Agricultural R&D Spending at a Critical Crossroads

Professor Philip Pardey
University of Minnesota

Professor Julian Alston
University of California

Nienke Beintema
IFPRI

Since 1980 many countries have changed the ways they invest in and organise public agricultural research and development (R&D). Support for public R&D has diminished, especially for near-market, applied, productivity-enhancing research, with funds being diverted to new agendas with environmental and food quality and safety objectives. These changes have important implications for sustaining productivity in developing countries, which in the past have relied on agricultural R&D spillovers from other countries. Some developing countries are becoming more self-reliant and developing their own R&D programs. However, the more disadvantaged countries will struggle to maintain productivity growth in the face of declining applicable spillovers.

Throughout the 20th century, improvements in agricultural productivity have alleviated poverty and starvation and fuelled economic progress. These productivity improvements have been closely linked to investments in agricultural research and development (R&D). However, in the past 25 years many countries have made major changes to the ways they fund and organise public agricultural R&D, and the incentives affecting private R&D. These changes raise questions about the prospects for sustaining productivity growth over the next 25 years and beyond. Early indicators suggest that a global slowdown in farm productivity may have already begun.

Agricultural R&D Trends

In the past, both developing and developed countries have been dependent on technology spillovers from a few of the world's affluent countries, both directly and through the system of International Agricultural Research Centres (IARCs) including the Consultative Group on International Agricultural Research (CGIAR). However, this trend changed towards the end of the 20th century in many countries, with public and private roles shifting. Support for public agricultural R&D slowed, especially for near-market, applied, productivity-enhancing research. In the world's most affluent countries, which traditionally provided the majority of the world's agricultural R&D investments, a slower growing, stagnant, or shrinking pool of public agricultural R&D funding is increasingly being diverted away from the traditional agenda towards environmental objectives, food quality and safety, and other objectives.

These changes mean that many countries (and especially developing countries) may have to become more self-reliant in the development of applicable agricultural technologies. Complete self-reliance will be beyond many countries, especially given recent and ongoing structural changes in science and scientific institutions, in particular the rise of modern biotechnologies and other high-tech agriculture, and the associated role of intellectual property (IP). The largest developing countries (Brazil, China and India) are making the transition; nevertheless, they have yet to overcome the problem of chronic underinvestment in agricultural R&D, and they have many problems to overcome with respect to the effective management and efficient use of their available resources.

The most disadvantaged countries will continue to rely on the supply of spillovers from other countries and from multinational efforts. However, current international investments in productivity-enhancing agricultural R&D seem too small to fill the vacuum being created by the changes in developed country research agendas.

Who, then, will do the R&D required to generate sustenance for a growing world population when, at least for another century, virtually all the population growth will occur in the poorer parts of the world?

Diverging Research Agendas

During the 1900s, the world's agricultural economy was transformed remarkably, fuelled by agricultural productivity growth, primarily generated by agricultural R&D that was financed and conducted by a small group of developed countries, especially the United States (US), but also France, Germany and Japan.

In an increasingly interdependent world, both developed and developing countries have been dependent on agricultural R&D conducted in the private and public laboratories of these few countries, even though they have not contributed to financing the activity.

However, dietary patterns and other priorities change as incomes increase. As a result, developed country research agendas are shifting. In particular, the past emphasis on simple productivity enhancement and enhancing the production of staple foods is declining in favour of interest in enhancing certain attributes of food (such as increasing demand for processed and so-called functional foods) and food production systems (such as organic farming, humane livestock production systems, localised food sources and 'fair trade' coffee). In contrast, food security concerns are still pervasive among less affluent communities, predominantly in developing countries.

In addition, to growing differences in consumer demand for innovation between developed and developing countries, agricultural R&D agendas may diverge because of differences in producer and processor demands. Farmers in developed countries are demanding high technology inputs that are often not as relevant for subsistence agriculture (such as precision farming technology or other capital-intensive methods).

Agribusiness in developed countries is demanding value-adding processes designed to meet consumer demands, and farm production technologies designed to satisfy evolving demands for farm products with specific attributes such as particular food, feed, energy, medical, or industrial applications.

As developed country agricultural R&D programs respond to these changing patterns of demand for innovations, the emphasis of the science is being skewed in ways that could undermine the international spillovers that have traditionally contributed significantly to gains in food production throughout developing countries of the world. These spillovers are not generally well understood and their importance is under-appreciated.

Other aspects of agricultural science policy, and the context in which it is conducted, are changing as well. In particular, the rise of modern biotechnology and enhanced intellectual property rights (IPRs) regimes mean that the types of technologies that were once freely available will be more difficult to access in the future.

Moreover, the new technologies may not be as portable as in the past. Biotech companies are mostly located in developed countries, particularly in the US, and tend to emphasise technologies that are locally applicable.

These and other factors limit incentives for companies to develop technologies for less-developed countries. Hence, some fear less-developed countries may become technological orphans, abandoned by their former private- and public-sector benefactors in developed countries.

New Pressures for Self-Reliance

International spillovers of public agricultural R&D results are extremely important as they have profound implications for the distribution of R&D benefits between consumers and producers, and thus among countries (Alston 2002). They have also contributed to a global underinvestment in agricultural R&D, which the existing public policies have only partly succeeded in correcting. The stakes are high because the benefits from agricultural technology spillovers are worth many times more than the investments that give rise to them.

The world's least affluent countries have depended on spillovers of technologies from industrialised countries (especially from the US, but also the United Kingdom, France and others) both individually and through their collective action via the CGIAR.

Until recently, much of the successful innovative effort in most developing countries was applied at the very last stage of the process, selecting and adapting varieties for local conditions using breeding lines and other materials developed elsewhere. Only a few larger countries, such as Brazil, China and India, were able to achieve much by themselves at the more upstream stages of the research and innovation process, even for improved crop technologies for which conventional breeding methods are widely applied.

Until recently, that strategy of conducting adaptive research and relying on spillovers for basic material was reasonable, given an abundant and freely accessible supply of suitable materials; at least for the main temperate-zone food crops.

Changes in the emphasis of developed country agricultural R&D, combined with new IP rules and practices in conjunction with an increased use of modern biotechnology methods, have already begun to spell a decline in the public pool of new varieties. In addition, the other main source of varietal materials, the CGIAR, has changed its emphasis and is scaling back its role of providing finished material or advanced breeding lines.

The reduction in spillovers from these traditional sources will mean that less-developed countries will have to find new ways of meeting their demands for new varieties.

Pervasive Underinvestment

Although investment in agricultural R&D has high returns and has played a major role in helping to provide food for large and expanding populations, support for this form of R&D is declining. Underfunding of agricultural R&D is pervasive, especially in developing counties. This trend is alarming given:

- the continuing and substantive growth of populations, especially in developing countries
- an increasingly scarce and deteriorating natural resource base
- the pervasive pockets of hunger and poverty that persist in developing countries, in many cases despite impressive national average productivity increases
- the growing divergence between developed country research agendas and the priorities of developing countries.

The problem of underfunding may worsen, especially for agricultural R&D that is related to the production of food staples in less-developed countries, as evidenced by the recent funding trends.

Public Research Investments

Worldwide public investment in agricultural R&D increased by 51% in inflation-adjusted terms between 1981 and 2000 from an estimated $15.2 billion to $23 billion in 2000 international dollars. During the 1990s, for the first time, developing countries as a group provided more of the world's public agricultural R&D than developed countries did (Figure 1).

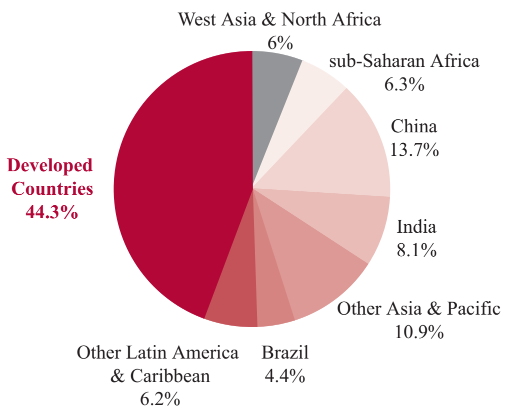

Figure 1: Global public investment in agricultural R&D: 2000.[a]

[a] Data is reported in international dollars based on purchasing power parity conversions of local currency units in 2000 prices.

Source: Pardey et al. 2006a

The Asia and Pacific region has continued to gain ground, accounting for an ever-larger share of the developing country total since 1981. In 2000, just two countries from this region, China and India, accounted for 39.1% of developing country expenditure on agricultural R&D; a substantial increase from their 22.9% combined share in 1981. In stark contrast, sub-Saharan Africa continued to lose market share, falling from a 17.3 to 11.4% share of the developing country R&D investment total between 1981 and 2000 (Pardey et al. 2006a).

Paralleling spending patterns for all the sciences, agricultural R&D has become increasingly concentrated in a handful of countries. Just four countries (the US, Japan, France and Germany) accounted for 66% of the public R&D conducted by developed countries in 2000; about the same as two decades before. Similarly, just five developing countries (China, India, Brazil, Thailand and South Africa) undertook 53.3% of the developing countries' public agricultural R&D in 2000, up from 40% in 1981.

Meanwhile, in 2000, a total of 80 countries with a combined population of approximately 625 million people conducted only 6.3% of total agricultural R&D (Pardey et al. 2006a).

The patterns of spending growth are uneven. Certainly, the more recent rates of increase in inflation-adjusted spending for all developing regions of the world failed to match the rapid ramping up of public agricultural R&D spending that Pardey and Beintema (2001) reported for the 1970s.

The growth in spending for the Asia and Pacific region as a whole rebounded in the late 1990s from the slower growth rates observed for the 1980s. This was especially so in China and India during the 1996 to 2000 period, in both instances reflecting government policies to revitalise public R&D and improve its commercialisation prospects, including linkages with the private sector.

Spending growth throughout the Latin American region as a whole was more robust during the 1990s than the 1980s; although the recovery was more fragile and less certain for some countries in the region (such as Brazil, where spending contracted at the close of the 1990s).

Overall investments in agricultural R&D in sub-Saharan Africa failed to grow by more than 1% per annum during the 1990s; the continuation of a longer-term slowdown (Beintema & Stads 2004). Even more concerning is the fact that approximately 50% of the 27 African countries for which national total estimates are available, spent less on agricultural R&D in 2000 than in 1991 (Beintema & Stads 2004).

A notable feature of the trends was the contraction in support for public agricultural R&D among developed countries. While spending in the US increased in the latter half of the 1990s, public R&D was massively reduced in Japan (and also, to a lesser degree, in several European countries) towards the end of the 1990s, leading to a decline in developed country spending as a whole for the decade.

The more recent data reinforce the longer-term trends observed earlier. Namely a fairly widespread scaling back, or at best a slowing down of support for publicly performed agricultural R&D among developed countries is occurring. In part, this points to a shifting emphasis from public to privately performed agricultural R&D, but also to a shift in government spending priorities.

Inevitably, this will affect productivity prospects in agriculture for the countries in question. Pardey et al. (2006b) suggest a more subtle and arguably more important consequence is that a slowdown or cutback in developed country spending will curtail the future spillover of ideas and new technologies from developed and developing countries.

Developed-developing country linkages will be even more attenuated as the funding trends proceed in parallel with other policy and market developments. These include strengthening IPRs and biosafety regulations, and a reorientation of developed country R&D agendas away from productivity gains in food staples towards concerns for the environmental effects of agriculture and food quality, as well as the medical, energy, and industrial applications of agricultural commodities.

With developed countries as a group still accounting for 44% of public agricultural R&D worldwide (and nearly 80% of all science spending) the consequences of a continuation of these funding, policy, and market trends is likely to be particularly pronounced in terms of the productivity-enhancing effects on food staples.

In addition to these broad trends, other aspects of agricultural R&D funding that have important practical consequences are also of concern. For example, undue variability in R&D funding continues to be problematic for many developing country research agencies. This is especially troubling for agricultural R&D given the long gestation period for new crop varieties and livestock breeds, and the desirability of long-term employment assurances for scientists and other staff (Pardey et al. 2006b).

Variability encourages an over-emphasis on short-term projects or on projects with short lags between investment and outcomes, and adoption. It also discourages specialisation of scientists and other resources in areas of work where sustained funding may be uncertain, even when these areas have high pay-off potentials.

Public Agricultural R&D Intensities

Turning now from absolute to relative measures of R&D investments, developed countries as a group spent $2.36 on public agricultural R&D for every $100 of agricultural output in 2000; a sizable increase over the $1.41 spent per $100 of output two decades earlier, but slightly down from the 1991 estimate of $2.38 (Figure 2). This longer-term rise in R&D intensity in developed countries starkly contrasts with the group of developing countries where there was no measurable growth in the intensity of agricultural R&D (i.e. agricultural R&D spending expressed as a percentage of agricultural gross domestic product). In 2000, developing countries spent just $0.53 on agricultural R&D for every $100 of agricultural output.

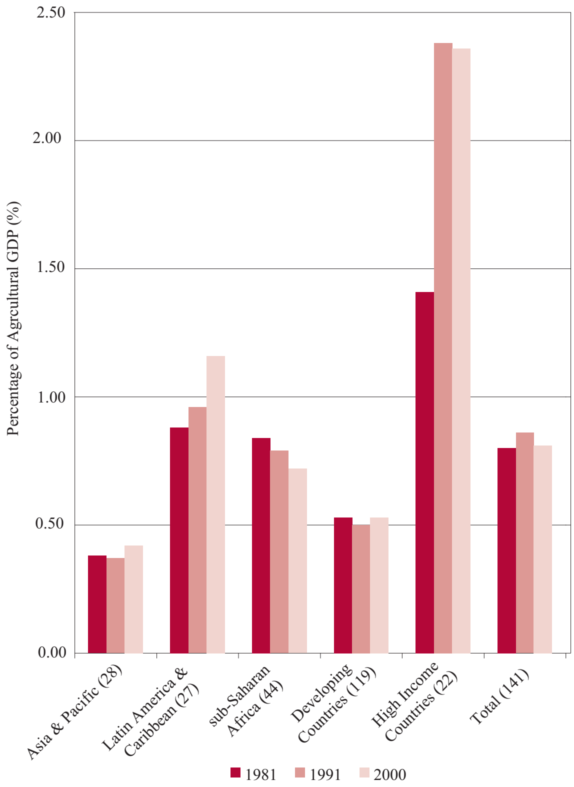

Figure 2: Regional comparisons of public agricultural R&D intensities: 1981–2000.

Source: Pardey et al. 2006a

At first glance the rise in developed country intensity ratios and the stagnating R&D intensities for developing countries appears to misrepresent the trends in spending, which showed that the growth in investments in agricultural R&D in developing countries significantly outpaced the corresponding growth in investments in agricultural R&D in developed countries (i.e. 3.13 versus 2.11% per annum from 1981–2000). Delving deeper, agricultural output grew much faster in aggregate for developing versus developed countries over the previous several decades, so that the faster growth in aggregate agricultural R&D spending among developing countries had, nonetheless, barely kept pace with the corresponding growth in output. In addition, more than half of the developed countries, for which data were available, had higher R&D intensity ratios in 2000 than 1981. The majority spent in excess of $2.50 on public agricultural R&D for every $100 of agricultural gross domestic product. Only 10 of the 26 countries in sub-Saharan Africa in the sample had higher intensity ratios in 2000 than in 1981, while most countries in the Asian and Latin American sample increased their intensity ratios from 1981 to 2000 (9 out 11 Asian countries and 8 out of 11 Latin American countries).

Other research intensity ratios are also revealing. Developed countries spent $692 per agricultural worker in 2000; more than double the corresponding 1981 ratio while developing countries spent just $10 per agricultural worker in 2000, an increase of less than 50% over the 1981 figure. These developed-developing country differences are, perhaps, not too surprising. A much smaller share of the developed country workforce was employed in agriculture, and the absolute number of agricultural workers declined more rapidly in developed countries than it did in the developing ones.

While only some segments of society are directly involved in agriculture as producers, everyone consumes agricultural outputs, therefore agricultural R&D spending per capita is instructive. These new data signalled a break with earlier trends. For developed countries, spending per capita rose substantially from 1981 to 1991 (a continuation of earlier trends documented by Pardey & Beintema 2001), but declined thereafter so that spending per capita in 2000 had slipped well below 1991 levels. This developed country reversal was driven mainly by developments in Japan, although only half the developed countries continued to increase their per capita spending on agricultural R&D throughout the 1990s.

Per capita spending rates were much lower among developing compared with developed countries; typically less than $3 per capita for developing countries (especially those in Africa) whereas 59% of the developed countries invested more than $10 per capita in 2000. Nonetheless, and in contrast to the group of developed countries, spending per capita for the group of developing countries continued to rise from $2.09 per capita in 1981 to $2.72 in 2000. The outliers to this general trend are sub-Saharan Africa, where agricultural R&D spending per capita has continued to decline since 1981, and Latin America, where spending per capita declined from $5.43 in 1981 to $4.94 in 1991 and $4.96 in 2000.

Private Agricultural R&D Investment

In agriculture, in particular, it is difficult for individuals to fully appropriate the returns from their R&D investments, and it is widely held that some government action is warranted to ensure an adequate investment in R&D (Pardey et al. 2006b). The private sector has continued to emphasise inventions that are amenable to various IP protection options such as patents, and more recently, plant breeders' rights and other forms of IP protection.

Private investments in agricultural R&D, similar to investments in all forms of R&D, are motivated and sustained by the returns to innovation reaped from the investment.

IP policies and practices are but one dimension of the incentive to innovate. Potential market size and the cost of servicing the market, which in turn are dependent on the state of communication and transportation infrastructure, farm structure and size, and farm income, are important dimensions as well. So too is the pattern of food consumption. As incomes rise, a larger share of food expenditure goes to food processing, convenience and other attributes of food, areas where significant shares of private agricultural R&D effort are directed.

The private sector has a large presence in agricultural R&D, but with dramatic differences between developed and developing countries and among countries. In 2000, the global total spending on agricultural R&D (including pre-, on- and post-farm oriented R&D) was $36.5 billion. Approximately 37% was conducted by private firms and the remaining 63% by public agencies. Notably, nearly 94% of that private R&D was performed in developed counties, where some 55% of the agricultural R&D was private (Table 1).

In developing countries, only 6% of the agricultural R&D was private, and there were large disparities in the private share among regions of the developing world. In the Asia and Pacific region, around 8% of the agricultural R&D was private, compared with only 2% of the R&D throughout sub-Saharan Africa.

The majority of private R&D in sub-Saharan Africa was oriented to crop-improvement research, often (but not always) dealing with export crops such as cotton in Zambia and Madagascar and sugarcane in Sudan and Uganda. Almost two thirds of the private R&D performed throughout the whole region was carried out in South Africa.

The private share of agricultural R&D spending in Organisation for Economic Co-operation and Development (OECD) countries grew steadily from nearly 44% in 1981 to over 55% in 2000 (Table 1). These increasing private shares reflected increasing industry R&D by the farm-input supply and, especially, the food processing sectors.

Table 1: Private sector share of total agricultural R&D: 1981–2000.

Region	1981 (%)	1991 (%)	2000 (%)
Australia	5.9	20.2	23.5
Japan	36.6	48.4	58.6
United States	50.1	54.3	54.6
Other (19)	45.7	48.5	56.9
Total	43.9	49.6	55.2

Source: Compiled by authors from data reported at www.asti.cgiar.org

Around the general trend was much country-specific variation. In the US the private share inched up from 50.1% (compared with an OECD average of 43.9%) in 1981 to 54.3% by 1991, and changed little thereafter. According to these data, Japan conducted slightly more of its agricultural R&D in the private sector than the US. The private share of Australian agricultural R&D has also grown from a small base of 5.9% in 1981 to 20.2% in 1991, then more slowly during the next decade to 23.5% of the total in 2000.

Policy Implications

Agricultural R&D is at a crossroads. The close of the 20th century marked changes in policy contexts, fundamental shifts in the scientific basis for agricultural R&D, and shifting funding patterns for agricultural R&D in developed countries. These changes imply a requirement for both rethinking of national policies and reconsidering multinational approaches to determine the types of activities to conduct through the CGIAR and similar institutions and how these activities should be organised and financed.

Even though there is no evidence to suggest that the world can afford to reduce its rate of investment in agricultural R&D and there is every indication that more should be invested, it cannot be assumed that developed countries will play the same role as in the past.

In particular, countries that in the past relied on technological spillovers may no longer have that luxury available to them in the same ways or to the same extent. This change can be seen as involving three elements:

1. The types of technologies being developed in the developed countries may no longer be as readily applicable to less-developed countries as they were in the past.

2. Those technologies that are applicable may not be as readily accessible because of IP protection of privately owned technologies.
3. Those technologies that are applicable and available are likely to require more substantial local development and adaptation, calling for more sophisticated and more extensive forms of scientific R&D than in the past.

In short, different approaches may have to be devised to make it possible for countries to achieve equivalent access and tap into technological potential generated by other countries, and in many instances countries may have to extend their own agricultural R&D efforts farther upstream, to more fundamental areas of the science.

Conclusion

The balance of global agricultural R&D investments is shifting in ways that will have important long-term consequences, especially for the world's least affluent countries. The primary reason is changes in supply and demand for agricultural technologies in developed countries, which have been the main producers of agricultural technologies.

These countries seem unlikely to provide the quantities of productivity-enhancing technologies, suitable for adaptation and adoption in food deficit countries, that they did in the past. This trend has been compounded by a scaling back of developed country support for the international agricultural R&D system, which has already diverted its own attention away from finished productivity-enhancing technologies, especially for staple food crops.

A shift in R&D agendas is forcing a rethinking of some national and multinational policies. National Governments can take some initiatives in national agricultural R&D policy, such as: enhancing IP and tailoring the institutional and policy details of IPRs to best fit local circumstances; increasing the total amount of government funding for their national agricultural R&D systems; introducing institutional arrangements and incentives for private and joint public-private funding; and improving the processes by which agricultural R&D resources are administered and allocated.

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Note

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About the Authors

Philip Pardey is a professor in the Department of Applied Economics at the University of Minnesota where he also directs the International Science and Technology Practice and Policy (InSTePP) Center. He was previously a senior research fellow at the International Food Policy Research Institute, Washington DC, and prior to 1994 at the International Service for National Agricultural Research in The Hague, the Netherlands. He studies productivity growth and technical change, and a broad ranging set of science and technology policy issues.

Julian Alston is a professor in the Department of Agricultural and Resource Economics of the University of California, Davis and Associate Director, Science and Technology, of the University of California Agricultural Issues Center. Prior to beginning in his current position in 1988, Dr Alston was the chief economist in the Department of Agriculture and Rural Affairs in Victoria, Australia. He is a fellow of the American Agricultural Economics Association and a distinguished fellow of the Australian Agricultural and Resource Economics Society.

Nienke Beintema is head of the Agricultural Science & Technology Indicators (ASTI) initiative, International Food Policy Research Institute (IFPRI) in Washington, D.C. The ASTI initiative compiles, processes, and makes available internationally comparable data on institutional developments and investments in agricultural R&D worldwide. Nienke is a citizen of the Netherlands and earned a master's degree in economics from the University of Groningen.