on all farmers since it is unlikely that farmers will voluntarily pay a research levy (a "free rider" problem). Because of spillovers to other commodities (or to other regions in the case of regionally organized levies) and the long-term nature of research, it is possible that farmers will decide to fund research at suboptimal levels and emphasize applied and adaptive research with relatively short-term payoffs. Thus, basic research may remain underfunded. The matching of farmer contributions with funds from public revenues is one way of improving incentives for funding of more basic research.

Who executes the research funded by farmers? Producer organizations that collect research levies may execute research themselves. However, there is no reason to expect producer organizations to be the most efficient suppliers of research services, except for adaptive research undertaken to test and refine technologies on-farm. In some countries it is the government that collects the levy and executes the research. A possible efficient alternative is likely to be some form of a competitive grant system that is open to all parties, including public research institutes and the private sector.

Although producer levies account for only a small share of the total funding resources into developing countries' AR4D, they have become an important source for some specific countries and (export) crops. Colombia is probably the most advanced country in these terms; the country has 13 producer organizations that are either conducting their own research or financing research done by others, mainly through the income of production and export levies.[10] In 2006, more than 90 percent of research carried out by the country's four principal producer associations (coffee, sugarcane, oil palm, and rice) is financed through commodity taxes levied on private-sector production or exports. During the past few decades, other LAC countries such as Costa Rica, Guatemala, and Honduras also established production tax regimes to fund research, mainly on coffee and sugar.

Malaysia, Papua New Guinea, and Sri Lanka in the APC region have also introduced commodity levies for export crops. The mechanisms for collecting revenues and the shares allocated to research vary across commodities and countries. Research in Malaysia (for oil palm and rubber), Papua New Guinea (for cocoa, coffee, and oil palm), and Sri Lanka (for tea, coconut, and rubber) is largely financed through export levies, but, in contrast to LAC, most of the research is conducted by government agencies and not independent producer organizations.

In a number of SSA countries, funding of research on export crops by commodity levies dates back to colonial times. Currently significant shares of coffee, tea, cotton, tobacco, cashew, and sugarcane research are financed this way in Kenya and Tanzania and to a lesser extent Uganda.

In addition to national mechanisms for funding, there are significant regional and global mechanisms in place to coordinate, fund, and execute research. At the subregional level several networks coordinate the execution and funding of regional research activities as for example, Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA) in SSA and the Cooperative Program for the Technological Development of the Agro-food and Agro-industry in the Southern Cone (PROCISUR) in LAC. At the regional level, the Forum for Agricultural Research in Africa (FARA) in SSA, the Asia-Pacific Association of

[10] A few producer organizations such as the ones for flowers and potatoes have not introduced commodity taxes but instead receive voluntary contributions from their members

Agricultural Research Institutions (APAARI) in APC, and the Regional Fund for Agricultural Technology (FONTAGRO) and Forum for the Americas on Agricultural Research and Technology Development (FORAGRO) in LAC are relevant examples. At the global level, the Consultative Group on International Research (CGIAR) constitutes the best example of global consortia that conduct and increasingly fund international AR4D.

While the CGIAR is an alliance of research centers, national governments from developing and high-income countries, international and regional organizations, and private foundations also conduct key strategic international research. The argument for international public research can be seen as related to several characteristics: the scale of the research goes beyond what one country would provide freely, the product is of wide interest, and the research addresses issues that are crucial for the world but may not reflect the agenda of any one benevolent (and sufficiently rich) donor. It may also respond to the idea of reliable trusteeship for the world's resources (especially germplasm). It should also be recognized that there are some nonmarket objectives or problems that may be poorly supported by policymakers in some countries, but where future problems may be averted through international actions. Several factors determine the effective division of research labor among public (national, regional, global), civil society organizations (including farmers' organizations and NGOs) and private-sector companies. Who should pay for such research (how much and under which mechanism) is a policy question open for discussion.

At the international level, it seems that there is growing consensus that, in addition to increasing funding, much more harmonization is needed, both in funding and execution, to be able to effectively tackle large global AR4D challenges. With growing opportunities for cross-country technology spillovers and national–regional–international research alliances, it is access to new technological knowledge from various sources, both domestic and international, that is important. Since access to technology is closely related to capacity to generate technology, the strengthening of national, regional, and global research systems seems to complement each other.

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