Original Article

Agricultural R&D Expenditure in Africa: An Analysis of Growth and Volatility

Gert-Jan Stads* and Nienke Beintema

International Food Policy Research Institute, Washington DC, USA.

*E-mail: g.stads@cgiar.org

Abstract Agricultural research and development (R&D) investment is positively associated with high returns, but these returns take time – often decades – to develop. Consequently, the inherent lag from the inception of research to the adoption of new technologies calls for sustained and stable R&D funding. This article introduces a quantitative measure to assess volatility in agricultural R&D spending. It reveals that agricultural R&D spending in Sub-Saharan Africa (SSA) has been substantially more volatile than in other developing regions, which is the consequence of low levels of government funding, coupled with a high dependence on short-term and *ad hoc* donor and development bank funding. Rather than relying too much on external funding, SSA governments need to clearly identify long-term priorities, design focused and coherent agricultural R&D programmes accordingly, and commit sufficient funding for their implementation, while donor funding needs to be better aligned with national priorities. Moreover, diversification of funding sources is needed to better absorb funding shocks.

L'investissement en R&D agricole est positivement associé à des rendements élevés, mais ces rendements prennent du temps, souvent plusieurs décennies, à se développer. Par conséquent, le décalage inhérent entre le début de la recherche et l'adoption de nouvelles technologies rappelle le besoin de financements soutenus et stables pour la R& D. Cet article introduit une mesure quantitative pour évaluer la volatilité des dépenses en R&D. Il révèle que les dépenses en R&D agricole en Afrique sub-saharienne (ASS) sont beaucoup plus volatiles que dans d'autres régions en développement, ce qui est la conséquence du faible niveau de financement du gouvernement, allié à une forte dépendance sur les financements à court terme et *ad hoc* des bailleurs de fonds et des banques de développement. Plutôt que de trop compter sur un financement externe, les gouvernements d'Afrique subsaharienne doivent définir clairement leurs priorités à long terme, concevoir en conséquence des programmes de R&D agricole ciblés et cohérents, et engager des fonds suffisants pour leur mise en œuvre, tandis que le financement des bailleurs de fonds doit être mieux aligné sur les priorités nationales. En outre, la diversification des sources de financement est nécessaire pour mieux absorber les chocs de financement.

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Introduction

Much evidence shows that investments in agricultural research and development (R&D) have tremendously enhanced agricultural productivity around the world over the past five decades (Alston *et al*, 2000; Alene *et al*, 2006; Alston *et al*, 2006; Alene and Coulibaly, 2009), which in turn has led to higher incomes, lower poverty levels, greater food security and better nutrition (Evenson and Gollin, 2003; World Bank, 2007; IAASTD (International Assessment of Agricultural Knowledge, Science and Technology for Development), 2008). In Africa south of the Sahara (SSA), however, lower absolute levels of agricultural R&D spending have somewhat limited the overall impact of agricultural R&D on agricultural productivity compared with other regions. The long-term rates of return of agricultural R&D in SSA have been lower than in developed regions (Alston *et al*, 2000), and SSA has benefited less from spillovers of agricultural technologies developed elsewhere (Johnson and Evenson, 2000). Nonetheless, Alene and Coulibaly (2009) found that agricultural research has contributed significantly to productivity growth in SSA since the early 1980s, and argue that with more efficient agricultural extension, credit and input supply systems, the effects of agricultural R&D on productivity growth and poverty reduction would have been even greater. Given the continued challenges SSA faces in terms of rapid population growth, adaptation to climate change, and rising and volatile food prices, investing in agricultural R&D remains crucial for accelerating agricultural productivity growth and reducing poverty in the future.

Despite the well-documented evidence that the payoffs to agricultural research are considerable, many countries in the region continue to underinvest in agricultural research. Given the substantial time lag between investing in research and reaping its rewards – which is usually decades, not just years – agricultural research requires a long-term commitment of sufficient levels of sustained funding. African governments have limited public resources and are severely challenged when it comes to allocating these resources efficiently across sectors of the economy – including agriculture, infrastructure, health and education (Fan *et al*, 2009). Long agricultural research cycles rarely coincide with short-term election cycles, shifting political agendas and changes in government budget allocations. The inability to extract short-term political credit acts as a disincentive on the part of policymakers to commit to long-term agricultural R&D investments, thereby jeopardizing future research planning and outputs. Given low investment levels by governments, agricultural R&D in many SSA countries is highly dependent on donor and development bank funding, which by nature is mostly short term and *ad hoc*, and often causes major fluctuations in a country's yearly agricultural R&D investments (Beintema and Stads, 2014).

This article presents long-term trends in public agricultural R&D investments and funding sources in SSA. It provides a brief overview of the existing literature on macroeconomic volatility and volatility in donor funding in developing countries, and it introduces a measure for quantifying volatility in agricultural R&D expenditures and funding over time. The article assesses the degree of volatility in agricultural R&D expenditure across SSA countries, and it determines which funding sources have been the main drivers of volatility since 2000. The final section of the article draws conclusions and provides policy recommendations.

Data and Method

The analysis in this article is based on comprehensive data sets derived from primary surveys conducted in SSA by the Agricultural Science and Technology Indicators (ASTI) programme of the International Food Policy Research Institute during 2001–2014. ASTI data sets are collected and processed using internationally accepted definitions and statistical procedures for compiling R&D statistics developed by the Organisation for Economic Cooperation and Development and the United Nations Educational, Scientific and Cultural Organization. So as to facilitate cross-country comparisons, all financial data have been converted to 2005 purchasing power parity (PPP) prices using the World Bank's World Development Indicators (World Bank, 2013). PPPs measure the relative purchasing power of currencies across countries by eliminating national differences in price levels for a wide range of goods and services.

ASTI data cover 40 SSA countries, which together contribute 94 per cent of the region's agricultural gross domestic product (World Bank, 2013). Public agricultural R&D is defined here to include government, higher education and non-profit agencies that are involved in agricultural R&D. The private for-profit sector is excluded because of difficulties obtaining financial information from private enterprises.[1]

In order to measure the degree of volatility in yearly agricultural R&D spending levels across SSA countries, a commonly used method of calculating price volatility in finance and output volatility in macroeconomics was applied to ASTI's financial data.[2] The so-called volatility coefficient quantifies volatility in agricultural R&D spending by applying the standard deviation formula to average 1-year logarithmic growth of agricultural R&D spending over a certain period (Guellec and Ioannidis, 1997; Durlauf *et al*, 2005). Growth in agricultural R&D spending (g_s)can be expressed as follows:

$$g_s = \ln\left(\frac{s_t}{s_{t-1}}\right) \qquad s = 1, \ldots, N,$$

where s is agricultural R&D spending (in constant prices) and t represents the year. Subsequently, the volatility coefficient (V) of agricultural R&D expenditures can be calculated by taking the standard deviation of growth in yearly agricultural R&D spending, that is,

$$V = \sqrt{\frac{1}{N}\sum_{s=1}^{N}(g_s - \mu)^2}, \text{ where } \mu = \frac{1}{N}\sum_{s=1}^{N} g_s.$$

Countries with few or no changes in yearly spending levels or those with steady (positive or negative) growth have low volatility coefficients. In contrast, countries with erratic fluctuations in spending levels from one year to the next have high volatility coefficients. A value of 0 indicates 'no volatility', countries with values between 0 and 0.1 were classified as having 'low volatility', countries with values between 0.1 and 0.2 were considered to have 'moderate volatility', and countries with values above 0.2 fell into the 'high-volatility' category.

Kruskal–Wallis statistical analyses were performed to investigate differences in volatility coefficients across a variety of country parameters (income level, geographic subregion, size of the national agricultural research system and spending intensity). In addition, a Friedman test was applied to investigate distribution differences in institute-level volatility by funding source over time.

Trends in Public Agricultural R&D Spending in SSA[3]

Public agricultural R&D investments for SSA as a whole totalled US$1.7 billion 2005 constant PPP dollars in 2011 (or $0.8 billion in 2005 constant US dollars). This was more than one-third higher than the $1.2 billion in 2005 PPP dollars (or $0.6 billion in 2005 US dollars) recorded in 2000. A breakdown by country, however, reveals that the growth in SSA-wide spending during 2000–2011 was largely driven by just a handful of (mostly larger) countries. Close to half of regional growth in public agricultural R&D expenditures during this period was attributable to increased spending in just two countries: Nigeria and Uganda. Ghana, Kenya and Tanzania also recorded relatively high increases in total spending during 2000–2011 and each accounted between 5 and 8 per cent of total growth during the same period.

Though increases and decreases in the absolute levels of agricultural R&D spending of the region's larger countries overshadow those of many of the smaller countries, a closer look at relative shift in investment levels over time reveals important cross-country differences and challenges. During 2000–2011, 16 of the 30 SSA countries for which a full set of time-series data was available experienced growth in public agricultural R&D spending in excess of 1 per cent per year (Figure 1). Seven countries experienced near-zero growth rates (of between −0.9 and 0.2 per cent) and an additional seven countries experienced negative annual growth, ranging from −1.2 to −13.6 per cent a year. The large number of countries experiencing negative or stagnant annual growth clearly highlights the challenge of two-speed growth in agricultural R&D in SSA: Overall spending in the region has grown substantially since the turn of the millennium, but it has been extremely uneven, and it has bypassed many countries. Nonetheless, there are early indications signalling the reversal of negative or stagnant spending trend in an increasing number of smaller countries in recent years. Just looking at the 2008–2011 period (rather than the 2000–2011 period), 20 of the 30 SSA countries for which full time-series data were available saw an increase in agricultural R&D spending.

Instead of looking at absolute levels of agricultural R&D investment, another way of comparing commitment with public agricultural R&D investment across countries is to measure total public agricultural R&D spending as a percentage of agricultural output (AgGDP). This relative measure indicates the intensity of investment in agricultural research. In 2011, SSA as a whole invested \$0.51 for every \$100 of agricultural output on average, which was well below the African Union's New Partnership for Africa's Development's (NEPAD) and the United Nations' (UN) national R&D investment target of 1 per cent of agricultural GDP or more (NEPAD (New Partnership for Africa's Development, Office of Science and Technology), 2006; UNSDN (United Nations Sustainable Development Network), 2013). In 2011, just 10 of the 39 countries for which agricultural R&D intensity ratios were available met the 1 per cent target (Figure 2). In contrast, 18 countries recorded intensity ratios lower than 0.5 per cent. These intensity ratios show that public support for agricultural R&D in most SSA countries is still far too low to sustain viable agricultural R&D programmes capable of addressing current and future priorities. In a large number of countries, a significant majority of government funding is allocated to staff

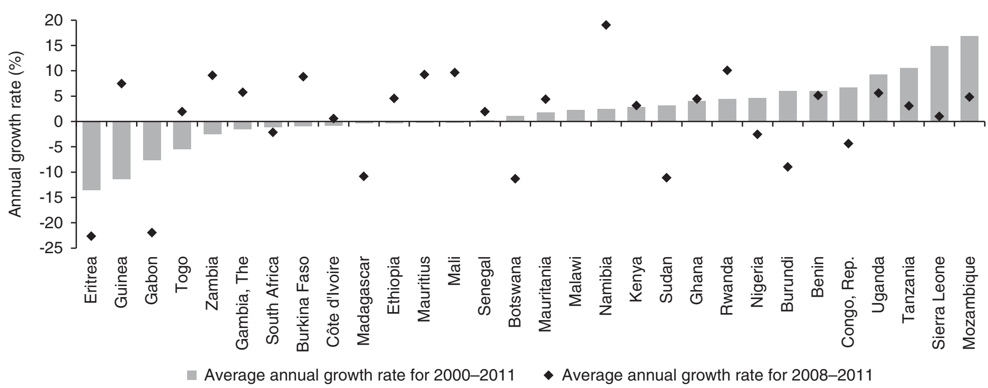

Figure 1: Annual growth in agricultural R&D spending, 2000–2011 and 2008–2011.
Note: Compound yearly growth rates are calculated using the least-squares regression method. The figure excludes Cape Verde, Central African Republic, Chad, Democratic Republic of Congo, Guinea-Bissau, Lesotho, Liberia, Niger, Swaziland and Zimbabwe because time-series data did not date back to 2000. The 2008–2001 annual growth rate for Malawi (26.5 per cent) is off the scale.
Source: Compiled by authors from ASTI database (ASTI (Agricultural Science and Technology Indicators), 2001–2014).

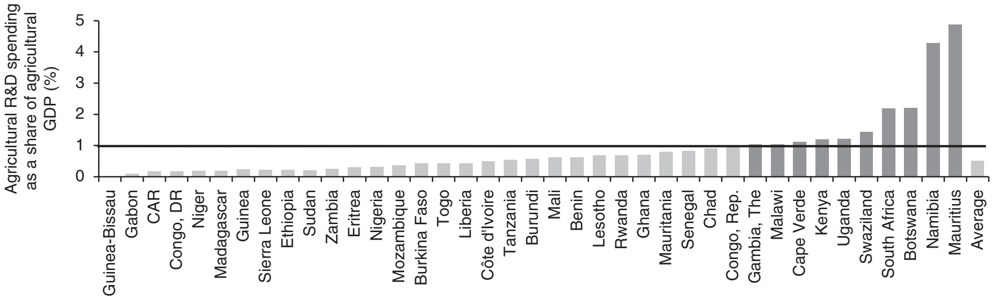

Figure 2: Agricultural R&D intensity ratios, 2011.
Note: The horizontal line represents the 1 per cent investment target recommended by NEPAD and the United Nations.
Source: Compiled by authors from ASTI database (ASTI, 2001–2014).

salaries, leaving comparatively small shares to support the actual day-to-day costs of running research programmes.

Volatility in Annual Public Agricultural R&D Spending[4]

Time lags are unavoidable between the point of investing in agricultural R&D and that of attaining tangible benefits from it (Alston *et al*, 2006); in the interim, long-term stable and sufficient funding is required. However, in some SSA countries, such as Burkina Faso, Gabon and Tanzania, yearly agricultural R&D investment levels have fluctuated widely over time (Figure 3). The reasons for year-to-year spending fluctuations are manifold and differ greatly across countries.

A wide body of literature exists on the impact of macroeconomic volatility on economic growth and performance in developing countries. This literature has focused primarily on volatility across countries, thereby setting the issue within an international context. Substantial empirical evidence has demonstrated that increased macroeconomic volatility has a negative impact on economic growth, or is at least closely associated with slower growth (Hnatkovska and Loayza, 2004; Agion *et al*, 2005; Fatás and Mihov, 2006; Perry, 2009). This is unsurprising given the broad consensus that high macroeconomic volatility likely slows down investment (because investment flows depend on expected rewards and risks), as well as biasing investments towards short-term returns (Servén, 1997). High macroeconomic volatility has also been associated with lower investment in human capital, for similar reasons (Krebs *et al*, 2005).

In addition, a vast amount of literature has focused on the volatility of aid flows to developing countries. Aid flows are found to be more volatile than government revenues, household consumption or GDP, and aid volatility tends to reinforce macroeconomic instability and slow down economic growth (Bulíř and Hamann, 2003; Fielding and Mavrotas, 2008; Desai and Kharas, 2010). Desai and Kharas (2010) note that some degree of aid volatility is caused by events in recipient countries (for example, regime change, natural disasters and civil wars), but that volatility in aid flows is primarily because of donor behaviour, including bad planning and shifting priorities.

A number of studies have analysed fluctuations in R&D expenditure in developed countries, where – unlike developing countries (Beintema *et al*, 2012) – most research is conducted by the private sector. These studies find strong evidence that economic growth is positively correlated

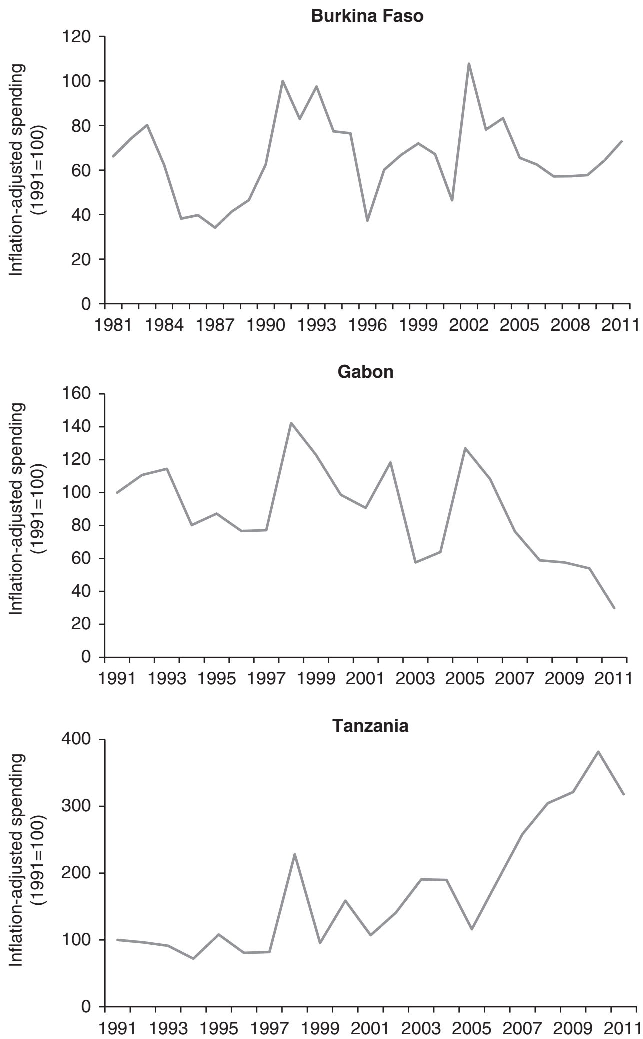

Figure 3: Long-term public agricultural R&D spending, selected African countries, 1981/1991–2011.
Source: Compiled by authors from ASTI database (ASTI, 2001–2014).

with R&D expenditure, and that long-term basic research will be reduced before applied research during economic downturns (Guellec and Ioannidis, 1997; Wälde and Woitek, 2004). Recent empirical results from Johnstone *et al* (2011) provide support for the hypothesis that increased volatility of public R&D spending in environmental technologies has a negative impact on innovation. Their measure includes both direct government expenditures for R&D undertaken by government agencies and public universities and government provision of grants and tax credits for R&D undertaken by the private sector. Cullen *et al* (2014) also provide evidence of the negative economic effects of R&D volatility. Yet, they also highlight the 'entrenchment' argument, where steady R&D investment could reflect problems of moral hazard and a lack of control of the quality of research projects and their impacts. Although Cullen *et al* (2014) refer to the private sector, the issues raised are relevant to the public sector as well.

No literature was found on public R&D funding volatility in developing countries; however, empirical findings from the literature on macroeconomic and aid volatility suggest that extreme volatility in agricultural R&D funding is similarly harmful to the institutional stability and long-term outputs of agricultural R&D. This is supported by substantial anecdotal evidence. The completion of the multimillion dollar World Bank-funded National Agricultural Research Program (1990–1998) in Niger, for example, led to an 80 per cent decline in the National Agricultural Research Institute of Niger's (INRAN) funding in 1999, when the institute's research activities ground to a halt. Government funding to INRAN was insufficient to cover the costs of salaries, forcing the institute to generate (limited) funding internally through the sale of seeds and renting out farm equipment (Stads *et al*, 2010). By the time new large-scale donor funds arrived, the institute had already lost a large number of highly qualified researchers and its R&D infrastructure was in dire need of upgrading. The case of INRAN in Niger is not unique. Numerous examples from across SSA indicate that, upon the completion of multimillion dollar projects, agricultural research institutes have been plunged into financial hardship and an uncertain future, forcing them to cut research programmes and lay off staff. Large fluctuations in annual investment levels are thus thought to slow down technical change and the release of new varieties and technologies in the long run, which in turn can have a negative impact on agricultural productivity growth and poverty reduction.

On the basis of complete ASTI time-series data on agricultural R&D expenditures for the 2001–2011 period, volatility coefficients could be calculated for 30 SSA countries (Figure 4). The mean volatility coefficient for the 31 countries over this period totalled 0.22, which was twice as high as the mean volatility coefficient for 12 low- and middle-income countries in the Asia-Pacific region (0.11) and 8 Latin American countries (0.11) over the 2000–2008 period (Beintema *et al*, 2012).[5] Moreover, agricultural R&D spending in SSA was also markedly more volatile than agricultural output in SSA (0.10) during 2001–2011.[6]

Understandably, a large degree of variation was recorded across SSA countries. Those with the highest degree of fluctuation in yearly agricultural R&D spending were Sierra Leone (0.45), Sudan (0.38), Gabon (0.37), Mauritania (0.37), Burkina Faso (0.32) and Tanzania (0.31). In contrast, annual agricultural R&D spending in countries like Rwanda, South Africa and the Republic of Congo was found to be more stable, with volatility coefficients of just 0.04, 0.08 and

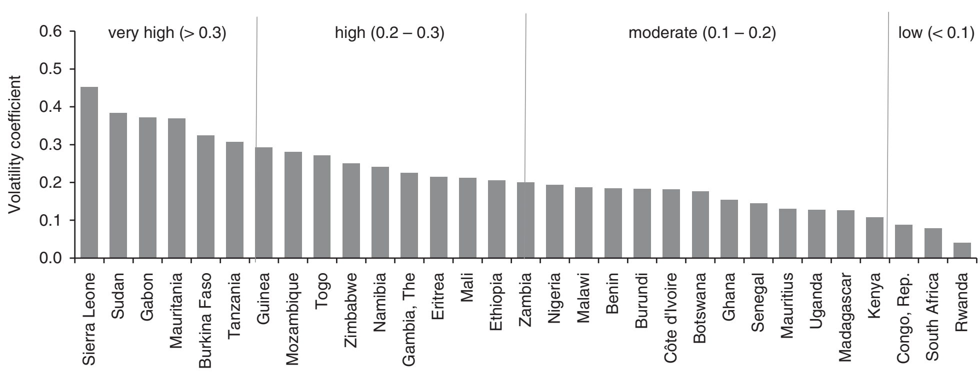

Figure 4: Agricultural R&D spending volatility by country, 2001–2011.
Note: The figure excludes Cape Verde, Central African Republic, Chad, Democratic Republic of Congo, Guinea-Bissau, Lesotho, Liberia, Niger, Swaziland and Zimbabwe because time-series data did not date back to 2001.
Source: Compiled by authors from ASTI database (ASTI, 2001–2014).

0.09, respectively. It is important to note that volatility in spending at the agency level is typically higher than at the country level because aggregate fluctuations tend to hide idiosyncratic spending shocks. Similarly, the volatility coefficient for agricultural R&D investments for the 31 sample countries combined (that is, the standard deviation of yearly growth in total SSA agricultural R&D investment during 2001–2011) is just 0.04, which indicates that spending in SSA as a whole is less volatile than spending in the individual countries.

In an attempt to find an explanation for these large cross-country differences in volatility coefficients, the SSA countries were categorized by a number of broad characteristics: (i) the intensity of public investment in agricultural R&D as an indicator of government commitment to agricultural growth through science; (ii) the size of the national agricultural R&D system (NARS) in terms of full-time equivalent (FTE) researchers in order to assess whether economies of scale impact spending volatility; (iii) income level and (iv) geographic region. We conducted a Kruskal–Wallis test to determine whether there are differences in volatility between these groups of countries. The hypothesis of each test was that the distribution of the volatility coefficient was the same across groups of countries, and the test assessed the probability that differences in volatility between groups occurred by chance. No evidence was found that volatility is correlated with NARS size, income level or geographic region (Table 1). However, the test did reveal significant differences in volatility by spending intensity. Investments in countries spending more than 1 per cent of their AgGDP on agricultural R&D were significantly less volatile than those in countries spending lower shares of their AgGDP on agricultural R&D.

Table 1: Volatility coefficients by country grouping, 2001–2011

	Mean volatility coefficient	*Sample size*	*P-value*
Volatility by income level			0.7648
Low income	0.22	17	—
Lower middle income	0.21	8	—
Upper middle income	0.20	5	—
Volatility by subregion			0.3345
West and Central Africa	0.24	15	—
East Africa	0.22	7	—
Southern Africa	0.17	8	—
Volatility by NARS size			0.5926
More than 500 FTEs	0.20	7	—
Between 200 and 500 FTEs	0.21	6	—
Less than 200 FTEs	0.22	17	—
Volatility by spending intensity			0.0270
More than 1.0 per cent of AgGDP	0.16	8	—
Between 0.5 and 1.0 per cent of AgGDP	0.21	9	—
Less than 0.5 per cent of AgGDP	0.26	13	—

Note: Countries with a GNI per capita of $1025 or less are classified as low-income countries; lower middle-income countries have a GNI per capita between $1026 and $4035; and upper middle-income countries have a GNI per capita between $4036 and 12 475 (World Bank, 2013). West and Central Africa includes Benin, Burkina Faso, Republic of Congo, Democratic Republic of Congo, Gabon, The Gambia, Ghana, Guinea, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone and Togo. East Africa includes Burundi, Eritrea, Ethiopia, Kenya, Sudan, Tanzania and Uganda. Southern Africa includes Botswana, Madagascar, Malawi, Mauritius, Namibia, South Africa, Zambiaand Zimbabwe. NARS size and spending intensity are for 2011. FTE indicates full-time equivalent research staff; AgGDP indicates agricultural gross domestic product. The *P*-values express the probability of no difference in volatility and were measured using a Kruskal–Wallis test.
Source: Calculated by authors from ASTI database (ASTI, 2001–2014).

A closer look at a subsample of 82 agricultural R&D agencies from 25 SSA countries for which complete time-series data by cost category were available for the entire 2001–2011 period shows that volatility in agricultural R&D spending is mainly caused by fluctuations in non-salary expenditures, which is not surprising.[7] On average, salary expenditures turned out to be less than twice as volatile as operating and programme costs, and more than seven times less volatile than capital investments. Though these averages mask some important cross-agency differences, the results were relatively consistent across countries and institutes. Eighty-eight per cent of the sample agencies had a higher volatility coefficient for non-salary spending than for salary spending.

Funding Sources of Agricultural R&D and Shifts Over Time

In order to analyse the main causes of volatility in yearly agricultural R&D investment levels, it is important to gain insight into how agricultural R&D is funded across SSA. A significant degree of cross-country and cross-agency variety exists in terms of agricultural R&D funding (Figure 5). In some countries, the national government funds the bulk of agricultural R&D activities, whereas other countries are extremely dependent on external funding from donors and development banks. R&D agencies in certain countries manage to generate large amounts of funding internally by selling goods and services, while in other countries the proceeds of such

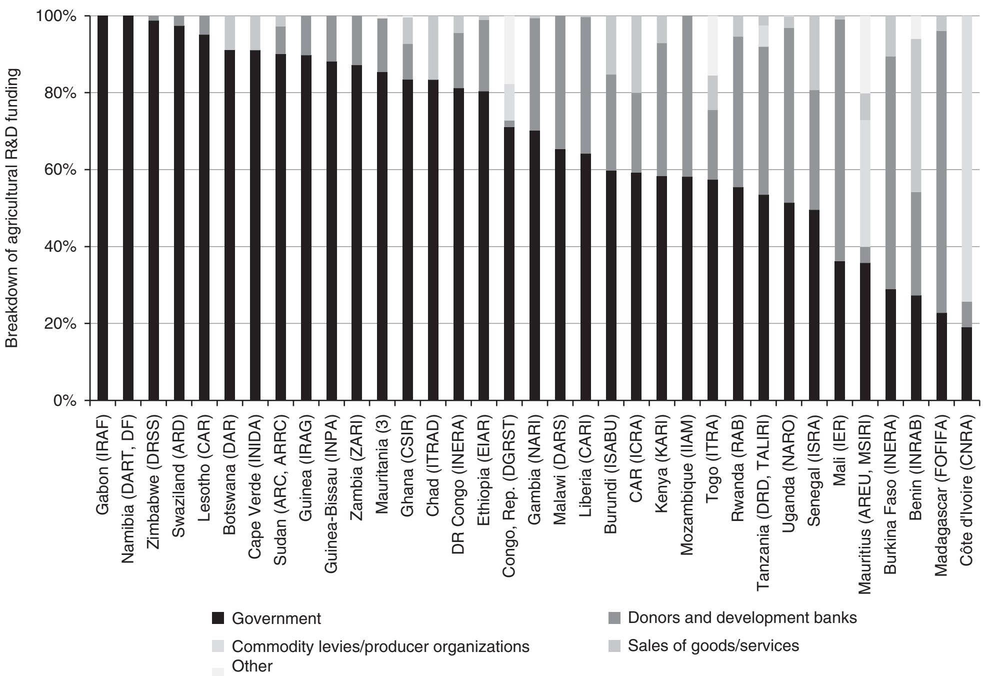

Figure 5: Relative shares of funding sources of main agricultural R&D agencies, 2011.
Note: Eritrea, Niger, Nigeria, Sierra Leone and South Africa are excluded because of a lack of complete data. The three agencies in Mauritania are CNERV, CNRADA and IMROP. The category 'Commodity levies/producer organizations' includes contributions through export or production levies. For full agency names and further details, see the ASTI Directory at www.asti.cgiar.org/pdf/ASTI-Directory-2011.pdf.
Source: Compiled by authors from ASTI database (ASTI, 2001–2014).

sales are transferred directly to the Treasury, discouraging agencies from generating own income. Moreover, a number of countries have put funding systems in place whereby the private sector finances a share of agricultural R&D, either through taxation or subscription dues (Beintema and Stads, 2011). It is very important to stress that in a large number of countries the bulk of government funding is allocated to salaries, and thus the cost of operating actual research programmes and of developing and maintaining R&D infrastructure and equipment is highly dependent on donor contributions and other funding sources (Figure 6).

Shifts in yearly allocations from one or more funding sources can have a large positive or negative impact on overall agricultural R&D spending levels. In recent years, increased government support has translated to an increase in scientist salaries (for example, Ghana, Nigeria and Uganda), as well as enhanced funding for R&D programmes, equipment and infrastructure (for example, Nigeria and Uganda). Changes in government policy can also have severe negative effects on funding levels at agricultural R&D agencies. Governments are often forced to adjust previously approved funding levels downward during the financial year in response to lower than anticipated revenues or shifts in priorities (for example, Zambia and Gabon).

Donor and development bank funding is also a major cause of volatile agricultural R&D spending over time. This type of funding is typically short term and *ad hoc*, and in many instances the completion of large projects funded by donors or development banks has caused abrupt declines in agricultural R&D spending (for example, Burkina Faso, Burundi and Niger). Often national governments are in no position to fill the funding gap when large donor projects come to an end.

Rising or falling world market prices for cash crops can also have a significant impact on funding levels, especially those derived through a direct tax on production or export of a certain crop. The Cocoa Research Institute of Ghana, for example, benefited greatly both from an increase in cocoa prices and an increase in the country's cocoa production beginning in 2003–2004. In contrast, overall funding to the Mauritius Sugar Industry Research Institute has steadily decreased over time following falling world market prices of sugarcane and the subsequent

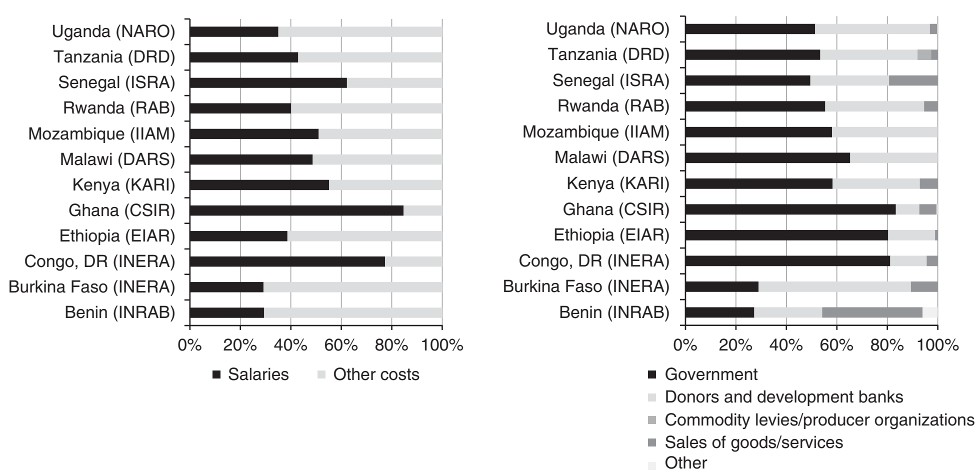

Figure 6: Comparison of public research spending allocations and funding sources, selected institutes, 2011.

Note: The category 'Commodity levies/producer organizations' includes contributions through export or production levies. For full agency names and further details, see the ASTI Directory at www.asti.cgiar.org/pdf/ASTI-Directory-2011.pdf.

Source: Compiled by authors from ASTI database (ASTI, 2001–2014).

decline in national production levels. Global coffee prices have been more volatile over time, and this is clearly reflected in the funding received by Kenya's Coffee Research Foundation through commodity levies from one year to the next.

Volatility by Funding Source

Given the long period from the inception of agricultural R&D to the adoption of a new variety or technology, sustained and stable funding is needed to achieve high returns to agricultural R&D (Alston *et al*, 2006). Extreme volatility in funding, be it from national governments, foreign donors or other sources, can have a severely negative impact on the continuity of R&D programmes and on long-term research outputs. In efforts to curtail future volatility, it is important to identify the main drivers of funding volatility in agricultural R&D across countries over the past decade. The volatility coefficient, introduced earlier in this article, is a useful tool for comparing the relative stability of different funding sources over time and across countries. It is important to note, however, that not all funding volatility is bad *per se*. A sudden injection of government or donor funding to rehabilitate R&D infrastructure after a civil war, for example, is of course a positive thing.

Detailed 2001–2011 time-series data on agricultural R&D funding sources were available for 71 large public sector agricultural R&D agencies from 26 SSA countries. A breakdown of volatility by funding source reveals that overall funding from donors and development banks is extremely volatile, more than three times more volatile than government funding, which itself is far from stable (Table 2). Funding from producer organizations and commodity boards, internally generated resources through the sale of goods and services, and other funding sources also showed relatively large fluctuations from one year to the next. Interestingly, the mean institute-level volatility (0.38) is lower than the volatility of each of the individual funding sources, indicating that in many cases shocks in one funding source are to some extent absorbed by reverse shocks in other funding sources.[7, 8]

The regional averages presented above mask a large degree of cross-country and cross-agency variety. Of the 71 agencies, 20 had a higher volatility coefficient in government funding than in donor funding. However, it is important to note that 16 of these 20 agencies did not receive any donor and development bank funding at all during 2001–2011. Singling out the main national agricultural R&D agencies that derive at least a 10 per cent share of their total 2001–2011 funding from donors and development banks presents a different picture. Of these 28 agencies, 23 recorded higher volatility in annual donor funding levels than in government funding levels. In many cases, donor funding was three or four times more volatile than government funding. Most agencies that derive a considerable share of their total funding from donors and

Table 2: Volatility coefficients by agricultural R&D funding source, 2001–2011

Funding source	*Government*	*Donors and development banks*	*Other funding sources*	*Total*	χ^2	*P-value*
Mean volatility	0.42	1.31	0.94	0.38	14.7113	0.0006

Note: Given that log transform can only be applied to non-zero values, a value of 0.001 was added to zero values. This had a negligible impact on the individual institutes' and overall volatility coefficients, and allowed for the calculation of volatility coefficients of institutes without donor funding or internally generated income during a certain year. The χ^2-distribution was calculated with a Friedman test. The *P*-values express the probability of no difference in volatility and were measured using a Kruskal–Wallis test.
Source: Calculated by authors from ASTI database (ASTI, 2001–2014).

development banks are based in low-income countries or countries that have only recently attained lower middle-income status. Agricultural R&D agencies in economically more advanced countries are much less dependent on volatile donor funding (Figure 7). The dots in Figure 7 indicate the average share of donor funding in total agricultural R&D funding for the main agencies in each country during 2001–2011. The lines intersecting the dots range from the highest annual share of donor funding in total agricultural R&D funding during 2001–2011 to the lowest share. The shorter the line, the lower the spread in the share of donor funding over time. For example, an average of 32 per cent of total funding received by the Institute of Agricultural Science of Burundi during 2001–2011 was derived from donors and development banks. However, the overall share of donor funding ranged from 9 per cent in 2003 to 60 per cent in 2004, indicating large shifts in donor funding from one year to the next.

Abundant empirical evidence suggests that volatility in donor funding is costly, particularly in less developed countries with weak institutions, and that measures to reduce volatility would significantly enhance the value of donor aid (Bulíř and Hamann, 2003; Fielding and Mavrotas, 2008; Kharas, 2008). Although most national governments in SSA publicly recognize the need for rapid development of agriculture in order to reduce poverty, they are struggling to allocate sufficient resources to agricultural R&D. In many countries, the bulk of government appropriations is spent on staff salaries, which leaves the costs of actual research programmes and necessary infrastructure upgrades largely dependent on volatile funding from donors, competitive grants or the private sector. Although competitive salaries are crucial to maintaining a critical mass of qualified researchers, it is equally important to provide these scientists with well-funded research programmes and well-equipped research laboratories, which requires long-term, sustainable investment in non-salary expenditures.

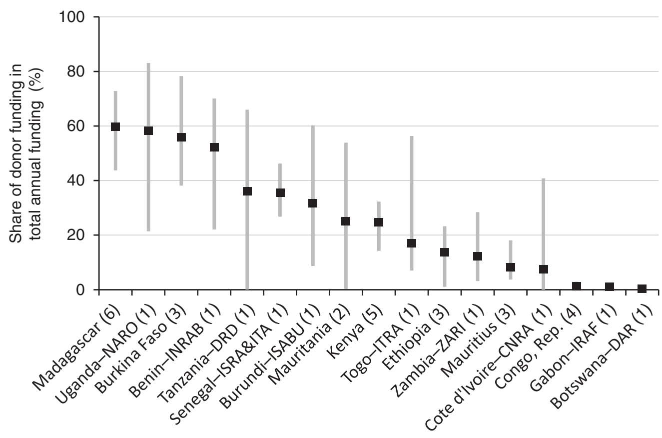

Figure 7: Average and spread of donor funding as a share of total agricultural R&D funding, selected institutes, 2001–2011.

Note: Total annual funding includes funding for salaries, operating and programme costs, and capital investments. Donor funding includes loans from development banks. The figures in parentheses indicate the number of agencies included in the country. Madagascar includes CNARP, CNRE, CNRIT, CNRO, FIFAMANOR and FOFIFA; Burkina Faso includes CNSF, INERA and IRSAT; Kenya includes KARI, KEFFRI, KIPPRA, KIRDI and KMFRI. Ethiopia includes ARARI, SARI and TARI; Mauritius includes AREU, ED and FARC; Ghana includes ARI, FORIG, FRI, OPRI, PGRRI, WRI and MFRD; Republic of Congo includes CRAL, CRCRT, CRHM and GERDIB; Nigeria includes FIIRO, LCRI, NCRI, NIFFR, NIFOR, NIHORT, NIOMR, NRCRI, NSPRI, NVRI and RRIN. For full agency names and further details, see the ASTI Directory at www.asti.cgiar.org/pdf/ASTI-Directory-2011.pdf.

Source: Compiled by authors from ASTI database (ASTI, 2001–2014).

This article revealed that African agricultural research institutes that receive little government funding, and that are highly dependent on funding from donors and development banks, are more vulnerable to funding shocks on average than are institutes funded mostly by their governments. Uncertain inflows of funding have a considerably negative impact on the long-term implementation of R&D programmes, and often on much-needed rehabilitation of R&D infrastructure. In Burkina Faso, for example, 90 per cent of government funding received by the National Environment and Agricultural Research Institute is spent on salaries, leaving the funding of actual research programmes and much-needed rehabilitation of research equipment and infrastructure almost entirely in the hands of donors and development banks. Peaks in operating expenditures and capital investments during 1981–2011 largely coincided with peaks in funding from two consecutive World Bank-funded projects (see Figure 3). The closure of these projects has seriously disrupted day-to-day operations and prevented the recruitment of researchers.

Conclusion and Policy Recommendations

Despite the fact that agricultural R&D spending in SSA increased by more than one-third in real terms during 2000–2011, overall investment levels in most countries are still well below the levels required to sustain agricultural R&D needs. In 2011, SSA invested just 0.51 per cent of agricultural output in agricultural R&D, well below the UN's and NEPAD's 1 per cent minimum national R&D investment target. Agricultural R&D investment is positively associated with high returns (Alston *et al*, 2000; Alene and Coulibaly, 2009), but these returns take time – often decades – to develop. Consequently, the inherent lag from the inception of research to the adoption of a new technology or the introduction of a new variety calls for sustained and stable R&D funding (in addition to efficient extension, credit and input supply systems, and an enabling policy environment).

The time-series data presented in this article, however, reveal that agricultural R&D funding in many SSA countries has been far from stable over time and that R&D spending for the region as a whole shows much higher volatility compared with spending in other developing regions of the world. Low levels of government funding, coupled with a much higher dependence on donor and development bank funding compared with other regions, is the main driver of SSA's high volatility in agricultural R&D expenditures. In a large number of SSA countries, particularly low-income countries, national governments fund little more than the salary costs associated with agricultural R&D, leaving the costs of actual R&D programmes and rehabilitation of R&D infrastructure largely dependent on short-term and *ad hoc* funding provided by donors and development banks. There is extensive anecdotal evidence of agencies reverting into financial crisis upon the completion of large donor-funded projects, forcing them to cut research programmes and lay off staff. Some countries appear to devolve too much of the critical decision making on research priorities to donors and development banks, with the result that the research agendas of many agricultural research agencies across SSA are skewed towards short-term goals that are not necessarily aligned with national and (sub-)regional priorities.

Many studies have assessed the impact of funding shocks on developing economies, concluding that volatility is costly and that it negatively effects long-term macroeconomic growth (Hnatkovska and Loayza, 2004; Agion *et al*, 2005; Fatás and Mihov, 2006; Perry, 2009). Studies conducted in the developed world have found support for the hypothesis that increased volatility of public R&D spending has a negative long-term impact on innovation (Swift, 2008; Johnstone *et al*, 2011). A thorough analysis of the long-term effects of funding volatility on agricultural R&D outputs and agricultural productivity in SSA was beyond the scope of the current study, and would require detailed multi-decade time-series data, which were not available. Ample anecdotal evidence, however, strongly suggests that severe fluctuations in annual agricultural R&D funding exacerbate uncertainty at the institute level and render long-term R&D budget, staffing and planning decisions more difficult. Consequently, the continuity of research programmes is imperilled in the short run, as is technical change and the release of new varieties and technologies in the long run.

While many governments have increased their commitment to agricultural research in recent years, funding in many countries is still often insufficient for the day-to-day operation of research programmes. African governments have limited public resources, and the prospects for future development assistance to these governments are uncertain. Mobilizing domestic political support for agriculture, and especially for agricultural R&D, has been difficult. One reason for this is the inherently long time lag between investing in research and attaining tangible benefits. Public agricultural R&D therefore competes for funding with other important public domains, such as health and education. Nonetheless, higher levels of government funding are necessary not just for competitive researcher salaries, but also to support the fundamental non-salary-related expenses required to conduct research. This includes fundamentals like office space and equipment, computer hardware and software, water and electricity, telecommunications infrastructure, and appropriate laboratory and field infrastructure and equipment. Rather than relying too much on donors and development banks to fund critical research areas, governments need to be more at the forefront and clearly identify their own long-term national priorities and design relevant, focused and coherent agricultural R&D programmes accordingly. Donor and development bank funding needs to be closely aligned with these national priorities, and consistency and complementarities among donor programmes need to be assured. Finally, mitigating the effects of any single donor's abrupt change in aid disbursement is crucial, highlighting the need for greater funding diversification, for example, through the sale of goods and services or by attracting complementary investment from additional sources, such as the private sector. This, in turn, requires that national governments provide a more enabling policy environment for private sector R&D in terms of tax incentives, protection of intellectual property rights and regulatory reforms to encourage the spill-in of international technology. All these measures are necessary to put an end to the rollercoaster that has characterized agricultural R&D funding in SSA to date.

Notes

1. For more information on ASTI methodology, visit www.asti.cgiar.org/methodology.
2. Cariolle (2012) identifies three main measures to quantify volatility: volatility as the standard deviation of the growth rate of a variable, volatility as the standard deviation of the residual of an econometric regression and volatility as the standard deviation of the cycle isolated by a statistical filter. These techniques vary in terms of the choice of reference value and the way in which deviations from the reference value are calculated. We recognize some of the limitations of calculating volatility based on the standard deviation of the growth rate, but given the relatively small sample of just 31 SSA countries, we believe the method is sufficient to highlight cross-country differences in volatility in agricultural R&D spending.
3. This section draws largely on Beintema and Stads (2014).
4. This section draws largely on Stads (2011), who analysed agricultural R&D spending and funding volatility in SSA for the 2001–2008 period. The availability of new data from 39 SSA countries up to the year 2011 allowed for an updated analysis.
5. This is an unweighted average. Country-level agricultural R&D expenditure data for 2009–2011 were unavailable for Asia-Pacific and Latin America.
6. Agricultural GDP data were taken from World Bank (2013).
7. The sample includes 82 large agricultural research agencies in Benin, Botswana, Burkina Faso, Burundi, Republic of Congo, Côte d'Ivoire, Eritrea, Ethiopia, Gabon, The Gambia, Ghana, Guinea,

Kenya, Madagascar, Mali, Mauritania, Mauritius, Namibia, Nigeria, Senegal, Sudan, Tanzania, Togo, Uganda and Zambia. Combined, these agencies accounted for 31 per cent of total agricultural R&D spending in SSA in 2011. Given that log transform can only be applied to non-zero values, a value of 0.001 was added to each agency's salary, operating and capital investments. This had a negligible impact on the individual institutes' and overall volatility coefficients, and allowed for the calculation of volatility coefficients of institutes without capital spending during a certain year.

8. Although the data allowed for the calculation of a volatility coefficient for funding derived from commodity levies and producer organizations, this coefficient was irrelevant at the SSA level as only a handful of countries generate funding for agricultural R&D this way and therefore the mean would be skewed.

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