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COST ASPECTS OF AFRICAN AGRICULTURAL RESEARCH

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ABSTRACT

Spending per scientist declined precipitously within African agricultural R&D agencies over the past several decades. In 1991, average cost per researcher across 147 R&D agencies was $119,300 in 1985 international dollars—or US$59,500 when measured in United States rather than international dollars—34 percent below the corresponding 1961 figure. This trend reflects the rapid growth in numbers of scientific staff compared with the slow growth in funds to support them. Comparatively low, and often shrinking, real salaries per scientist are a factor too. African scientists were paid an average of US$5,000 in 1991 (or roughly US$7,500 with fringe benefits included), while comparable average salaries for academic staff working in large public universities in the United States were $58,889 (or $72,667 with fringe benefits included).

The new, agency-level data reported in this paper reveal significant variation in the costs per scientist not apparent from the country averages. From the 147 agencies for which we have data, spending per scientist in 1991 ranged from a low of $16,400 for WRRU, Zambia, to $400,000 for ARD, Swaziland (in 1985 international dollars). There were 67 agencies (46 percent) that spent less than $100,000 per scientist per annum. We used some simple econometric procedures applied to a sub-sample of 107 agencies in 21 countries to investigate reasons for the large variation in costs per scientist. The intensity of support staff per scientist and the intensity with which expatriate researchers are used are important sources of variation. Larger stations lowered the costs and having more stations raised costs, but not significantly so. An agency's organizational type had a significant influence on its costs. Semipublic agencies typically spent considerably more per scientist than government agencies with 1991 figures of $207,700 for the former, compared with around $104,600 for the latter (in 1985 international dollars). GDP per capita and various other unspecified, country-specific effects also accounted for much of the observed variation in costs per scientist.

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1. INTRODUCTION

The costs of carrying out government business has become an increasingly contentious policy and management issue the world over. For those Sub-Saharan African (hereafter referred to as African) governments seeking to rein in public spending and reshape the role of government, often with prodding from the IMF and the World Bank via programs of structural adjustment, these public finance issues have become especially pressing.

While public spending on agricultural research typically accounts for less than 1.2 percent of total public spending throughout African countries, it represents a sizable share of public spending on agriculture. The amount of money spent on agricultural R&D has grown considerably in real terms since the 1960s, albeit with much reduced (in some cases declining) rates of growth in more recent years. Moreover, public funding of agricultural R&D is pivotal, often accounting for over 80 percent of all R&D spending in a country. Combined with the general pressures on public budgets is increasing concern on the part of local finance ministries and donor agencies, as to how efficiently these public funds are being spent, and how successful such spending is in providing the desired social returns.

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Assessing the benefits flowing from African agricultural R&D is an important topic, but one that is dealt with elsewhere (see, for example, Pardey et al. 1999) The focus of this paper is squarely on the cost side of the benefit-cost calculus.

Calculating R&D costs is a tricky business. Producing meaningful, comparative measures is problematic because there is little uniformity nor clarity in the way public agencies report their spending. Aggregating local expenses denominated in local currencies and donor funding reported in foreign currencies is complicated. Dealing with periods of rampant and sometimes poorly measured inflation and capricious changes in distorted exchange rates also poses significant problems.

Notwithstanding these difficulties, in this paper we present and discuss new data on the costs of African agricultural research. Previous time series data report aggregate, national trends;[1] here we present disaggregated, survey data that (for some aspects) include 341 research agencies located in 37 African countries. Our intent is to summarize and assess the variation in these cost data, paying particular attention to differences among the various kinds of R&D organizations. While these cost data can provide useful benchmarks for policymakers and others when assessing the cost structures of local R&D agencies, our objective is not to provide rules of thumb in terms of the appropriate costs per scientist, the optimal factor shares (e.g., shares of labor, capital, operating costs) or a mix of fixed versus variable costs, and so on. Rather, we seek to calibrate the cost performance of African agricultural research agencies and develop an understanding of the

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[1] See, for example, Pardey, Roseboom, and Beintema (1997) for the most comprehensive and up-to-date aggregate data, and the references therein for earlier compilations.

economic and political aspects that shape these cost structures. Given that a large share of the costs of a labor-intensive activity like research involves the direct and indirect costs of scientists and support staff, we give special attention to these aspects in this paper.

The paper is structured as follows. In section 2 we describe some measurement and classification issues that provide a basis for interpreting the cost data. Section 3 gives a perspective on the labor aspects of African agricultural R&D, labor being the largest cost component of most research agencies. The following section constitutes the core of the paper: in it we present and interpret the cost data, specifically reviewing developments regarding total costs, cost shares, and cost-per-scientist ratios using a new set of institutional-level data. We end section 4 by statistically assessing the importance of various factors that account for the large variation in the cost-per-scientist ratios that are evident among African agricultural research agencies. In section 5 we present and discuss details related to the salaries and benefits afforded research staff. Section 6 concludes the paper.

2. SOME CLASSIFICATION AND MEASUREMENT ISSUES

The detailed institutional data reported here are potentially insightful, but bring with them their own set of problems; most immediately, how to usefully treat and summarize these data. For summary purposes, we opted to group R&D institutions according to three characteristics: the first of a functional nature, namely the socio-economic objective cum field-of-science orientation of the research, and the latter two of an institutional nature, specifically the type and the size of each organization.[2]

To summarize the functional orientation of the R&D, we grouped the observations into six categories according to the principal research focus of each organization. We identified those agencies engaged in research targeted to four subsectors in agriculture (broadly defined)—specifically agencies engaged primarily in either crops, livestock, forestry, or fisheries research. A number of agencies were involved in research that spanned two or more of these commodity sectors (e.g., both crops and livestock R&D), and these we classified as "multisectoral" agencies. A sixth group of research institutes included those agencies that did not fit easily into one of the commodity categories, even though some of their research may have direct consequences for a particular part of the agricultural sector. This group included a somewhat disparate set of agencies working on environmental and natural resource issues related to agriculture, agricultural mechanization, farming systems research, and socio-economics research.[3]

We also grouped the agencies into three institutional categories, namely government, university, and semipublic agencies. The first two categories are self evident, the last needs some explanation. A semipublic agency was taken to be an R&D organization that had a good deal of managerial and financial autonomy from

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[2] OECD (1994) provides a more complete discussion of the functional versus institutional aspects of classifying R&D.

[3] Conversely, this is not meant to imply that the commodity institutes do not undertake such research. Rather, what research they do along these lines is done explicitly within the framework of an identifiable program of commodity research.

government.[4] Typically, semipublic agencies are managed by industry commodity groups. For government research organizations, a further distinction was made between national agricultural research organizations (NAROs) and other, non-NARO agencies. An agency was designated a NARO if, in the context of the domestic agricultural sector, it had a comprehensive research agenda in terms of commodity coverage and spatial orientation, and also accounted for more than one-half of a country's agricultural research capacity (for more details see Roseboom, Pardey and Beintema 1998). There are 341 research agencies from 37 countries in our 1991 sample; 22 agencies were designated as NAROs.

Finally, agencies were classified according to their size as indicated by the number of full-time equivalent (fte) researchers working for each agency in 1991 and by their respective colonial histories. A breakdown of the 341 agencies included in our sample, classified according to some of these functional and institutional categories, is provided in Table 1. Government agencies accounted for 58 percent of the 341-agency sample (and about 88 percent of the fte researchers) and universities about 38 percent; only 4 percent were classified as semipublic agencies. Around one-third of the agencies, employing over one-half of the fte researchers, conducted research that spanned multiple sectors. Around 15 percent of the agencies undertook research specific to either crops or livestock, 7 percent of the agencies were involved in forestry research and 6 percent in fisheries research.

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[4] Financial indicators are the most readily measurable aspects of "autonomy." For this study, agencies receiving at least one-quarter of their income from sources other than government or international donors (e.g., as revenue from compulsory taxes or marketing-board profits) were redeemed semipublic operations.

Table 1 Institutional orientation of African agricultural research agencies, 1991

Commodity focus	Government		Semipublic	Universities	Total	
	NAROs	non-NAROs			Count	Share
			(*number of agencies*)			(*percentage)*
Crops	--	33	10	11	54	15.8
Livestock	--	30	1	22	53	15.5
Forestry	--	20	1	4	25	7.3
Fisheries	--	19	--	3	22	6.5
Other	--	42	--	34	76	22.3
Multi-sector	22	33	--	56	111	32.6
Total	*22*	*177*	*12*	*130*	*341*	*100*
			(*fte researchers*)			
Crops	-	1,067	204	34	1,305	15.2
Livestock	-	728	2	169	898	10.5
Forestry	-	319	23	24	366	4.2
Fisheries	-	460	--	15	475	5.5
Other	-	643	--	103	745	8.7
Multi-sector	3,083	1,255	--	446	4,784	55.8
Total	*3,083*	*4,472*	*229*	*791*	*8,574*	*100*

Source: Compiled by authors from survey data.

Note: Based on a sample of 341 agricultural research agencies in 37 Sub-Saharan African countries.

Converting cost data denominated in various current, local-currency units to a figure that is reported on a comparable basis is fraught with difficulties and the conversion method used can have major consequences on the values reported and their interpretation. Most of the expenditure data in this paper are reported in 1985 international dollars. Expenditures were compiled in current local currency units, deflated to 1985 prices using local implicit GDP deflators obtained from the World Bank's World Tables (1995), and then converted to international dollars using purchasing power parity (PPP) rates for 1985 obtained from Summers and Heston (1991). An international dollar is set to equal one U.S. dollar, but the currency conversion uses a broader basket of prices to compare cost structures among countries than is the case when market exchange rates are used. Market exchange rates only compare the relative prices of *traded* goods and services, while most of the inputs into agricultural research agencies, like inputs into government services more generally, are not traded internationally. The currency conversion approach we use is intended to provide a cross-country comparison of the *quantity* of resources used in research, represented by the cost-of-research figures.

3. THE COMPOSITION OF LABOR

The labor share of total agricultural R&D costs throughout agricultural research agencies in Africa averaged 60 percent in 1991. Thus an appreciation of differences in staffing profiles is indispensable to understanding the changing pattern of costs of African agricultural research.

Both the quantity and quality of labor are relevant in analyzing differences in the costs of agricultural R&D. However, for an intrinsically creative enterprise like research, it is hard to get a meaningful, summary measure of the research “quality” of the labor committed to the effort. If labor markets were functioning properly, wages (including fringe benefits) would provide a useful—indeed almost ideal—indication of the quality of the staff input into research. Wages would capture the market’s best guess about the productive potential of an individual, which in turn is driven by a host of nature and nurture factors. Unfortunately, the civil service regulations that dictate the conditions under which scientific staff are employed give little opportunity for the price mechanism to signal these productive differentials properly.

In the absence of suitably disaggregated price data we must turn to other available, and admittedly incomplete, measures of the quality of the research labor force. Our data include measures of the degree status of scientific staff as well as the composition of the overall staff, which includes scientific, technical, and other support staff. We also have data on the role of expatriate scientists in national agricultural research systems. Expatriate researchers and better-trained staff are usually more costly than national staff or staff with less formal qualifications. As the composition of the research staff changes so too will the cost structures of these research organizations.

RESEARCH PERSONNEL TRENDS

Pardey, Roseboom, and Beintema (1997) summarized the general trends in R&D personnel. In 1991, agricultural research agencies across 48 African countries employed just over 9,100 fte researchers, some 16,000 technicians, and around 72,000 other support staff. With an average of nearly 10 support staff per researcher there were close to 100,000 person years devoted to agricultural R&D throughout Africa in 1991.

The number of agricultural researchers working in national agencies throughout Africa (including South Africa) has grown rapidly over the past three decades, from an estimated 2,000 fte researchers in 1961 to about 9,100 in 1991; an annual rate of growth of 5.2 percent (compared with an increase in the overall African workforce of 2.5 percent per annum). At the same time the share of expatriate researchers working in national research agencies declined dramatically from more than 50 percent in 1961 (90 percent if South Africa is excluded) to about 9 percent in 1991.[5] The formal qualification standards of national researchers improved significantly over time. Few African nationals working in agricultural R&D agencies held degrees at the time of political independence in the early 1960s. By the early 1980s, about 45 percent of the national researchers were trained to postgraduate level, and by 1991 this share had grown to nearly 65 percent.

Public-sector agricultural research in Africa is done mainly by government agencies: in 1991 they employed 87 percent of the fte scientists working in African agricultural R&D, down slightly from their 91-percent share three decades earlier. Semipublic agencies employ a minor share of the total—3.5 percent in 1991—while universities employed 10 percent, double their 1961 share. The increasing research role of universities is a feature of agricultural research endeavors in other regions of the world. Pardey, Roseboom, and Craig (1999) report similar trends among OECD countries, where universities accounted for 43 percent of the national, public spending on agricultural R&D by 1993, compared to their 39-percent share in 1981.

Figure 1 provides an indication of the research orientation of African agricultural scientists, based on a sample of 24 NARSs, representing an estimated 79 percent of the total number of researchers in the region. Taking this sample to be representative of the whole region, we estimate that from a 1991 total of 9,130 fte agricultural scientists, 3,821

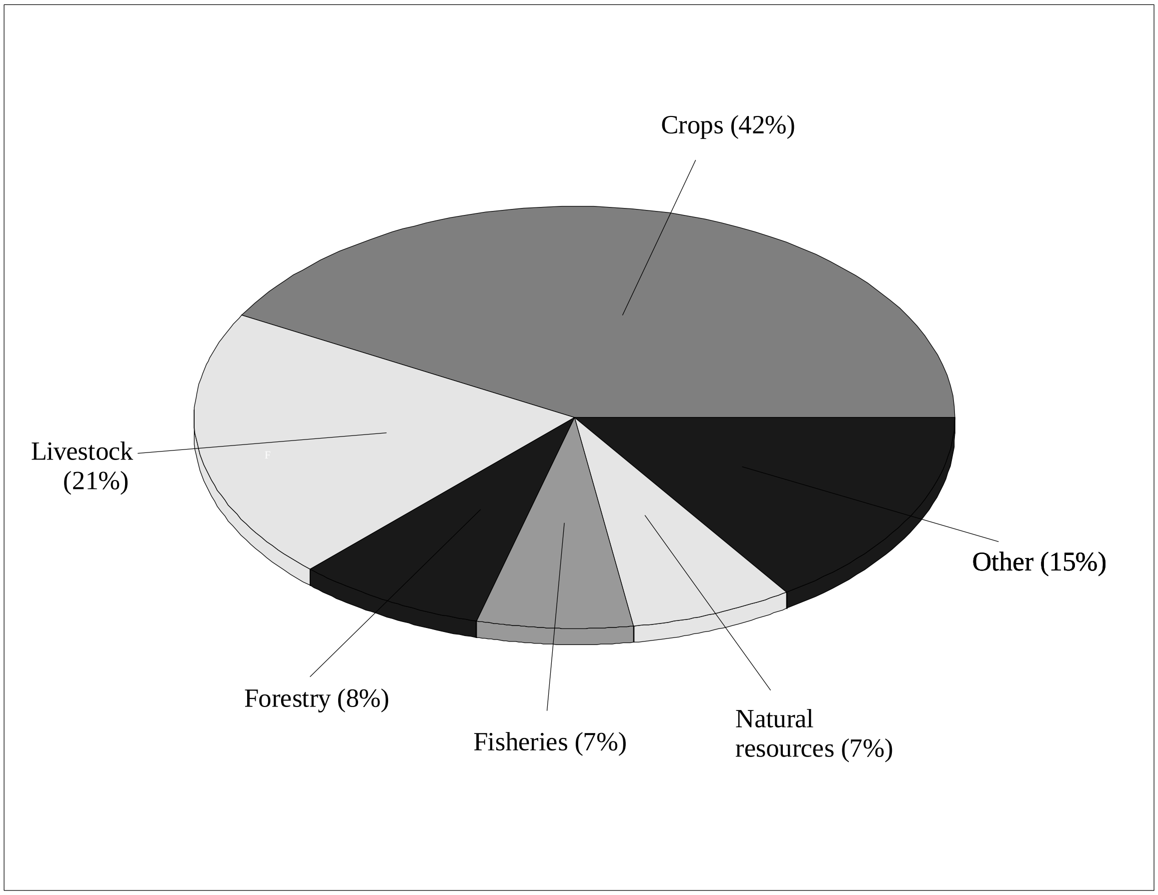
[5] Aside from South Africa and Zimbabwe, most African research institutions were almost completely staffed with expatriate researchers in 1961.

were involved in crop research, 1,914 in livestock, 728 in forestry, 617 in fisheries, and 638 in natural resources, with the remaining 1,411 involved in other lines of research.

Figure 1 Research orientation of African agricultural scientists, 1991

STAFFING PROFILES

In this section we document and discuss the trends related to the changing role of expatriate scientists, the educational status of national researchers, and the composition of research staff, highlighting the major differences in the intensity of use of support staff.



Expatriate Researchers

Agricultural R&D throughout colonial Africa was principally staffed with (mostly European) expatriate researchers. Subsequent development toward domestic agencies staffed with domestic scientists occurred in different countries and different agencies at different rates. Past patterns of colonization and, relatedly, the rate and nature of transition from a colonized to a politically independent nation state, loom large as a factor in accounting for the changing role of expatriate scientists in African agricultural R&D. But colonial factors are not the only relevant aspects; other influences include the development of local training capacities and opportunities for continued training abroad, the pace and pattern of general economic and institutional developments, and the degree to which donor support was linked to the provision of expatriate staff. The 1991 data in Table 2 summarize the uneven developments that have occurred toward domestically staffed, national research agencies.

In 1991, more than 20 percent of the researchers in agencies located in former Portuguese and French colonies were expatriates—significantly higher shares of expatriate staff than were commonly found in former British and Belgian colonies. Throughout much of British Africa the local agricultural research structures were ceded

Table 2 Expatriate scientists in African agricultural R&D, 1991

Organizational Structure	Colonial history						Commodity orientation						
	Belgium[a]	France[b]	Portugal[c]	U.K.[d]	None[e]	Total	Crops	Livestock	Forestry	Fisheries	Other	Multi-sector	Total
	(fte national and expatriate researchers)						*(fte national and expatriate researchers)*						
Government													
NAROs	49	935	37	1,774	288	3,083	--	--	--	--	--	3,083	3,083
non-NAROs	249	959	36	1,950	1,278	4,472	1,067	728	319	460	643	1,255	4,472
Semipublic	--	--	--	175	54	229	204	2	23	--	--	--	229
Universities	23	207	3	433	126	791	34	169	24	15	103	446	791
Total	*321*	*2,100*	*76*	*4,331*	*1,746*	*8,574*	*1,305*	*898*	*366*	*475*	*745*	*4,784*	*8,574*
	(percentage expatriates)						*(percentage expatriates)*						
Government													
NAROs	24.5	17.0	27.0	8.4	5.6	11.2	--	--	--	--	--	11.2	11.2
non-NAROs	5.2	23.7	27.8	3.8	0.3	7.4	5.1	3.7	8.2	10.4	1.6	13.0	7.5
Semipublic	--	--	--	2.3	0	1.7	2.0	0	0	--	--	--	1.7
Universities	10.8	24.2	40.0	8.6	0	11.5	21.8	11.9	4.6	1.7	26.1	7.9	11.5
Total	*8.6*	*20.8*	*27.9*	*6.1*	*1.2*	*9.0*	*5.1*	*5.2*	*7.5*	*10.1*	*5.0*	*11.4*	*9.0*

Source: Compiled by authors from survey data.

Note: Based on a sample of 341 agricultural research agencies in 37 Sub-Saharan African countries.

[a] Includes agencies from Rwanda and Zaire (now Congo).
[b] Includes agencies from Benin, Burkina Faso, Cameroon, Congo, Côte d'Ivoire, Gabon, Guinea, Madagascar, Mali, Mauritania, Niger, Senegal, and Togo.
[c] Includes agencies from Cape Verde, Guinea-Bissau, and Mozambique.
[d] Includes agencies from Botswana, Gambia, Ghana, Kenya, Lesotho, Malawi, Mauritius, Nigeria, Sierra Leone, Sudan, Swaziland, Tanzania, Uganda, Zambia, and Zimbabwe.
[e] Includes agencies from Ethiopia, Namibia, and South Africa.

to the new governments as an integral part of the country's administrative structures at independence. In many cases the flow of financial and technical support for research from Great Britain to its former colonies contracted quite quickly thereafter. In contrast, France continued to manage, execute, and fund agricultural R&D in most of her former colonies for many years following political independence. Eventually, these arrangements collapsed as domestic governments sought managerial and operational control over the public research activities in their countries, with consequent accelerated rates of reduction in the number of French expatriate researchers throughout Francophone Africa in more recent years.

Soon after Congo's independence in 1960, on the eve of the civil war, there were about 260 Belgian researchers working in the country—about 10 percent of the total number of researchers working throughout Africa at that time. The war led to an emergency repatriation of Belgian researchers, and a subsequent collapse of the entire national agricultural research agency (INEAC). In neighboring Rwanda and Burundi, however—which were also served by INEAC during colonial times—the Belgians continued to play a leading role in agricultural research for many years after those countries gained independence. Similarly, Portuguese researchers maintained a substantial presence for some years throughout Angola, Cape Verde, Guinea-Bissau, Mozambique, Sao Tome and Principe, countries that did not achieve political independence until as late as 1975.

Table 2 also highlights some significant institutional differences in the role of expatriate scientists. Irrespective of colonial histories, expatriates account for a larger share of the researchers working in universities than in government research facilities. The role of expatriate staff in African universities reflects a concerted effort by donor agencies to help develop the tertiary education sector throughout Africa. For example, throughout the 1970s, numerous U.S. land grant universities were paired with African agricultural universities and American university staff were seconded to work for a time in their counterpart African institutions. Similar schemes to encourage residences of expatriate research scientists in African universities were initiated by many other donor agencies, especially those from European countries.

Expatriate scientists had only a marginal presence in the 11 semipublic agencies in the former British colonies for which we have data; a figure well below the corresponding share of expatriate staff in universities and government agencies. Moreover, those government agencies engaged in forestry and fisheries research and those having a broader, multi sectoral orientation, relied more heavily on expatriate scientists than those government agencies that focused more narrowly on crops and livestock research.

Degree Status

We have already noted the dramatic improvement in the formal qualifications held by national researchers, namely from around 45 percent with postgraduate degrees in 1981 to over 60 percent so trained a decade later. Beintema, Pardey, and Roseboom (1998) document these developments in more detail, in particular the role of African universities in bringing these changes about. In Table 3 new data on the pattern of qualifications held by researchers grouped according to various institutional and research-orientation criteria are presented as an aid to understanding the cost differentials presented in the following section.

About one-fifth of the nearly 7,000 African agricultural scientists working in 37 African countries in 1991 held a PhD degree (41 percent were trained to MSc level and 38 percent held BSc degrees). Almost one-quarter of these doctoral scientist years were located in universities; less than 20 percent of the researchers working for government and semipublic agencies had PhD degrees, and nearly half these “public-sector” scientists were only trained to the BSc level. Despite the considerable growth in trained scientists over the past several decades, the total number of researchers throughout Africa with a doctorate degree in 1991 was still less than the number of doctorates employed in just two state agricultural experiment stations (SAESs) in the United States—specifically, California and New York.

Doctorally trained agricultural scientists are also geographically concentrated. Agencies located in just three countries (Nigeria, South Africa, and Sudan) accounted for 45 percent of all the doctoral agricultural scientists working in public agricultural R&D agencies in 48 African countries: the remaining 45 countries, accounting for two-thirds of the region’s population, employed an estimated total of 972 fte agricultural scientists with doctoral degrees. Although some progress has been made in terms of raising the qualification status of agricultural researchers during the past few decades, clearly there is much left to be done. There are also sizable differences in the degree status of researchers across different lines of research. Table 3 points to a concentration of

Table 3 Degree status of African researchers, 1991

	Degree status				Degree status				Number of institutes
	PhD	MSc	BSc	Total	PhD	MSc	BSc	Total	
	(*fte researchers*)				(*percentage*)				
Type of organization									
Government									
NAROs	349	945	1,202	2,496	14.0	37.9	48.1	100	20
non-NAROs	738	1,596	1,267	3,602	20.5	44.3	35.2	100	146
Semipublic	36	82	107	225	16.0	36.4	47.6	100	12
Universities	331	244	59	634	52.2	38.5	9.3	100	113
Total	*1,454*	*2,868*	*2,635*	*6,956*	*20.9*	*41.2*	*37.9*	*100*	*291*
Research orientation[a]									
Crops	285	498	344	1,127	25.3	44.2	30.5	100	37
Livestock	175	299	195	669	26.2	44.7	29.1	100	26
Forestry	33	137	125	295	11.2	46.4	42.4	100	17
Fisheries	30	152	144	325	9.2	46.6	44.2	100	15
Other	84	210	262	556	15.1	37.7	47.2	100	35
Multi-sector	516	1,329	1,506	3,351	15.4	39.7	44.9	100	48
Total	*1,123*	*2,623*	*2,576*	*6,322*	*17.8*	*41.5*	*40.7*	*100*	*178*

Source: Compiled by authors from survey data.

[a] Degree status by research orientation includes only government and semi-public agencies (excluding universities) from a sample of 178 agricultural research agencies located in 37 Sub-Saharan African countries.

doctoral degrees in the specialized crop and livestock agencies; the multi sectoral NAROs, many of whom also undertake much crop and livestock research, do not appear to be especially well endowed with doctoral scientists. Presuming that the average research orientation for our 37-country sample was representative of the overall African average, we scaled up the data in Table 3 to develop some 48-country estimates. Thus, pooling the specialized and multi sectoral (NARO) agencies engaged in crop or livestock research, we estimate that in 1991, about two-thirds (some 1,200 fte scientists) of all the African agricultural scientists with doctoral degrees researched these two commodity areas. We also estimate that the entire African continent (i.e., including all 48 countries and all types of agencies) had only 110 fte scientists with doctorates working on forestry research, and 90 PhDs engaged in fisheries research. This leaves 350 fte PhDs, 110 of whom we estimate worked on natural resource (especially soil science) research and 240 on various "other" topics involving socioeconomics, food processing, and agricultural mechanization research.

Support Staff

Another dimension of the research labor force that significantly shapes the cost structures of African agricultural research agencies is the amount and composition of the support staff. In a subsample of 115 agricultural research agencies located in 23 countries, the 1991 weighted average was 9.7 support staff per researcher, with 1.7 of these support personnel designated as technical staff. The other support staff held non-technical positions, some were qualified administrative personnel, but most were laborers, watchmen, drivers, cleaners, and so on, jobs that entail fairly limited formal training. The total number of support staff per scientist ranged from 0.8 (IRSSH, Burkino Faso) to 63 (Tea Research Foundation, Malawi); the range for the technical support staff to scientist ratio was 0.1 (Agrimetrics Institute, South Africa) to 12.5 (Cocoa Research Institute, Nigeria). Table 4 presents some summary, frequency distributions of these various support-staff-to-scientist ratios.

Almost 90 percent of the agencies in our sample employed somewhere between 0.5 and 4.0 full-time-equivalent technical staff per scientist, and between one and 30 non-technical support staff. In 1991 public agricultural research agencies in the United States averaged 2.6 support staff per scientist year (USDA 1992), while Cremers and Roseboom (1997) report a ratio of four to one for some selected, major public agricultural research agencies in Latin America. Taken at face value, this suggests that African agricultural research agencies are grossly overstaffed in terms of the number of support staff they employ per scientist. Thus, there is a widespread perception that African governments (like many governments elsewhere) have a propensity to use public agencies to address national employment concerns rather than give research managers the discretion to follow employment practices that are conducive to a more optimal use of scarce public research resources. Of course, issues such as the relative price of skilled versus unskilled staff, differences in the focus of the research being carried out (e.g., more applied, adaptive types of R&D may involve more field trials than laboratory based R&D and, consequently, require more unskilled or semiskilled field staff), institutional aspects

Table 4 Support-staff-to-scientist ratios

Staffing ratios	Number of institutes	Share of researchers	Share of institutes
		(*percentage*)	
Technical support staff per researcher			
Less than 0.5	5	3.6	4.3
0.5 - 1	29	24.1	25.2
1 - 2	42	50.0	36.5
2 - 4	33	20.9	28.7
Greater than 4	6	1.4	5.2
Other support staff per researcher			
Less than 1	10	3.2	8.7
1 - 4	33	30.2	28.7
4 - 8	26	37.4	22.6
8 - 15	29	20.5	25.2
15 - 30	10	4.0	8.7
Greater than 30	7	4.7	6.1
Total support staff per researcher			
Less than 2	10	5.8	8.7
2 - 5	26	26.5	22.6
5 - 10	35	38.2	30.4
10 - 20	30	22.7	26.1
20 - 40	9	5.1	7.8
Greater than 40	5	1.7	4.3

Source: Compiled by authors from survey data.

Note: Based on a sample of 115 agricultural research agencies (excluding universities) in 23 Sub-Saharan African countries.

(including the scale and geographic dispersion of each agency),[6] and so on, would need to

[6] Notice in Table 4, the frequency distributions of the support staff-to-scientist ratios are more concentrated when denominated in terms of the number of researchers rather than the number of institutes. This suggests that those institutes at the extremes of the distribution are among the smaller agencies, where scale is denominated by the number of scientists.

figure into any serious economic assessment as to the suitability of the prevailing mix of scientific and support staff.

Certainly, at first glance, the data in Table 5 belies the notion that the employment structures of public agencies per se have led to bloated and uneconomic support-staff-to-scientist ratios in Africa. The semipublic agencies, typically managed by and (presumably) more responsive to the research demands of various industry groups, employ almost twice as many support staff per scientist as do government agencies. Quite a number of the semipublic agencies, however, operate large agricultural holdings as revenue-raising operations, and consequently employ large numbers of unskilled or semiskilled support staff to run these operations. The practice of running commercial operations as an integral part of the activities of a research institution is not limited to semipublic agencies: many government agencies also engage in commercial agricultural undertakings. This practice has helped some cash-strapped research institutions, but the public-ownership aspect of much of the land used for commercial farming limits the ability of research managers to sell or lease out these farming concerns, even if it makes more economic sense to do so.

In analyzing our data, we found no systematic tendency for larger than average or more geographically dispersed research agencies to have abnormal support-staff-to-scientist ratios. Neither was there any correlation between per capita income and support-staff-to-scientist ratios: there was no evidence that richer or poorer African countries employed significantly different numbers of support staff relative to the number of scientists.

Table 5 Support-staff-to-scientist ratios by institutional category

Type of organization	Technicians per researcher	Other support per researcher	Total support per researcher	Number of institutes
Government				
NAROs	1.7	6.0	7.7	15
non-NAROs	1.6	9.4	11.0	92
Semipublic	2.3	16.0	18.3	8
Total	*1.7*	*8.0*	*9.7*	*115*

Source: Compiled by authors from survey data.

Note: Based on a sample of 115 agricultural research agencies (excluding universities) in 23 Sub-Saharan African countries.

4. RESEARCH COSTS

An economic appraisal of the costs of R&D can draw usefully on the costs concepts commonly used in production economics; this includes distinguishing between different types of costs—be they fixed or variable, or relatedly, labor, operating, or capital costs—and assessing the changes in costs per unit of output as the scale and scope of the research operation changes. As fixed costs (e.g., the capital costs involved in land, equipment, and buildings) are spread over a larger quantity of output, the costs per unit of output typically fall, and economies of scale or size are said to exist. The presence of significant size economies would point to possible gains from consolidating research facilities. Similarly, there may be significant cost savings to be gained from sharing capital costs (such as buildings, laboratory facilities, and equipment) across different lines of research (e.g., operating integrated breeding facilities across various crops rather than stand-alone, commodity-specific facilities). Economists dub these savings “scope economies.”

While these cost constructs are useful in principle in thinking about the structure of costs for R&D institutions, unfortunately they are difficult to apply in practice because there is no readily available measure of research output against which to juxtapose the research costs. Nonetheless we draw on these economic concepts when analyzing the different cost structures of African agricultural agencies. Specifically, we begin with a brief review of the total costs of agricultural research in the region and the evolution of those costs for different types of R&D institutions. Next we document and discuss cost shares, distinguishing between labor, operating, and capital costs, and then we deal at some length with a newly constructed cost-per-scientist series. We identify the substantial differences across different types of institutions in this cost indicator and then present a more formal, statistical accounting of the sources of variation in the measure.

TOTAL COSTS

In 1991, the total cost of public agricultural R&D throughout Africa was about $966 million (1985 international dollars), in real (inflation adjusted) terms significantly more than double the $360 million spent three decades earlier. Pardey, Roseboom, and Beintema (1997) document these R&D spending trends in some detail for 19 African countries and show that the rate of growth in real spending slowed substantially over time, from 6.8 percent per annum in the 1960s to an annual rate of just 0.1 percent from 1981 to 1991. But there was a considerable variation among countries. Between 1981 and

1991, total research costs in five countries rose by more than 4 percent per annum, while spending in another five countries declined by more than two percent annually.

African agricultural research agencies vary widely in terms of their total annual costs, ranging from less than $50,000 to more than $50 million (1985 international dollars). Table 6 provides an indication of the cost profiles for 147 government and semipublic agencies, stratified according to their research focus and organizational structure. Only 16 of the 147 agencies had total costs in excess of $10 million in 1991: 11 of these agencies were multi sectoral NAROs. Among the more specialized single-sector agencies, crop research institutes tended to spend more than agencies engaged in either livestock, forestry, or fisheries research. Agencies focusing on socioeconomic, environmental, or food-processing research, not specific to a particular subsector, have comparatively smaller annual budgets.

COST SHARES

Table 7 reports cost shares for 64 government and semipublic agencies from 17 countries for the period 1986-1991. These data suggest that overall cost *shares* were reasonably stable throughout this period, although public agencies consistently allocated a greater share of their total spending to personnel and a significantly smaller share to operational inputs than did semipublic agencies.

Table 6 Cost profiles of agricultural research agencies, 1991

Cost categories[a]	Research focus						Type of organization			
	Crops	Livestock	Forestry	Fisheries	Other[b]	Multi-sector	NAROs	non-NAROs	Semipublic	Total
					(number of institutes)					
Less than 0.5 million	1	3	6	1	11	0	0	21	1	22
0.5 - 1 million	4	7	2	4	5	2	0	21	3	24
1 - 2 million	2	3	4	3	7	3	0	22	0	22
2 - 4 million	11	3	1	4	5	4	2	23	3	28
4 - 6 million	3	3	1	1	1	4	1	11	1	13
6 - 8 million	7	1	1	1	1	3	3	10	1	14
8 - 10 million	5	0	1	0	0	2	1	4	3	8
10-15 million	1	1	0	1	0	4	4	2	1	7
15-20 million	0	0	0	0	0	2	2	0	0	2
20-30 million	1	0	0	0	0	3	3	1	0	4
Greater than 30 million	0	0	0	0	0	3	2	1	0	3
Total	*35*	*21*	*16*	*15*	*30*	*30*	*18*	*116*	*13*	*147*
					(millions 1985 international dollars)					
Total expenditures	190.7	54.2	30.1	43.7	43.4	369.0	301.7	366.6	62.7	731.0
Weighted average per agency	5.4	2.6	1.9	2.9	1.4	12.3	16.8	3.2	4.8	5.0

Source: Compiled by authors from survey data.

Note: Universities are not included.

[a] In 1985 international dollars.
[b] Includes agencies engaged in socioeconomic, environmental, and food-processing types of R&D not specific to a particular sub-sector.

Table 7 Institutional perspectives on cost shares

	Cost shares				Expenditures per researcher[a]			
	1986	1988	1990	1991	1986	1988	1990	1991
	(*percentage*)				(*thousands 1985 int. dollars*)			
NAROs								
Personnel	60.7	54.8	57.6	56.0	71	71	66	62
Operating	26.8	26.2	29.1	27.4	31	34	34	30
Capital	12.5	18.9	13.3	16.5	15	25	15	18
Total	*100*	*100*	*100*	*100*	*117*	*130*	*115*	*110*
non-NAROs								
Personnel	58.3	59.2	62.7	65.6	77	71	67	71
Operating	28.4	26.8	24.5	22.7	38	32	26	24
Capital	13.3	14.0	12.8	11.8	18	17	14	13
Total	*100*	*100*	*100*	*100*	*132*	*119*	*108*	*108*
Semipublic agencies								
Personnel	52.2	51.0	47.1	50.4	130	119	104	103
Operating	33.3	32.5	34.9	35.0	83	76	77	72
Capital	14.4	16.4	18.0	14.6	36	38	40	30
Total	*100*	*100*	*100*	*100*	*249*	*233*	*221*	*204*
Total agencies[b]								
Personnel	58.8	56.7	59.3	60.4	76	73	68	68
Operating	28.1	26.9	27.3	25.6	36	34	31	29
Capital	13.1	16.3	13.4	14.0	17	21	15	16
Total	*100*	*100*	*100*	*100*	*130*	*128*	*115*	*113*[c]

Source: Compiled by authors from survey data.

Note: Based on data from 57 government agencies (i.e., 11 NAROs and 46 non-NAROs) and seven semipublic agencies in 17 countries.

[a] Weighted averages.
[b] Government and semipublic agencies.
[c] This total based on a sample of 64 agencies is lower than the corresponding cost-per-scientist figure of $119,300 reported in the text based on a sample of 147 agencies.

The stability in these overall cost shares belies the dramatic inter-institutional differences in the underlying cost structures. Table 7 also reports the cost components for government and semipublic institutes on a per-researcher basis. Semipublic institutes committed nearly twice the quantity of resources per scientist than government institutes, and this difference persists across the personnel, operating, and capital cost components. This points to significant, and possibly very important, differences in the way government and semipublic agencies allocate their research budgets. This finding also holds if we limit our sample agencies to include only those that are located in countries with semipublic agencies.

The prevailing sentiment among many observers (Spurling et al. 1992; World Bank 1992; Weijenberg et al. 1993 and 1995; and Taylor et al. 1996) is that research throughout Africa is severely curtailed because of inadequate operational resources. The quantitative evidence in Table 7 seems to contradict this view, particularly for the semipublic institutes, but it may be that a disproportionate share of operational funds are consumed by burdensome administrative overhead and the maintenance and upkeep of an extensive network of (comparatively small) research stations and farms. This seems especially so for government agencies. These funds might never find their way into bench-level research. For the semipublic institutes, the relatively high operational costs per researcher may partly arise because such institutes commonly earn much of their income from estate farm operations that employ significant numbers of field staff. Disentangling farm costs from research-related costs is difficult.

For an alternative look at spending-per-scientist ratios, Table 8 presents 1991 expenditures per researcher denominated in current U.S. dollars, rather than the international dollar figures presented elsewhere in this paper. Cross-country cost comparisons based on official market exchange rates (while subject to the significant problems induced by pervasive exchange rate distortions in Africa) may be more familiar to those who actually fund research.

Table 8 Research cost categories on a per scientist basis, U.S. dollars, 1991

	Personnel costs			Operating	Capital	Total
	Local	Technical assistance	Total			
	(current U.S. dollars per researcher)					
Burkina Faso	21,469	33,117	54,586	22,074	22,056	98,716
Cape Verde	41,231	42,857	84,088	28,048	2,244	114,380
Côte d'Ivoire	35,878	56,471	92,349	25,316	2,707	120,372
Ethiopia	16,171	8,586	24,757	10,530	10,088	45,374
Ghana	25,074	10,185	35,259	9,859	22,813	67,930
Kenya	19,118	12,660	31,778	10,771	6,772	49,320
Madagascar	6,545	25,140	31,685	8,680	2,664	43,028
Malawi	20,054	22,599	42,653	19,133	7,477	69,262
Mali	14,676	16,190	30,866	12,173	8,812	51,851
Mauritius	35,307	0	35,307	25,737	9,298	70,341
Niger	34,134	27,273	61,407	3,920	1,615	66,942
Nigeria	10,462	1,812	12,274	6,357	4,591	23,221
Rwanda	28,813	36,735	65,547	17,072	4,533	87,152
Senegal	34,484	45,031	79,515	17,965	3,498	100,978
South Africa	66,088	0	66,088	18,929	6,133	91,150
Togo	20,753	30,000	50,753	15,079	6,115	71,946
Zimbabwe	34,610	16,744	51,355	15,791	9,281	76,426
Weighted average	*29,965*	*12,763*	*42,728*	*13,634*	*7,089*	*63,450*

Source: Adapted from Pardey, Roseboom, and Beintema (1997).

Note: For 1991 we assumed that the salary costs of expatriate researchers were, on average, US$150,000. This figure includes all benefits and additional costs of supporting an expatriate researcher and his or her family in Africa.

A noteworthy feature of these data is the large share of expenditures per researcher due to technical assistance costs. Nine of the 17 countries in Table 8 spent more on the salaries of expatriate researchers than on the salaries of local staff. Often, however, there is little agricultural research managers can do about this aspect; technical assistance costs are generally incurred by donors and there is little fungibility between local and expatriate expenses.

COSTS PER SCIENTIST

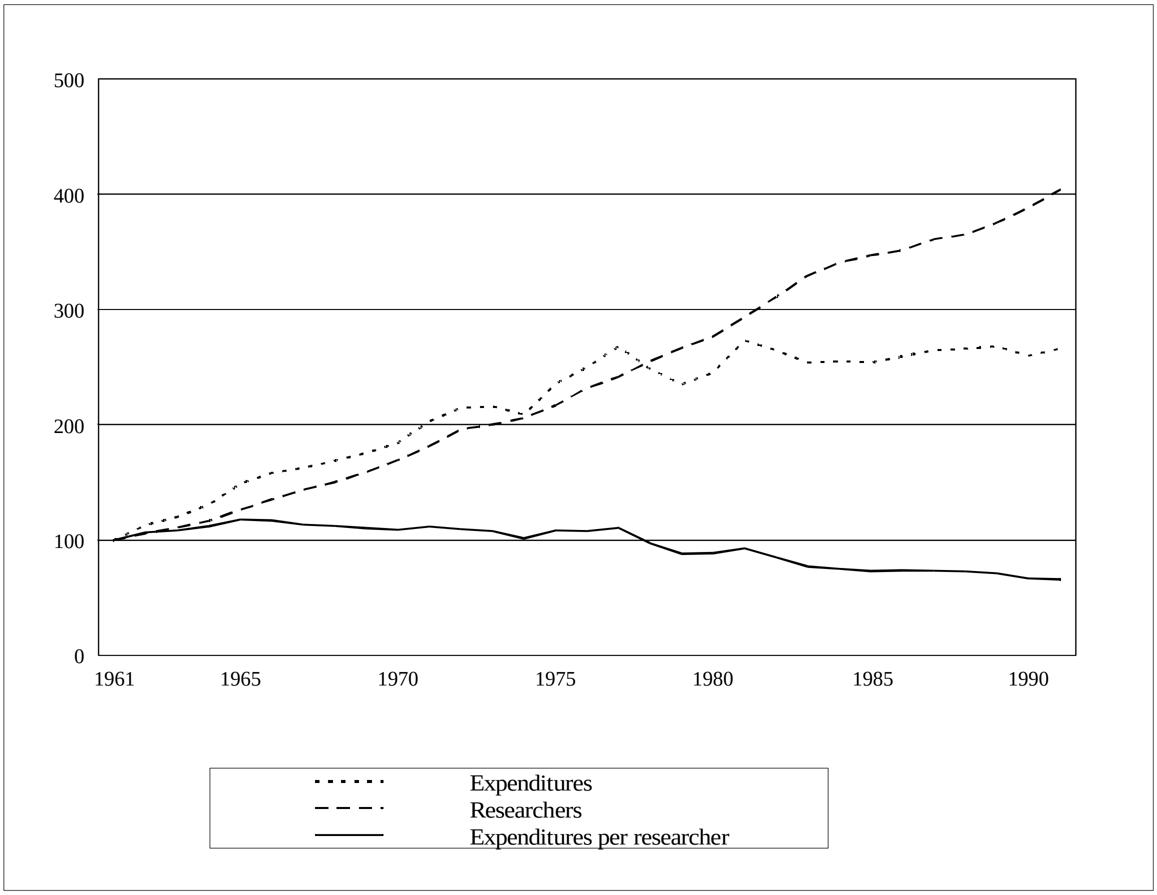
General Trends

In real (inflation adjusted) terms African agricultural research expenditures stalled around the mid-1970s. The number of researchers continued to grow, with the result that, overall, costs per scientist declined by nearly 30 percent between 1981 and 1991 (Figure 2). Based on a 19-country sample, we estimate that about one-tenth of this cost decline is attributable to the substitution of national scientists for expatriate researchers—the former typically costing six times less than the latter. Nigeria and South Africa employed few expatriate scientists by 1981. Excluding these two countries from the 19-country sample, then over one-third of the decline in the average cost-per-scientist ratio represents this labor substitution effect.

Institutional Perspectives

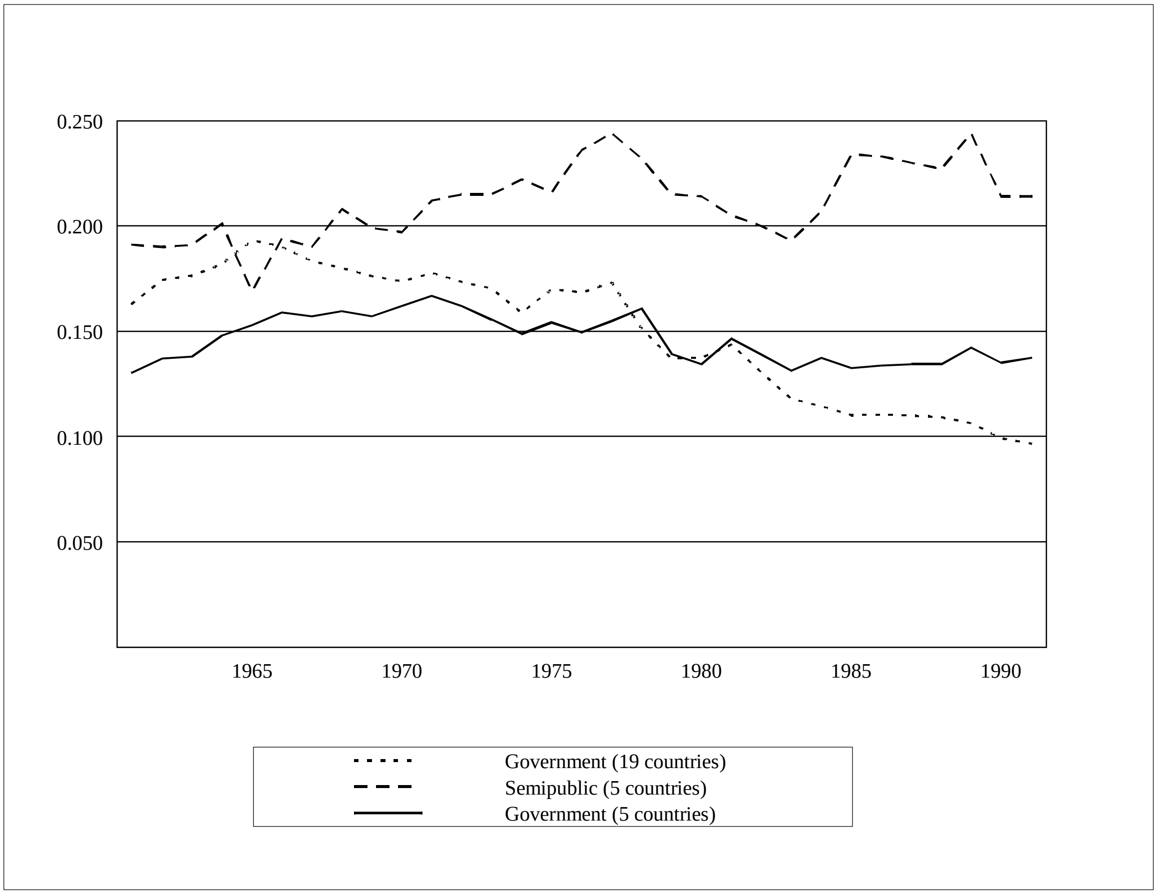
In Figure 3 we plot real, cost-per-scientist ratios for government and semipublic agencies from 1961 to 1991. The government institutions include 122 agencies operating

Figure 2 Overall researcher, ependiture, and cost-per-scientist trends, 1961-91 (index, 1961 = 100)



in 19 countries that collectively spent $567.8 million (1985 international dollars) in 1991; the semipublic series represents 13 institutes spread across five countries with expenditures totaling $50.4 million in 1991. Semipublic agencies report cost-per-scientist ratios that are substantially higher than the corresponding ratios for public agencies. Moreover, this group of semipublic agencies spent 12 percent more per scientist in 1991 than they did in 1961, while the government agencies spent 36 percent less.

Figure 3 Costs per scientist, 1961-91 (millions 1985 int. dollars)



These inter-institutional differences are less dramatic when the sample of government agencies is drawn from the same five countries as the semipublic agencies (specifically, Kenya, Malawi, Mauritius, South Africa, and Zimbabwe). Costs per scientist in the government agencies in these five countries, averaged across all five, remained roughly constant during 1961 to 1991 against the 12 percent increase experienced in semipublic agencies. These averages, however, mask a good deal of cross-country variation. Government agencies in Zimbabwe and South Africa spent about 20 percent more per scientist in 1991 than in 1961, while those in Kenya, Malawi, and Mauritius spent about 40 to 60 percent less.

More detailed and comprehensive cross-sectional data (147 agencies across 27 countries) are available for 1991. In that year, an average of $119,300 (1985 international dollars) was spent in salaries and benefits, support staff, and operational and capital inputs per scientist.[7] The range around this average is large: the Water Resources Research Unit in Zambia spent a total of only $16,400 per scientist in 1991, the Agricultural Research Division in Swaziland about $400,000 per scientist. Figures 4a and 4b give some indication of the distribution of the costs per scientist among the 147 agencies in this sample. Around three-quarters of these agencies reported cost-per-scientist ratios in the $50,000 to $200,000 per scientist range. A cumulative, weighted distribution of cost-per-scientist shares, in which each institute's cost ratio is weighted by the number of researchers in the institute, is plotted in Figure 4b. When the respective size of each institute is taken into account, 84 percent of the sample falls within the $50-200,000 range (compared with 77 percent for the unweighted cost shares), suggesting that those institutes with extremely low or high cost ratios tend to be the smaller institutes.

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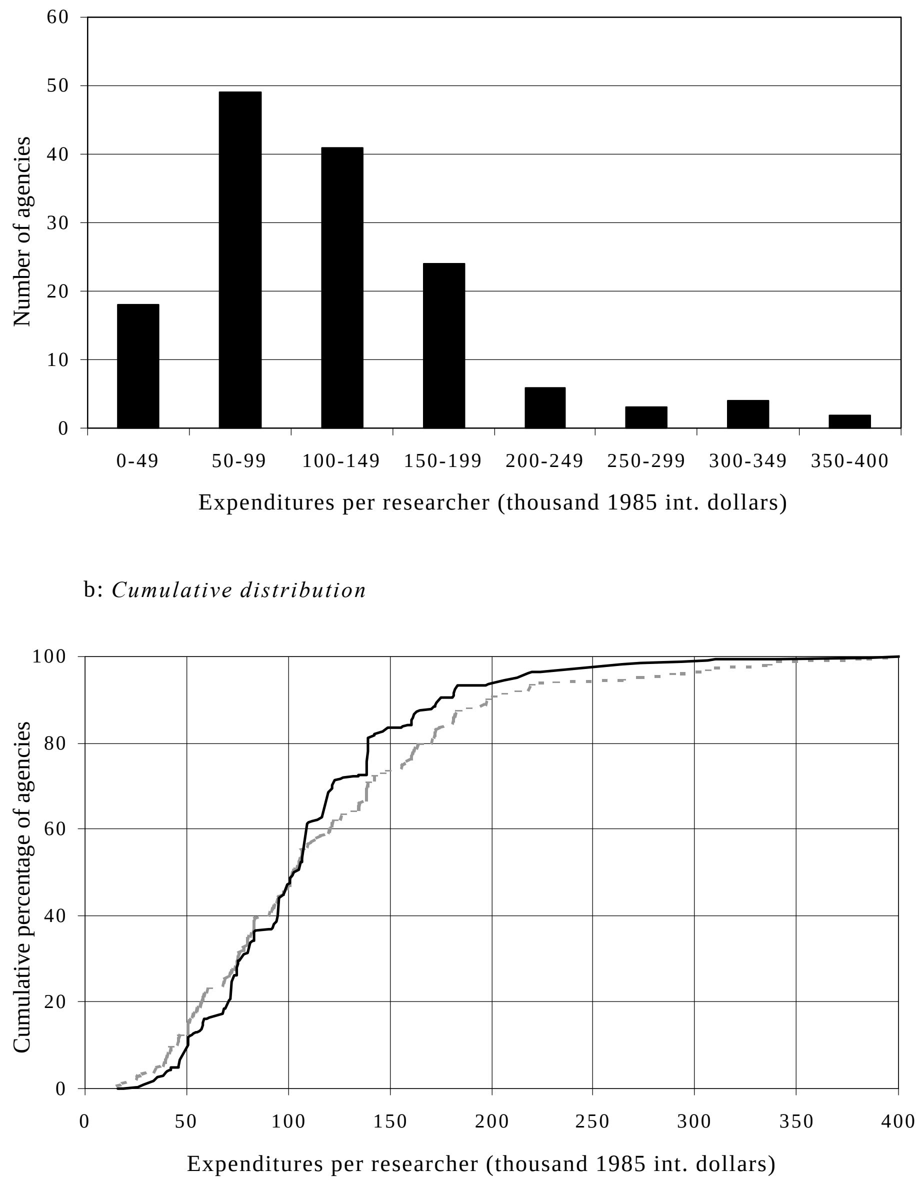
[7] The corresponding figure in U.S. dollars using market exchange rates (rather than purchasing power parities) to do the currency conversion, is US$59,500 per scientist. Netting out expatriate salaries, and calculating the total costs per national scientist gives figures of $109,300 and US$54,500 (1985 prices), respectively.

Figure 4 Frequency distributions of costs per scientist, 1991

a. *Simple distribution*

b: *Cumulative distribution*



Note: The grey dashed line plots unweighted observations, the solid line weighs observations for each by the number of researchers employed.

Accounting for Cost Differentials

Cost-per-scientist ratios clearly vary by a wide margin across various research agencies. Is this because some agencies are better managed and thus more efficient than others? Does variation in the research focus contribute to the differential? Are there institutional or broader, economy-wide infrastructural factors that contribute to the variation? Does the size and scope of a research agency matter much? It would be useful for research managers, finance ministries, and donors alike to get a better feel for the sources of these cost differentials and their relative importance. Rather than tackle this issue on a piecemeal basis, we elected to use a simple, multivariate regression approach to investigate the sources of differences among agencies in their cost-per-scientist ratios.

We grouped the likely sources of variation into three broad categories:

- Quality and composition of the scientific staff (Group 1)
- Intensity of input use in research (Group 2)
- Various institutional and infrastructural aspects (Group 3)

Given the sizeable share of R&D spending on staff, differences in the quality and composition of the scientific staff is likely to be an important source of variation in research costs. Clearly higher-quality research staff (as indexed, here, by postgraduate degree status) would push up salaries and fringe benefits, and hence the cost-per-scientist ratio. Expatriate staff are generally more costly than national staff, so a higher proportion of expatriate staff is also likely to increase average costs per scientist.

The second group of factors relates to the intensity of input use. Obviously, those agencies that commit more operating, capital, and other inputs per scientist will have higher cost-per-scientist ratios. If we had access to detailed, standardized budget data it would be a simple matter to isolate the cost components and categorize each agency in terms of the mix and quantity of inputs used, but these data simply do not exist. Instead we must resort to other methods to “decompose” the cost totals into their cost components. One notable feature of African R&D agencies is the comparatively large numbers of support staff per scientist (Table 4). To estimate the cost consequences of this aspect we included two variables in our empirical model. Specifically, we measured the intensity with which each agency invested in technical as well as other support staff, hypothesizing that the cost consequences of additional technical personnel would vary from that of additional, non-technical staff.

Our third group of explanatory variables includes a range of other institutional and infrastructural aspects. One set of institutional variables relates to various size and structure elements. To investigate the possibilities of economies of size effects, a variable proxying the size of the agency (the number of scientists) was included. Research agencies that are more geographically dispersed in terms of their headquarters and substation structure are likely to incur additional costs.[8] A variable measuring the number of stations per agency was included to capture this effect. Lucas (1967) and Prescott and Visscher (1980) argued that the unit cost of adjustment for a firm is an increasing function of the rate of adjustment. In this context, it is possible that rapidly growing agencies

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[8] If this geographical dispersion in stations reflects an underlying variation in the agroecological basis for agriculture then it may call for more site-specific and hence intrinsically more expensive, R&D. But it may be that the location of stations reflects the outcome of rent-seeking political processes. Unfortunately we do not have the basis for discriminating between these two possibilities.

(measured here by the rate of growth of research staff) incur additional costs slotting incoming scientists into on-going programs of research or putting new equipment and buildings through a "shakedown" period before reaching their productive potential. The faster the rate of growth the higher these adjustment costs may be.

The orientation of the R&D being performed by each agency can also influence the costs of doing research. A common view is that maintaining animal herds (including the labor, buildings, and pastureland required to sustain these herds) means that livestock research is intrinsically more costly than crops research. Certainly this is borne out by recent data on public-sector research in the United States. Alston et al. (1999) calculated that in 1994, animal research cost about $320,000 per scientist per annum, while crops research was $230,000.[9] To explore these types of effects, we included a number of dummy variables that differentiated agencies according to their principal research orientation (multi sectoral, crops, livestock, forestry, fisheries, and other). A dummy variable is a dichotomous variable coded as equal to one if some characteristic is present and equal to zero if it is not. The dummy variable for one of the categories—the default category—must be omitted from the regression in order avoid the "dummy-variable trap," wherein the model is overidentified so that none of the coefficients can be estimated. Here we set the default to be agencies carrying out crops research.

We also included an additional set of dummy variables to represent the NARO

[9] They also showed that the gap between the cost of livestock and crops research narrowed markedly over the past 25 years; presumably the more rapid shift towards modern biotechnology methods in the crop sciences has increased the cost of this science at a faster rate than the animal sciences.

versus semipublic status of a research agency (setting government agencies not classified as NAROs as the default). These particular variables represent a host of organizational and management aspects not reflected in the other variables included in this analysis. Thus, it is difficult to anticipate whether these aspects would, on balance, increase or decrease the costs of doing research.

Per capita income was another variable we included to reflect the net consequences of a broad set of other, unmeasured factors that may influence research costs. As per capita incomes increase, one may expect that the focus moves toward more basic lines of R&D; research that would be expected to increase costs per scientist. Also, relatedly, richer countries may invest more per scientist in terms of capital equipment, and allocate more operational funds than do poorer countries, both of which would act to increase the cost ratios measured here. Conversely, the improvements in general infrastructure, such as better communications and transportation, that come with increases in per capita income are likely to lead to cost savings that would drive down costs per scientist. Finally, a set of country dummy variables was also included to represent those omitted variable effects that varied among but not within countries.

It is from these variables that we developed the empirical regression model, which in the linear form we used, is given by:

$$c = \mathrm{b}_0 + \mathbf{b_1}\,\mathbf{G_1} + \mathbf{b_2}\,\mathbf{G_2} + \mathbf{b_3}\,\mathbf{G_3} + \epsilon\ , \qquad (1)$$

where c is the cost per researcher (expressed in 1985 international dollars), b_0 is the intercept, $\mathbf{b_i}$ is a vector of slope coefficients, $\mathbf{G_i}$ is a corresponding matrix of explanatory variables for the three groups discussed above (I = 1, 2, and 3), and ϵ is the error term.

Table 9 provides some summary statistics for the continuous variables included in this regression model. All data refer to the year 1991. Spending per scientist averaged $115,216 for this 107-observation sample, ranging from $21,913 to $400,146. The values of all the explanatory variables varied markedly among agencies. For example, although an average of 68 percent of the scientific staff held postgraduate degrees, all the scientists in some agencies were so trained while in other agencies none of the scientific staff were trained above the BSc level. Similarly, the size of R&D agencies varied from 532 fte researchers to a mere 1.6 fte scientists, while per capita income for the countries in this sample varied from $316 to $5,291.

Table 10 gives the conditional means of the spending-per-scientist estimates for the dichotomous (zero-one) variables included in the model. The 29 agencies conducting crops research spent an average of $166,129 per scientist in 1991, more than the average reported for agencies engaged in any other class of commodity research. Semipublic agencies spent an average of $207,686 per scientist, nearly double the amount spent by NAROs and non-NAROs alike. The two agencies in Rwanda for which we had data, averaged $166,981 per scientist, over four times the amount spent by agencies in Tanzania.

Table 9 Variables used to account for research cost differentials

Variables	Sample mean	Standard deviation	Values	
			Minimum	Maximum
Costs per scientist (1985 int. dollars)	115,216	67,631	400,146	21,913
Group 1				
Percentage postgraduates	68.0	23.8	100.0	0
Percentage expatriates	8.4	13.1	55.6	0
Group 2				
Technical-support-staff ratio	1.9	1.6	12.5	0.1
Other-support-staff ratio	8.9	10.5	60.1	0.2
Group 3				
Size: number of researchers	45.9	69.4	532.0	1.6
Structure: number of stations	5.9	5.9	34.0	1.0
Growth research staff, 1981-91 (%)	4.4	6.4	25.2	-12.9
GDP per capita (1985 int. dollars)	1,344	1,146	316	5,291

Source: Authors calculations.

Note: Sample includes 107 government and semipublic agencies located in 21 African countries.

Table 10 Conditional mean costs per scientist

Default category	Number	Mean	Standard deviation	Explanatory variable included	Number	Mean	Standard deviation
Research focus							
Crop	29	166,129	76,528	Multisector	22	118,548	60,981
				Livestock	16	99,700	50,181
				Forestry	9	79,956	37,116
				Fisheries	12	106,238	54,388
				Other	19	69,089	40,541
Organization							
Non-NARO	83	104,282	60,093	NARO	13	106,782	39,436
				Semipublic	11	207,686	80,724

continued

Table 10 (cont'd)

Default category	Number	Mean	Standard deviation	Explanatory variable included	Number	Mean	Standard deviation
Country							
Burkina Faso	9	106,602	62,579	Cape Verde	1	131,708	-
				Cote d'Ivoire	3	86,218	41,132
				Ethiopia	3	118,313	68,526
				Ghana	8	148,397	83,846
				Kenya	5	162,007	129,061
				Madagascar	3	77,869	25,656
				Malawi	4	165,954	77,756
				Mali	3	76,662	19,265
				Mauritius	1	149,188	-
				Niger	2	74,515	14,931
				Nigeria	18	100,983	46,869
				Rwanda	2	166,981	7,504
				Senegal	2	107,704	44,340
				South Africa	15	143,250	54,466
				Sudan	3	50,579	0
				Tanzania	4	39,520	13,161
				Togo	4	84,766	37,839
				Zambia	8	59,549	36,165
				Zimbabwe	8	156,197	61,816

Source: Authors calculations.

Note: See table 9.

Table 11 presents the results from estimating various versions of this model.[10] Regression 1 includes a base set of group 1, 2, and 3 variables, regression 2 adds dummy

[10] Omitted variables, if correlated with those variables included in the model, may bias the estimated coefficients and confound their interpretation. Panel data estimation techniques can deal with some of these problems (see Craig, Pardey, and Roseboom 1997 for a recent example) but unfortunately we were limited to a single cross section of data here.

variables representing the research focus and organizational structure of the agencies, and regression 3 includes a set of country dummy variables. Taken together, these variables accounted for more than half the observed variation in spending per scientist. In summary, the statistical evidence reveals that:

- Although researchers with a postgraduate degree typically received salaries and benefit packages that were 20 to 30 percent larger than their BSc counterparts, they generally accounted for a minor share of total costs (often less than three percent), and there was comparatively little variation among agencies in the share of scientists holding postgraduate degrees. For these reasons, perhaps, differences in the quality of researchers (proxied here as the share of scientific staff with postgraduate degrees) had no measurable effect on cost-per-scientist ratios.
- Reducing the proportion of expatriates also lowered the cost-per-scientist ratio and the magnitude of the effect is substantial. Thus, the comparatively small share of expatriates working in African research agencies during the year of our data, 1991, is offset by the relatively large effect each expatriate has on the overall cost-per-scientist ratio, meaning that a variation in expatriate intensities was a significant source of variation in total research costs.
- Increasing the intensity of technical and other support ratios gave rise to significant increases in cost-per-scientist ratios. As would be expected, a one- percent increase in the intensity of technical support had a larger effect on our cost ratio than a similar increase in the intensity of non-technical support staff.
- Larger research agencies (as indexed by the number of scientists) have lower cost-

per-scientist ratios, although this effect had variable significance across the various forms of the regression model reported in Table 11. We also found evidence that increasing the number of experimental stations increased cost ratios. Typically an additional station entailed around $400 - $2,000 of additional costs per scientist per annum.

- In general, there was no measurable difference in spending per scientist when research agencies were grouped according to the commodity orientation of their research. The exception was forestry research, which seems to spend much less per scientist than other forms of research in Africa. This suggest that forestry research in Africa may involve less technically demanding, and thereby less costly, types of R&D. Contrary to the U.S. evidence cited above, livestock research was not significantly more expensive per scientist than crops research. However, there were indications in our institutional data (not captured in the regression model) that agencies specializing in veterinary research are more costly per scientist than those engaged in livestock production research.
- Regression models 2 and 3 distinguished among agency types, be they NARO or non-NARO government agencies or semipublic agencies. They show that semipublic agencies spent a good deal more per scientist than their more tightly focused public counterparts. These cost differences are likely to reflect differences in spending on operational and capital inputs given that size effects are already

included in the model.[11]

- Per capita income, taken here to reflect a whole host of institutional, infrastructural, and political aspects not otherwise represented in the empirical models, is a uniformly significant source of variation in spending per scientist ratios; richer African countries spend significantly more per scientist than do poorer ones. The country dummies, which reflect omitted variable effects that vary among but not within countries, are also jointly significant.

Table 11 Cost-per-scientist regression results

Variables	Regression number		
	(1)	(2)	(3)
Intercept	-1,013 (-0.05)	23,156 (0.87)	25,355 (0.64)
Group 1			
Percentage postgraduates	163 (0.79)	206 (0.98)	590[b] (1.94)
Percentage expatriates	1,594 (4.14)[a]	1,548 (4.13)[a]	1,404 (3.05)[a]
Group 2			
Technical-support-staff ratio	7,799 (2.47)[a]	5,072 (1.66)[b]	4,248 (1.39)
Other-support-staff ratio	3,846 (8.15)[a]	3,006 (6.08)[a]	2,971 (5.32)[a]

continued

[11] Recall that NAROs are typically larger operations than non-NAROs and involve more experimental stations. There is some suggestion in our data that costs per scientist declined with increasing agency size but costs increased as the number of stations increased.

Table 11 (cont'd)

Variables	Regression number		
	(1)	(2)	(3)
Group 3			
Size: number of researchers	-50 (-0.47)	-142 (-1.32)	-139 (-1.07)
Structure: number of stations	410 (0.33)	1,231 (0.97)	1,998 (1.39)
Growth research staff, 1981-91 (%)	848 (1.10)	408 (0.56)	-594 (-0.68)
GDP per capita (1985 int. dollars)	29 (6.61)[a]	21 (4.56)[a]	--
Multisector research	--	6,670 (0.36)	2,434 (0.13)
Livestock research	--	-7,036 (-0.46)	-2,082 (-0.13)
Forestry research	--	-35,550 (-1.86)[b]	-33,498 (-1.79)[b]
Fisheries research	--	-11,576 (-0.67)	-3,282 (-0.20)
Other research	--	-25,506 (-1.58)	-19,871 (-1.21)
NARO	--	-3,186 (-0.13)	-4,994 (-0.17)
Semipublic agencies	--	64,996 (3.70)[a]	72,523 (3.79)[a]
Country dummies	not included	not included	included
Adjusted R^2	0.537	0.580	0.645
Degrees of freedom	98	91	72

Source: Authors' calculations.

Note: See table 9.

[a] Significant at the 99-percent level; [b] significant at the 90-percent level.

5. RESEARCH SALARIES AND BENEFITS

Labor costs are a dominant share of total R&D costs, so an understanding of the structure of salaries and benefits of research staff is central to an understanding of the costs of doing research. Moreover, the remuneration packages received by research staff also have important efficiency consequences given the incentive effects associated with these packages. How much people are paid relative to their performance and their alternative opportunities, their prospects for pay increases, the timeliness with which they are paid, and the purchasing power of their wages are all critical determinants of the incentives afforded research staff. Consequently, salaries and benefits will have a direct and often dramatic impact on the ability to recruit and retain talented researchers and support staff, the levels of absenteeism (as staff seek additional employment often simply to make modest ends meet), and the overall morale and productivity of a research agency. Institutionalized corruption and other rent-seeking activities can creep in if salaries fail to meet basic needs, or slip too far behind alternative opportunities. These incentive issues involve fundamental management and policy concerns that go well beyond their research cost implications. Here we focus on the latter aspect but remain sensitive to these broader implications in our treatment of our new data on research salaries and benefits.

CIVIL SERVICE REMUNERATION IN AFRICA

In 1991, over 87 percent of the agricultural researchers in Africa were employed by government agencies, so by way of background we begin with a brief review of the available evidence concerning civil service remuneration in Africa. Efforts to reform government sectors as part of a broader program of IMF- and World Bank-supported, structural-adjustment initiatives have been a feature of economic policy reforms in many African countries in recent years. The World Bank, for example, was party to a total of 57 lending operations with civil-service reform components in 27 African countries between 1981 and 1992 (Dia 1993).[12]

Salaries

Developing a civil-service sector was often an explicit policy initiative for many countries in post-colonial Africa. But as economic growth began to slow (and in some cases even deteriorate) governments increasingly acted as an "employer of last resort." Many governments even "guaranteed" jobs for university graduates thereby contributing to the sustained and rapid increase in research personnel. Cohen (1993), for example, noted that during 1981-86, the Kenyan public service employed three-quarters of the country's new graduates. In many African countries such policies resulted in a long-run trend of growth in public employment exceeding growth in public revenues.

During the 1980s, 22 African countries experienced rates of inflation in general prices in excess of 10 percent per annum, and for eight of them the annual average rate of inflation exceeded 40 percent per annum. These chronically high rates of inflation had a number of longer-term effects that were compounded by short-term spikes which saw

[12] For a discussion of these issues see Lindauer, Meesok, and Suebsaeng (1988), Nunberg (1988), Robinson (1990a and b), Schiller (1990), Mackenzie and Schiff (1991), Stevens (1992), Dia (1993), and Cohen (1993).

inflation rates pushed even higher.[13] Over the longer-term, nominal, public-sector pay raises often fell short of inflation rates, which gradually eroded the purchasing power of these public-sector salaries (for additional details see Robinson 1990a and b; Lindauer et al. 1988; Nunberg 1988; and de Merode 1991). There was also a tendency for salary scales in government agencies to be compressed (often as minimum wages have risen faster than the salaries at higher pay scales), perhaps contributing to a change in the mix of staff employed.

Episodic (but still all too frequent) inflationary spikes not only eroded the purchasing power of salaries, but often gave rise to distorted cost structures as managers frequently dipped in to capital and operating budgets to meet shortfalls in salary-related expenses.

Benefits, Supplements, and Allowances

In addition to their base salaries, most civil service staff receive a package of benefits as well as salary supplements and other allowances. It is not uncommon in Africa for the total costs of these non-salary items to exceed base-salary costs. Nunberg (1988), for example, noted that “for many civil servants, wages may constitute as little as 25 percent of the total remuneration package.” In part, this situation may have its roots in

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[13] In contrast, a number of African countries, experienced quite modest rates of inflation throughout the 1980s. These were mainly the countries that linked their currencies with the French franc. This policy resulted in chronically overvalued exchange rates that imposed their own costs on the respective domestic economies and led to significant devaluations of the CFA franc in 1994.

colonial practices, when additional provisions such as free housing and hardship allowances were introduced to attract qualified (expatriate) professionals. More recently, however, as official salaries have fallen prey to inflation effects and other distortions, benefits have become a major component of remuneration packages for national staff as well, raising their own set of management and policy problems.

Certainly well-run and transparent public schemes, particularly related to pension and health benefits, can be privately and socially productive and provide positive incentive effects. However, where benefits packages extend further into gray areas the prospects for rent-seeking activity (including corruption) can have powerful and unproductive disincentive effects. Scarce resources that could more productively be spent elsewhere run the risk of being diverted into securing and maintaining "benefits packages."

REMUNERATION OF AGRICULTURAL RESEARCHERS IN AFRICA

As part of our science and technology survey of African agricultural research agencies we sought salary and fringe benefits data for entry-level personnel in five categories: researchers trained to PhD, MSc, and BSc levels, research technicians, and agricultural laborers. Usable data were obtained from 69 research institutes operating in 22 countries. Although these data are far from complete nor wholly comparable, they do provide a first and fairly comprehensive look at this important dimension of the cost structures of African agricultural research agencies.[14]

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[14] Many of the survey respondents reported only part of their benefits packages. Typically the health and pension parts of the packages were reported but not other parts of the package. Consequently, our data provide a lower bound estimate of the size of these

In the early 1990s, the average annual base salary of an agricultural researcher with an MSc degree was about US$5,000, ranging in our sample from as low as a few hundred dollars per annum to nearly US$15,000. In Table 12, countries were classified according to their average, base-salary level. With a few exceptions, the reported base salaries varied little among institutes within a country. Not surprisingly, higher salaries are paid in the richer African countries. Salaries are also above the African average in some of the FCFA countries. However, these data refer to the period before the devaluation of the CFA franc in 1994, so that may no longer be the case. Countries that stood out as having extremely low base salaries (less than US$500 per annum) were Sierra Leone, Tanzania, Uganda, and Zaire.

Given the preliminary and spotty nature of the data and the currency conversion problems involved in dealing with value data such as this, we opted to index each institution's reported salary and fringe benefits on the remuneration package received by a researcher with an MSc degree—this being the most widely reported category in our sample. Various salary and benefits indexes are reported in Table 13. Averaging across the whole sample we see that both the salary and benefit differentials between laborers and doctoral scientists are about the same: entry level scientists with PhDs earned roughly four times more than agricultural laborers. However, it is likely that our data (in some cases) significantly under-report the benefits received by more-qualified staff compared with

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non-salary aspects of the remuneration package.

unskilled or semiskilled staff.[15]

Table 12 Base salaries of agricultural researchers with an MSc-degree, early 1990s

Less than US$ 1,000	US$ 1,000-3,000	US$ 3,000-6,000	US$ 6,000-9,000	Greater than US$ 9,000
Nigeria	Gambia	Burkina Faso	Cape Verde	Botswana
Sierra Leone	Malawi	Ethiopia	Côte d'Ivoire	Gabon
Sudan	Mali	Ghana	Senegal	Namibia
Tanzania	Mauritania	Kenya		Seychelles
Uganda		Mozambique		South Africa
Zaire		Niger		
		Rwanda		
		Togo		
		Zambia		
		Zimbabwe		

Source: Compiled by authors from survey data.

Note: Salary data were compiled in current, local currency units and are reported here in corresponding current U.S. dollars using the annual average exchange rate from the World Bank (1995).

Our data do point to an especially large variation among institutions in their reported salary and benefits differentials. At one end of the distribution, the salaries and

[15] The types of “gray” benefits omitted from the figures reported to us are likely to include the use of public land and other facilities for farming purposes and the direct, supplementary payments to staff through consultancies with private firms and collaboration with international agencies and other, bilateral arrangements. Given that donor funding accounted for 45 percent of the reported costs of agricultural R&D throughout Africa in 1991, informal payments by donor agencies could constitute a major share of the unreported benefits received by African research staff.

Table 13 Index of salaries and benefits for agricultural researchers

	Income	Benefits	Total
		(*index, MSc = 100*)	
Sample average			
PhD	116.4	115.5	114.1
MSc	100.0	100.0	100.0
BSc	84.4	84.7	84.0
Technician	60.5	53.9	58.3
Laborer	28.2	26.9	26.9
Ten institutes with the largest income differential			
PhD	106.2	113.2	106.7
MSc	100.0	100.0	100.0
BSc	82.7	74.5	79.3
Technician	43.3	30.4	38.7
Laborer	13.6	5.2	10.4
Ten institutes with the smallest income differential			
PhD	113.8	111.2	113.1
MSc	100.0	100.0	100.0
BSc	88.1	95.0	90.6
Technician	69.5	67.8	70.2
Laborer	41.7	56.2	47.1

Source: Compiled by authors from survey data.

benefits paid to doctoral scientists were nearly 10 times the corresponding cost of laborers. At the other end of the distribution, the salary and benefit differentials narrowed dramatically with doctoral scientists paid only twice as much as laborers. Interestingly, six of the 10 countries with agencies reporting the smallest salary and benefits differentials had comparatively high rates of inflation (at least 15 percent per annum for the period

1987-91), while only one of the 10 countries reporting the largest salary differentials had an inflation rate greater than 15 percent per annum.

Table 14 provides an indication of the share of reported benefits in the total costs of various classes of research labor. According to these estimates, an average of one-third of the cost of an African agricultural scientist is of fringe benefits, whereas fringe benefits constitute only a quarter of the costs of a laborer working for a research agency. As noted above, however, we suspect the benefits are understated, likely more so for scientists than for laborers, given that scientists have greater access to forms of benefits beyond the pension and health insurance components—such as housing, car and travel allowances—that were commonly reported in our survey. Table 14 points to significant variation among research agencies in the share of total staff costs attributable to benefits. Indeed for some agencies nearly three-quarters of the total staff costs for scientific and support personnel alike consists of fringe benefits while for other agencies non-salary costs are a negligible part of the total.

Table 14 Fringe benefits as a percentage of total remuneration package

Staff status	Average	Lowest observation	Highest observation
Researchers		(*percentage*)	
PhD	30.9	3.0	77.4
MSc	31.4	1.3	77.4
BSc	30.6	0	71.4
Technician	27.0	0	74.1
Laborer	24.5	0	71.9

Source: Compiled by authors from survey data.

Note: Data report average fringe benefits.

6. CONCLUSION

Although in real terms the overall cost of African agricultural R&D grew 2.7 fold between 1961 and 1991, growth stalled throughout the 1980s and, for a significant number of countries, contracted quite markedly. An especially worrisome trend is a 34-percent decline in spending per scientist since 1961.

Our data do not support the perception by some that African agricultural research is “expensive” by international standards, at least in terms of costs-per-scientist per year. Averaging across 147 R&D agencies, spending per scientist in 1991 was $119,300 (1985 international dollars), with 75 percent of the institutions (and 84 percent of the researchers) falling in the $50,000 to $200,000 range. A comparable 1991 cost figure for the U.S. agricultural experiment stations was $202,340 (1985 prices) per scientist year. International differentials in salaries are even more pronounced. Salaries of African scientists averaged around US$5,000 per annum in 1991 (perhaps, increased by 50 percent if fringe benefits are included). By comparison, salaries of academic staff working in large public universities in the United States—a proxy for the salaries of SAES scientists—averaged US$58,889 in 1991, increasing to US$72,667, if fringe benefits are included. These large international disparities in remuneration for scientists make it especially difficult for African agencies to recruit and retain talented research staff.

Delving below these broad, national trends, we document major differences among African R&D institutions in their cost structures. In particular the semipublic agricultural research agencies stand out as having cost-per-scientist ratios that are substantially higher than the corresponding ratios for government agencies. Moreover, while the costs per scientist employed by government agencies declined (particularly so after 1980), costs per semipublic scientist increased. Although the costs per government scientist in Africa are generally well below developed-country standards—even after accounting for price differentials in doing the conversions from local currencies to U.S. dollars—these costs seem neither especially low nor high compared with similar costs in other developing regions.[16] Addressing these cost (and, implicitly, the salary and benefits) differentials will be crucial to any efforts to continue to develop the human capital aspects of African agricultural research, especially given the increasing international mobility of trained research personnel.

Our econometric exercise provides some indication of why spending per scientist varies among agencies. The intensity of support staff per scientist and the intensity with which expatriate researchers are used are important sources of variation in cost-per-scientist ratios. For each additional technician working with a scientist, spending per scientist ratios increase between $4,200 and $7,800 (1985 international dollars). Marginal increases in non-technical support staff add around $3,000 to these costs. The overall size and physical structure (specifically, the number of stations) had predictable consequences for costs per scientist, but these effects were not statistically significant. Semipublic agencies spent a good deal more per scientist than NARO and non-NARO agencies,

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[16] In 1991, average costs per scientist in Africa were slightly lower than those in Latin America (Cremers and Roseboom 1997), but appear substantially higher than those in Asia (Pardey, Roseboom, and Fan 1998). Pardey, Roseboom, and Anderson (1991) reported similar regional differences in costs per scientist for the period 1981-85.

although there was no discernable difference in spending among NAROs and non-NAROs. As GDP per capita increases, so too does spending per scientist (with every dollar increase in GDP per capita raising the spending per scientist by \$20 - \$30). The country dummy variables were also jointly significant, and taken together with the GDP per capita results indicate that there are a host of other institutional and infrastructural variables not explicitly included in our empirical model that account for a sizable share of the cost differentials.

What are some of the more immediate policy implications flowing from this assessment of African R&D costs? Clearly there are a number of general development parameters (proxied in our case by a per capita-income or country dummy variables) that are difficult for policymakers or research managers to deal with in the short run, but that nonetheless have a significant bearing on the cost structures of African agricultural R&D agencies. However, there are a substantial number of other factors (such as streamlining support staff, making judicious use of expatriate staff, and, perhaps, consolidating disparate research facilities and rationalizing smaller stations) that point to the possibilities of significantly restructuring the costs of African agricultural research agencies.

By international standards, it seems that public-sector agricultural research agencies in Africa are not especially costly in terms of their spending per scientist, but there is much variation in cost structures among agencies and, implicitly, substantial room for restructuring these costs. The really relevant question is, however, not whether costs can be curtailed, but whether the social benefits following from the research justify the expenditure. There is some African evidence available on that matter (see, for example, Pardey et al. 1999), but more and better evidence is needed. Moreover, the low and deteriorating structure of salaries and benefits afforded African researchers and the lack of adequate funding to meet operational research costs may have its overwhelming effect in terms of undermining the staff morale and the operational efficiencies of a research agency, which go to the heart of its ability to generate the benefits expected from the investments made.

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