Chapter 2

Agricultural Public Spending in Africa Is Low and Inefficient

We begin the evaluation of public agricultural spending in Africa with a broad overview using metrics of both quantity and quality. This chapter first analyzes the patterns of agricultural public spending, in comparison with other forms of public spending, across different developing regions of the world.[1] While optimal levels of spending will of course depend on characteristics of countries and regions, it is nonetheless informative to see how Africa stacks up to other regions. The chapter also provides evidence on the returns to public spending in the agricultural sector in Sub-Saharan Africa, considering total agriculture spending and agricultural research spending, using data on 34 Sub-Saharan countries from 1980 to 2012. Annex 2A synthesizes evidence on the impacts of different types of agricultural public spending in Africa.

Most of the studies commonly cited in reference to the body of work on the returns to agricultural public spending in Africa were conducted with data prior to 2003. But recent trends in agricultural spending on the continent—especially following the commitment by African leaders in 2003 to increase their annual spending on agriculture to 10 percent of total national spending—are quite different from the trends associated with the periods previously analyzed. Compared with the trends in the 1980s and 1990s, for example, the share of agricultural spending in total spending and the growth of agricultural spending in 2001–10 declined (table 2.1). Therefore, new evidence on the returns to agricultural public spending that accounts for recent trends in spending and productivity is warranted.

The main results for the trends and impacts of different types of agricultural public spending in Africa are in table 2.2. Between 1980 and 2012, total agricultural spending increased at an average of 0.8 percent a year and constituted 4 percent of total spending (far below the Comprehensive Africa Agriculture Development Programme [CAADP] 10 percent target) and 4.7 percent of agricultural value added. Furthermore, a 1 percent increase in total agricultural spending is associated with a 0.1–0.3 percent increase in agricultural output or productivity.

Table 2.1 Agricultural Public Spending and Productivity in Sub-Saharan Africa, 1971–2010

	Years and values			
Indicator	**1971–80**	**1981–90**	**1991–2000**	**2001–10**
Agricultural output growth rate (%)	1.0	2.7	3.1	2.6
Agricultural output per hectare (constant 2004–06 US$)	163[a]	182[b]	192[c]	219[d]
Agricultural spending (% of total spending)	—	7.1	3.3	3.1
Agricultural spending (% of agriculture value added)	—	4.9	3.0	3.9

Source: Benin 2015.
Note: — = not available.
a. Data from 1980.
b. Data from 1990.
c. Data from 2000.
d. Data from 2009.

Table 2.2 Key Trends in and Impacts of Different Types of Agricultural Public Spending in Africa

Objective area and indicator	**Estimate**
Main trends in spending	
Total agriculture spending in constant 2005 PPP$, 1980–2012	—
Annual average growth rate (%)	0.8
Annual average share in total spending (%)	4.0
Annual average share in agriculture value added (%)	4.7
Research spending in constant 2011 PPP$, 1981–2011	—
Annual average growth rate (%)	–0.1
Annual average share in agriculture value added (%)	1.1
Estimated impacts of spending	
Total agriculture, elasticity	0.1–0.3
National and CGIAR research, ROR (%)	22–55
Irrigation, ROR (%)	11–22
Extension, ROR (%)	8–49
Extension, benefit-cost ratio	6.8–14.2
Rural roads, benefit-cost ratio	7.2

Source: Benin 2015.
Note: CGIAR = Consultative Group on International Agricultural Research; PPP = purchasing power parity; ROR = rate of return. — = not available.

The returns vary for spending on different agricultural functions, 22–55 percent for research, 8–49 percent for extension, and 11–22 percent for irrigation. The new estimates in this chapter show that total agricultural spending yielded an average return of 11 percent, but agricultural research spending yielded an average return of 93 percent.

Overall, the higher returns to agricultural research spending (93 percent) than to total agricultural spending (11 percent) reflect the low and declining research spending intensities in the continent. Because the returns to agricultural research spending take time—typically a decade—to develop, having a stable and sustained agricultural research funding will be critical for maintaining the high returns and, consequently, for accelerating agriculture-led development in the continent. And because agricultural spending encompasses spending on functions (such as research, extension, irrigation, marketing, or subsidies) that are expected to have different productivity effects, the estimated low return to total agricultural spending (which was actually negative in several countries and in some groups of countries) suggests that more disaggregated analysis is needed to better inform priorities for agricultural spending.

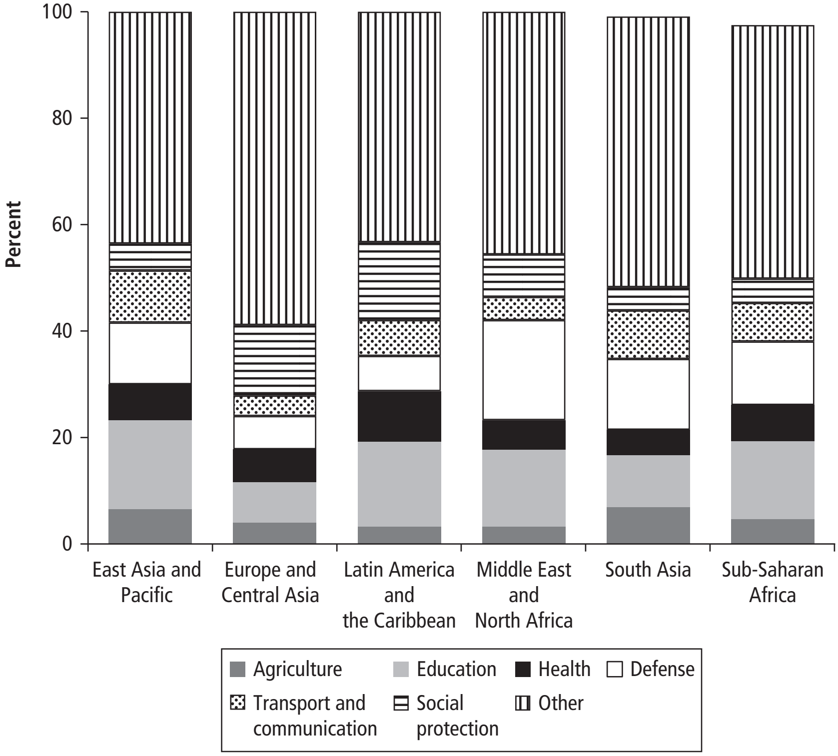
Trends and Composition of Spending

Sectoral Composition of Total Spending in World Regions

To compare how different developing regions prioritize agricultural public spending, figure 2.1 summarizes the composition of total spending by functional classification in terms of share of total spending over the entire period (box 2.1).[2] Social protection attracted the largest share in the developing regions of Europe and Central Asia and Latin America and the Caribbean. In the other developing regions, education was the top spender (10–17 percent), except in the Middle East and North Africa, where defense was the top spender at 17 percent. For most regions, defense and social spending (education, health, and social protection) ranked second, third, and fourth. Spending on infrastructure (transport and communication) and agriculture attracted the smallest shares at 3–7 percent, with some slight differences. In South Asia, infrastructure and agriculture ranked third and fourth at 9 percent and 7 percent, respectively, whereas in Sub-Saharan Africa infrastructure ranked third with 7 percent.

Overall, the rank of sectoral spending did not change much from 1980 to 2012, especially for the top three spenders (table 2.3). Changes were most notable for the bottom three spenders, with the rank and share of agriculture

Figure 2.1 Annual Average Agricultural Spending Share in Total Spending, 1980–2012



Source: IFPRI Statistics on Public Expenditures for Economic Development database.
Note: Data for Europe and Central Asia are from 1995 to 2012.

spending faring the worst and declining over time (table 2.4). In Latin America and the Caribbean, agriculture was ranked sixth in 1980–89, 1990–99, and 2000–12, with the annual average share dropping from 3–4 percent in 1980–89 to 2 percent in 2000–12. In Sub-Saharan Africa, the rank of agricultural spending dropped from fourth in 1989 at 7 percent to sixth in 2000–12 at 3 percent. Only in South Asia was agriculture ranked higher than sixth in all the three subperiods, although its share declined over time, ranking third in 1980–89 at 9 percent, fourth in 1990–99 at 7 percent, and fifth in 2000–12 at 5 percent.

Trends in Total Agricultural Spending

Growth in agriculture spending was erratic in many of the regions (figure 2.2a). East Asia and the Pacific experienced the fastest growth at an annual average of 7.5 percent over 1980–2012, followed by Europe and Central Asia at 6.0 percent,

BOX 2.1

Sources of Data

The analysis in this chapter draws on data from three main sources: the Statistics on Public Expenditures for Economic Development (SPEED) database (IFPRI), the Regional Strategic Analysis and Knowledge Support System (ReSAKSS) database (IFPRI), and the Agricultural Science and Technology Indicators (ASTI) database (IFPRI). The SPEED database contains information on government spending in eight sectors (agriculture, transportation and communication, education, health, social security, defense, mining, and fuel and energy) for 147 countries (including 39 from Africa) from 1980 to 2012. The ReSAKSS database contains information on government agricultural spending on African countries only (54 in total) from 1980 to 2014. The ASTI database contains information on governmental and nongovernmental spending in agricultural research for 71 countries (including 42 from Africa) from 1981 to 2012.

To do the comparative analysis of trends in different parts of the world, we follow the standard regional classifications presenting results for six regional groups: East Asia and Pacific, Europe and Central Asia, Latin America and the Caribbean, Middle East and North Africa, South Asia, and Sub-Saharan Africa. We analyze the trends over three subperiods: 1980–89, 1990–99, and 2000–12.

Table 2.3 Annual Average Sectoral Spending Share in Total Spending, 1980–2012
Percent

	East Asia and Pacific	Europe and Central Asia	Latin America and the Caribbean	Middle East and North Africa	South Asia	Sub-Saharan Africa
1980–89						
Agriculture	9	—	4	4	9	7
Defense	13	—	9	22	14	14
Education	17	—	15	13	8	15
Health	6	—	10	5	4	6
Social protection	3	—	15	8	4	4
Transport and communication	12	—	8	6	11	10
1990–99						
Agriculture	6	4	4	3	7	4
Defense	13	6	7	20	14	14
Education	16	8	16	16	10	15
Health	6	6	9	6	5	6
Social protection	5	7	13	5	4	4
Transport and communication	9	3	7	3	9	6

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Table 2.3 (continued)

	East Asia and Pacific	Europe and Central Asia	Latin America and the Caribbean	Middle East and North Africa	South Asia	Sub-Saharan Africa
2000–12						
Agriculture	5	4	2	2	5	3
Defense	9	7	4	14	12	8
Education	17	7	17	14	12	14
Health	7	7	9	6	6	8
Social protection	8	20	16	11	4	6
Transport and communication	8	5	5	4	7	6

Source: IFPRI Statistics on Public Expenditures for Economic Development database.
Note: Data for Europe and Central Asia are from 1995 to 2012. — = not available.

Table 2.4 Rank and Share of Agricultural Spending in Total Spending, 1980–2012

	1980–89		1990–99		2000–12	
	Rank	Share (%)	Rank	Share (%)	Rank	Share (%)
East Asia and Pacific	4	8.9	5	6.2	6	4.6
Europe and Central Asia	—	—	5	4.1	6	3.9
Latin America and the Caribbean	6	4.1	6	3.7	6	2.2
Middle East and North Africa	6	4.1	5	3.2	6	2.5
South Asia	3	9.0	4	6.6	5	5.1
Sub-Saharan Africa	4	7.4	6	3.5	6	3.0

Source: IFPRI Statistics on Public Expenditures for Economic Development database.
Note: Data for Europe and Central Asia are from 1995 to 2012. Ranks are from 1 to 6, with 1 being the top rank. — = not available.

Latin America and the Caribbean at 4.3 percent, South Asia at 4.2 percent, and the Middle East and North Africa at 2.8 percent. Agricultural spending increased at a much slower pace in Sub-Saharan Africa (0.8 percent).

With the rapid growth in agricultural spending in East Asia and the Pacific, spending per capita increased almost fourfold from US$25 in 1980–89 to US$96 in 2000–12 (figure 2.2b).[3] Per capita spending remained stagnant in Latin America and the Caribbean at US$47–US$52, and increased by more than 50 percent in the Middle East and North Africa from US$61 in 1980–89 to US$97 in 2000–12. Sub-Saharan Africa and South Asia experienced the least

Figure 2.2 Agricultural Spending, 1980–2012

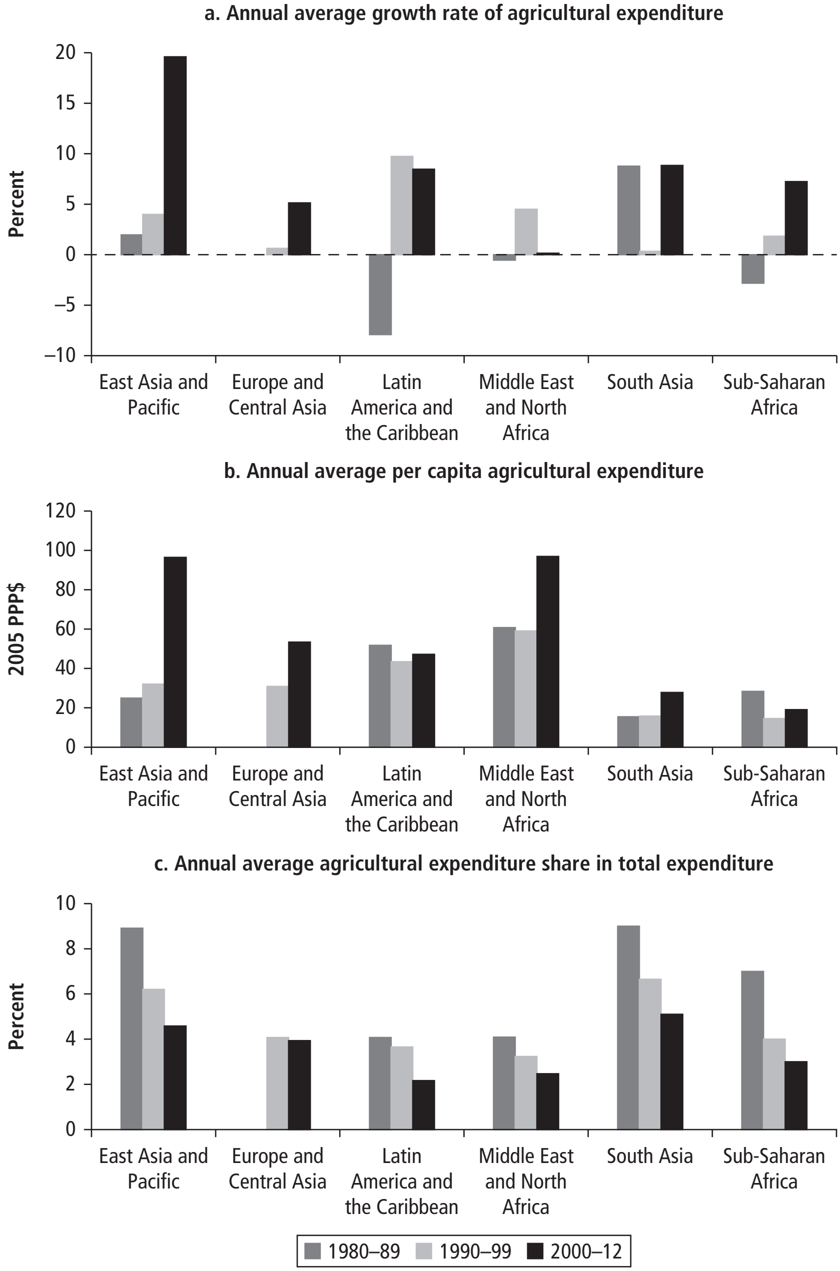

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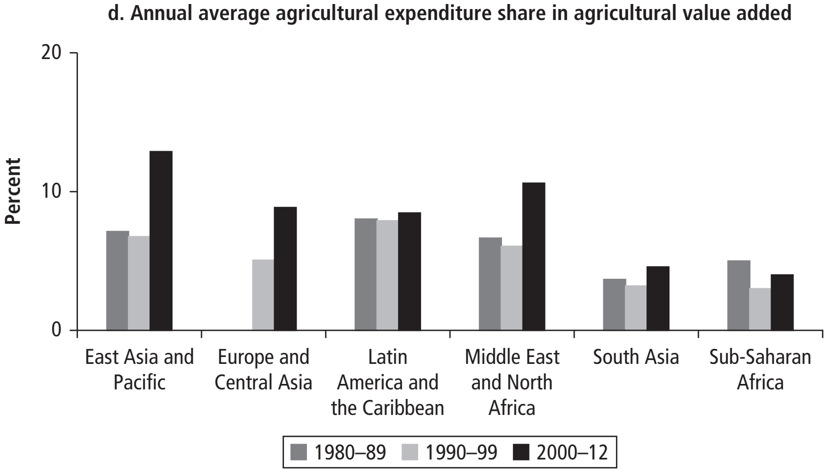
Figure 2.2 (continued)



Source: IFPRI Statistics on Public Expenditures for Economic Development database.
Note: Data for Europe and Central Asia are from 1995 to 2012. PPP = purchasing power parity.

per capita spending, although increasing in South Asia from US$15 in 1980–89 to US$28 in 2000–12 but declining in Sub-Saharan Africa from US$28 in 1980–89 to US$19 in 2000–12. This puts Sub-Saharan Africa far behind the other regions in recent years.

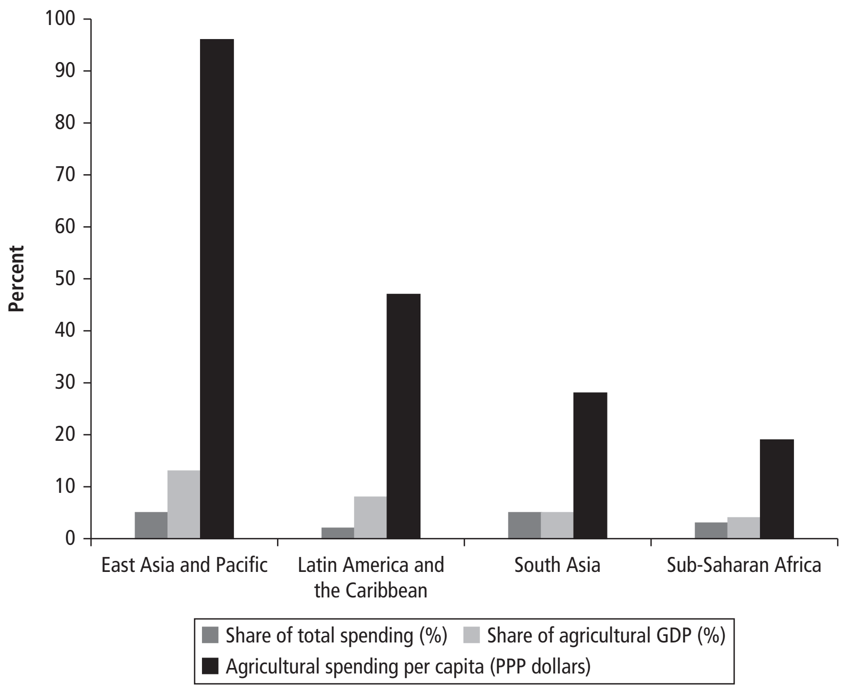
In 2000–12, the share of agricultural spending in total spending was around 2–5 percent in East Asia and the Pacific, Europe and Central Asia, Latin America and the Caribbean, and the Middle East and North Africa, but 3–5 percent in South Asia and Sub-Saharan Africa (figure 2.2c). And the share of agricultural spending in agricultural value added was 8–13 percent in East Asia and the Pacific, Europe and Central Asia, Latin America and the Caribbean, and the Middle East and North Africa, but 4–5 percent in South Asia and Sub-Saharan Africa (figure 2.2d).

In the 2003 Maputo Declaration, African heads of state and government agreed that spending on agriculture was inadequate and set a goal of investing 10 percent of their total national spending to agriculture. This goal was reaffirmed in the Malabo Declaration in 2014, and assisting countries to increase the quantity and quality of public agricultural spending has been a major objective of CAADP. There is also an aspirational goal of increasing agricultural annual growth rate to 6 percent for Sub-Saharan countries, though growth is not a policy variable under the direct control of governments the way public spending is.

By volume, public agricultural spending in Africa tends to lag behind other developing regions by several metrics. Agricultural spending as a share of overall public spending is substantially lower than that in other regions, particularly East Asia and the Pacific and South Asia (figure 2.3). In 2014, only Burkina Faso, Malawi, Mozambique, and Zimbabwe had met or surpassed the 10 percent target (Malawi and Mozambique consistently surpassed it), with three countries (Zambia, Niger, and Rwanda) close behind at 9 percent (figure 2.4). By another metric—public spending on agriculture as a share of agricultural GDP—spending is also substantially lower in Africa than in other regions. By yet another metric—spending per capita—Africa also registers the lowest spending by far among regions, and this has declined by around 40 percent between the 1980s and the 2000s (see figure 2.2b).

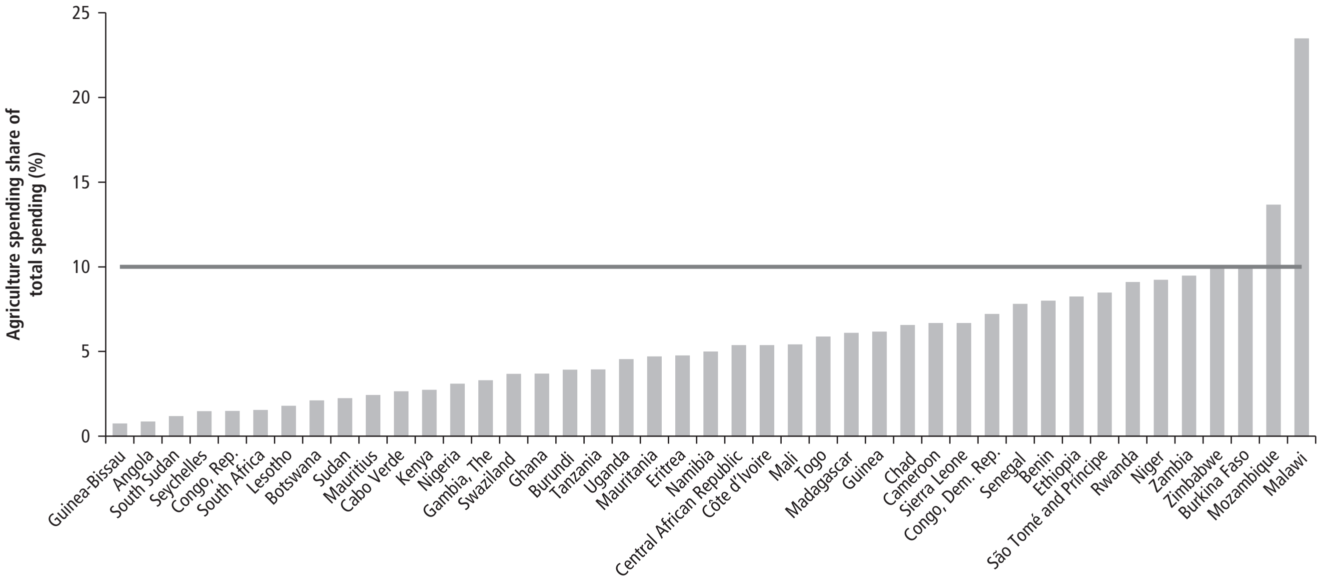
While almost all countries are spending below the 10 percent target, country conditions and thus spending contexts differ widely across Sub-Saharan Africa. For instance, the spending target is arguably less meaningful for such countries as

Figure 2.3 **Public Agricultural Spending Lags behind Other Regions, 2000–14**



Source: IFPRI Statistics on Public Expenditures for Economic Development database.
Note: The figure represents public agricultural spending across regions. GDP = gross domestic product; PPP = purchasing power parity.

Figure 2.4 Almost All African Countries Fall Short of 10 Percent Target of Public Spending, 2014



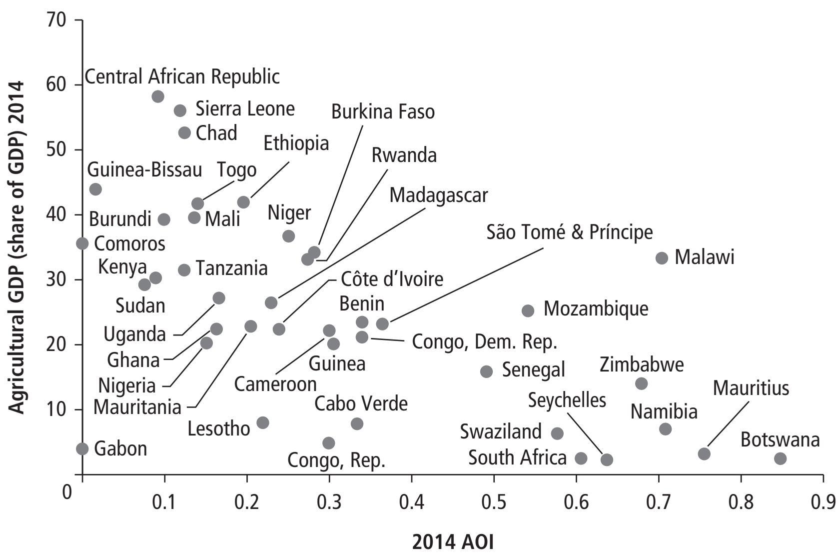
Source: IFPRI Regional Strategic Analysis and Knowledge Support System data.
Note: The figure represents public agricultural spending share in Sub-Saharan countries.

South Africa and Botswana, with small agricultural GDP shares in the overall economy. An alternative indicator of public sector budgetary commitment to agriculture is the Agriculture Orientation Index (AOI), defined as agriculture's share of public spending relative to its share in the economy.[4] An AOI value of 1 would indicate that the government spends a share of its budget on agriculture exactly proportionate to agriculture's contribution to gross domestic product (GDP) (figure 2.5).

No country in Africa has an AOI of 1 or more, although some come close. Overall, most African countries spend much smaller proportions of the public budget on agriculture than the sector's share in the economy. Of the 47 countries for which the AOI can be computed, the index in 31 is less than 0.3. There is no reason why expenditure must be allocated exactly in proportion to each sector's contribution to the economy; however, large deviations signal a need for deeper analysis by policy makers.

While the numerical goal of 10 percent is somewhat arbitrary, and the failure to meet this target arguably is not so worrisome, the AOI also appears to demonstrate underspending on the sector in most countries. Even more problematic is the persistent negative trend across three decades in agricultural spending as a share of both agricultural GDP and total public spending in Sub-Saharan Africa (table 2.5).

Figure 2.5 No Country in Africa Spends as Much on Agriculture as Agriculture Contributes to the Economy, 2014



Source: World Bank calculations using SPEED database.
Note: AOI = agriculture orientation index; GDP = gross domestic product.

Table 2.5 Agricultural Spending Is Low in Almost All Sub-Saharan Countries

	Agricultural spending					
	As a share of total spending (%)			As a share of agricultural GDP (%)		
Country	**1980–89**	**1990–99**	**2000–14**	**1980–89**	**1990–99**	**2000–14**
Sub-Saharan Africa	**9.02**	**6.40**	**5.18**	**11.29**	**9.11**	**8.84**
Angola	—	1.14	1.40	—	5.02	6.83
Benin	—	8.26	6.17	—	4.00	4.11
Botswana	9.67	5.85	3.28	—	—	—
Burkina Faso	31.30	27.14	9.99	23.33	17.46	13.43
Burundi	—	4.90	3.42	—	2.65	2.07
Cameroon	5.59	4.16	4.43	4.95	2.67	3.29
Cabo Verde	—	—	2.91	—	5.15	—
Central African Republic	8.85	5.56	2.89	3.73	2.22	1.19
Chad	—	—	5.81	—	—	0.56
Congo, Dem. Rep.	—	5.11	2.46	—	1.33	2.27
Congo, Rep.	—	0.19	1.38	—	0.69	9.01
Côte d'Ivoire	2.21	3.40	3.27	3.08	3.22	2.78
Djibouti	—	—	—	—	—	9.27
Equatorial Guinea	—	—	1.11	—	—	—
Eritrea	—	7.58	5.28	—	26.59	18.81
Ethiopia	8.40	9.22	12.28	2.86	2.94	6.14
Gabon	—	—	—	—	—	—
The Gambia	9.58	7.57	6.23	10.38	5.04	4.80
Ghana	7.13	2.55	2.48	1.55	1.51	2.44

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Table 2.5 (continued)

Country	Agricultural spending					
	As a share of total spending (%)			As a share of agricultural GDP (%)		
	1980–89	1990–99	2000–14	1980–89	1990–99	2000–14
Guinea	—	—	8.09	—	—	7.36
Guinea-Bissau	12.32	0.80	1.15	11.26	0.32	0.33
Kenya	9.26	6.45	4.00	8.78	5.50	3.47
Lesotho	8.47	9.58	2.93	21.08	30.44	17.31
Liberia	6.05	2.90	4.56	5.88	3.69	0.08
Madagascar	8.24	10.24	8.12	18.66	6.51	4.43
Malawi	12.44	8.14	12.73	9.80	7.56	12.31
Mali	6.24	12.41	9.84	3.29	7.45	7.64
Mauritania	—	—	5.65	—	—	6.50
Mauritius	7.15	5.46	2.95	14.19	14.05	18.79
Mozambique	—	—	5.98	—	—	6.19
Namibia	—	6.49	5.02	—	23.44	18.91
Niger	14.45	23.25	13.57	7.47	10.33	8.57
Nigeria	2.03	2.03	3.21	1.16	1.12	2.05
Rwanda	—	—	4.39	—	—	3.62
São Tomé and Príncipe	—	—	6.93	—	—	11.15
Senegal	6.28	5.66	7.28	6.81	6.09	13.11
Seychelles	—	1.60	1.46	—	24.08	21.84
Sierra Leone	4.85	1.80	3.63	2.18	0.60	2.22
Somalia	—	—	—	—	—	—

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Table 2.5 (continued)

	Agricultural spending					
	As a share of total spending (%)			As a share of agricultural GDP (%)		
Country	**1980–89**	**1990–99**	**2000–14**	**1980–89**	**1990–99**	**2000–14**
South Africa	—	0.63	1.89	—	4.67	19.79
South Sudan	—	—	1.28	—	—	—
Sudan	11.77	12.63	5.15	5.30	0.42	3.03
Swaziland	8.82	7.13	3.27	15.43	15.72	14.43
Tanzania	7.04	6.16	5.72	—	2.56	3.39
Togo	8.96	3.99	5.58	9.56	2.51	3.29
Uganda	4.57	1.74	4.14	1.20	0.53	3.21
Zambia	12.20	2.99	7.99	28.37	4.73	12.47
Zimbabwe	9.75	5.85	11.92	27.39	28.06	7.79

Source: Benin 2015.
Note: GDP = gross domestic product; — = not available.

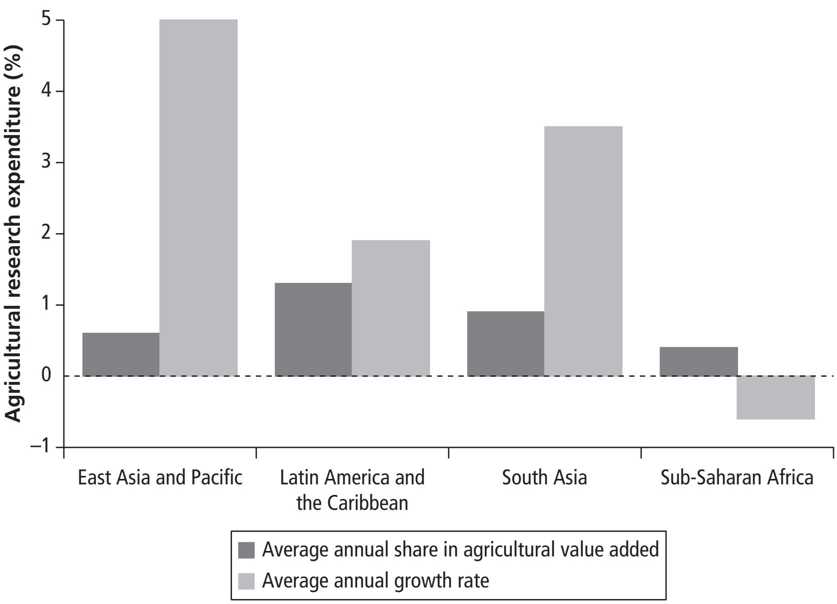
Trends in Different Types of Agricultural Spending

Aside from the Agricultural Science and Technology Indicators (ASTI) database on agricultural research spending, there are no similar time series, cross-country comparable databases on the major types of agricultural public spending such as irrigation, extension, marketing infrastructure, and farm support subsidies. The one that offers data most closely suited for the type of analysis desired is the Monitoring African Food and Agricultural Policies (MAFAP) database for a limited set of countries in Sub-Saharan Africa from 2006 to 2013 (FAO). These data, however, do not allow a comprehensive comparative analysis across the different types of spending in all Sub-Saharan Africa countries over as long a time period as we report below for spending on agricultural research.

Agricultural Research Spending

In the ASTI database, the data measured in 2011 PPP$ are unbalanced in time and country coverage.[5] Thus, although we continue with the same type of comparative analysis, as in previous sections, across the regions, the results should be interpreted with caution. Growth in agricultural spending in Sub-Saharan Africa was negative compared with the growth rates in the other regions (figure 2.6), but it did improve over time, going from an annual average

Figure 2.6 Public Agricultural Research Spending in Africa Is Low Compared to Other Regions and Declining, 2000–11



Source: IFPRI Agricultural Science and Technology Indicators data.

growth rate of −2.7 percent in 1980–89 to −2.3 in 1990–99 and −0.6 in 2000–11. In 2000–11, East Asia and the Pacific experienced the fastest growth at 5.0 percent a year, compared with South Asia at 3.5 percent, and Latin America and the Caribbean at 1.9 percent. Spending on research constituted about 1.1 percent of agricultural value added in Sub-Saharan Africa in each year in 1980–2011. In the most recent decade of 2000–11, the share was 0.9 in Sub-Saharan Africa compared with 1.3 percent in Latin America and the Caribbean, 0.6 percent in East Asia and the Pacific, and 0.4 percent in South Asia.

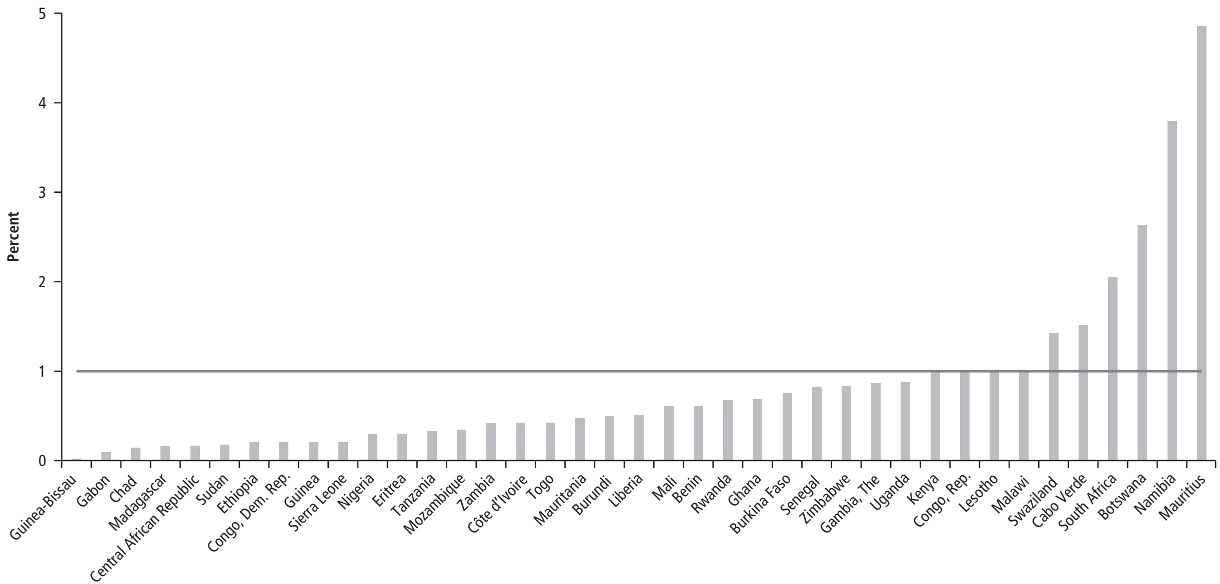
Close to 40 percent of the 37 countries covered in Sub-Saharan Africa spent at least 1 percent of the agricultural value added on research, the target set by the African Union's New Partnership for Africa's Development (figure 2.7). Botswana, followed by Mauritius, Namibia, and South Africa, had the highest shares of at least 2 percent per year. Several of the countries with large research spending budgets in absolute terms, including Nigeria, Ethiopia, Tanzania, and Ghana, spent less than 0.7 percent of the equivalent of their agricultural value added each year on average. Unfortunately, in around half of all African countries the absolute volume of spending is either stagnant or falling (figure 2.6).

Other Types of Agricultural Spending

The countries in the MAFAP database are Burkina Faso, Ethiopia, Ghana, Kenya, Malawi, Mali, Mozambique, Tanzania, and Uganda, covering different periods from 2006 to 2013. We analyze the data on agriculture-specific spending less subsidies to consumers, and then aggregate into the five main categories of spending: (a) research, (b) irrigation (made up of subsidies on capital for on-farm irrigation and infrastructure and general support to off-farm irrigation), (c) extension (made up of technical assistance, training, and extension and technology transfer), (d) marketing (made up of payments to input suppliers, processors, traders and transporters, and general support to various off-farm services and infrastructure, including inspection, feeder roads, storage, and marketing), and (e) subsidies (made up of payments to producers for inputs and on-farm services).[6]

The original data are in 2011 PPP$ and we analyze the annual average shares of spending on each of the five categories.[7] In the countries with data to compare the composition of spending, input subsidies dominate in the majority of countries, accounting for at least a third of overall agriculture spending (ranging from 30 percent in Kenya to 70 percent in Malawi). Extension and advisory services also generate particularly large shares in some countries, for instance in Ethiopia and Uganda, where they average 35 percent. Research and development (R&D) has a consistently small share. Spending to deliver marketing and irrigation are also crucially neglected. The data are not adequately disaggregated to be able to determine how public agricultural spending is allocated across different functional uses in ways that are reliably comparable across a large number of Sub-Saharan countries. But it is clear that many countries have

Figure 2.7 **Only Six Public Budgets in Sub-Saharan Africa Spend One Percent or More of Agricultural GDP on Research, 2011**



Source: IFPRI Agricultural Science and Technology Indicators data.
Note: The figure represents agricultural research spending as a share of agricultural GDP. GDP = gross domestic product.

a narrow scope in spending patterns, allocating large shares of their public funds on input subsidy programs, at the expense of high-return investments in core public goods.

Spending on agricultural R&D is worth an especially close look, given the strong evidence that returns to investments in this area are consistently high around the world and in Sub-Saharan Africa. Yet agricultural R&D capacity in Sub-Saharan Africa has remained low by international norms. Over the last decade, spending on agricultural research constituted about 0.4 percent of agricultural GDP in Sub-Saharan Africa, compared with 1.3 percent in Latin America and the Caribbean, 0.6 percent in East Asia and the Pacific, and 0.9 percent in South Asia. And Africa was the only region where agricultural research spending fell on average over this period.

Therefore, it is not surprising that in 2006, in its commitment to implementing an agriculture-led development agenda, the African Union's New Partnership for Africa's Development (NEPAD) set an additional target to increase public spending on agricultural R&D to at least 1 percent of agricultural GDP. This is similar to the level of funding that high-income countries devote to research, and the level of funding to Embrapa, Brazil's highly successful research agency, for example, whose success is attributable to funding and a number of other characteristics and policies (box 2.2). Yet, few African

BOX 2.2

Embrapa, a Model of Agricultural Research

Embrapa was created in 1973 as an agricultural research organization under Brazil's Ministry of Agriculture, and has been a major contributor to the remarkable and systematic increases in agricultural productivity that Brazil has enjoyed over the past four decades. In the process, Embrapa has become one of the leading agricultural research organizations in the developing world. Because it has worked effectively on issues important for large commercial agriculture as well as with issues that are crucial for the success of millions of small poor farm enterprises, the Embrapa experience is instructive for agricultural research approaches in Africa.

Some factors in Embrapa's success generate lessons for efforts to strengthen the effectiveness of agricultural research in Africa (Correa and Schmidt 2014; Rada and Valdes 2012).

Adequate public funding. Embrapa has been able to secure and sustain a budget of roughly 1 percent of agricultural GDP over the past 25 years. This level of

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Box 2.2 (continued)

sustained investment is necessary to achieve the long-term objectives of agricultural research and could be a reasonable benchmark for Africa, consistent with NEPAD's current target.

Mix of core and project funding. Embrapa's core funding has been sufficient to maintain staffing and facilities and cover other fixed expenses—but this has exhausted 90 percent of the core funding, leaving little room for variable operational expenses. Embrapa has consistently raised additional project funding from private sector and development partners to enable its aggressive research and programs. This mix of substantial and stable core funding with significant project funding serves as a good example for similar programs in Africa.

Independence from bureaucratic impediments. Embrapa was established as a publicly funded and owned company semiautonomous from the government structure. This has afforded a degree of flexibility (in salaries and planning, for example) that has been essential in building a world-class research staff. This is a model not widely seen in Africa, but would be feasible as an institutional option.

Independence from political mandates. This has made it possible for Embrapa to apply disciplined professional focus and professional approaches to its core objectives, relatively unconstrained by short-term political interference. This has greatly facilitated successful achievement of long-term research objectives.

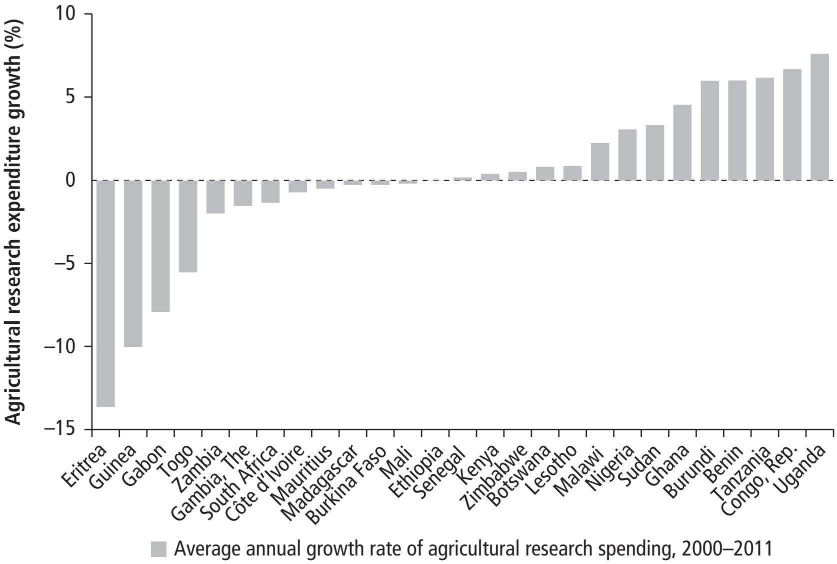
Independence in dealing with partners. Embrapa has attained a stature that allows it to work with the private sector, development partners, and the CGIAR system as an equal. As a result, Embrapa has been able to enjoy the benefits of these partnerships even while maintaining focus on its own agenda.

Sustained investment in human capital. Embrapa has offered competitive salaries (not bound by the general civil service salary structure), has relentlessly supported advanced training for its staff, and has recruited new staff with advanced degrees. Twenty percent of Embrapa's budget was invested in the education and training of its employees between 1974 and 1982 alone. Currently, three-fourths of Embrapa's 2,000 researchers hold a PhD.

International collaboration and research excellence. From the beginning, researchers were drawn from leading universities, setting a high standard of research excellence.

Intellectual property rights (IPR) consistent with development objectives. Pursuing an open innovation system and IPR policy in the agricultural sector facilitated technology transfer, diffusion of new cultivars, and the filing of international patents. An IPR policy that favored social well-being rather than benefiting corporations allowed new technology to be disseminated at production costs only. This experience is of particular relevance for improving research impact in Africa—where rules for transfer of new technologies have been rather restrictive to a detrimental effect.

Figure 2.8 **Half the Countries Have Zero or Negative Spending Growth for R&D, 2000–11**

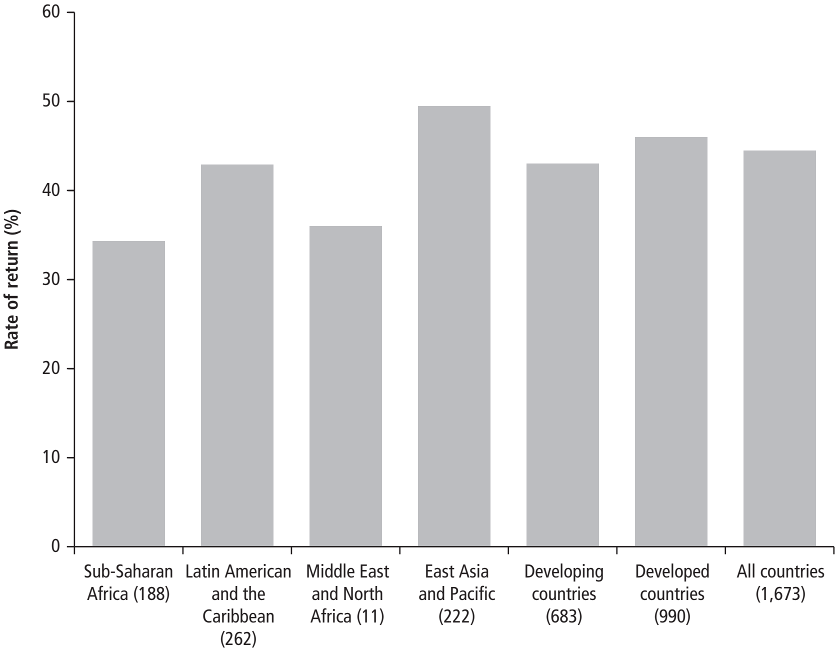


Source: IFPRI Agricultural Science and Technology Indicators data.
Note: The figure represents annual growth in agricultural R&D spending. The figure excludes Cabo Verde, the Central African Republic, Chad, the Democratic Republic of Congo, Guinea-Bissau, Liberia, Mauritania, Mozambique, Namibia, Rwanda, Sierra Leone, and Swaziland because time series data did not date back to 2000. R&D = research and development.

countries have hit this target. A closer look at the relative shift in the patterns of spending in agricultural R&D in Sub-Saharan countries over time reveals important cross-country differences and challenges. During 2000–11, half the Sub-Saharan countries experienced near-zero or negative growth in agricultural R&D spending (figure 2.8).

In sum, from several angles there are troubling signs that agricultural research is severely underfunded in Africa. First, there is considerable evidence that a dollar spent on research has a much higher economic return than a dollar spent on other activities, indicating that taking a dollar from elsewhere and putting it into research would raise overall returns (figure 2.9). Second, despite the ostensible political commitment to agriculture R&D in Africa, a minority of Sub-Saharan countries have met the NEPAD target of investing 1 percent of agricultural GDP in this activity. Third, apart from the levels, even the growth in spending on African R&D in many African countries has in recent years been low or even negative.

Figure 2.9 Returns to R&D Are Uniformly High



Source: Benin 2015.
Note: Average rates of return from public spending on agricultural research and development across studies in several regions; numbers of studies that calculated rates of return in each region are in parentheses.

How Spending Benefits Agriculture

One can conceptually classify the beneficial effects of high-quality public agricultural spending in four channels: advancing technology, enhancing knowledge and skills, reducing transaction costs, and attracting private capital. Each of these channels can be identified with particular classes of programmatic spending to provide goods or services that have the characteristics of "public goods," and public spending in each of them has been empirically demonstrated to be highly productive (see annex 2B for a more comprehensive exposition of the earlier literature on these channels). In addition, agricultural spending can play an important role in confronting challenges of recently emerging issues, which will need to be taken into account when determining spending priorities in the future. These include adaptation to increased risks associated with climate change and lowering emissions from agriculture, the latter of which is an important global public good (box 2.3). In addition, appropriate spending choices in agriculture can help improve the nutritional status of the population (box 2.4).

BOX 2.3

Public Spending for Emerging Priorities: Enhancing Climate Resilience

Intergovernmental Panel on Climate Change (IPCC) (2014) projects that without (successful) adaptation, temperatures could increase in excess of 2°C above preindustrial times, potentially reducing food crop yields in parts of Africa between 10 percent and 20 percent. Conclusions of a World Bank (2013) study are even more dire: the world could warm by 4°C (or 7.2°F) above pre-industrial levels by the end of this century if there is not concerted action to reduce greenhouse gases now. For Sub-Saharan Africa, this would mean significant yield decreases in the near term under relatively modest levels of warming. Under 1.5°C–2°C warming, median yield losses of around 5 percent are projected, increasing to median estimates of around −15 percent (range −5 percent to −27 percent) for 2°C–2.5°C warming. Under 3°C–4°C warming, there are indications that yields may decrease by around 15–20 percent across all crops and Sub-Saharan Africa regions. There is also increasing empirical evidence that elevated atmospheric CO_2 will lower protein and micronutrient concentrations of cereal grains and thereby reduce the nutritional quality of food and fodder. While agriculture is arguably the sector most heavily impacted by global warming, it is also an important contributor to the problem: it produces 10–12 percent of manmade greenhouse gases, and is the largest producer of non-CO_2 greenhouse gases, especially methane. A large part of agriculture's emissions come from land use change, in particular deforestation, and as noted earlier, Africa is the only region where the majority of production increases have come from expanding area, generally at the expense of forests.

In Africa, as around the world, a "climate-smart agriculture" (CSA) approach is needed to achieve the triple win of enhancing agricultural productivity, mitigating emissions of greenhouse gases, and helping farmers adapt to climate change. CSA involves the generation and adoption of locally appropriate technologies, policies, institutions, and investments through the following four kinds of interventions: (a) management of farms, crops, livestock, aquaculture, and capture fisheries to enhance resource management to produce more with less while increasing resilience to climate-related shocks; (b) the restoration of degraded lands for productive agriculture and forestry; (c) ecosystem and landscape management to enhance not only productivity but also ecosystem services that are critical for sustaining resource use efficiency and climate change-resilient productivity; and (d) knowledge, finance, and decision support services for farmers and land managers to enable them to adopt and implement the necessary changes.

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Box 2.3 (continued)

Most of the investments for climate change mitigation (low carbon growth) and adaptation (resilience building) will need to be made by farmers and other private sector agents. But this will require proactive government policies, planning, and investments to provide information, incentives, and an enabling environment to encourage communities, households, and the private sector to change their behaviors, consumption, and investment choices. Many climate resilient investments will not be very different from good investment choices even not taking climate change into account: building resilience has great benefits in any case. But their value is amplified by the changes that will occur with global warming. Policy will rely on a range of policy levers: information, regulation, taxation, and public spending. Public expenditure is an important part of this policy package. Public investments for CSA are essential to ensure (a) the necessary science and technology R&D breakthroughs that will be needed for resilience to the projected climate shocks, (b) the development of cyber data and decision support simulation platforms across multiple and interacting sectors, and (c) creating an appropriate incentive framework for private sector investments and action in CSA and resilient landscapes.

With respect to spending priorities, CSA approaches entail greater investment in (a) managing climate risks, (b) understanding and planning for transitions to newly adapted cropping and livestock systems and livelihood options, and (c) reducing greenhouse gas emissions from fertilizer and livestock practices and from land use change leading to further deforestation and loss of biomass and soil carbon. The successful implementation and scaling up of CSA requires a landscape-scale approach to harness the spatial and time-based synergies of the food, energy, and water subsystems.

There are, however, distinct challenges facing the allocation of public and private investments in CSA: (a) the uncertainty with regard to climate change impacts, because model forecasts are significantly different, especially at local scales; (b) the extended time horizon over which climate change impacts will unfold, which extends far beyond political cycles; (c) the distributional consequences of climate change and disparate incidence of measures to both mitigate and adapt to it, including the fact that the benefits of adaptation are felt locally, while those of mitigating emissions are felt globally; (d) managing the unintended consequences of policies (such as diesel or electricity subsidies for irrigation pumps and insurance subsidies that encourage development in flood-prone areas) and the extent to which international agreements will shape national policy and planning processes; and (e) the need to put in place adequate institutional arrangements.

Climate change has only recently been identified as a specific area of focus for public expenditure reviews (PERs); an extensive review of African country PERs found none related to climate change at the country-specific level. Greater incorporation of climate change considerations into expenditure reviews could help address the challenges of planning expenditures for CSA by identifying opportunities to build flexibility and learning into institutional and policy responses to minimize adverse effects of uncertainty, analyzing trade-offs between short- and long-run measures, quantifying distributional implications of alternative policies and investments, and planning how to take advantage of resource flows in the global climate change architecture.

BOX 2.4

Public Spending for Emerging Priorities: Making Agricultural Spending More Nutrition-Sensitive

Some of the most important policies and public investments for making agriculture more nutrition-sensitive are undertaken not solely—or even primarily—for their positive effects on nutrition, but this may be an important ancillary benefit (Tanimichi Hoberg 2015). The class of intervention with perhaps the strongest empirical link to nutrition is empowering women, which has led to increased production of nutrient-dense foods for household consumption (such as with biofortified crops and homestead gardens). If women had the same access to productive resources as men (by removing legal and customary barriers that bar them from equal access), they could increase yields on their farms by 20–30 percent. This could raise total agricultural output in developing countries by 2.5–4 percent. Investing in women also has high payoffs for nutrition, because women tend to spend more of their discretionary income on factors that positively affect nutritional outcomes, such as education, health care, and food (consumed at home). Among all aspects of women's empowerment, the most relevant for nutrition are increasing women's access to and control over resources—which is particularly important in African agriculture given the significant role played by women in production and marketing.

Policies and investments in many African countries exhibit a strong bias toward staple foods, mainly cereals and root vegetables. These include crop-specific fertilizer subsidies, credit subsidies, grain procurement for food stocks, price supports, and irrigation infrastructure aimed at specific crops (particularly rice). These policies have inadvertently crowded out the production of nonstaple nutrient-rich crops such as fruits, vegetables, and pulses.

In Africa, two-thirds of available food supply is either a cereal or tuber crop, high in dietary energy but typically low in micronutrients and protein (nutrient-light). Only about 20 percent of the food supply is in the nutrient-dense food category (vegetables, fruits, and pulses). This contrasts with non-African countries where the nutrient-light share is less than half (48 percent) and the nutrient-dense share is 35 percent. Shifting the mix requires rethinking strategies that focus budgetary and other support on staple food crops—and going beyond staple grains to crop-neutral strategies. Nonstaples require a different kind of public and private support system such as farmer training, transport systems, cold storage systems, and information systems that allow for better functioning of markets for perishables and development of value chains. Reversing the old policies can also reap great benefits in productive efficiency by encouraging production of products in which the country has a real comparative advantage.

Specific nutrition-focused interventions in the production stage could include:

- Biofortification through plant breeding and agronomic approaches to increase concentrations of key nutrients in staple food crops
- Micronutrient-fortified fertilizers to correct deficiencies of nutrients in order to improve crop yields

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Box 2.4 (continued)

- Home production of dairy, fruits and vegetables, and small-scale aquaculture and fisheries (the financial sustainability of these interventions has yet to be tested as these schemes, to date, are largely limited to heavily subsidized interventions)

  Other options involve postharvest interventions:

- Aflatoxin control in the long term through research and more immediately through deployment of aflatoxin management practice
- Food fortification through the addition of micronutrients to processed foods, and consumer education, for example, through consumer guidelines

Advancing Technology

Research creates knowledge, which is both nonexcludable and nonrivalrous. Of course, some knowledge can be embodied in a physical commercial product (such as improved seed varieties) with benefits that are excludable and rivalrous but the knowledge itself is not. Much evidence shows that investments in agricultural R&D have tremendously enhanced agricultural productivity around the world over the past five decades, which in turn has led to higher incomes, lower poverty levels, greater food security, and better nutrition (Alston, Pardey, and Piggott 2006; Evenson and Gollin 2003; World Bank 2008). In Sub-Saharan Africa, numerous studies show that the rates of return to agricultural research are consistently high, in the range of 22–55 percent (Alene et al. 2009; Thirtle, Piesse, and Lin 2003), and the next section reports some new (and improved) estimates of the benefits.

Improving Knowledge and Skills

Public spending on education, extension, and information services can raise the knowledge and skills of farmers and others engaged in agricultural production. These investments create significant positive externalities through demonstration effects and peer-to-peer learning of benefits from adopting new productivity-enhancing technology. This is important since agricultural production processes are becoming increasingly knowledge-intensive, requiring precise and timely information. Of 375 estimates of returns to extension services reported globally, 44 were in Africa, with a mean return of 43 percent (Evenson 2001). Evidence also points to significant research-extension linkages, and the returns to extension services tend to be higher in a context of rapid technological change (Anderson and Feder 2007). Public spending on farmers' education has a significant positive effect on agricultural productivity and the adoption of improved agriculture technologies (Fan and Zhang 2008; Fuglie and Rada 2013).

The transmission of technologies depends on the rate that new technologies become available, and the productivity gain is limited by the weakest link in this chain. The new technological improvements available on the shelf require effective extension and adaptive research to prosper in local contexts. The balance between R&D and extension has long been an issue, since critics have suggested that many of these workers had nothing to extend owing to weak research and development. In addition, extension has tended to be the poor relation at the bottom of the funding chain (Feder et al. 2010; Thirtle and van Zyl 1994). This has resulted in entire budgets being spent on recurrent items like salaries, even while there were no fuel or parts for vehicles and thus no farm visits.

Reducing Transaction Costs

Transaction costs are an important determinant of market integration (Sadoulet and de Janvry 1995). Public spending on infrastructure can improve access to input and output markets, reducing the cost of agricultural inputs and technologies. Rural roads are arguably the most critical element of public infrastructure for agricultural growth in developing countries, reducing travel times, transport costs, and in-transit spoilage (Calderón and Servén 2004). This tends to raise the prices farmers receive for their products—and lower the prices they pay for inputs (Dorosh, Dradri, and Haggblade 2009). The value of price information is also high for farmers since it facilitates their access to markets and reduces reliance on intermediaries, getting them better prices for inputs and products (see annex 2B for a more detailed exposition of the literature) (Aker and Mbiti 2010; Deichmann, Goyal, and Mishra 2016; Torero 2015).

Attracting Private Capital

Public investments raise the productivity of other factors of production, attracting private capital. One example is investing in large irrigation infrastructure, which opens the door to on-farm investments. Public investment in dams and canals for irrigation, for example, increases private investment in irrigation systems, as demonstrated by evidence from India (Fan, Hazell, and Thorat 2000).

The benefits from inspection and quarantine services that prevent public outbreaks of plant, animal, and human diseases lay the foundation for private market development. Many of the other kinds of investments mentioned above can also complement private sector investment. Public R&D have been shown to have significant crowding-in effects on private R&D in Ireland and the United States, with estimated elasticities in the range of 0.10 to 0.28 (Görg and Strobl 2006; Malla and Gray 2005). It is also sometimes argued that spending on programs to subsidize greater use of inputs has the objective of demonstrating to poor farmers the benefits of inputs, thereby encouraging them to continue using inputs and spending their own money after the subsidies end.

Enhancing Equity

Public spending in agriculture is also often justified on equity grounds, especially salient given the concentration of the poor in rural areas, most of whom rely primarily on agriculture (directly or indirectly) for their livelihoods. One argument for fertilizer subsidies, for example, is that they could help poor farmers break out of a low-productivity poverty trap by raising yields and incomes so they can quit using risk-minimizing but low-productivity techniques (Jayne et al. 2015). The equity justification for spending naturally is stronger for programs that can actually be targeted at the poor, rather than diffusing their benefits, and for programs that demonstrate a high income multiplier effect. In Ethiopia, for example, impacts of spending on extension were found to compare favorably to several kinds of social sector spending with respect to progressivity, and were far superior to spending on subsidies (box 2.5).

BOX 2.5

Incidence of Agricultural Expenditure in Ethiopia

Budgetary allocations to the agricultural sector are among the highest in Africa, close to 13 percent on average from the 2003–14 period, almost half of which is spent on extension. The government has devoted significant resources to expanding extension services in Ethiopia, and there is currently one extension agent for every 472 farmers, which is the highest agent-to-farmer ratio in the world (30 percent higher than the next highest ratio in China).

High levels of spending on agriculture appear to have paid off, aiding high rates of inclusive agricultural growth that has driven poverty reduction in rural areas. The extension program has been one of the drivers of the very high levels of agricultural growth that Ethiopia experienced in the 2000s (Bachewe et al. 2015). High levels of agricultural spending are often justified as social spending, but how equitable is on-budget agricultural spending in Ethiopia?

Extension programs are often targeted to better-off, higher-potential farmers with the aim that they will act as model farmers to their less well-off neighbors. In order to capture the spillover effects of extension spending—that is, the benefit that accrues to other households in a village when some members receive extension services—estimates of spillover effects of extension in Ethiopia were taken from Krishnan and Patnam (2013). Krishnan and Patnam examine the impact of extension on technology adoption for farmers in Ethiopia, and the impact of technology adoption on the adoption of neighbors. An additional extension visit increases the probability of technology adoption by 3 percent. Technology adoption increases the adoption of five closest neighbors by 0.1 percent each, a total adoption increase of 0.5 percent. If benefits are accrued proportional to adoption, then 86 percent of spending is directly enjoyed and the remaining 14 percent is enjoyed by others that did not receive extension visits.

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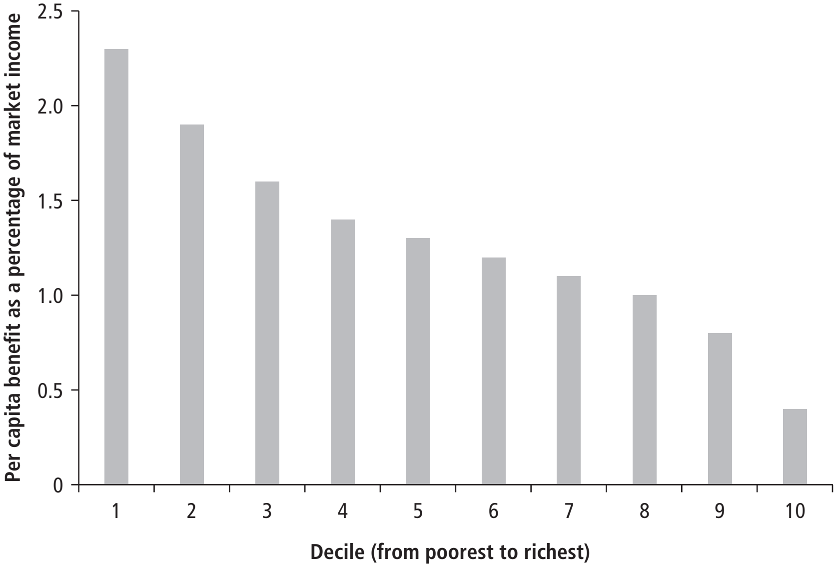
Box 2.5 (continued)

Figure B2.5.1 The Incidence of Extension Spending



Source: Household Consumption Expenditure Survey 2010/11.

Figure B2.5.1 shows the benefits received relative to the income of each decile, showing that spending as a share of market income is highest for the poorest decile. Extension spending comprises over 2 percent of income for the poorest decile. In figure B2.5.2, the progressivity of extension is compared to other government spending on social sectors using the analysis on the incidence of fiscal spending undertaken in Woldehanna et al. (2011). Sectors in which spending is progressive in both absolute and relative terms are those for which the Gini of spending is negative. Sectors in which spending is progressive in relative terms, but not in absolute terms (that is, not pro-poor) are those for which the Gini is positive but less than the Gini of market income. Sectors in which spending is regressive in both absolute and relative terms are those for which the Gini is positive and higher than the Gini of market income. Compared to other social spending, agricultural extension performs quite well. While it is not as progressive as spending on primary education, it is more progressive than spending on secondary education and about the same as spending on health. Subsidies are much less progressive than spending on agricultural extension programs.

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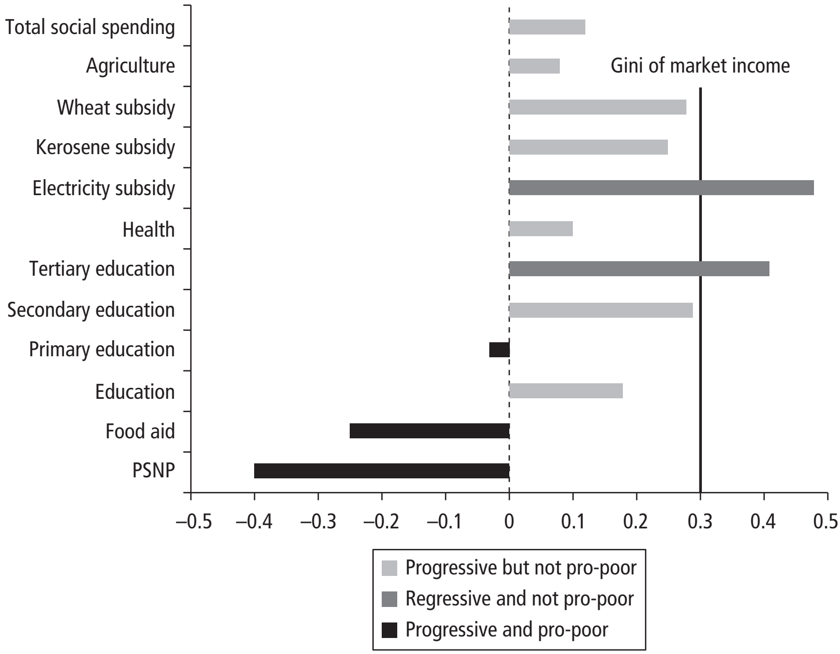
Box 2.5 (continued)

Figure B2.5.2 Comparison of Spending on Agriculture (Extension) and Other Social Spending



Note: PSNP = Productive Safety Net Program.
Source: Household Consumption Expenditure Survey 2010/11.

Public Spending Is Not Always Productive, However

This is a clear implication of the relatively low estimated elasticities, rates of return, and benefit-cost ratios from total agricultural expenditure compared with high benefits of certain categories of agriculture spending (Devarajan, Swaroop, and Zou 1996). In cases where aggregate spending has low or no measurable impact, this is presumably because the positive effects of effective spending are overwhelmed by the negative effects of ineffective spending. Spending can be unproductive or even reduce productivity of other spending for two basic reasons. First, governments sometimes spend on things that are not public goods. Studies that draw a distinction between public spending on public goods versus public spending on private goods, such as subsidies, empirically find the former to be much more productive and more effective in reducing poverty (see chapter 3) (López 2005; López and Galinato 2007). When governments supply private goods, there is a serious risk of displacing the private sector, which would generally be a more efficient provider. Second, even when there are clear failures in particular markets, government spending may not necessarily improve the situation. Inherent characteristics of government interventions can sometimes lead to "government failures," which may exacerbate the original problems caused by the market failure and produce unintended adverse ancillary effects (see chapter 5). We therefore turn below to new evidence on the returns to public spending on agriculture.

Returns to Agricultural Public Spending in Sub-Saharan Africa

This section provides updated evidence of the impacts of agricultural public spending by estimating the returns to public spending in Sub-Saharan Africa's agriculture sector, considering total agricultural spending versus agricultural research spending (box 2.6). We use data on 34 Sub-Saharan countries from 1980 to 2012. Details of the data, variables, and estimation methods are in annex 2A. As discussed earlier, there are various channels for the productivity effects of public agriculture spending to materialize, the effects are not the same for all types of spending, and the effects often materialize with a lag rather than contemporaneously.

Key Trends in Underlying Variables

Table 2.6 shows descriptive statistics of the variables used in the estimation, presented separately for the panel used to estimate the impact of total agricultural spending (34 countries from 1996 to 2012) and for the panel used to

BOX 2.6

Estimating Elasticities to Estimate Returns

Using a fixed effects (FE) model, we estimate an aggregate agriculture production function of two general forms: one that includes current and lagged values of total agricultural spending per hectare (gt_t, gt_{t-1}, …, gt_{t-5}), and another that includes current agricultural research spending per hectare (gr_t) and capital stock of agricultural research (sgr_t, which is derived from lagged values of *gr*). The effect of nonagricultural spending per capita (*ngt*) and other factors *x* are controlled for. The FE model addresses potential endogeneity of agricultural spending that may derive from unobserved, time-invariant variables, with instrumental variables on governance and political processes. Standard errors are estimated using three types of clusters—each country, different countries within the same agroecological zone, and different countries with the same number of years of participation in CAADP. Various statistical tests are performed to examine robustness, validity of the instruments, and multicollinearity of explanatory variables. The estimated elasticities with respect to spending are used to estimate the rate of return (ROR) for different countries.

Table 2.6 Summary Statistics, 1996–2012

	Panel for analyzing impact of total agricultural spending			Panel for analyzing impact of agricultural research spending		
	1996–2012	1996–2003	2004–12	1996–2011	1996–2003	2004–11
Agricultural value added, US$/ha (*y*)	158.72	140.74	174.69	154.05	140.02	167.02
Agricultural spending, US$/ha (*gt*)	6.48	4.47	8.25	6.98	4.94	8.86
Agricultural research spending, US$/ha (*gr*)	n.e.	n.e.	n.e.	1.00	0.96	1.03
Agricultural research capital, US$/ha (*sgr*)	n.e.	n.e.	n.e.	4.00	4.79	3.27
Nonagricultural spending, US$/capita (*ngt*)	257.21	224.18	286.56	289.48	254.90	321.42
Agricultural labor, number per hectare (*l*)	0.37	0.35	0.40	0.37	0.35	0.39
Agricultural capital, US$/ha (*k1*)	502.18	462.05	537.83	520.03	483.31	553.96
Fertilizer, kg/ha (*k2*)	2.79	2.59	2.97	3.52	3.48	3.55
Animal feed, kg/ha (*k3*)	59.64	48.09	69.90	67.19	57.72	75.94
Rainfall, mm (*R*)	1078.41	1074.38	1081.99	1013.82	996.68	1029.65
Irrigation, share (*I*)	0.01	0.01	0.01	0.01	0.01	0.01
Population density, number per sq km (*P*)	67.73	59.24	75.26	72.45	65.63	78.75
Technology, share (A)						
Low	0.24	0.25	0.24	0.20	0.19	0.22
Medium-low	0.27	0.27	0.27	0.28	0.31	0.26
Medium-high	0.26	0.27	0.26	0.32	0.34	0.30
High	0.23	0.22	0.24	0.19	0.16	0.22

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Table 2.6 (continued)

	Panel for analyzing impact of total agricultural spending			Panel for analyzing impact of agricultural research spending		
	1996–2012	**1996–2003**	**2004–12**	**1996–2011**	**1996–2003**	**2004–11**
Instruments (Z^G)						
Voice, −2.5 to 2.5	−0.67	−0.74	−0.61	−0.51	−0.57	−0.45
Law, −2.5 to 2.5	−0.81	−0.85	−0.76	−0.63	−0.64	−0.62
Regulation, −2.5 to 2.5	−0.66	−0.67	−0.64	−0.50	−0.49	−0.51
Stability, −2.5 to 2.5	−0.73	−0.82	−0.64	−0.59	−0.63	−0.55
Effectiveness, −2.5 to 2.5	−0.77	−0.76	−0.77	−0.63	−0.61	−0.65
Corruption, −2.5 to 2.5	−0.68	−0.68	−0.68	−0.57	−0.54	−0.59
Polity, −10 to 10	1.55	0.78	2.22	2.33	1.48	3.12
Durability, years	8.60	6.33	10.62	8.48	6.74	10.09
Number of observations	576	576	576	354	354	354
Number of countries	34	34	34	23	23	23

Source: Benin 2015.
Note: See annex 2B for detailed descriptions of variables. US$ is expressed in 2006 constant prices. n.e. = not estimated, since data were not available for some countries in panel.

Table 2.7 Determinants of Agricultural Spending in Sub-Saharan Africa, 1996–2012

	Agricultural spending, US$/ha (*gt*)		Agricultural research spending, US$/ha (*gr*)			
	Model 1	Model 2	Model 1	Model 2	Model 3	Model 4
Lags of agricultural spending						
gt_{t-1}	0.58 ***	0.57 ***	—	0.10 ***	—	0.08 **
gt_{t-2}	0.01	0.01	—	—	—	—
gt_{t-3}	–0.06	–0.06	—	—	—	—
gt_{t-4}	0.04	0.04	—	—	—	—
gt_{t-5}	–0.07 *	–0.07 *	—	—	—	—
Elasticity	0.49 ***	0.49 ***	—	—	—	—
Agricultural research capital (*sgr*)	—	—	0.52 ***	0.49 ***	0.54 ***	0.52 ***
Nonagricultural spending (*ngt*)	0.44 ***	0.44 ***	–0.02	–0.02	–0.02	–0.02
Lag of agricultural valued added (y_{t-1})	—	–0.06	—	—	–0.59 ***	–0.56 ***
Instruments (Z^G)						
Stability	0.15 ***	0.15 ***	—	—	—	—
Polity	—	—	0.03 ***	0.03 ***	0.03 ***	0.03 ***
Overall model statistics						
R-squared	0.74	0.74	0.20	0.22	0.26	0.27
F-statistic	82.21 ***	77.57 ***	5.99 ***	6.28 ***	7.98 ***	7.84 ***
IV tests						
Spending is exogenous (χ^2 statistic)	2.22	0.28	0	0.02	0.21	0.22
Underidentified (χ^2 statistic)	15.58 ***	15.58 ***	15.90 ***	16.94 ***	15.72 ***	16.51 ***
Instrument is weak (F-statistic)	15.53 ***	16.39 ***	16.05 ***	17.10 ***	15.80 ***	16.59 ***

Source: Benin 2015.
Note: See annex 2B for detailed description of variables. IV tests of the null hypothesis that: spending is exogenous using the Sargan-Hansen χ^2 statistic; underidentified = rank of matrix of first-stage reduced-form coefficients is underidentified, using the Anderson or Kleibergen-Paap Lagrange multiplier test with the χ^2 statistic; and weak = first-stage reduced-form equation is weakly identified using the Cragg-Donald or Kleibergen-Paap Wald test with the F-statistic. — = variable omitted from regression.
Significance level: * = 10 percent, ** = 5 percent, *** = 1 percent.

estimate the impact of agricultural research spending (23 countries from 1996 to 2011). For all the 34 countries, annual average agricultural value added per hectare (that is, land productivity) was US$159 in 1996–2012, rising by 24 percent from $141 in 1996–2003 (pre-CAADP period) to US$175 in 2004–12 (during CAADP).[8] Agriculture spending per hectare almost doubled from US$4.50 in 1996–2003 to US$8.30 in 2004–12. These represent an increase in the share of agriculture spending in total spending from 2.0 percent to 2.8 percent, respectively, far lower than the 10 percent Maputo Declaration target. Agricultural research spending per hectare remained stagnant at US$1, which represents a decline in the share in total agricultural spending from 19 percent in 1996–2003 to 12 percent in 2004–11.

For spending intensities, agricultural spending as a share of agricultural value added increased from 3.2 percent in 1996–2003 to 4.7 percent in 2004–12, whereas agricultural research spending as a share of agricultural value added declined from 0.7 percent in 1996–2003 to 0.6 percent in 2004–12. For other variables—with the exception of rainfall and irrigation, whose averages remained stagnant over the two subperiods—the data on labor, capital, fertilizer, animal feed, and population density show an increase between 14 percent and 45 percent. For technology, there is little change in the distribution of countries over time.

Table 2.7 shows the determinants of agriculture public spending. The results are consistent in different model specifications, involving exclusion or inclusion of the lag of value added per hectare (y_{t-1}) in the estimation of both the impact of total agricultural spending (*gt*) and agricultural research spending (*gr*), and exclusion or inclusion of the lag of total agricultural spending (gt_{t-1}) in the estimation of the impact of agricultural research spending (*gr*).

Sensitivity of Productivity to Agricultural Public Spending

Table 2.8 shows detailed results of the regression estimates, using different model specifications.[9] The model specification that includes the lag of value added per hectare (y_{t-1}) gives much higher explanatory power, with *R*-squared values ranging from 0.77 to 0.92 and an *F*-statistic of 89.3, compared with specification without it, with *R*-squared values ranging from 0.57 to 0.71 and an *F*-statistic of 38.27. The total elasticity to agricultural spending per hectare is estimated at 0.04, which is consistently estimated with the specification that includes the lag of value added per hectare and whether the standard errors are clustered. This means that a 1 percent increase in agricultural spending per hectare is associated with a 0.04 percent increase in agricultural value added per hectare. Compared with findings from other cross-country studies, this is lower than the estimated elasticity of 0.08 in Fan, Yu, and Saurkar (2008), for example.

Table 2.8 Impact of Total Agricultural Spending on Agricultural Value Added per Hectare in Sub-Saharan Africa, 1996–2012

	FE model 1					FE model 2				
Agricultural spending										
gt_t	–0.01					0				
gt_{t-1}	–0.01					0.01				
gt_{t-2}	0.03		r	c	a	0.02				a
gt_{t-3}	–0.03		r	c	a	–0.03	*	r	c	a
gt_{t-4}	0					0.01				
gt_{t-5}	0.07	***	r	c	a	0.04	***	r	c	a
Elasticity	0.04	**				0.04	**	r	c	a
Nonagricultural spending (*ngt*)	–0.08	***	r	c	a	–0.01				
Lag of agricultural valued added (y_{t-1})						0.65	***	r	c	a
Intercept	2.36	***				0.36				
Overall model statistics										
R-squared (within)	0.57					0.77				
R-squared (between)	0.71					0.93				
R-squared (overall)	0.70					0.92				
F-statistic	38.27	***	r			89.29	***	r		

Source: Benin 2015.
Note: See annex 2B for detailed description of variables. *R, c,* and *a* represent statistical significance at the 10 percent level for clustered standard errors by country (*r*), countries with the same years of participation in CAADP (*c*), and countries within the same agroecological zone (*a*).
Significance level for nonclustered standard errors: * = 10 percent, ** = 5 percent, *** = 1 percent.

Table 2.9 shows detailed results of the regression estimates, again for different specifications (exclusion or inclusion of the lag of value added per hectare, y_{t-1}) and for clustering the standard errors by different variables. Basically, the model specification that includes the lag of value added per hectare gives much higher explanatory power; including the lag of value added per hectare, however, absorbs the effects of several of the other explanatory variables, particularly capital, fertilizer, rainfall, irrigation, population density, and technology. In addition, exclusion or inclusion of the lag of total agricultural spending (gt_{t-1}) has no effect on the estimates.

The total elasticity of land productivity to agricultural research spending per hectare is estimated at 0.09, implying that a 1 percent increase in agricultural research spending per hectare is associated with a 0.09 percent increase in agricultural value added per hectare or land productivity. Compared with other cross-country studies for example, this is lower than the estimated elasticity of 0.17 in Alene and Coulibaly (2009) and 0.36 in Thirtle, Piesse, and Lin (2003), but higher than 0.04 in Fan, Yu, and Saurkar (2008). The estimated elasticities to agricultural public spending are in tables 2.9 and 2.10.

Table 2.9 Impact of Agricultural Research Spending on Agricultural Value Added per Hectare in Sub-Saharan Africa, 1996–2011

	FE model 1					FE model 2					FE model 3					FE model 4				
Agricultural research spending (*gr*)	–0.06	***				–0.06	**				0.02					0.02				
Agricultural research capital (*sgr*)	0.14	***	r	c	a	0.15	***	r	c	a	0.08	**	r	c	a	0.08	**	r	c	a
Total elasticity[‡]	0.08	**				0.09	**				0.09	***	r	c	a	0.09	***	r	c	a
Lag of agricultural spending (gt_{t-1})	—					–0.03					—					0				
Nonagricultural spending (*ngt*)	0.01					0.01					0.01					0.01				
Lag of agricultural valued added (y_{t-1})	—					—					0.63	***	r	c	a	0.63	***	r	c	a
Intercept	–0.90					–1.40				a	–0.85					–0.91				
Overall model statistics																				
R-squared (within)	0.54					0.54					0.73					0.73				
R-squared (between)	0.83					0.84					0.97					0.97				
R-squared (overall)	0.83					0.83					0.96					0.96				
F-statistic	27.89	***	r			26.18	***	r			60.54	***	r			56.34	***	r		

Source: Benin 2015.
Note: See annex 2B for detailed description of variables. FE = fixed effects. *R, c,* and *a* represent statistical significance at the 10 percent level for clustered standard errors by country (*r*), countries with the same years of participation in CAADP (*c*), and countries within the same agroecological zone (*a*). — = variable omitted from regression. Significance level for nonclustered standard errors: * = 10 percent, ** = 5 percent, *** = 1 percent.

Table 2.10 Rates of Return to Total Agricultural Public Spending in Sub-Saharan Africa, 1996–2012

	Agricultural spending, annual average (US$/ha)	Agricultural value added, annual average (US$/ha)	ROR (%)
Sub-Saharan Africa	6.48	158.72	11
Country			
Angola	3.14	45.03	1
Benin	17.44	430.19	11
Botswana	5.83	10.04	–25
Burundi	3.95	211.97	34
Cameroon	10.82	364.37	19
Central African Republic	1.40	136.37	65
Chad	0.27	51.68	128
Congo, Dem. Rep.	2.73	138.67	32
Congo, Rep.	1.89	31.17	3
Côte d'Ivoire	5.47	210.79	23
Ethiopia	8.11	143.33	5
Gambia, The	12.83	265.05	8
Ghana	4.59	230.11	32
Guinea	3.18	43.46	0
Guinea-Bissau	0.66	177.18	179
Kenya	6.39	176.93	14
Liberia	0.19	148.19	507
Madagascar	1.71	32.04	6
Malawi	18.65	176.57	–6
Mali	3.18	46.74	1
Mozambique	1.57	33.94	9
Namibia	3.20	16.45	–14
Niger	2.59	32.57	–1
Nigeria	8.52	413.59	31
Rwanda	12.77	525.39	25
Senegal	16.00	137.60	–7
Sierra Leone	5.39	254.55	30
South Africa	11.75	73.00	–11
Sudan	2.01	61.42	17
Swaziland	22.25	167.23	–9
Tanzania	4.62	142.81	17
Togo	6.42	226.00	20
Uganda	4.67	186.26	24
Zambia	5.47	48.73	–7

Source: Benin 2015.
Note: CAADP = Comprehensive Africa Agriculture Development Programme; ROR = rate of return.

ROR to Agricultural Public Spending

Based on the estimated elasticities of 0.04 and 0.09 for total agricultural spending and agricultural research spending, respectively, the ROR was calculated for all the countries together, countries with the same number of years of participation in CAADP, countries within the same agroecological zone, and then separately for individual countries. Ideally, the rates of return for the different groups of countries as well as for the individual countries should be based on group-specific and country-specific elasticities, which we are not able to estimate due to data limitations. Because the same estimated elasticities are used for the different groups and individual countries, the main factor driving the differences in the rates of return across the groups and countries are the differences in the ratios of value added to spending (see equation [2B.4] in annex 2B). The estimated rates of return, in addition to the annual average value added and spending, are in table 2.10 for the returns to total agricultural spending and table 2.11 for the returns to agricultural research spending.

Table 2.11 Rates of Return to Public Spending on Agricultural Research in Sub-Saharan Africa, 1996–2011

	Agricultural research spending, annual average (US$/ha)	Agricultural value added, annual average (US$/ha)	ROR (%)
Sub-Saharan Africa	1.00	154.05	93
Country			
Benin	2.09	423.45	123
Botswana	0.40	9.79	9
Burundi	1.09	209.42	116
Congo, Rep.	0.21	31.16	91
Côte d'Ivoire	1.08	210.13	118
Ethiopia	0.44	136.36	186
Gambia, The	2.48	264.36	64
Ghana	1.38	228.66	100
Guinea	0.14	43.35	183
Kenya	2.05	172.24	50
Madagascar	0.09	31.70	225
Malawi	1.50	174.96	70
Mali	0.34	45.60	81
Namibia	0.52	17.73	17
Nigeria	1.41	408.21	175
Senegal	1.34	135.86	61

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Table 2.11 (continued)

	Agricultural research spending, annual average (US$/ha)	Agricultural value added, annual average (US$/ha)	ROR (%)
Sierra Leone	0.58	258.94	270
South Africa	1.68	73.14	24
Sudan	0.13	61.42	287
Tanzania	0.54	145.38	162
Togo	1.12	221.16	119
Uganda	1.61	180.17	67
Zambia	0.29	48.06	98

Source: World Bank calculation based on model results.
Note: CAADP = Comprehensive Africa Agriculture Development Programme; ROR = rate of return.

Returns to Total Agricultural Spending

The results in table 2.10 show that total agricultural spending in Sub-Saharan Africa has an aggregate ROR of 11 percent, which is generally increasing with the number of years that countries have been participating in CAADP.

In general, countries with low or negative rates of return are those with high spending-to-value-added ratios, particularly those with ratios in excess of 10 percent including the group of countries that have yet to sign on to CAADP (ratio of 21 percent), the group of countries in the cool areas (16 percent), Botswana (58 percent), Malawi (16 percent), Namibia (19 percent), Senegal (12 percent), South Africa (16 percent), Swaziland (13 percent), and Zambia (11 percent). Similarly, groups of countries or individual countries with high rates of return are those with low spending-to-value-added ratios, particularly those with ratios of not more than 2 percent, including several countries emerging from civil war such as Liberia, Rwanda, and Sierra Leone.

Returns to Agricultural Research Spending

The results in table 2.10 show that the returns to agricultural research spending are much higher than the returns to total agricultural spending. The aggregate ROR to agricultural research spending is estimated at 93 percent, which is higher than the estimated ROR of 22 percent in Thirtle, Piesse, and Lin (2003) and 55 percent in Alene and Coulibaly (2009). The calculation of the ROR in Alene and Coulibaly (2009), for example, assumes a period of five years between initiation of research and the beginning of flow of benefits and, thus, imposes the constraint that the first five elasticity coefficients are jointly zero, contrary to what was estimated. Given that the estimated coefficients on all of research spending variables (one current and 1-year through 16-year lags) were statistically significant, the ROR would have been about 600 percent if the constraint was not imposed. Thirtle, Piesse, and Lin (2003) considered only the benefits in the fifth year following the research spending in their calculation of the ROR.

If a cumulative benefit method had been used, the estimated ROR would have been much higher than the 22 percent reported. The returns are also estimated for different groups of countries by the number of years of participation in CAADP and by agroecological zone.

As with the returns to total agricultural spending, groups of countries or individual countries with low rates of return are those with high research spending-to-value-added ratios, particularly those with ratios in excess of 2 percent, including the group of countries that have yet to sign on to CAADP, the group of countries in the cool areas, Botswana, Namibia, and South Africa. Similarly, countries with high rates of return are those with low spending-to-value-added ratios, particularly those with ratios of not more than 0.5 percent, including Ethiopia, Guinea, Madagascar, Nigeria, Sierra Leone, Sudan, and Tanzania.

Overall, the higher returns to agricultural research spending (aggregate ROR of 93 percent) compared with the returns to total agricultural spending (aggregate ROR of 11 percent) reflect the low and declining research spending intensities in the continent. For the 23 countries taken together, agricultural research spending as a share of agricultural value added declined from 0.7 percent in 1996–2003 to 0.6 percent in 2004–2012, which is far from the 1 percent targeted by the African Union's NEPAD. Furthermore, agricultural research spending on the continent, compared with other developing regions, has been highly volatile, due to low government funding and high dependence on short-term and ad hoc donor and other external funding (Stads and Beintema 2015).

Conclusion

Between 1980 and 2012, total agricultural spending in Africa increased at an average rate of 0.8 percent a year and constituted 4 percent of total spending (far below the CAADP 10 percent spending target) and 4.7 percent of agricultural valued added. The data on different types of agricultural spending, which are limited to nine countries from 2006 to 2013, show that agriculture spending in general had a narrow scope as expenditures on input subsidies and extension seemed to dominate in many countries. In contrast, spending on irrigation and marketing were relatively neglected, and spending on research was the least and accounted for less than 8 percent of the total agricultural spending in these countries.

Earlier evidence on the impact of agricultural spending in Africa showed that in the aggregate, a 1 percent increase in total agricultural spending is associated with a 0.1–0.3 percent increase in agricultural output or productivity. Regarding spending on different agricultural functions, the estimated returns are 22–55 percent for research, 8–49 percent for extension, and 11–22 percent for irrigation. Existing estimates of the returns to spending on agricultural marketing are complicated because public spending is bundled either with private-sector investment or with nonagricultural sector functions. For subsidies, poor targeting of subsidy programs has generally crowded out the use of counterpart commercial inputs and has negatively affected overall returns.

With new evidence on the returns to agricultural public spending in Sub-Saharan Africa, the aggregate return to total agricultural spending in Sub-Saharan Africa is estimated at 11 percent. The aggregate return to agricultural research spending is estimated at 93 percent, but the estimated returns vary substantially across countries and groups of countries. In general, the return to total agricultural spending was increasing with the number of years that countries have been participating in CAADP, with some observed variation by agroecological zones as well. There has been considerable experimentation with research models in Africa, and taking advantage of lessons from this experience can help raise the returns to this kind of investment in the future (box 2.7).

BOX 2.7

Lessons of Experience for Advancing Agricultural Research in Africa

Improving productivity growth in Africa will require revitalizing science and technology systems for agriculture. Even within the spending category of research, it is important to put each dollar to its most productive use. Doing this requires understanding the current status of research systems on the continent and identifying useful lessons to move the science and technology agenda forward regionwide.

For now, most investments in agricultural science and technology in Africa come from the public sector—well over 90 percent, as contrasted with a figure that has fallen below 50 percent in Europe and North America. In Africa, most public support for agricultural science and technology is through programs and institutions that belong to ministries of agriculture. Such public agricultural research systems in

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Box 2.7 (continued)

Africa have often stagnated. Since 2000, while investment in public R&D has grown by 20 percent across the region as a whole, the increases are concentrated in just a few countries (mainly Ethiopia, Kenya, Nigeria, and South Africa). Most national public agricultural research institutions and programs across the rest of the continent have declined, and they lack the resources to maintain a broad research portfolio.

Strategic leadership for agricultural research on the continent has been established through the CAADP and the Forum for Agricultural Research in Africa and its associated subregional agricultural research organizations. Among the areas of emphasis from these sources is developing regional collaboration in agricultural research. And research initiatives reflecting regional planning and approaches have expanded from less than 1 percent of all agricultural research activity to nearly 15 percent in the last several years.

The main lessons that are emerging from recent experience include the following:

- *Small national research programs should focus on areas of comparative advantage.* To remain relevant and viable, these smaller country-based research programs are most effective when they focus on and build unique expertise in a selective set of thematic topics that are particularly well-suited for, and are of highest priority, in their locations (bananas and cassava in Uganda, rice in Mali, cocoa in Ghana, and maize in Malawi). Such systems may also focus on adaptation and adoption for a wide variety of crops and livestock.
- *Regional approaches and planning improve efficiency and relevance*. Successful examples are the West Africa Agricultural Productivity Program and the East Africa Agricultural Productivity Program, with coordination from corresponding subregional organizations: West and Central Africa Council for Agricultural Research and Development (CORAF) and the Association for Strengthening Agricultural Research in East and Central Africa (ASARECA).
- *Expanding coordination with CGIAR programs.* Greater participation of African programs in CGIAR planning and priority setting, and greater participation by CGIAR centers in agricultural planning in Africa produces more relevant plans and more synergies in execution, under the CAADP-led Dublin process.
- *Agricultural universities and public agricultural research programs need to be closely linked.* Creating critical mass in staff and equipment enhances the quality of training for graduate students, and reduces the fragmentation of effort. Uganda and South Africa each feature shared research programs, shared laboratories and equipment, and joint appointments—and graduate students do some of their research under the guidance of staff at research organizations.
- *Coordinating public, private, donor-led, and NGO initiatives can enhance coherence and effectiveness.* The Alliance for a Green Revolution in Africa and its support for cocoa and rice research in West Africa show how partnerships can improve strategic

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Box 2.7 (continued)

planning and the implementation of common research and capacity building. Pooled donor funding for core budget support to subregional organizations can also help. Documenting the outcomes and impacts of agricultural research is critical to maintain funding.

- *Close links with agricultural extension systems and farmers are essential to facilitate adoption of research findings and to enhance the relevance of research.* In Ethiopia and Nigeria (and many other places on a small scale), researchers regularly develop and implement applied research programs with farmers in the field. They also work together to evaluate results over time and to plan follow-on research.

Annex 2A: Synthesis of Impacts of Agricultural Public Spending in Africa

The fundamental notion underlying the productivity effects of public spending is that public and private capital are complements in production, so that an increase in public spending leads to an increase in the public capital stock, which raises the productivity of private capital and other factors in production (Aschauer 1989; Barro 1990). We categorize the productivity effects according to four pathways of impact: technology advancing, human capital enhancing, transaction cost reducing, and private capital crowding. The evidence from past research on these pathways is summarized in table 2A.1.

Technology-advancing productivity effects typically derive from the yield-enhancing technologies of public spending in agricultural R&D.[10] Several studies (for example, Alene and Coulibaly 2009; Alene et al. 2009; Fan, Nyange, and Rao 2012; Fan, Yu, and Saurkar 2008; Fan and Zhang 2008; Fuglie and Rada 2013; Meenakshi et al. 2010; Thirtle, Piesse, and Lin 2003) show that the returns to agricultural research are substantially high in the range of 22–55 percent. As the summary of the studies shows, the bulk of the research on the impact of agricultural spending has focused on research spending.[11] The studies however do vary in many ways, including methodology, country and time series coverage, level and measure of research spending, and outcome indicators on which the impact is estimated.

On the outcome variable, for example, some indicators used include agricultural output, measured at the household level (for example, Fan, Gulati, and Thorat 2008) or national level (Thirtle, Piesse, and Lin 2003), and whether in

Table 2A.1 Estimated Elasticities, Rates of Return, and Benefit-Cost Ratios for Different Types of Agricultural Spending in Africa

Source	Years of spending data	Outcome variable and measure	Type or measure of spending	Elasticity	ROR (%) or BCR	Region or country	Number of countries/units
Evenson 2001	—	Various	Research	n.e.	Mean ROR = 43	Africa	44[a]
Thirtle, Piesse, and Lin 2003	1980–95	agGDP/ha	Research	0.36	ROR = 22	Sub-Saharan Africa	22
Fan, Yu, and Saurkar 2008	1980–2002	Agricultural output index	Research	0.04	n.e.	Africa	17
Fan and Zhang 2008	1982–99	Household agricultural output per capita	Research and extension	0.19	BCR = 12.4	Uganda	1
Alene and Coulibaly 2009	1980–2003	agGDP/ha	National and CGIAR research	0.38	ROR = 55	Sub-Saharan Africa	27
			National research	0.17	n.e.		
			CGIAR research	0.21	n.e.		
Alene et al. 2009	1971–2005	agGDP	National and CGIAR maize research	n.e.	ROR = 43	West and Central Africa	8–12
Meenakshi et al. 2010	—	DALYs saved	Biofortification research, breeding, maintenance, etc.	n.e.	BCR = 2–66	Sub-Saharan Africa	5
Fan, Nyange, and Rao 2012	1986–99	Total household income	Research	n.e.	BCR = 12.5	Tanzania	1

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Table 2A.1 (continued)

Source	Years of spending data	Outcome variable and measure	Type or measure of spending	Elasticity	ROR (%) or BCR	Region or country	Number of countries/units
Fuglie and Rada 2013	1961–2006	TFP	National research	0.04	ROR = 24–29	Sub-Saharan Africa	28
			CGIAR research	0.04	ROR = 55		
Evenson 2001	—	Various	Extension	n.e.	Mean ROR = 30	Africa	10[a]
Benin et al. 2011	2001–07	Household revenue per capita	Extension	n.e.	ROR = 8–49	Uganda	1
Wellard et al. 2013	2004–08	Staple crops	Extension	n.e.	BCR = 7.7	Ghana	1
	2002–11				BCR = 6.8–11.6	Malawi	1
	2004–08				BCR = 14.2	Uganda	1
Fan and Zhang 2008	1982–99	Household agricultural output per capita	Feeder roads	n.e.	BCR = 7.2	Uganda	1
Dixie and Tyler	1948–97	Equity value	Agroprocessing	—	ROR > 12		11[b]
2013					ROR = 0–12		11[b]
					ROR = −25–0		9[b]
					ROR < −25		53[b]
Inocencio et al. 2007	1967– 2003		Irrigation, new	n.e.	ROR = 11	Sub-Saharan Africa	45[b]
	1967– 2003		Irrigation, rehab		ROR = 14		

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Table 2A.1 (continued)

Source	Years of spending data	Outcome variable and measure	Type or measure of spending	Elasticity	ROR (%) or BCR	Region or country	Number of countries/units
	1970s		Irrigation, rehab		ROR = 4		
	1980s		Irrigation, rehab		ROR = 13		
	1990s		Irrigation, rehab		ROR = 22		
	1967– 2003		Irrigation, new		ROR = 14	North Africa	39[b]
	1967– 2003		Irrigation, rehab		ROR = 17		
Fan, Yu, and Saurkar 2008	1980–2002	Agricultural output index	Nonresearch	–0.07	n.e.	Africa	17
Fan, Yu, and Saurkar 2008	1980–2002	Agricultural output index	Total agriculture	0.08	n.e.	Africa	17
Mogues 2011	1993–2001	Household consumption spending per capita	Total agriculture	0.04–0.06 n.s.	n.e.	Ethiopia	1
Benin et al. 2012	2002–06	Household agricultural output per capita	Total agriculture per capita	0.22–0.26	BCR = 3.5–4.2	Ghana	1

Source: World Bank illustration based on cited sources.
Note: agGDP = agricultural valued added; BCR = benefit-cost ratio; CGIAR = Consultative Group on International Agricultural Research; DALY = disability-adjusted life year; n.e. = not estimated; n.s. = elasticity not statistically significant; ROR = rate of return; TFP = total factor productivity; — = not available or not applicable.
a. Indicates number of rates of return reported and included in the review.
b. Indicates number of projects included in the review.

level terms (Alene et al. 2009), partial factor productivity (Alene and Coulibaly 2009; Fan and Zhang 2008), or total factor productivity (Fuglie and Rada 2013). Other outcomes include income (Fan, Nyange, and Rao 2012), poverty (Alene and Coulibaly 2009; Thirtle, Piesse, and Lin 2003), and nutrition and health (Meenakshi et al. 2010). On the type and measure of research, most have been on national and international research (for example, Alene and Coulibaly 2009; Fuglie and Rada 2013; Thirtle, Piesse, and Lin 2003). Others have been narrower on specific commodities, such as maize research in the Alene et al. (2009) study, or on the type of research, such as biofortification in the Meenakshi et al. (2010) study.

On methods, most studies cited previously have used ex-post analysis and some have used ex-ante analysis (Meenakshi et al. 2010). Because the productivity effects or impacts of agricultural R&D investments tend to materialize with a long lag and can persist long afterward, different studies have used different approaches. Thirtle, Piesse, and Lin (2003), for example, consider a 5-year lag of agricultural R&D investments whereas Alene et al. (2009) consider a 16-year lag. The choice of the lag length is influenced by the length of the time series data used, with longer lag lengths being used in studies that have longer time series data. Because of these and other differences, each study tends to be unique, which limits their comparability for identifying the specific estimate of the ROR to agricultural research spending. The study by Evenson (2001), for example, reviews several studies on the impacts of research and extension, which show many of the differences discussed earlier. Of the 375 rates of return reported globally that could be classified by region, 44 were in Africa with a mean ROR of 43 percent.[12]

The human capital enhancing productivity effects derive typically from public spending in agricultural education and extension that raises the knowledge and skills of farmers and those engaged in agricultural production. This is important for successful agricultural enterprises because agricultural production tends to be complex and is increasingly becoming knowledge-intensive, considering precision agriculture and the use of information and communications technology, for example. Unfortunately, there are not many new studies estimating rates of return or benefit-cost ratios to extension in Africa.

The bulk of the studies were carried out in the 1980s and 1990s and are reviewed in the studies by Evenson (2001), for example. As with the review of the impacts of research done by Evenson (2001), there were 81 rates of return reported globally that could be classified by region. Ten were in Africa with a mean ROR of 30 percent.[13] The reviews by Evenson (2001) and Alston et al. (2000) highlight concern over data quality and cause-and-effect methodological issues, questioning the reliability of the moderate to high estimated returns to spending on extension. For example, the estimated large positive returns to extension spending in Kenya in the 1980s by Bindlish and Evenson (1997) were later found to be grossly overestimated with careful modeling of the confounding factors, but were included in the estimation by Gautam and Anderson (1999).

Recent studies on the impact of extension in Africa include Benin et al. (2011) on Uganda and Wellard et al. (2013) on Ghana, Mali, and Uganda. The study by Benin et al. (2011) found low to moderate returns, 8–49 percent, to spending on the national agricultural extension program depending on different assumptions of the treatment of the program and other factors. The study by Wellard et al. (2013) looks at the effect of different community-based and farmer-to-farmer extension approaches, with estimated cost-benefit ratios of 7.7 in Ghana, 6.8–11.6 in Malawi, and 14.2 in Uganda. In general, public spending on rural education, health, water, sanitation, and so on, by making the rural labor force more literate and healthier, may increase human capital accumulation in agricultural production (Schultz 1982). This is shown in the study by Fan and Zhang (2008), for example, which finds a significant positive effect of public education spending on agricultural productivity. Similar to agricultural R&D investments, human capital productivity effects materialize with a lag and can persist long afterward. Fan, Yu, and Saurkar (2008), for example, consider a 7-year lag of spending on agricultural extension in Uganda.

The transactions–cost reducing productivity effects are expected to derive from public spending on marketing infrastructure in the agricultural sector (for example, storage facilities, information, processing, and feeder roads) that contributes to improving access to input and output markets, reducing the cost of or increasing the returns to agricultural inputs and technologies, for example. Transactions cost is important, since it drives whether or not markets are integrated, thin, or fail (Sadoulet and de Janvry 1995). By facilitating the movement of goods and services and reducing the cost of doing business, public investment in rural infrastructure (such as roads, bridges, transportation, and energy) may raise the productivity of other forms of capital in agricultural production.

Unfortunately, estimates of the returns to public spending on agricultural marketing infrastructure are complicated, since the public spending is bundled with private-sector investment or with nonagricultural sector functions. For example, Dixie and Tyler (2013) analyze 122 agribusinesses established in Africa at different periods from 1948 to 1997 that were involved mostly with processing for export (especially palm oil, sugar, and tea). They also involved different public-private partnerships with the Commonwealth Development Corporation. There were 84 on which equity returns were assessed, and 22 had some positive ROR, with eleven having an ROR of up to 12 percent and the other 11 having an ROR greater than 12 percent. The remaining 62 had negative returns, with most (53) having losses of more than 25 percent. These estimates are the aggregate or average for the combined public and private investment, and the key to addressing the bundling is isolating the specific public-sector role and related spending and benefits, knowing that the returns to those specific parts may be greater or lower than the average or aggregate estimate.

Regarding the bundling with nonagricultural sector functions, a typical example is the study by Fan and Zhang (2008), which assesses the impact of feeder roads spending on agricultural output in Uganda. It finds that the benefit-cost ratio of investing in feeder roads is 7.2. Because feeder roads or rural roads have nonagricultural sector functions (such as enhancing the provision of education and health services), counting all spending on such roads overestimates the cost, which has similar implications for the returns to the agriculture-specific spending parts as discussed earlier for the agribusinesses.

Several studies assess the productivity or growth impact of infrastructure spending in Africa in general, which has indirect effects on improving markets or reducing transaction costs in the economy. Mogues (2011) and Benin et al. (2012) find significant positive effects of public spending on road infrastructure on agricultural productivity and household consumption spending. Different types of infrastructure have different impacts. The Fan and Zhang (2008) study on Uganda, for example, finds that the return to spending on feeder roads was three to four times higher than the return to spending on laterite, gravel, or tarmac roads. Similarly, different rates of return to different types of economywide infrastructure development in Sub-Saharan Africa have been reported—for example, 5 percent for railway rehabilitation, 17 percent for road upgrade, 24 percent for road rehabilitation, and 17 percent and 139 percent for road maintenance (Foster and Briceño-Garmendia 2010).

The crowding-in productivity effects of agricultural public spending on private capital are a commonly advanced rationale used to advocate for larger public spending on the sector. By raising the productivity of all factors in production, an increase in public spending is expected to cause an increase in private capital to the extent that public and private investment are complements. For example, public investment in dams and canals for irrigation is expected to increase private investment in irrigation systems on the farm, as shown in the study by Fan, Hazell, and Thorat (2000) on India. The importance of irrigation stems from the fact that high-yielding technologies (improved seeds, inorganic fertilizers, pesticides) require specific amounts of water at specific periods of plant growth, development, and flowering, which is risky under rainfed agriculture alone. Excessive irrigation can also be detrimental.

On the returns to public investment in irrigation, Inocencio et al. (2007) review 84 irrigation projects implemented in Africa (45 in Sub-Saharan Africa and 39 in the Middle East and North Africa) from 1967 to 2003 supported by the World Bank, African Development Bank, and International Fund for Agriculture Development. The projects involved different irrigation systems, with river diversion and river lift (or pond or lake) systems being the most common. For the ones in Sub-Saharan Africa, the estimated average ROR is 11 percent for the projects involving new developments and 14 percent for those involving rehabilitation. Those in the Middle East and North Africa had slightly higher returns: 14 percent for the projects involving new developments and 17 percent for those involving rehabilitation. The crowding-in effect is seen through the relative percentage contribution of donors, government, and farmers to the funds for the projects in Sub-Saharan Africa: 49-34-17, respectively, in the 1970s; 69-23-8, respectively, in the 1980s; and 28-15-57, respectively, in the 1990s.

The impact of the public-private partnerships in the agribusinesses discussed above also fits the crowding-in pathway. On the other agricultural functions, for example, Malla and Gray (2005) and Görg and Strobl (2006) find significant crowding-in effects of public R&D on private R&D in the United States and Ireland, with estimated elasticities in the range of 0.10 to 0.28. Typically, these involve the government subsidizing some private sector activities. Similar crowding-in arguments have been made for input subsidies in African agriculture, which involve subsidizing the price of the input sold in the market—especially for chemical fertilizers and mechanical equipment. In many cases, however, public spending on such subsidies have not increased overall use of the input, because poor targeting of the programs has crowded out use of commercial inputs since the bulk of the subsidized inputs has been provided to farmers who would have purchased them regardless (Jayne et al. 2013). Specific estimates of the return to spending on these programs in Africa is lacking.

The broader literature on public investment analysis also shows that not all types of public spending are productive (Devarajan, Swaroop, and Zou 1996). The relatively low estimated elasticities, rates of return, or benefit-cost ratios associated with total agricultural spending (Fan, Yu, and Saurkar 2008; Mogues 2011; Benin et al. 2012) or nonresearch spending (Fan, Yu, and Saurkar 2008)—compared with those for research, irrigation, extension, feeder roads, and so on—supports this (table 2A.1). In fact, the estimated impact of agriculture spending in Mogues (2011) was not statistically significant, but the estimated impact of nonresearch spending in Fan, Yu, and Saurkar (2008) was negative. Much spending is spent on salaries and other recurrent items, suggesting this type of spending may be less productive. For agricultural subsidies, for example, there are indirect price effects that may restrict or encourage production and supply of particular agricultural inputs and commodities. Thus, public spending on such subsidies rarely creates any productive capital, so the link with productivity is often weak. But the high rates of return shown for certain activities that likely involve large current spending as opposed to capital spending, for example, 139 percent for road maintenance (Foster and Briceño-Garmendia 2010), also suggest that not all current spending is unproductive.

Together, these findings of heterogeneous effects of different spending choices point to the need to identify and prioritize high-impact parts of agricultural spending. But this will be difficult to do comprehensively based on evidence assembled so far. This is because the underlying studies vary in many aspects (including methodology, country and time series coverage, and level and measure of spending and impact indicators), which limits their comparability for ranking different spending types, and for understanding how the impacts have evolved. The study by Fan, Gulati, and Thorat (2008) on India provides an example of the nature of evidence that is extremely useful for prioritizing investments (results shown in table 2A.2). It estimates returns in agricultural GDP and poverty reduction to public spending in agricultural R&D, irrigation, and fertilizer and credit subsidies as well as spending in rural roads, education, and power. The returns are estimated for different periods: 1960s–1970s, 1980s, and 1990s.

The results in table 2A.2 thus offer a rich comparative analysis of temporal returns to spending within and across agriculture and nonagriculture sectors, with the intertemporal speaking to the need to consider reprioritization. The results show, for example, that spending on roads, education, and R&D has the largest returns, but spending on fertilizer and power subsidies has the least returns. For subsidies, those on credit outperform those on irrigation, fertilizer, and power. Credit on subsidies is among the top two or three highest ranked within the agriculture spending portfolio, suggesting that some forms of subsidies are indeed favorable.

The analysis was possible by having disaggregated data on spending from 1951 to 1993 for different states in India. Even getting national-level spending data on African countries was challenging. Thus, more effort by governments and donors to invest in similar data collection activities in Africa is critical to generate the necessary evidence to prioritize high-impact parts of spending and agricultural spending in particular.

Table 2A.2 Returns in Growth and Poverty Reduction to Investments and Subsidies in India

	Return in agricultural GDP (RPS per RPS spending)								
	1960s–1970s			1980s			1990s		
	Return	R1	R2	Return	R1	R2	Return	R1	R2
Agricultural sector									
Research and development	8.65	2	5	7.93	1	2	9.50	1	1
Irrigation investment	8.00	3	6	4.71	2	4	4.37	2	4
Irrigation subsidies	5.22	4	7	2.25	4	6	2.47	4	6
Fertilizer subsidies	1.79	5	8	1.94	5	8	0.85	5	8
Credit subsidies	18.77	1	2	3.00	3	5	4.26	3	5
Rural sector									
Roads	19.99	1	1	8.89	1	1	7.66	1	2
Education	14.66	2	3	7.58	2	3	5.46	2	3
Power subsidies	12.06	3	4	2.25	3	6	1.19	3	7

(continued next page)

Table 2A.2 (continued)

	Return in rural poverty reduction (number of poor reduced per million RPS spending)								
	1960s–1970s			1980s			1990s		
	Return	R1	R2	Return	R1	R2	Return	R1	R2
Agricultural sector									
Research and development	642.69	2	5	409.00	1	3	436.12	1	2
Irrigation investment	630.37	3	6	267.01	2	4	193.21	3	5
Irrigation subsidies	393.70	4	7	116.05	4	7	113.47	4	6
Fertilizer subsidies	90.07	5	8	109.99	5	8	37.41	5	8
Credit subsidies	1,448.51	1	3	154.59	3	5	195.66	2	4
Rural sector									
Roads	4,124.15	1	1	1,311.64	1	1	881.49	1	1
Education	1,955.56	2	2	651.40	2	2	335.86	2	3
Power subsidies	998.42	3	4	125.50	3	6	59.15	3	7

Source: Based on Fan, Gulati, and Thorat 2008.
Note: RPS = retention pricing scheme. R1 = rank of return within sector, where 1 is the highest rank. R2 = rank of return across sectors, where 1 is the highest rank.

Annex 2B: Conceptual Framework and Description of the Data and Estimation Methods

Production Function

The aggregate production function for the agricultural sector in year t is modeled as:

$$Y_t = A_t * f\left(L_t, K_t, D_t, G, \boldsymbol{Z}_t\right) + e_t^Y \tag{2B.1a}$$

$$G_t = h\left(Y_t, \boldsymbol{Z}_t^G\right) + e_t^G \tag{2B.1b}$$

where Y is the value added of agricultural output; L is labor or the number of agricultural workers; K is the value of private capital and other intermediate inputs; D is agricultural land; G (representing G_t, $G_{t\text{-}1}$, $G_{t\text{-}2}$, …, $G_{t\text{-N}}$) is public agriculture spending with appropriate lag length q = 1, 2, …, N; $\boldsymbol{Z}$ is a vector of other factors affecting agricultural output; and A is a measure of total factor productivity (TFP). Rewrite equation (2B.1) in terms of per unit agricultural land area as follows:[14]

$$y_t = A_t * f\left(l_t, k_t, g, \boldsymbol{Z}_t^y\right) + e_t^y \tag{2B.2a}$$

$$g_t = h\left(y_t, \boldsymbol{Z}_t^g\right) + e_t^g \tag{2B.2b}$$

where $y = Y/D$, $l = L/D$, $k = K/D$, and g = G/D to represent value added, labor, capital, and agricultural spending per unit agricultural area, respectively; $\boldsymbol{Z}^y$ and $\boldsymbol{Z}^g$ are used to differentiate the vector of other factors that affect y and g, respectively; and e^y and e^g are random error terms in equations (2B.2a) and (2B.2b), respectively.[15]

Marginal Effects and Elasticities

Ignoring equation (2B.2b) for now, the total elasticity of land productivity with respect to public agriculture spending at any time t, which is defined as the ratio of the percentage change in land productivity (dy/y) to the percentage change in public agriculture spending (dg/g), can be obtained from equation (2B.2a) according to

$$\frac{dy_t / y_t}{dg_t / g_t} = \frac{\partial y_t}{\partial A_t} \sum_{q=0}^{\mathrm{N}} \frac{dA_t}{dg_{t-q}} \frac{g_t}{A_t}$$
$$+ \left[\frac{\partial y_t}{\partial l_t} \sum_{q=0}^{\mathrm{N}} \frac{dl_t}{dg_{t-q}} + \frac{\partial y_t}{\partial k_t} \sum_{q=0}^{\mathrm{N}} \frac{dk_t}{dg_{t-q}} + \sum_{q=0}^{\mathrm{N}} \frac{\partial y_t}{\partial g_{t-q}} \right] * \frac{G_t}{f(\cdot)}, \tag{2B.3}$$

where ∂ refers to the partial derivative, so that $\partial y_t / \partial g_{t-q}$, for example, measures the direct marginal effect of public agriculture spending on land productivity at time t and $\partial y_t / \partial k_t * \partial k_t / \partial g_{t-q}$ measures the indirect marginal effect through its effect on capital k. Together, the first terms on the right-hand side of equation (2B.3) capture the technology-advancing productivity effect of public agriculture spending. The first parts of the first and second terms in the brackets capture the human capital enhancing and transactions cost reducing productivity effects, but the second parts of the first and second terms in the brackets capture the crowding-in productivity effects. The elasticity of land productivity with respect to public agriculture spending is interpreted as the percentage change in land productivity (y) due to a 1 percent change in public agriculture spending per hectare (g).

ROR

Using $\hat{\vartheta}_t^{yG}$ to represent the estimated elasticity, the ROR can be obtained using equation (2B.4) as the discount rate (r) that equates the net present value of marginal productivities $\hat{\vartheta}_{t-q}^{yG} * \bar{y}$ over the relevant time periods of lag (that is, $q = 0, 1, \ldots, N$) to an initial or one-time public agriculture spending (g_0).

$$\sum_{q=0}^{N} \frac{\hat{\vartheta}_{t-q}^{yG} * \bar{y}}{(1+r)^q} = g_0 \tag{2B.4}$$

where $\bar{y}$ is the annual average agricultural value added per hectare and g_0 is equivalent to 1 percent of the annual average agricultural spending per hectare (that is, $0.01 * \bar{g}$). We use N = 10 in the actual calculations.

Data Sources and Empirical Approach

The main data constraint faced in the estimation lies with public spending, which has been compiled from SPEED (IFPRI) and ReSAKSS (IFPRI) for total government spending (*TE*) and total agriculture spending (*GT*) from 1980 to 2014 (table 2B.1). Spending on agricultural research (*GR*) and number of research scientists (*GS*) were obtained from ASTI (IFPRI) for 1980 to 2012. Agricultural production data were compiled from the World Development Indicators (WDI, World Bank) and FAOStat (FAO) as shown in table 2B.1. These include data on agricultural value added (*Y*), agricultural land area (*D*), agricultural labor (*L*), crop and livestock capital, chemical fertilizers, feed (*K*), and irrigation (*I*). Data representing $\boldsymbol{Z}^y$ were obtained

Table 2B.1 Description of Variables, Data, and Sources Used in Estimating Productivity Effects of Public Agriculture Spending

Variable	Description/disaggregation	Years available	Data source
Total spending (*TE*)	Total government spending in constant 2006 currency	1980–2014	ReSAKSS, SPEED (IFPRI)
Agricultural spending (*GT*)	Government spending on agriculture (crops, livestock, forestry, fishery, and research) in constant 2006 US$	1980–2014	ReSAKSS, SPEED (IFPRI)
Agricultural research spending (*GR*)	National agricultural research spending, including salary-related expenses, operating and program costs, and capital investments by government, nonprofit, and higher education agencies. Original values in current local currency units (LCUs) were deflated using the ratio of GDP in constant 2006 US$ to GDP in current LCUs.	1981–2011	ReSAKSS, SPEED (IFPRI), WDI (World Bank)
Agricultural research scientists (*GS*)	National agricultural researchers in full-time equivalent (FTE)	1981–2011	ASTI (IFPRI), WDI (World Bank)
Agricultural valued added (*Y*)	Net output (gross output less intermediate inputs) in constant 2006 US$. Original values in current LCUs were deflated using the ratio of GDP in constant 2006 US$ to GDP in current LCUs.	1961–2014	WDI (World Bank)
Agricultural land area (*D*)	Hectares of land, including arable land, land under permanent crops, meadows, pastures, and forests	1961–2014	FAOstat (FAO)
Agricultural labor (*L*)	Total economically active population engaged in or seeking work in agriculture, hunting, fishing, or forestry	1961–2012	Benin and Nin Pratt 2015 based on FAOStat
Capital (*K1*)	Sum of gross fixed capital stock in constant 2006 US$ • Crop capital: land development, plantain crops, and machinery and equipment • Livestock capital: animal stock, structures for livestock, and milking machines	1961–2012	Benin and Nin Pratt 2015 based on FAOStat
Fertilizer (*K2*)	Metric tons of nitrogen, phosphorus, and potassium nutrients consumed	1961–2012	Benin and Nin Pratt 2015 based on FAOStat
Animal feed (*K3*)	Metric tons (maize equivalent) of edible commodities fed to livestock	1961–2012	Benin and Nin Pratt 2015 based on FAOStat

(continued next page)

Table 2B.1 (continued)

Variable	Description/disaggregation	Years available	Data source
Rainfall (*R*)	Total rainfall in mm	1960–2013	HarvestChoice
Irrigation (*I*)	Share of agricultural area equipped with irrigation	1960–2013	FAOstat (FAO)
Population density (*P*)	Total population divided by the total land area in persons per sq km	1961–2014	WDI (World Bank)
Agroecology (*AEZ*)	Dummy variable representing the dominant agroecological zone within the country: 1 = subtropic; 2 = tropic, cool, semiarid or arid; 3 = tropic, cool, semihumid or humid; 4 = tropic, warm, semiarid or arid; 5 = tropic, warm, semihumid or humid; 6 = other	2015	HarvestChoice
CAADP	Number of years since country signed a CAADP compact, measured in 2012	2012	AU-NEPAD 2015
Technology (*A*)	Dummy variable representing the level of technology at specific time periods (1961–69, 1970–79, 1980–89, 1990–99, and 2000–12): 1 = low, 2 = medium low, 3 = medium high, 4 = high	1961–2012	Benin and Nin Pratt 2015
Instruments (Z^G)	Governance indicators with range –2.5 to 2.5:	1996–2013	WDI (World Bank)
• Voice	• Voice and accountability	1961–2014	Polity IV Project (CSP)
• Stability	• Political stability and absence of violence		
• Effectiveness	• Government effectiveness		
• Regulation	• Regulatory quality		
• Law	• Rule of law		
• Corruption	• Control of corruption		
• Polity	Political regime characteristics:		
• Durability	• Combined polity score, –10 to 10		
	• Durability of regime, number of years		

Source: Benin 2015.
Note: CAADP = Comprehensive Africa Agriculture Development Programme; FTE = full-time equivalent; GDP = gross domestic product; LCUs = local currency units.

from other sources, including precipitation and agroecological zones from HarvestChoice, population density from World Bank (2015), and participation in CAADP from AU-NEPAD (2015).

The level of technology (A) is measured using a time dummy variable representing the level available at specific time periods (1961–69, 1970–79, 1980–89, 1990–99, and 2000–12), based on the total factor productivity (TFP) estimates in Benin and Nin Pratt (2015). We use the quartiles of the TFP estimates as the cutoff points (table 2B.2) to categorize the level of technology, where 1 = low if the estimated TFP is less than the quartile 1 cutoff point; 2 = medium low if the estimated TFP is greater than the quartile 1 cutoff point but less than the quartile 2 cutoff point; 3 = medium high if the estimated TFP is greater than the quartile 2 cutoff point but less than the quartile 3 cutoff point; and 4 = high if the estimated TFP is greater than the quartile 3 cutoff point. Data representing $\boldsymbol{Z}^G$ were obtained from two sources: the Worldwide Governance Indicators project for six dimensions of governance (voice and accountability; political stability and absence of violence; government effectiveness; regulatory quality; rule of law; and control of corruption) from 1996 to 2013 (World Bank); and the Polity IV project on political regime characteristics and transitions for a combined (democracy and autocracy) polity score and durability of regime (CSP).

Although the data were compiled for all countries in Africa on the various indicators for all years available, the actual panel used in the estimation is dictated by data availability on all the relevant indicators for at least 10 consecutive years, with the data on spending and governance indicators the most limiting. Thus, the final data set used is an unbalanced panel on 35 countries on total agricultural spending and 24 countries on agricultural research spending as shown in table 2B.3.

Table 2B.2 Annual Average TFP in African Agriculture and TFP Quartile Cutoff Points, 1961–2012
Index, 1961 = 1.00

TFP quartile cutoff	1961–69	1970–79	1980–89	1990–99	2000–12
0 (minimum TFP)	1.00	1.00	1.00	1.00	1.01
Cutoff 1	1.03	1.06	1.09	1.13	1.19
Cutoff 2	1.05	1.10	1.18	1.19	1.28
Cutoff 3	1.08	1.18	1.24	1.39	1.47
4 (maximum TFP)	1.28	1.52	1.82	2.10	2.65

Source: World Bank calculation based on Benin and Nin Pratt 2015.
Note: TFP = total factor productivity.

Table 2B.3 Coverage of Countries in the Panel Data

Spending type	Years	Countries
Total agriculture (*GT*)	1996–2012	Benin; Botswana; Burundi; Central African Republic; Chad; Congo, Rep.; Côte d'Ivoire; Ethiopia; Gambia, The; Ghana; Guinea; Guinea-Bissau; Kenya; Liberia; Madagascar; Malawi; Mali; Mauritius; Mozambique; Namibia; Nigeria; Rwanda; Senegal; Sierra Leone; South Africa; Sudan; Swaziland; Tanzania; Togo; Uganda; Zambia
	1997–2012	Congo, Dem. Rep.
Agricultural research (*GR*)	1996–2011	Benin; Botswana; Burundi; Congo, Rep.; Côte d'Ivoire; Ethiopia; Gambia, The; Ghana; Guinea; Kenya; Madagascar; Malawi; Mali; Mauritius; Nigeria; Senegal; Sudan; South Africa; Togo; Uganda; Zambia
	2000–11	Tanzania
	2001–11	Namibia; Sierra Leone

Sources: World Bank compilation based on ASTI, ReSAKSS, and SPEED (IFPRI), and World Bank 2015.

Notes

1. Much of this chapter is based on a background paper (Benin 2015).
2. There may be differences in the trends because of differences in the data due to updates and revisions in the spending data as well as other variables such as population, total and agricultural GDP, purchasing power parity (PPP) converters, GDP deflators, and exchange rates used in calculating various spending indicators.
3. All monetary values in this section are in 2005 purchasing power parity dollars (PPP$).
4. AOI = [(Ag PE/Total PE)]/(Ag GDP/GDP)].
5. See Beintema and Stads (2011), Benin and Yu (2013), and Stads and Beintema (2015) for further comparative analysis across different subregions and countries in Africa. There may be differences in the trends presented in those studies and this one due to differences in data.
6. In the MAFAP data, general support to agricultural infrastructure was broken down into feeder roads, off-farm irrigation, and other infrastructure. In Mali however, this disaggregation was not available, and so we assumed 50 percent of the aggregate to off-farm irrigation and 50 percent to other off-farm infrastructure.
7. Similar analysis is presented in Benin, McBride, and Mogues (2016), which uses a previous version of the data set on five countries (Burkina Faso, Kenya, Mali, Tanzania, and Uganda) from 2006 to 2010. As such, there may be differences in the trends presented in that study and this one.
8. All monetary values are expressed in 2005 prices.
9. See Benin (2015) for further discussion on the instrumental results.
10. Technologies may be biological (such as genetically-modified organisms and hybrids), chemical (such as fertilizers and pesticides), mechanical (such as tractors

and implements), or informational (husbandry, value chains, and early-warning systems).

11. See Mogues, Fan, and Benin (2015), a recent review of the evidence on the impacts of different types of public spending in and for agriculture.
12. This was estimated by the sum of product of the share of the rates of return in a category (0.27 in 0–20, 0.27 in 21–40, 0.18 in 41–60, 0.11 in 61–80, 0.11 in 81–100, 0.05 in 100+) and the midpoint of the category (10, 30, 50, 70, 90, 110).
13. This was estimated by the sum of product of the share of the rates of return in a category (0.4 in 0–20, 0.3 in 21–40, 0.2 in 41–60, 0.1 in 61–80) and the midpoint of the category (10, 30, 50, 70).
14. We could have alternatively divided through by L or K to arrive at similar results, though with different interpretations—for example, labor productivity instead of land productivity.
15. To explicitly capture the different pathways of productivity effects of g discussed in annex 2B of this chapter, equations (2B.1a) and (2B.2a) could have been written to make A, l, and k as functions of g, as done in Benin (2015).

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