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**SOUTH AFRICAN AGRICULTURAL RESEARCH AND
DEVELOPMENT: A CENTURY OF CHANGE**

by

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ABSTRACT

The 20th Century saw substantive shifts in the structure of agriculture and agricultural production in South Africa. Farm size grew, farm numbers eventually declined, and production increasingly emphasized higher-valued commodities, notably a range of horticultural crops. The real gross value of agricultural output grew steadily (by 3.32 percent per year) from 1910-1981, but declined thereafter (by 0.21 percent per year from 1982-2008). These long-run sectoral changes provide a context to present and assess an entirely new data series on public agricultural R&D (and related regulatory and extension) spending and associated scientist trends. South African agricultural R&D has been affected by a series of major policy changes. These are also documented and discussed here, along with the associated institutional changes regarding the conduct and funding of public agricultural R&D in South Africa. We reveal a number of disturbing trends, including an effective flat lining of the long-run growth in total agricultural R&D spending that took hold in the 1970s, an erratic path of funding per scientist, and a loss of scientific personnel in recent decades. Moreover, South Africa has lost ground relative to its competitors in international commodity markets such as the United States and Australia in terms of the intensity of investment in agricultural R&D. These developments are likely to have long-term, and detrimental, consequences for the productivity performance and competitiveness of South African agriculture. They deserve serious policy attention as the 21st Century unfolds, with a firm eye to the long-run given the long lags (often many decades) that typify the relationship between agricultural R&D spending and productivity growth.

1. Introduction

It is generally accepted that the agricultural sector is an important, and, arguably, one of the most important sources of long-term economic growth for the South African economy, as it is for many other economies around the world (Van Zyl et al. 1988). In turn agricultural R&D is seen as a significant source of growth for the sector (Thirtle and Van Zyl 1994). Hence, science and technology policies are inextricably intertwined with the country's long-run economic growth and development performance. Science and technology policies are also interconnected with trade policies—as exemplified by numerous biosafety, phytosanitary, intellectual property and other regulatory aspects that directly affect the cross-border flows of new knowledge and new technologies. They also play a role in foreign policy more broadly, not least as a source of knowledge and technology spillovers to other parts of Africa. In addition, one of South Africa's overarching policy goals is to redress the inequities of the apartheid era and help families rise above and move beyond the restraints of that regime. Thus, not only the economic efficiency but also the income distribution implications of (agricultural) R&D have a bearing on overall science policy objectives, along with the details by which those policies are implemented.

As with the rest of the economy, the South African agricultural sector (especially the fruit, wine, and sugar industries) have long been dependent on exports, increasingly so since democratization in 1994.¹ Thus the technical changes that (agricultural) R&D bring

¹ For almost a century stretching back to 1910 the agricultural sector in South Africa has almost always maintained a positive trade balance. The ratio of agricultural exports to agricultural outputs (AgGDP) was typically in excess of 31 percent (except for the World War II years when it dropped to 18 percent) and reached an all time high of 70 percent in 2005 (DAS 2009). After a downturn that bottomed out at R9.37 billion (constant 2000 prices) in 1993, at the end of the sanctions years, agricultural exports grew thereafter by 5.6 percent per annum to total R18.21 billion in 2006. After the abolition of the controlled marketing era in 1997, the composition of export commodities changed markedly, with fruit (35 percent of agricultural exports), wine (13 percent), and sugar (13 percent) now

about are critical for maintaining competitive advantages in international markets, especially in relation to the cost and quality of South African agricultural produce.

All of these aspects give rise to a myriad of financial and policy pressures on the South African science and technology sector (including agriculture), not all necessarily steering these R&D-oriented sectors in the same direction. To disentangle and properly assess the near- and longer-term implications of these numerous policy perceptions requires an understanding of some empirical benchmarks about the evolution of the R&D sector and its current status. Taking a long-run view is paramount. Alston et al. (2008 and 2010) show that the productivity payoffs to agricultural R&D spending in the United States peak after a lag of 24 years and persist for upwards of 50 years; a result that is likely to apply with equal force to other countries, including South Africa. To make meaningful agricultural science policy choices requires that decision makers be cognizant of these long lags, while also adjusting to new and emerging economic realities.

In this paper we present, and begin to interpret, an entirely new set of long-run, in-depth indicators of South African agricultural R&D.² We also place those indicators in a more comprehensive science policy context. Not only are the technical boundaries between the agricultural and broader bio-sciences blurring, but the policy realities bearing upon agricultural R&D in South Africa are increasingly affected by policy pressures arising elsewhere in the economy. Juxtaposing general science developments against corresponding agricultural R&D trends informs, and thereby, hopefully, will improve these inter-related policy processes. It also helps shape private (including pre-, on-, and post-

being the most valuable export commodities, replacing commodities such as wool and maize that were dominant agricultural exports as recently as the 1980s.

² Parts of this paper draw on Liebenberg (2010), which builds on and extends earlier work by Liebenberg and Kirsten (2006), Liebenberg et al. (2004) and Roseboom et al. (1995).

farm) decisions as well; an important consideration given the private sector's increasingly important role in South Africa as both a funder and performer of R&D, in conjunction with its longstanding role as a user of the results of research.

Technical change requires much more than the new ideas and new technologies that flow from R&D. It also requires supporting regulatory and technical services to facilitate the transfer, uptake, and efficient use of these technologies. For this reason, we also give some attention to public spending developments concerning these broader technology support services.

Finally, the increasing international interconnectedness of science and technology demands that domestic policy formulation processes be fully cognizant of rest-of-world developments. To this end, we place some of our South African science spending indicators in a comparative international setting. In particular we include selected comparative R&D indicators for sub-Saharan Africa, the United States and Australia.

2. Changing Economic, Institutional and Policy Contexts

2.1 Agriculture in the South African Economy

In 2006, the gross domestic product (GDP) of South Africa was US\$255 billion, making it the world's 28th largest economy, next in line after Denmark which produced \$275 billion in total output that year, but well ahead of Iran, Argentina, and Ireland (World Bank 2008). Normalized against a population of 47.4 million (making it the 25th most populous country in the world) South Africa's GDP per capita was US\$5,162 in 2006—57th in a global ranking on this score, just behind Argentina and immediately ahead of Kazakhstan and Panama. South Africa's economy is especially important in a sub-Saharan

African context.³ Its 2006 production accounted for 34.6 percent of the region's entire GDP. It also had the region's fifth ranked GDP per capita (behind Equatorial Guinea, Seychelles, Gabon, and Botswana), with 32 of the remaining 40 countries in the region producing less than \$2,000 per capita that year.

After adjusting for inflation, South African agricultural GDP contracted by 0.61 percent per year from 1981, compared with growth of 2.62 percent per year for GDP overall. Thus agricultural GDP represents a declining share of the South African economy (since 2005 its share varied between 2.4 and 2.8 percent, compared with 12.3 percent in 1961), although the agricultural economy still employed more than 1.32 million farm workers, about 10.6 percent of the South African labor force in 2006.

In 2006, South Africa's agricultural GDP was US\$6.9 billion, placing it 35th worldwide on this score (World Bank 2008). Its agricultural trade was 2.7 percent of South Africa's GDP in 2006, with agricultural exports accounting for about 6.9 percent of total exports (DAS 2009). This is significantly less than its export share in 1932, when agriculture accounted for 78.4 percent of total South African exports. Since then agricultural exports as a share of the country's total exports declined steadily to bottom out at 6.5 percent in 1993, where after the agricultural share grew to an average of 8.2 percent for the period 1994 to 2007. South Africa has always been a net exporter (by value) of agricultural products. In 1975, agricultural exports exceeded imports by R20.7 billion, but the lingering effects of sanctions on imports from South Africa due to the apartheid regime

³ These comparisons used market exchange rates to denote output in U.S. dollars. Other values in this paper are designated in dollars only (as a short hand for international dollars) and use purchasing power parities (PPPs) to perform the necessary currency conversions. PPPs are an alternative currency converter (to the commonly used market exchange rates) that explicitly account for cross-country price differentials. Using PPPs to denote output measures in dollars rather than U.S. dollars, South Africa's per capita GDP is \$8,477, dropping the country to 67th in the international per capita GDP rankings in 2006 (World Bank 2008).

combined with a failure to remain internationally competitive has seen the country barely able to sustain its net agricultural exporter status in recent years.

Table 1 and Figure 1 provide an overview of the significant structural changes affecting South African agriculture since 1910. The total farmed area grew to a peak of 91.8 million hectares in 1960, declining steadily to 82.2 million hectares in 1996, where it has more or less stabilized since. Total farm numbers followed a similar pattern, peaking in 1953 at 119,600, and declining at an average rate of 1.23 percent per year thereafter, so that by 2002 the number of farms had dropped to less than half the number that prevailed five decades earlier. The interplay between changing farm numbers and the total area in farms meant that average farm size declined during the first half of the 20th century (from 1,019 hectares in 1910 to 730 hectares in 1952) and increased during the second half of the century to average 1,640 hectares in 2000. Average farm size has continued to grow, and in 2002 was 1,833 hectares per farm.⁴

[Table 1: *The changing structure of South African agriculture, 1910-2004*]
[Figure 1: *Area, number and average size of farms, 1918-2007*]

In 1910, agricultural output (as indexed by AgGDP, a value-added measure of agricultural output) accounted for 19.3 percent of total economic output (GDP) (Table 1).⁵ The agricultural share of total economic output declined steadily throughout the 20th century, to just 2.5 percent by 2006. After adjusting for inflation, the absolute size of the agricultural economy grew almost every decade until the 1970s—at an overall average

⁴ Preliminary *Agricultural Census* results indicate a continuing increase in average farm size to about 2,000 hectares per farm and a continuing decline in farm numbers to 39,982 in 2007 (Statssa 2009).

⁵ AgGDP excludes output from the (processed) food sector. Statistics South Africa (2006) reports that the combined output of the farm and agribusiness sectors (including food and fibre processors, distributors and the relevant parts of the beverage industries like wine and beer—all of which are reported in the national accounts as part of the manufacturing sector) would almost double the sectoral share, such that the combined food and agricultural industries would constitute about one-third of total GDP.

annual rate of 3.38 percent per year from US\$2.4 billion (R9.3 billion) in 1910 to US\$11.8 billion (R45.9 billion) in 1974 (both measured in 2000 prices). From 1910 to 1928 agricultural output grew by 1.8 percent per year. After the depression of the early 1930s and a severe drought for 4 years that ended in 1934, the agricultural economy experienced a period of strong growth in conjunction with expanded farmer settlement and agricultural development support and produced US\$9.1 billion (R35.4 billion) of output in 1951, an increase of 8.95 percent per year for the 1934 to 1951 period. During the period 1951 to 1974, output growth slowed to an average of 2.27 percent per year. The agricultural economy then declined to a low point of US\$6.8 billion (R26.1 billion) in 1992, reflecting in part the effects of another severe drought in the 1991 and 1992 cropping seasons. Thereafter agricultural output rebounded to a peak of US\$9.6 billion (R37.1 billion) in 2002, after which international market pressure, changing domestic agricultural policies and economy-wide influences, and adverse weather conditions saw a period of decline.

The number of people economically engaged in agriculture grew virtually uninterrupted for 60 years from 1910 to the 1970s, when it reached 2.4 million. As reported, the number of farms increased over the same period from 76,149 to 90,422 in 1970 after peaking at 119,556 in 1952. With farm numbers continuing to decline thereafter, AgGDP per economically active person engaged in agriculture continued to grow in inflation-adjusted (2000 prices) terms, from US\$3,333 (R12,899) per capita in 1970 to US\$6,747 (R26,111) per capita in 2004.

The mix of agricultural output changed markedly over the years (Table 1 and Figure 2, Panels a and b). In 1911 about 55 percent of the value of South African agricultural output was livestock products, with wool (20 percent), dairy (19 percent) and cattle and

sheep (each contributing 15 percent) accounting for 68 percent by value of livestock production. By 2008 the livestock share had shrunk considerably, although still a substantial 44 percent of agricultural output by value (with poultry production accounting for 55 percent of this total). The fields crops share was 34 percent in 1911, grew to 47 percent in 1971 (due largely to an expansion of cereals and sugarcane production), declined significantly to 28 percent in 2004 and then regained some market share to reach 33 percent in 2008. A reduction in maize and wheat production accounted for most of the post-1971 decline. The share of horticultural output expanded consistently over the entire period since 1910; starting at 10 percent that year and increasing to 23 percent by 2008. Up until the late 1980s the growth in the value of horticultural output was steady, averaging 3.9 percent per year—aided in part by improvements in cold chain management. After a brief reversal in output growth from 1989 until 1992, the sector had impressive rates of growth in the wine, deciduous and citrus fruit industries in response to improved access to international markets as rest-of-world sanctions against imports from South African were scrapped.

[Figure 2: *The changing composition of agricultural output, 1911-2008*]

These aggregate economic changes fail to reveal the different development paths followed by black versus white farmers. Throughout most of the post-unification period (specifically from 1913, but intensively so from the 1930s), the sustained and substantial government support to agriculture was biased towards white commercial farmers. Lacking a commensurate amount of public support, black farmers suffered as a consequence. The Land Act of 1913 and the Co-operatives Act of 1920 are two key examples of discriminatory public policy. The Land Act confined land ownership by blacks to

dedicated native reserves, while the Co-operatives Act excluded black farmers from participating in farmer cooperatives. In 1925 the Farmer Assistance Board (the predecessor of the Agricultural Credit Board) was established to assist farmers with soft loans in the aftermath of the recession of the early 1920s. Black farmers were once again excluded from accessing these government backed credit programs, and they were also excluded from participating in the farmer settlement programs introduced in the late 1930s.⁶ Ostensibly government support structures within the homelands and the self-governing territories were to take care of the needs of black farmers, but in fact these programs either failed to materialize or were never developed to the extent they were for the white commercial farming community.

The effect of these discriminatory policies over time is shown in Table 2 where the current relative contribution of black farmers to national production and land ownership is compared with its share in national farming activities pre-1960 (prior to the establishment of the homeland and self-governing territories). The share of farmed area owned by black farmers varied little from 1918 to 1991, averaging around 15 percent. This share then doubled to almost 31 percent of total farmed area by 2000, while the share of maize, wheat, sorghum and pumpkin output produced by black farmers was substantially less in 2000 compared with earlier years. Likewise, the share of the country's cattle and poultry stock

⁶ A host of other initiatives were launched after the unification of South Africa to improve the productivity of the agricultural sector. Government provision of research, extension, training and subsidized soil and veld conservation works were intended to help establish a vibrant farming community, often by way of farmer settlement programs. Tenant farmers were provided with the necessary training and post-settlement extension support. In addition, the government made available startup packages that included all the required means of production, with the repayment of these start up costs (including the cost of purchasing the farmland) beginning after a five year grace period. These schemes targeted new farm settlers according to their soldier status, racial status, and unemployment status, and incumbent farmers according to their farm size or farm profitability (or lack thereof). None of these attributes are necessarily good indicators of the potential productivity and profitability of farms or the prospective social payoff to public investments in these schemes. Liebenberg (2010) provides new data on the public investments directed to farmer settlement and survival schemes in South Africa during the 20th century.

held by black farmers had contracted a little by 2000, although the sheep population on black-owned farms had marginally increased from 1960 to 2000.

In addition, to the Land Reform and Restitution initiatives that were implemented beginning in 1994, the South African government established several programmes to support black farmers. These include the Land Redistribution for Agricultural Development programme (launched in 2000), the Comprehensive Agricultural Support Programme (CASP) that provides post-settlement support to targeted black farmers, whether they acquired land through private means or as part of a land reform programme, and the Micro-Agricultural Financial Institutions of South Africa (MAFISA) programme that extends micro-finance services to economically active poor rural households, small farmers, and agribusinesses. MAFISA provides loans to emerging farmers not served by the Land Bank although the program is administered by the Land Bank on behalf of the Department of Agriculture (DOA 2009). The roll-out of these programmes to date has been slow, and it is too early to judge their effectiveness.

[Table 2: *Black farmers share of area farmed and planted and national production of selected crops, 1918-2002*]

Taken as a group these agricultural indicators point to a long period of both physical and economic expansion in agriculture stretching from 1910 through to the 1950-1970 period. The 1950s and 1960s were a period of transition (at least for commercial agriculture), characterized by continued economic growth of agriculture, but growth that took place in the context of farm consolidation, a continued, and perhaps even accelerating change in the composition of farm output, and a movement of labor out of agriculture as opportunities in other sectors of the economy competed for labor used within agriculture. These sizable structural shifts have important implications for—and in turn have no doubt

been affected by—the amount and nature of R&D and the accompanying technical and institutional changes striving to sustain economic development and productivity growth in agriculture going forward. It is to these developments in science and technology that we now turn.

2.2 General Science and Technology Developments

The beginnings of organized scholarly and scientific endeavors in South Africa trace back to at least the formation of local professional societies. Marais (2000, pp. 176-178) reports that the South African Institution and the South African Literary Society, both established in 1829, were amalgamated three years later to form the South African Literary and Scientific Institution. The South African Philosophical Society, forerunner to the Royal Society of South Africa, was established in 1877. Almost 30 years later, in 1903, the South African Association for the Advancement of Science was formed and began publishing the *South African Journal of Science*, probably the best known scientific journal in South Africa.

Citing Kingwell (1990, pp. 4-5) and Smit (1984, p. 6), Marais (2000) noted that the Industries Advisory Board (IAB) formed in 1916 “... was the first attempt in South Africa at public support for academic and industrial research...(p.177).” Liebenberg (2010) established that public support for agricultural R&D in South Africa (and its precursor republics and colonies) preceded the activities of the IAB by several decades. In fact, the kudos for the earliest organized and publicly supported R&D in South Africa likely rests with a range of research activities funded by and largely carried out within the Departments of Agriculture of the former Boer Republics and Colonial government. *The Cape Agricultural Journal* published by the Department of Agriculture of the Cape Colony

appeared in 1889 and reported on the results of research carried out by the Department plus other scientists working in other institutions. For example, research into rinderpest—a highly contagious viral disease, often fatal for domesticated cattle—was undertaken during the 1890s by Professor Theiler, the veterinarian for the Transvaal Republic (Diesel and Fourie 1952). The Transvaal Department of Agriculture established a Veterinary Bacteriology Laboratory in 1897 followed by a Division of Chemistry in 1902 that surveyed, classified and systematically studied the soils supporting South African agriculture (De Villiers 2002).

Notably, harnessing research done elsewhere to address the production problems of South African farmers (R&D spillovers in contemporary economic parlance) was a feature of publicly supported agricultural research since its inception. Union of South Africa expenditure reports show that Professor Nuttall of Cambridge University was commissioned in 1911 to investigate the causes and control remedies of East Coast Fever.⁷

In common with many Commonwealth States, it took until the period immediately following World War II before government ramped up its policy attention to science and technology and public support of R&D (Pardey, Roseboom and Anderson 1991). The Council for Scientific and Industrial Research (CSIR) was established in Pretoria in 1945

⁷ In fact the *Estimates of Expenditure of the Union of South Africa* for the fiscal year 1910-11 reports that the Department of Agriculture obligated Grants-in-Aid to the amount of £18,000 to various agricultural societies and provided funding for bacteriologists, veterinary laboratories and various other research-related activities or divisions, such as, Botany and Agronomy, Tobacco and Cotton, Horticulture, Viticulture, Entomology. These funds also helped underwrite the cost of maintaining government run agricultural and experimental farms. These agencies and activities constituted the research and extension capacity of the Agricultural Department of the Boer Republics and colonies that formed the Union of South Africa in the early part of the 20th Century. Additional allocations of a research nature were made under Vote 21 for Agricultural Education, which included support for the agricultural colleges and the experimental farms attached to them. Research infrastructure support also received significant allocations from the Public Works Department, and the Buildings, Furniture and Fittings Vote. On average additional expenditure from other government departments to the agricultural portfolio amounted to roughly 20 percent of the total budget allocation for agriculture (including research) and agricultural education during the formative years of the Union of South Africa.

under the leadership of Basil Schonland who had been a scientific adviser to Field Marshal Montgomery. CSIR is now the dominant, and in many cases, the only publicly funded agency undertaking a range of industrial R&D.⁸ It also does some research related to forestry and agriculture, including agricultural chemicals, biotechnology, food processing and the environment.

Initially, much of the country's agricultural R&D was decentralized and performed in a set of department-based research institutes (DBRIs) distributed across the country according to climatic zones and the pattern of agricultural production. At least in earlier times, these DBRIs had comparatively close links to publicly supported extension agents and university researchers, with a legal framework to foster further physical and institutional integration by way of the Stellenbosch-Elsenburg College of Agriculture Act of 1926 (Act 45 of 1926). Public medical research was also based in a range of DBRIs.

In the late 1980s the state science system was re-organized into a set of Science Councils organized around scientific disciplines or fields of science (for example, the Council for Geosciences and the South African Bureau of Standards) as well as the Foundation for Research Development (FRD) that was spun out of CSIR as a funding agency. The present nine statutory Science Councils are each constituted through their own act of parliament and report to different ministers. The Agriculture Research Council (1992) was the last of the Councils to come into being, literally on the eve of democracy.

A White Paper on Science and Technology (DACST 1996) introduced an "innovation system" approach to science and technology policy formulation in South

⁸ CSIR's industrial R&D agenda included research in radar, nuclear physics, nuclear weapons, aeronautics, operation research, and command and control technologies, and over time has expanded to include research on mining, transport, construction, testing and standards and environmental studies.

Africa. The public policy instruments to finance R&D also drew attention in the White Paper. Prior to 1996, public-sector support for R&D was channeled through two Parliamentary Votes. An Education Vote involved a block grant approach to funding R&D conducted by the universities. The Science Vote had three lines of funding for R&D. One involved block funding earmarked for research carried out by the universities and managed on an agency basis by the Foundation for Research and Development and the Medical Research Council (MRC). Another involved a line of base funding for each of the statutory Science Councils. A third line of funding was a competitive funding mechanism for research conducted by private institutions. Provision was also made in the White Paper related to tracking and evaluating science. This led to the introduction of a Performance Measurement System for the Science Councils and the re-vitalization of the then moribund series of R&D Surveys. It was hoped that the new funding mechanisms would steer the Science Councils to realign their activities to the goals of the government's Reconstruction and Development Programme, which happened to some extent, but by and large the Science Councils carried on with their core business with little substantive changes.

Over the past decade and a half there were a series of measures to promote innovation including direct financial support for research by way of the Support Program for Industrial Innovation (1993), the Technological Human Resources for Industry Program (1993), the Innovation Fund (1997), the South African Research Chairs Initiative (2005), as well as indirect support by way of the enhanced tax allowance for industrial R&D (RSA 2007). Higher education has also been restructured, largely with the intent of undoing the divisions of apartheid, promoting redress through laws on employment, procurement and asset equity, and facilitating foreign students or foreign trained professionals to study or

work in South African universities and Science Councils. Notably, in 2004 a journal subsidy scheme administered by the Department of Education saw a dramatic increase in the grant paid per publication authored by university academics.⁹

2.3 Performance of Public Agricultural R&D

Institutional History

Formal agricultural research in South Africa pre-dates the establishment of the Union of South Africa, with some research institutes, for example Onderstepoort, established in the Zuid Afrikaanse Republiek in 1897. The evolution of the research service largely parallels that of the Department of Agriculture until the early 1990s, as described by Roseboom et al. (1995).¹⁰ The Department of Agriculture was formed in 1911 from 18 divisions that existed under the former British colonies of Natal and the Cape and the two Boer Republics. At that time, the research services were housed almost without exception as subdivisions of the Department of Agriculture's inspection and regulatory services divisions, with the same being true of extension. Certain other research undertakings that today form part of agricultural research were located in various other government departments. An example is irrigation research, which initially resided in the then

⁹ The journal subsidy scheme dates back to the mid-1980s. In its current configuration, the scheme retroactively pays South African higher-education institutions for each publication affiliated to an institution that appears in journal titles abstracted by the Expanded Science Citation Index, the Arts and Humanities Citation Index, and the International Bibliography of the Social Sciences, as well as those peer reviewed journals on a supplementary list recognized by the Department of Higher Education and Training (DHET). In 2004 the funding formula was revised and the unit value of each publication increased substantially from around R25,000 per publication to (currently) R105,000. These publication payments now represent an important source of university income. Around 11 percent of the university funding distributed by the DHET is tied to measurable "research outputs," including recognized professional publications and the number of masters and doctoral students who successfully complete a degree. In some instances, a portion of the grant is credited to the academic's research account; in other instances all the funds are retained in a central university account. Each university sets its own policy regarding what proportion of the grant, if any, is passed on to the author(s) of the publication. Notably, the parliamentary allocation to higher education (including payments for research and teaching outputs) is set to rise from R15.3 billion in FY2008/09 to R19.0 billion in FY2011/12 (RSA 2009).

¹⁰ See Roseboom, Pardey and Beintema (1998), Roseboom et al. (2000) and Beintema, Pardey and Roseboom (2004) for earlier perspectives on agricultural R&D developments within South Africa. Beintema and Stads (2004) help quantitatively place South African agricultural R&D within a regional context.

Department of Irrigation. Only later did it join and has subsequently remained with the Department of Agriculture. The Chemistry Services Division of the Department of Agriculture, formed in 1910, was the sole public provider of scientific support to the country's regulatory capacity through its analytical chemistry laboratories. It took until 1960 for the Division to be relieved of all its chemical analysis responsibilities for sectors other than agriculture (De Villiers 2002).

Identifying salient eras in the historical evolution of South African agricultural research is complicated by the numerous structural changes that the Department of Agriculture has undergone in its various guises since its establishment. These institutional changes were ostensibly driven by the changing political and economic developments facing the agricultural sector, which according to Kirsten and Van Zyl (1996) involved three distinct phases of structural change. The first phase (1910-1940s) involved the initial efforts to segregate white and black farmers, in terms of their participation in the economy and their ownership of land. This phase lasted until after World War II.

The second phase (1940s-1980s) encouraged the commercialization of white farming through the adoption of modern mechanical and biological technologies, within a policy environment that favored expanding the production of large-scale, owner-operated farms. In this period of 'grand apartheid' the balkanization of the country was completed, with the establishment of four 'independent' countries: Transkei, Bophuthastwana, Venda, and Ciskei (TBVC), and another six 'self-governing territories' (SGTs) into which the majority of Africans were corralled on a tribal basis. During this phase, the 'homelands' of the TBVC and SGT statelets operated within a policy environment that emphasized large-scale development projects under expatriate management aimed at cash crop production, such as

tea plantations. This strategy came at the expense of efforts to promote staple food production. Politically sanctioned racial discrimination and policy-induced agricultural price distortions proved unsustainable.¹¹ The pressures to redress these policies began to intensify during the 1980s.

This heralded a third period of structural change, beginning in the early 1980s and still on-going. This phase is largely characterized by a reversal of the policies of the previous two periods; notably removal of the racial barriers between black and white agriculture, and increased liberalization and democratization of the agricultural sector. Other significant drivers of change in the large-scale farming sector include legislation on the security of land tenure of labor tenants working on large farms as well as the stipulation of minimum wages (Deininger and May 2000; Hall 2004). Both of these legislative initiatives are deemed to have reduced the amount of hired labor on farms, although their effect on the use of labor-saving technologies is uncertain. However, other factors were in play. For example, Van Zyl et al. (1995) inferred that the decline in farm employment can be ascribed to distortionary policy measures (tax incentives on depreciation) in the market for capital equipment during the 1970s to 1980s, and the reasons for the continuing decline in on-farm employment since their study was completed has not yet been conclusively identified.

Change processes regarding the agricultural research and extension system followed a similar, albeit slightly different timeline than these broader phases of change affecting South African agriculture. During the first phase, the agricultural research system, then

¹¹ Virtually all the major agricultural livestock and grain commodities were marketed through a single channel, namely commodity-specific Control Boards that administered either a fixed price or maintained production controls. The cost of support payments (see Table 1) were severe in years where the subsidies paid in support of protecting farmers domestically against 'exceptionally low' (often heavily subsidized) international prices, but they eventually proved financially and politically unsustainable (Kirsten and Van Zyl 1996).

housed largely in the Division of Education and Research, underwent a protracted process to consolidate all the government functions related to agriculture within the Department of Agriculture. Beginning in 1913, the administration of agricultural education, including the agricultural colleges at Elsenburg, Cedara, Potchefstroom and Grootfontein (and Glen in 1919), was transferred from the Department of Education (DoE) to the Department of Agriculture (DoA). In 1920 all extension activities were gradually transferred to the agricultural colleges. In that same year administrative responsibility for the Faculty of Agriculture at the University of Stellenbosch was transferred from the DoE to the DoA. The Faculties of Agriculture at the Universities of Pretoria and Natal followed in 1940 and 1948, respectively.

During the first 12 years of its existence, the expanding DoA gave increasing emphasis to agricultural education. Beginning in 1924, however, the emphasis shifted to providing more extension services. In that year a new Extension Division was established to promote stronger links with the farming community and coordinate the extension effort between the colleges and the various divisions within DoA. In addition, it was decided that the five agricultural colleges should concentrate their efforts on the principal farming enterprises in their respective (agro-ecological) regions. For example, Elsenburg was to focus on winter grains and horticulture and Potchefstroom more on summer grains and slaughter cattle. Arguably, this policy placed constraints on the future development of the relevant regions into new or so-called “non-traditional” farming enterprises. In 1926, the colleges were transferred to the Extension Division, which was then reconstituted as the Division of Agricultural Education and Extension, incorporating the Publications Division. Subsequent restructuring during the next two decades saw a shift in focus away from

merely transferring knowledge to one of developing new skills and capacities. A concerted effort was also made until the late-1960s to train staff through the provision of bursaries to study abroad in areas where the country had limited skills.

The second substantive phase of institutional change entailed the specialization of services. In 1952-53 the Technical Services branch of the DoA was organized into three main branches, 10 national divisions (an additional one was added in 1960), three special institutes (a fourth added in 1956), and six agro-ecological entities referred to as Regional Services and Education (increased to seven in 1961). In 1958 the Department of Agriculture was split into two departments with the new Department of Agricultural Economics and Marketing taking responsibility for developing and administering agricultural economic policy, orderly marketing of agricultural products, government controlled pricing schemes, overseeing cooperatives, commodity inspections, conducting economic surveys of agricultural conditions, collecting statistics, and engaging in marketing research. The Department of Agricultural Technical Services (DATS) focused on production issues and provided services such as agricultural research, education and extension, and certain regulatory and control services (for example, soil conservation and livestock inspection services). During this period remuneration of professional staff was increased substantially.

Early in 1970, responsibility for the faculties of agricultural were again transferred to the Department of Education. This effectively ended the de facto South African version of the U.S. land grant system, wherein the provision of agricultural education, research, extension and training service were integrated into a university based research environment. Soon thereafter (in 1975 to be precise), government expenditures on all non-

security departments were severely curtailed to support demands of increased military spending. Extension services were especially hard hit. The farmer settlement program of DACLT was closed and extension officers were directed to work only with farmer study groups within the context of a ‘programmed extension’ framework. One-on-one visits between farmers and extension officers were discouraged.

Beginning in the early 1980s government structures underwent several additional rounds of rationalization. This introduced a third phase in the development of the nation’s public research sector which merged the three departments involved in agriculture into one Department of Agriculture and began the gradual process of establishing national commodity research institutes. The first such institute was the Grain Crops Institute, fashioned from the crop research units within the regional institutes (now known as Agricultural Development Institutes, or ADIs). This change was duplicated in Agricultural Engineering Services in response to recommendations made by several internal committees of enquiry that investigated the provision of agricultural research, extension and training services (Bruwer 1989).

More Contemporary Developments

In 1984, the move to a tri-cameral parliamentary structure forced the reintroduction of two separate agricultural departments.¹² This reorganization left all the public agricultural R&D agencies residing in a white own affairs department with no mandate to

¹² Following a 1983 referendum, a three-chamber parliament divided along racial lines—involving the House of Assembly representing white interests, the House of Representatives representing colored interests, and the House of Delegates representing the interests of Indians—was established in 1984. All government affairs pertaining to agriculture were conducted via a “general” affairs department addressing the concerns of all three chambers and an “own” affairs (technical services) department addressing the specific interests of the House of Assembly and its white constituents. The homelands of the TBVC and SGTs statelets each had their own, supposedly independent, government structures representing the interests of black South Africans, and each with their own Department of Agriculture.

assist in the homeland areas. A notable feature of the public R&D system at this time was the high degree of ineffectiveness of the regional institutes and, specifically, the extension services. Around 40 percent of the total of 809 extension officer positions were vacant at this time, with estimates that a further 329 officers were required to meet the demand for extension services (Bruwer 1989). These inadequacies combined with the growing pressure to deregulate and privatize government services, provided the impetus to establish an Agricultural Research Council in 1992. This Council was to be responsible for all the agricultural research functions of the national government including a mandate to serve farmers in the homelands. It was envisaged that the ARC's establishment would release resources within the DATS to improve the effectiveness of the extension services and allow it to place greater emphasis on 'whole farm planning' (farming systems research).

ARC's establishment marks a possible fourth phase in the institutional evolution of public agricultural research in South Africa. This phase led to a fragmentation of the research and extension services. The establishment of the research focused ARC in 1992 as a standalone parastatal cum public entity was followed by the subdivision of the former seven Agricultural Development Institutes into nine provincial departments of agriculture, paralleling broader public sector changes that came into being as part of the 1994 constitutional reforms. Institutes that formerly operated within broadly defined agro-ecological zones were now structured according to provincial boundaries, which in most cases do not reflect suitable agro-ecological boundaries for conceiving and targeting agricultural R&D. Farmer study group structures that linked with adaptive research and extension activities were severely disrupted, and so too were the institutional arrangements

designed to coordinate local initiatives with national research agencies such as the ARC institutes.

With its Science Council designation, the ARC initially operated under the policy of Framework Autonomy (introduced in 1986) funded on the basis of a baseline formula and reporting to parliament.¹³ Oversight of the country's science system was formerly assigned to a Science Advisory Council reporting directly to the State President. This effectively gave the ARC large degrees of freedom in its operations, ostensibly under the guidance of institute-specific advisory panels (that included industry representation) which in practice never became fully operationalized. The national policy on science, engineering and technology institutions (so-called SETIs) was further reconfigured in 1997 with funding mechanisms consisting of a parliamentary grant for core funding and a competitively bid Innovation Fund designed to direct research toward identified national imperatives (DACST 1996). All non-core income generated through contract research for government departments, industry and the private sector was considered external income, and projects funded by this means were charged on a "full-cost" basis. The principle of selling (research) services to the market is enshrined in the Public Finance Management Act of 1999.

A System wide Review of the Science Councils in 1997 (DACST 1998) severely criticized the ARC for its perceived lack of performance, skewed personnel demographics and low involvement in black agriculture and other areas that essentially were the responsibility of the former regional institutes prior to 1994. The ARCs inability to adequately address these criticisms and gain the support from its line department (i.e., the

¹³ The baseline funding included core funding sufficient to cover the "... costs of basic infrastructure (expertise and other capacity) necessary for the realization of the aims of the institution (DNE 1988, p. 43)."

DoA) for the maintenance of its funding levels exposed the organization to severe budgetary cuts under the new competitive parliamentary grant system. The first was a 15 percent cut in 1998-99, followed by another 7 percent reduction in 1999-2000, a further 5 percent in 2000-01, and 2 percent cut in 2001-02.¹⁴ These cuts in core funding limited the ARC's ability to honor its informal co-funding agreement with agricultural industries prior to its formation, whereby funding from industry was to be matched on a 30 percent industry versus 70 percent government basis. Levy collection mechanisms were revoked and the industry Control Boards ceased to exist when the new Marketing of Agricultural Products Act came in to force in 1996. One immediate, but as it turned out, shorter term consequence was that commodity and producer organizations were no longer able to raise sufficient funds to meet contracted project costs in time to offset the cuts in core funding to the ARC.

Several initiatives have followed since. The first was the creation of a National Agricultural Research Forum (NARF), which as a consensus seeking entity has gained credence as a vehicle to inform the Department of Agriculture and all other stakeholders on agricultural research policy issues. Insights gained from NARF deliberations, plus concerns raised by other Science Councils facing similar constraints, moved DACST (which became the Department of Science and Technology, DST, in 2002) to revise its research funding and governance policies under a new national research and development strategy. This new approach a) placed greater responsibility on each line department with administrative responsibilities for a Science Council (for example the Department of Agriculture in the case of the ARC) to fund the science services requested of the Council,

¹⁴ In fact all the Science Councils received a large cut in 1998-99, with the exception of the Medical Research Council (MRC) which received a substantial increase in funding to address the HIV/AIDS pandemic.

and b) created a mechanism for DST and the relevant line departments to fund centers of scientific excellence (DST 2002). Under the guidance of a new national R&D strategy, NARF finalized a national agricultural R&D strategy in 2007 that builds on the structures created by DST (DOA 2008).

3. Science and Technology Trends

3.1 Overall vs Agricultural Science Spending

In FY1966, South Africa's gross expenditure on research and development (GERD) measuring total public and private R&D spending in all fields of science, was \$769.5 million (R36.5 million), representing 0.43 percent of gross domestic product (GDP) (HSRC 2007).¹⁵ After growing at an annual average rate of 5.2 percent per year in inflation-adjusted terms during the period 1966 to 2006, GERD totaled \$5.2 billion (R16.5 billion) in FY2006, around 0.95 percent of GDP (Figure 3).¹⁶ The rate of growth in GERD spending picked up in recent years, averaging 7.2 percent per year from 1993 to 2006, reflecting, in part, the higher priority placed on overall public R&D spending during this period. In contrast, real agricultural R&D spending decreased by 0.83 percent per year over the same period.

[Figure 3: *GERD and agricultural R&D spending, 1966-2006*]

Figure 4 shows a range of research intensity ratios, including total and public GERD relative to GDP and public agricultural R&D spending relative to agricultural GDP.

Overall GERD as a share of GDP grew from just 0.43 percent in 1966 to 0.95 percent in

¹⁵ Unless otherwise stated, all dollar denominated values in the text were converted to international dollars using the relevant purchasing power parity indexes. Values denominated in U.S. dollars were converted from their respective local currency units using average annual market exchange rates. See Khan and Blankley (2008) for more details regarding contemporary developments in the overall R&D system in South Africa.

¹⁶ The text amounts are denominated in international dollars (as per footnote 3). Using market exchange rates, the FY1966 GERD total in U.S. dollars was \$237.1 million and \$1,599.9 million in FY2006 (both figures in 2000 prices).

2006, with a generally increasing intensity of R&D spending aside from the sizable drop in FY1993.¹⁷ An imputed public-only GERD series is also shown. The pattern of change over time in the intensity of public research mirrors that of total GERD, with the combined share of private for-profit and not-for-profit research changing gradually during this period—in 1983 private research accounted for 49.9 percent of all research, 57.2 percent in 2006.

[Figure 4: *Intensity of total and public GERD and public agricultural R&D, 1966-2006*]

In 2006, the ratio of public investment in agricultural R&D relative to the value of agricultural output (AgGDP) was 2.5 percent, considerably higher than the 0.4 percent intensity of public investment in all areas of research relative to the overall size of the South African economy (Figure 4). Moreover, over the past decade and a half at least there has been no discernable upward trend in the public GERD intensity ratio and almost no growth in the public agricultural R&D ratio over the corresponding period.¹⁸ These similar intensity trends belie the substantial differences that underlie these intensity ratios. Figures 3 and 6 reveal that growth in real public agricultural R&D spending stalled for the past thirty years or so (albeit with significant fluctuations around this stagnant trend) whereas public GERD spending increased substantially during the past decade and a half. However, the substantive real growth in public GERD spending (2.21 percent per year from 1983-2006) was almost matched by the corresponding rate of real GDP growth (2.26 percent per year), and so the intensity of R&D investment in the overall economy barely deepened during this period. Likewise, public agricultural R&D growth of 0.30 percent per year

¹⁷ Blankley and Khan (2005) discuss the details of the survey structure and responses that underpin these GERD estimates, thus helping to calibrate their precision and the coverage and consistency of these data.

¹⁸ In fact both the agricultural R&D intensity ratio and the GERD intensity ratio have changed little since the early 1980s.

more or less matched the growth in real agricultural GDP (0.37 percent per year from 1985-2006), so investments in agricultural R&D also failed to intensify, but in the case of agriculture the total amount of annual investment failed to grow, whereas overall public investments in science grew quite rapidly.

These public-sector R&D trends in conjunction with a gradual (and, more recently, accelerating) increase in the overall intensity of public and private R&D investment in the South African economy since 1966 signal a shift in the orientation of South African R&D. Figure 5 reveals a significant drop in the share of GERD directed to the applied sciences and technologies (often referred to as problem-solving research), as well as the engineering and agricultural sciences. The natural sciences, information and communication technologies, and the social sciences have all increased their respective shares of total science spending. The medical and health sciences saw the greatest gains, jumping from 10 percent of GERD in FY2002 to 15.1 percent just five years later, more than double the total spending directed towards agricultural R&D in that year.

[Figure 5: *GERD spending by field of science, FY2002 and FY2006*]

3.2 Agricultural R&D Spending

Long-Run Trends

Measured in inflation-adjusted, year 2000 prices, South Africa invested just \$32.2 (R68.9) million on public agricultural R&D in 1910. Real public agricultural R&D spending grew steadily by an average of 5.1 percent per year until 1952 (Figure 6). The pace of growth accelerated to 7 percent over the subsequent 19 years to total \$404.7 (R866.4) million by 1971. Spending on public agricultural R&D then declined by an average of 2.9 percent per year in inflation adjusted terms from 1971 to \$268 (R574)

million in 1980 and thereafter recovered somewhat to reach \$351 (R752) million in 2007. Notably, real public spending in agricultural R&D failed to grow significantly after 1972—except for a brief jump to \$415 (R890) million in 1993 brought about by structural adjustment payments during the establishment of the ARC. In fact, if external income generated by the ARC is excluded, public agricultural R&D spending for every year in the entire 1971-2007 period was less than the inflation-adjusted 1971 amount of R866 million.¹⁹ In 2007, with the external income generated by the ARC excluded, direct public investment in agricultural R&D was equal to just 70 percent of the corresponding 1971 figure. Several of the switching points in the growth of public agricultural R&D spending coincide with changes in the administrative structure of public agricultural research agencies, others relate to changes in science policy more generally.

[Figure 6: *Public agricultural R&D spending trends, 1910-2007*]

The institutional implications of these policy changes are revealed in Figure 7, Panels a and b. The shares attributable to the national (i.e., ARC and its precursor agencies) and higher education institutions have waxed and waned over the years, but there has been no sustained shift in the share of public agricultural research conducted by national agencies. ARC and its predecessor agencies accounted for 57 percent of the total in 1910, growing to 63 percent in 1948, and 70 percent in 1998, but in more recent years fluctuating around 60 percent. A counterpoint to the generally flat but fluctuating share accounted for by national agencies was an increase in the higher-education share (from 10.3 percent in 1910 to 20 percent in 1986, and 18 percent in 2007). The share of public agricultural R&D conducted by regional (now provincial government) agencies has been especially volatile. From 1910

¹⁹ By way of comparison, in 2007, the United States spent \$3.77 billion on public agricultural R&D, equivalent to \$1.45 billion (2000 prices) more than it did in 1971 despite a slowdown in the average annual rate of growth during the 1970-2007 period compared with the rate of growth during the previous 50 years (Alston et al. 2010).

to 1952 regional agencies performed about 33 percent of total public agricultural R&D. This increased dramatically in 1952-53 when the Agricultural Education and Experiment Stations were reconfigured as regional services institutions with a dramatic increase in the estimated research-related budget allocation to these services. The regional share of total public agricultural R&D expanded over the subsequent 19 years (to average 45 percent from 1952/53 to 1973/74). Since 1992/93 they have averaged 22 percent.

Beginning in 1971 the administrative oversight of the faculties of agriculture was moved from the DoA to the DoE. Inflation adjusted spending on agricultural research conducted at the universities increased slightly until 1975 and thereafter stalled at around \$55 (R118) million. From 1967 to 1973 university funding for agricultural research declined, then increased erratically until 1993, followed by a relatively drastic decline in 1994 in the aftermath of the establishment of the ARC. University performed agricultural research inched upward from 1994 until 2003, then grew at a faster pace to reach \$62.8 (R133.7) million in FY2007, returning these agencies to the amount spent on agricultural research throughout the 1980s.

[Figure 7: *Institutional structure of public agricultural R&D spending, 1910-2007*]

Spending on regionally performed R&D experienced a marked downturn during 1971 to 1975 (declining from \$183.8 to \$124.6 million, or R393.4 to R266.8 million) in the immediate wake of the transfer of the faculties of agriculture to the DoA. It continued to contract at a slower rate until 1993, followed by a jump in 1995 when the provincial dispensation came into effect. Its current level is still well below that of its peak in FY1971.²⁰ Spending on national and regionally performed agricultural R&D grew in

²⁰ The changeover to the new constitutional dispensation and with it the incorporation of the administrations of the former homelands and self governing territories, saw a marked increase in the overall public expenditure on

parallel from 1951 through to the mid-1970s, and then also declined until 1979. For the subsequent 15 years spending on R&D done by national agencies fluctuated around a slowly declining trend, while spending by regional institutes contracted sharply. From a localized peak in FY1989, spending at both the national and regional institutes contracted sharply in inflation adjusted terms with wide fluctuations in the past three years, but began increasing again in FY2001 for regional agencies and in FY2003 for national institutes. Overall the spending patterns in the post-1970 period point to a good deal of institutional instability, with a marginally negative rate of growth (-0.04 percent per year) compared with the decades that preceded 1970.²¹

The spending relativities among public agricultural R&D and the supporting technology transfer and regulation cum inspection services has also shifted, in some cases substantially, over the years. Figure 8 shows that R&D accounted for a fluctuating but generally slowly growing share of agricultural R&D and regulatory services spending from 1911 (28.8 percent) until 1998 (74 percent). Thereafter it declined precipitously to a 57.8 percent spending share by 2005 occasioned by a dramatic decline in both the nominal and inflation-adjusted commitment to agricultural research during this period as well as an increase in spending on administrative and regulatory services.²² Not shown in this graph are the farmer support subsidies and general assistance payments to agriculture that for many decades were orders of magnitude larger than the funds directed to research and technically related services (Table 1).

agriculture by these regional centres, mostly driven by spending on farmer settlement support and land restitution administration. Their expenditure on R&D, however, remained fairly stable.

²¹ By comparison, spending grew at an average rate of 7.04 percent per year during the period 1952 to 1971, and 5.1 percent per year from 1911 to 1952.

²² The reported increase in the share of administrative costs may in part reflect changed accounting practices, wherein some costs previously charged directly to R&D programs are now treated as a central overhead cost.

[Figure 8: *Public funding of agricultural R&D and technology related services, 1910-2007*]

During the period 1910 to 1953 the Department of Agriculture struggled to settle on an institutional structure that best met its perceived service delivery demands. This period saw the transfer of the colleges and faculties of agriculture to the control of the Department of Agriculture under the Research and Extension Division and the creation of a formal Extension Service within this division from 1921 onwards. A separate division for extension was formally inaugurated in 1925 (Van Vuren 1952). It was also an era when racial policies on land segregation and farmer settlement programs to address the so-called ‘poor-white’ issue dominated the R&D agenda. Combating livestock disease epidemics (such as East Coast Fever) dominated budget allocations toward regulatory services and affected the focus of research (Figure 8).

Beginning in the early 1950s, the agricultural development agenda increasingly began to emphasize the modernization of agriculture and regional research gained significant policy and financial support. These funding and institutional shifts accelerated some trends that had already been in place. The livestock emphasis of public agricultural R&D declined, specialist services (addressing soil, climate, water, plant protection and engineering concerns) gained a greater share, as did horticulture (Figure 9). Farming systems research (often the emphasis of the revitalized regional institutes) markedly increased its share of R&D spending totals, especially during the 1960s and 1970s.

[Figure 9: *Research focus of public agricultural R&D spending, 1910-2007*]

The formulation and implementation of a policy of “optimal agricultural development” during a 15 year period from 1968 to 1983 (Roseboom et al. 1995), combined with the transfer of the universities to the Department of Education and the

termination of the farmer settlement program of the Department of Agricultural Credit and Land Tenure, resulted in marked change in the relative importance of the various research service providers. The higher-education sector marginally increased its share of the agricultural research spending total as the country became increasingly reliant on training its own scientists as international isolation increased as a reaction to the apartheid regime. The synergy between the regional and national institutes became less pronounced with strongly diverging trends in spending toward the early 1990s.

The national budget allocations at the time were also dominated by expenditures on the national defense and security forces in response to growing domestic unrest. Spending on agricultural R&D in the early 1990s was influenced by the establishment of the ARC, restructuring of the regional institutes to form the provincial departments of agriculture inclusive of the agricultural administrations of the former homelands, and demands for farmer support as a result of a severe drought which reached its peak in 1991-92. Research services at the provincial departments were hard hit by this given the enormity of the budgetary demands faced by provincial legislatures in meeting the demands of restructuring at the provincial level in order to incorporate the homeland administrations and to take control over certain formerly national functions in education, welfare and security. In the midst of this came the closure of the Agricultural Credit Board and the Control Boards which, in the case of the Credit Board, saw a spike in investments as commitments for farmer assistance under some of its programs was wound up. The ARC was protected from these developments to some extent through its core funding being determined by on a base-line (or cost-based) formula arrangement overseen by the Public

Service Commission and Department of Finance, but this was soon to change (Liebenberg and Kirsten 2006).

From 1997 the research investment trends of the ARC, the provincial departments and universities followed distinctly different paths. Each agency now falls under different accounting authorities or line departments, with no effective overarching coordinating mechanisms within government to guide investments in R&D across these institutions. The more recent increases in agricultural R&D spending at provincial agencies is largely driven by the farmer settlement and land restitution and reform needs of the Land Redistribution for Agricultural Development Act and the Comprehensive Agricultural Support programs. Moreover, the agricultural research activities of the provincial departments of agriculture lie outside the purview of the National Advisory Council on Innovation that oversees and evaluates the Science Councils such as the ARC. Under the new national R&D strategy the provincial departments do, however, have access to funding from competitively bided funds and funding from DST for Centers of Excellence.

Research Intensities

To place agricultural research expenditures in a more meaningful context, it is common practice to scale such data according to the size of the agricultural sector and various other criteria. Table 3 shows selected agricultural research and extension intensity ratios for selected decades from 1910 to 1990 and for each year since 2003, revealing wide fluctuations in expenditure intensity over the course of the century. In all cases there was a marked increase in investment intensities from 1910 to the 1930s reflecting the shift in the priorities of rural development policies. The growth in most of these research and extension intensities stalled in 1990, with the exception of investment per farm which

continued to increase from an inflation adjusted \$6,013 (R12,872) in 1990 to \$8,787 (R18,809) in 2007. This reflects a substantial reduction in farm numbers, evident since the 1993 *Census of Agriculture*, which is also accompanied by an increase in average farm size. After an initial period of growth during the early half of the 20th Century, extension intensities declined to levels that are now well below that of the 1910s, with the strongest decline occurring since the 1970s. Another notable feature of these trends is the divergent pattern of research and extension intensities. From the 1930s to the 1970s, the growth in extension intensities outpaced the growth in R&D intensities. Thereafter extension intensities shrank to levels typically around a tenth or less of the corresponding agricultural research intensities that prevailed in more recent years.

[Table 3: *Alternative agricultural research intensity ratios, 1910-2007*]

International Intensity Relativities

Placing South African developments in an international context, Figure 10, Panel a shows that agricultural GDP shrank as a share of overall GDP for Australia and the United States as well as South Africa throughout the 20th Century. The trend (and value) of the agricultural GDP to GDP ratio in South Africa and Australia are similar, but the corresponding ratio for the United States declined at a faster rate (and was generally considerably below) the South African figure. Notwithstanding the Australian and South African similarities in the agricultural shares of their respective economies, Figure 10, Panel b reveals that South Africa invested more intensively in agricultural research than Australia (and the United States) for the first three quarters of the 20th Century. In the early 1970s the relativities changed, with South Africa generally falling below Australia (and well below the United States) in terms of public agricultural R&D intensity as the pace of

investment in agricultural R&D faltered as did the growth of the South African agricultural economy.

[Figure 10: *Comparative intensity trends in the United States, Australia and South Africa, 1910-2006*]

Notwithstanding South Africa's recent poor intensity performance relative to Australia and the United States, in the year 2000, South Africa's intensity of commitment to agricultural R&D per unit of agricultural GDP (\$2.50 of research spending per \$100 of agricultural output) is on par with the corresponding high-income average of \$2.36 reported by Pardey et al. (2008). However, South Africa has about half the spending on agricultural R&D per capita of the general population and about a fifth of the spending per capita of the economically active agricultural population compared with the corresponding average intensity ratios of the high-income countries.

3.3 Scientist Trends

A total of 120 researchers were engaged in public agricultural R&D in South Africa in 1911, about half employed by the Department of Agriculture and the other half (52 researchers) by the faculties of agriculture and the regional experiment stations. This grew steadily to a total of 503 researchers in 1940, declined briefly to 445 researchers during the Second World War, and then resumed growing. In the two decades following World War II, the total number of researchers increased from 618 in 1949 to 903 in 1976 (representing an average annual rate of growth of 1.8 percent per year). The total number of agricultural researchers continued to grow for the following 20 years (at a rate of 2.0 percent per year), peaking at an estimated 1,322 researchers in 1996. From 1997 through 2003, voluntary retrenchments and net attrition in the public and semi-public sectors saw the number of (full-time equivalent) fte researchers decline to 1,055 (a contraction of 3.1 percent per year

for an overall loss of 20 percent of the country's total scientific research capacity in the agricultural sciences). The number of fte scientists working for ARC peaked in 1996 at 761, dropping precipitously to bottom out at 443 researchers in 2004, with small increases thereafter to 496 in 2008. Preliminary estimates suggest that growth in the total number of fte researchers working for public agricultural R&D agencies in South Africa stalled in the mid-1980s and totaled 1,044 fte researchers in 2007, a little lower than the 1,213 fte researchers employed in 1985.²³

Table 4 summarizes the qualification profiles of researchers for various groupings of institutes in the various public-sector research services for various years beginning in 1961 (Roseboom et al. 1995; Liebenberg et al. 2004). Research technicians and other support staff are excluded from these figures. The qualification profile of the different groupings is quite distinctive. A significant share of the fte researchers at the regional institutes and provincial departments of agriculture, ARC institutes, and the universities held postgraduate degrees in 1961 and that share increased as one proceeds from the regional institutes, through the ARC, to the universities. In 1993, 13 percent of the researchers at the regional institutes held a PhD compared with 52 percent at the universities. This in part reflects the fact that the regional institutes focus more on applied and development research, while universities do more basic research. Across all sectors of the system, the qualification profile improved slightly from the 1960s to the early 1990s.

[Table 4: *Degree status of university and national and regional institute personnel*]

Figure 11, Panel a, summarizes trends in the number of researchers at the national and regional (including universities) institutes since 1910. The significant jump in the number of research staff at the regional institutes in the early 1960s coincides with the

²³ See Kahn et al. (2004) for a discussion of the exodus of R&D personnel from South Africa during this time.

increase in the number of regional institutes from 6 to 7 and implementation of the amended Soil Conservation Act (Act 37 of 1960), which involved an almost threefold increase in the nominal budget in 1960/61. There was a run up in the total number of researchers during the 1980s when the national institutes received greater autonomy and the status of some was raised from a research center to that of an institute headed by a Director. A decline in the number of researchers at regional and national institutes began in 1996, initially in response to voluntary retrenchment initiatives introduced to reduce the size of government. During the initial years of this decline the contraction was much faster among the regional institutes. The decline in the number of researchers at national institutes picked up pace after 1998-99 and bottomed out at levels equal to those that prevailed in the pre-1980 period. Figure 11, Panel b indicates that the decline in the number of ARC researchers from 1997 to 2008 has disproportionately affected those holding BSc degrees (which decreased by 9.8 percent per year), while those holding PhD and MSc degrees contracted at a slower but still substantial rate (i.e., they declined by 2.46 and 2.94 per year, respectively).

[Figure 11: *Public sector agricultural researcher trends, 1910-2008*]

Juxtaposing the personnel trends in Figure 11 with the real spending trends in Figure 7 gives an indication of the change in overall support per scientist for those working in national institutes. From 1910 to 1930, spending per researcher in the national institutes declined in real terms by 4.6 percent per year (Figure 12). It then increased by 2.8 percent annually until 1957 with the exception of a decrease in the immediate post World War II years that lasted until 1952, when a major restructuring of the agricultural services occurred. Thereafter spending per scientist again grew by 4.7 percent annually until 1971.

From 1972 spending per researcher in the national institutes decreased by 2.7 percent per year until 1988, and then resumed growing at 4.9 percent per annum until 2005. Thus real spending per scientist has been quite variable, and in 2005 at R1.07 million (\$450,000) per scientists was only 25.2 percent higher than its contemporary peak of R0.854 million (\$399,000) in 1970/71; an implied average annual growth rate of just 0.7 percent per year over this 36 year period.

[Figure 12: *Real spending per ARC scientist, 1910-2007*]

4. Funding Public Research

The sources and forms of funding for publicly performed research not only influence the amount of research conducted but also the types of research undertaken, including the balance between strategic (or longer-term R&D) versus more applied (shorter-term research), or between crops versus livestock research, or between research on particular crops and particular livestock commodities or specific problems confronting agriculture. The balance between research oriented to maintaining and enhancing farm productivity versus research directed to other aspects such as the environmental dimension of agriculture, food safety, biodiversity, and human health and nutrition can also be influenced by the way in which funds are forthcoming. Here we provide some indications of contemporary changes in the structure of funding of publicly performed agricultural research in South Africa using data on the various sources of funding for research conducted by the institutes of the ARC.

4.1 Overview

Until 1992 research by the Department of Agriculture relied heavily on block grant funding from the national government.²⁴ The commodity oriented Control Boards (such as the Wheat Board, Tobacco Board, Maize Board and so on) which operated under the statutory marketing structures for agricultural that existed under various guises from 1937 to 1992 were an additional source of support. Allocations to agricultural research were made from levy income generated by way of the marketing schemes promulgated under the Agricultural Marketing Act of 1968.

In 1992, ARC institutes began diversify their sources of funding (Figure 13). The reported share of government core-funding for ARC dropped from 89.8 percent in 1992-93, to 76.2 percent in 1995-96. The target was to reduce the share of government funding to 70 percent by 2000 in line with a general understanding reached with organized agriculture prior to the establishment of ARC. The ARC exceeded this target by about 11 percent. By 2001-02 the share of ARC funding from government in the form of block grants had fallen to 53 percent of total revenue. Since then core funding has crept up to 62 percent of total funding by 2007-08, mostly driven by increases in funding from the DoA and DST in an effort to redress shortfalls in funding government commissioned diagnostic and research services provided by the ARC. In addition, DST now provides funding earmarked for the maintenance of national assets (genebank, reference collections of fungi, insects and

²⁴ Government budget reports since 1910 show that the Department of Agriculture has typically generated some income through the sale of farm products and research materials, as well as the fees charged for diagnostic services. The share of total income (inclusive of non-research service income) to total expenditure by the departments has varied between 29 and 17 percent from 1915 to 1933. Thereafter it fluctuated around 10 percent until 2005, after which it declined to around 5 percent of total departmental expenditure. An interesting aspect of the pre-depression years was that research stations often produced a surplus above costs. In addition during these early years of the 20th Century, expenditure on agriculturally related operations by non-agriculturally related departments such as post and telecommunication, police, and prisons was equivalent to upwards of 20 percent of the total expenditures incurred by the Department of Agriculture (Union of South Africa, 1910-1930).

pathogens), while the DoA provides additional funds directed towards the maintenance of the country's physical research infrastructure (RSA 2009).

[Figure 13: *Funding sources for ARC, 1992-2008*]

Income generated by providing diagnostic services and selling research materials, including the sale of plant and livestock products, breeder seed, and revenues from royalties and technology license fees accounted for roughly 11 percent of ARC's non-core income in 1992/93. This form of funding began to increase from 1997, reaching a 24.7 percent share of total funding by 2007-08

The source of funds varies markedly among ARC institutes. Table 5 shows the relative share of the various non-core sources of support for each of the 12 ARC institutes (including headquarters) for each of the fiscal years 1995-96, 2002-03 and 2007-08. For most of the institutes the major source of non-core income was from research services, except for veterinary research, citrus and subtropical crops and agricultural engineering where a range of other sources predominate. Most institutes have quite diversified sources of support, but only in the case of livestock, deciduous fruit, plant protection and soil, climate and water has there been a sustained increase in the share of income generated from research services. The crop related institutes (specifically, the grain crops, industrial crops, and small grains institutes) have sourced a large share of their non-core income from the provision of research services, whereas agricultural engineering, has received none of its funding from this source but relied heavily on the sale of advice services to secure non-core sources of support.

[Table 5: *Non-core sources of support for ARC institutes, various fiscal years*]

4.2 Non-Government Sources of Support

The policy governing the activities of Science Councils in South Africa classify all sources of funding other than the parliamentary grant as private and is commonly referred to as external funding (DACST 1996). For the purpose of this analysis private funding is redefined as funding originating from non-government sources, including commodity trust funds and levies from producer organizations along with research funding from private firms. ARC's formal policy is to charge full cost for all research and other services performed on behalf of external clients. Many clients balked at this pricing policy and as a practical matter the common practice is to currently undertake contracted research on a 50:50 cost sharing basis. Typically only operational costs (i.e., scientist salaries and the cost of materials used in carrying out the research) are included. Some ARC institutes include overhead costs to recoup some of the costs of the physical and administrative support costs of the institutes, but this practice varies among clients and institutes and rarely if ever includes any of the central or corporate headquarter cost incurred by ARC.

The year 1997 was an important transition year with significant implications for industry support for ARC research. In that year the commodity Control Boards overseeing managed marketing schemes ceased to exist, as did the producer levy schemes that underwrote the commodity stabilization funds and other costs incurred by these Control Boards. It took several years before a new set of statutory levy schemes were in place under the legislative authority of the Marketing of Agricultural Products Act of 1996 (Act 47). In 1998, just seven industries agreed to a levy scheme, by 2007 the number had grown to only 11 industries. Levy income is used to provide collective goods to farmers in each of the respective industries, including promotional services for local and export markets,

product development, quality control, sectoral transformation activities, plant improvement and research. The National Agricultural Marketing Board oversees the collection and disposition of these levy funds. For ARC, another significant source of industry support comes by way of the commodity trust funds that developed as a redeployment of the closing balances of the pre-1997 commodity stabilization reserves that are now overseen by their respective boards of trustees, which includes industry and ministerially appointed representatives.

The share of levy income directed to agricultural R&D varies markedly across industries and among years within an industry (Table 6). For example, in 2007 the Citrus Levy directed 64 percent of its levy income to R&D, whereas the Dairy Levy and Red Meat Levy each spent only 3 percent of their income on research. The types of research supported by levy funds also vary. For example, in 2007 around 79 percent of the levy income collected by the winter cereal industry was direct to projects addressing the response of crops to changes in external factors affecting them, such as diseases and pests (NAMC 2007). Notably the share of statutory levy income earmarked for agricultural research projects has declined over the past three years, from 42 percent of the total levy income in the 2006 to 32 percent in 2008 (NAMC 2009). The ARC's share of the levy income allocated to research has also declined from 42 percent in 2007 to 37 percent in 2008 (NAMC 2008 and 2009).

[Table 6: *Annual contribution by commodity organizations to agricultural research, 1999–2008*]

Another concern is that even if funding from the commodity trusts to the ARC was increased so that all the levy income collected was allocated to research, this would represent only 23 percent of total ARC external income. Moreover, if all the income

generated through research services was assumed to come from private clients, only two thirds of the crops institutes would be deemed to be earning more than half their external (non-core) income from private sources.

As a share of non-core funding, contract research executed by ARC increased from an average of about 30 percent during the first three years of its establishment to 38 percent in 1995-96. By 2007-08 this has increased to 49 percent. However, many of these contracts are with public agencies and often government parastatals such as Onderstepoort Biological Products Ltd. and other Science Councils. Thus the increase in the share of contract research performed by ARC overstates the degree to which government has reduced its share of funding for publicly performed agricultural R&D. But at a minimum this contract-client arrangement has laid the basis for a market for R&D goods and services that, in principle at least, can increase the degree to which this public system is responsive to the demands placed upon it.

5. Conclusion

Government sponsored agricultural research in South Africa stretches back more than a century. In 1911 public agencies employed a total of 120 scientists and spent a total of \$32.2 million (or R68.9 million, both in 2000 prices) on agricultural research. In 2007, there were 1,279 scientists and the investment had grown to \$352.1 (R753.8) million. Agricultural research spending grew unevenly over time: real spending grew by an average of 5.1 percent per year from 1911 to 1950 increasing to 7 percent per year from 1950 to 1971, at which point spending effectively ceased growing. During the rapid growth phase of the 1950s and 1970s, spending on agricultural research grew faster than agricultural output so that the intensity of investment in public agricultural research (i.e., agricultural

R&D spending as a share of agricultural GDP) increased from 0.8 percent in 1911 to 2.46 percent in 1983, but barely budged over the subsequent two and a half decades reaching only 2.5 percent by 2007.

The early 1970s was a switching point in another notable sense. During the six previous decades South African agriculture maintained a higher intensity of investment in public agricultural research than two of its main global competitors, the United States and Australia. South Africa gradually fell behind after the early 1970s, and now trails the United States and Australia in terms of its public agricultural research intensity. Perhaps not surprisingly, South Africa appears to have sustained a competitive edge during the decades prior to 1970, with a strong growth in agricultural exports and more muted but still pronounced growth in its net agricultural trade surplus. However, agricultural exports and net trade balances have declined precipitously in more recent decades.

The balance of public agencies conducting agricultural R&D has also changed over the past century. National and regional agencies performed the lion's share of the research for the first half of the 20th century. The regional institutes reached their zenith by the early 1970s, at which time they performed around 48 percent of the public agricultural R&D compared with 42 percent conducted by national institutes and 10 by universities. By 2007 the balance among research performers had changed markedly. The regional share had fallen to 23 percent, not much in excess of the university share which stood at 18 percent, while the national share had grown to 60 percent.

For a good part of the past 50 years, industry has financed some of the research conducted by public agencies. The share of funding from industry sources has fluctuated over time and varies among commodities and types of research. Most of it is now directed

to research conducted in national institutes, and in recent years accounted for about 20 percent of the funds flowing to the Agricultural Research Council.

From a long-term perspective these developments are generally positive. From small beginnings at the turn of the last century, South Africa grew its capacity to educate agricultural scientists and developed the institutional capacity to self finance and conduct the R&D required to develop its agricultural sector. From a short-term perspective the picture is less rosy. The amount of real funding for public agricultural R&D failed to grow since 1992, the intensity of investment in agricultural R&D also stagnated, and the country has lost a substantial number of well trained and experienced agricultural scientists. These more recent developments are cause for concern and suggest it is time to carefully and creatively rethink and revitalize South African agricultural R&D. The policy decisions and institutional actions taken over the next few years will help determine the destiny of the country's agricultural sector for the century that lies ahead.

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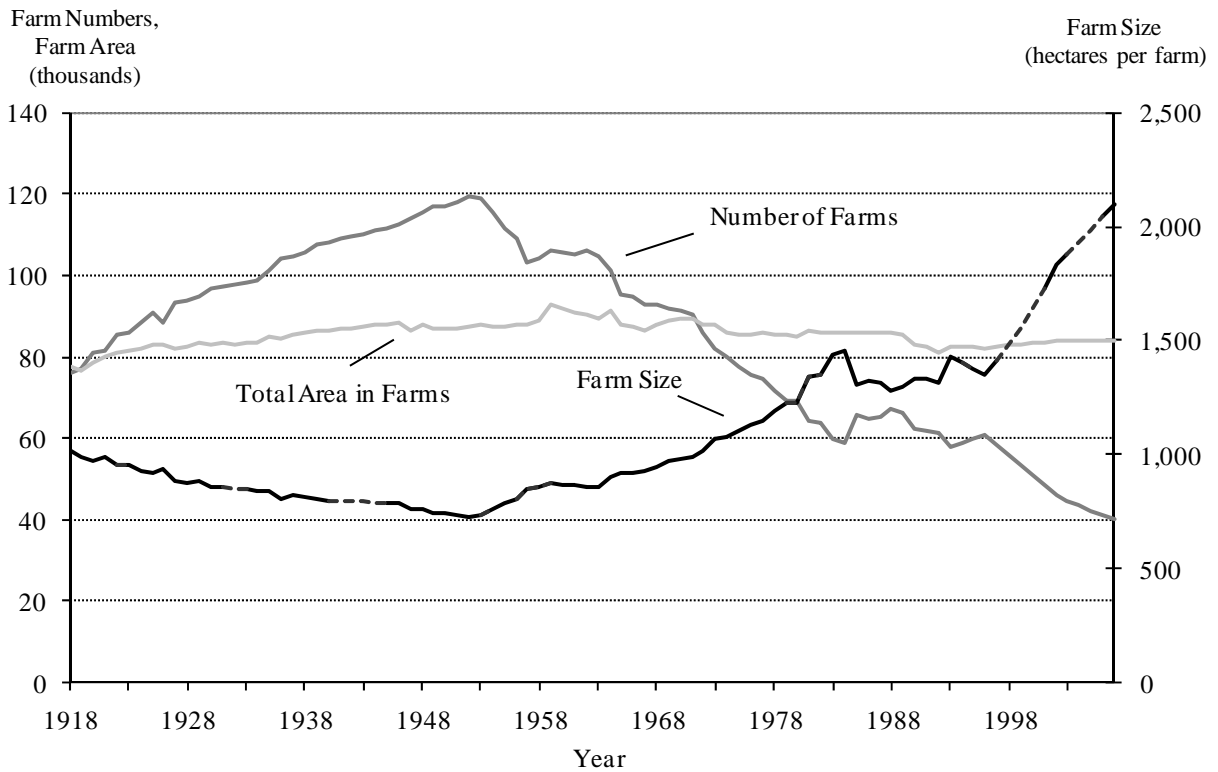
Table 1: *The changing structure of South African agriculture, 1910-2007*

	Unit	1910s	1920s	1930s	1940s	1950s	1960s	1970s	1980s	1990s	2000-07
Farming Structure											
Farm Number	Number	76,622	88,305	101,299	111,938	112,305	99,114	79,842	64,540	59,108	44,575
Total Area	1000 ha	77,042	81,810	84,339	87,392	88,150	89,256	86,814	85,862	82,404	83,701
Average Farm Size	ha	1,006	928	833	781	788	817	1,094	667	1,260	1,400
Economic Contribution											
AgGDP	R million (2000)	9,207	10,596	10,379	18,223	33,136	35,508	37,594	35,877	30,201	31,217
Contribution to GDP	Percent	19.0	17.6	12.0	12.7	15.2	9.9	6.8	5.0	3.7	3.0
Labour											
Economically Active in Agriculture	'000				1,913	1,509	1,635	2,483	1,181	1,213	1,406
Agricultural Share of Total Farm Employees	Percent				42	33	29	31	14	10	12
	'000	553	488	749	887	882	968	1,639	1,235	1,185	835
Value of Production											
Field Crops	R million (2000)	3,567	4,490	5,239	8,837	14,983	20,267	26,524	23,657	15,677	16,722
Horticulture	R million (2000)	757	1,397	2,222	4,058	5,322	7,658	9,525	10,323	11,392	14,493
Livestock	R million (2000)	5,337	6,687	6,745	11,643	19,602	20,533	21,761	24,775	20,518	24,352
Total	R million (2000)	9,661	12,575	14,206	24,538	39,907	48,458	57,810	58,755	47,586	55,567
Share of Production Value											
Field Crops	Percent	37	36	37	36	38	42	46	40	33	30
Horticulture	Percent	8	11	16	17	13	16	16	18	24	26
Livestock	Percent	55	53	47	47	49	42	38	42	43	44
Govt Expenditure on Agriculture											
Dept of Agriculture (DoA)	R million (2000)	166.3	222.7	314.6	388.5	636.5	1,134.3	1,331.0	1,953.7	2,014.3	260.0
Agricultural Subsidies	R million (2000)	2.7	5.4	569.1	935.2	1,878.8	2,384.5	3,020.2	2,286.0	597.3	121.2
Total Spending on Agriculture	R million (2000)	171.7	239.7	915.0	1,377.6	2,534.8	3,766.9	4,579.9	5,217.5	3,218.9	3,559.9
Total Government Spending	R million (2000)	4,798	6,191	9,412	19,087	27,838	50,751	107,242	150,327	204,496	257,582
R&D	R million (2000)	51.2	74.0	105.0	162.5	286.9	546.2	553.0	495.5	598.6	582.1
Regulatory Services	R million (2000)	26.0	41.6	68.5	103.7	155.2	256.2	270.4	271.7	350.1	249.6
DoA/Govt Spending	Percent	3.5	3.6	3.3	2.0	2.3	2.2	1.2	1.3	1.0	1.3
Subsidies/Govt Spending	Percent	0.1	0.1	6.0	4.9	6.7	4.7	2.8	1.5	0.3	0.0
R&D/DoA Spending	Percent	30.8	33.2	33.4	41.8	45.1	48.2	41.5	25.4	28.4	17.9
R&D/AgGDP	Percent	0.6	0.7	1.0	0.9		1.5	1.5	1.4	2.0	1.9
Services/DoA Spending	Percent	15.1	17.4	7.5	7.5	6.8	5.9	5.9	5.2	10.9	7.0
Total Spending on Agriculture/ Total Government Spending	Percent	3.6	3.9	9.7	7.2	9.1	7.4	4.3	3.5	1.6	1.4

Sources: Compiled by authors and Liebenberg (2010).

Notes: Data represent 10-year averages (e.g. 1910s is average of 1910-1919), except for 2000-07, which includes eight years of data. Total spending on agriculture reported here reflects the actual expenditure without adjustment for the structural changes in 1994/95 brought about by the inclusion of the agricultural administrations of the former homelands and the self governing territories.

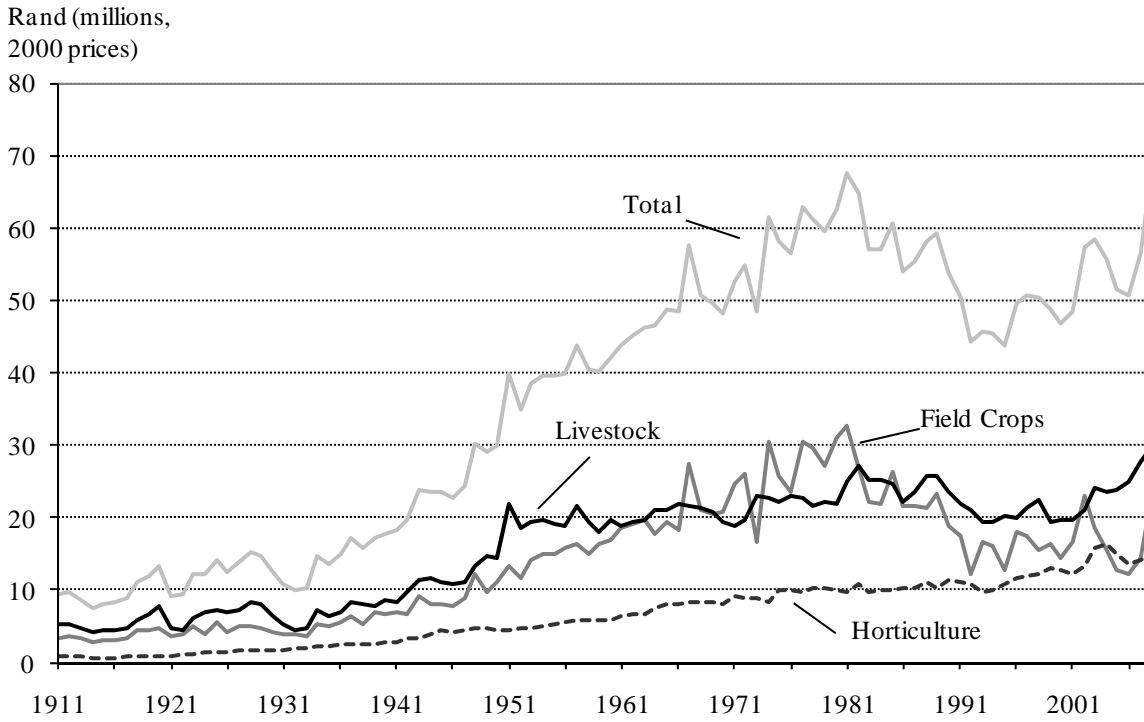
Figure 1: Area, number and average size of farms, 1918-2007



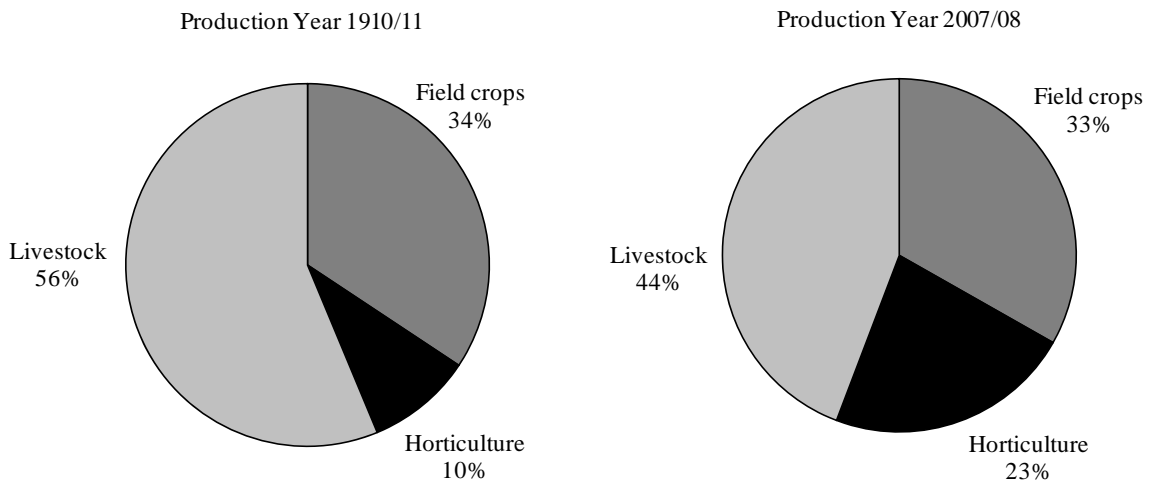
Sources: StatsSA (2009a), and DAS (2009).

Notes: Farm area is measured as total hectares in farms. Farm numbers are a total count of farms. Statistical definitions of a farm changed over time. For example, Union of South Africa (1948) defined a farm as all “occupied farms in rural areas,” as well as any occupied holding greater than 0.86 hectare in an urban areas that was producing agricultural output for sale. Presently only commercial farms or business entities registered for Value Added Tax and/or Income Tax are designated as a farm for the purpose of statistical compilations (Statssa 2009b).

Figure 2: *The changing composition of agricultural output, 1911-2008*
 Panel a: Gross value of agricultural production by sector, 1911-2008



Panel b: Sector share in gross value of production



Sources: StatsSA (2009a), and DAS (2009).

Table 2: *Black farmers share of area farmed and planted and national volume of production of selected crops in South Africa: 1918-2002*

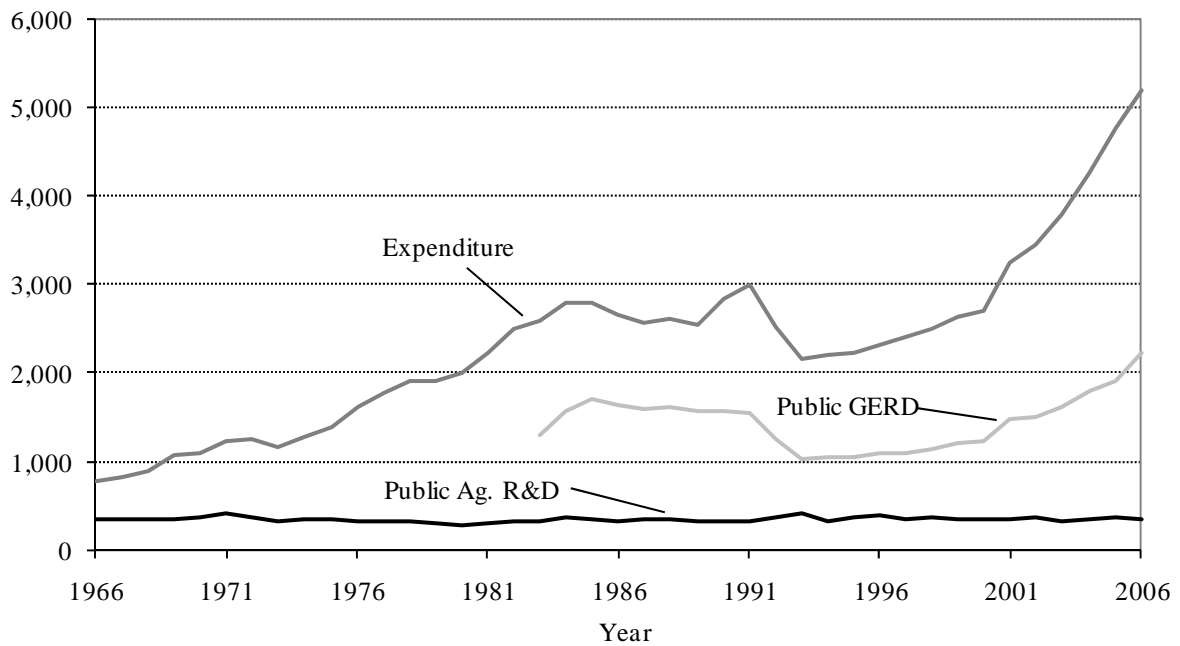
Year	Area of farms	Area Planted	Production volume of:				Number of		
			Maize	Wheat	Sorghum	Pumpkins	Cattle	Sheep	Poultry
<i>Percentage</i>									
1918	16.4	27.2	23.2	3.5	74.3	36.3	24.5	14.4	34.9
1930	-	-	23.0	-	77.0	-	51.1	10.8	-
1937	-	-	-	-	81.0	-	-	09.9	-
1950	-	-	18.8	1.7	46.4	-	41.0	11.7	31.3
1960	15.4	16.9	13.0	1.5	34.7	-	38.8	09.5	38.8
1991	14.4	15.2	-	-	-	-	-	-	-
2002 ^a	30.9	14.4	3.0	0.0	0.1	17.3	30.1	10.1	29.1

Sources: OCS (1918, 1932), Union of South Africa (1939), BCS (1952, and 1963) and DAS (2009).

Notes:^a The share estimates for 2002 are based on the reported shares of production value.

Figure 3: *GERD and agricultural R&D spending, 1966-2006*

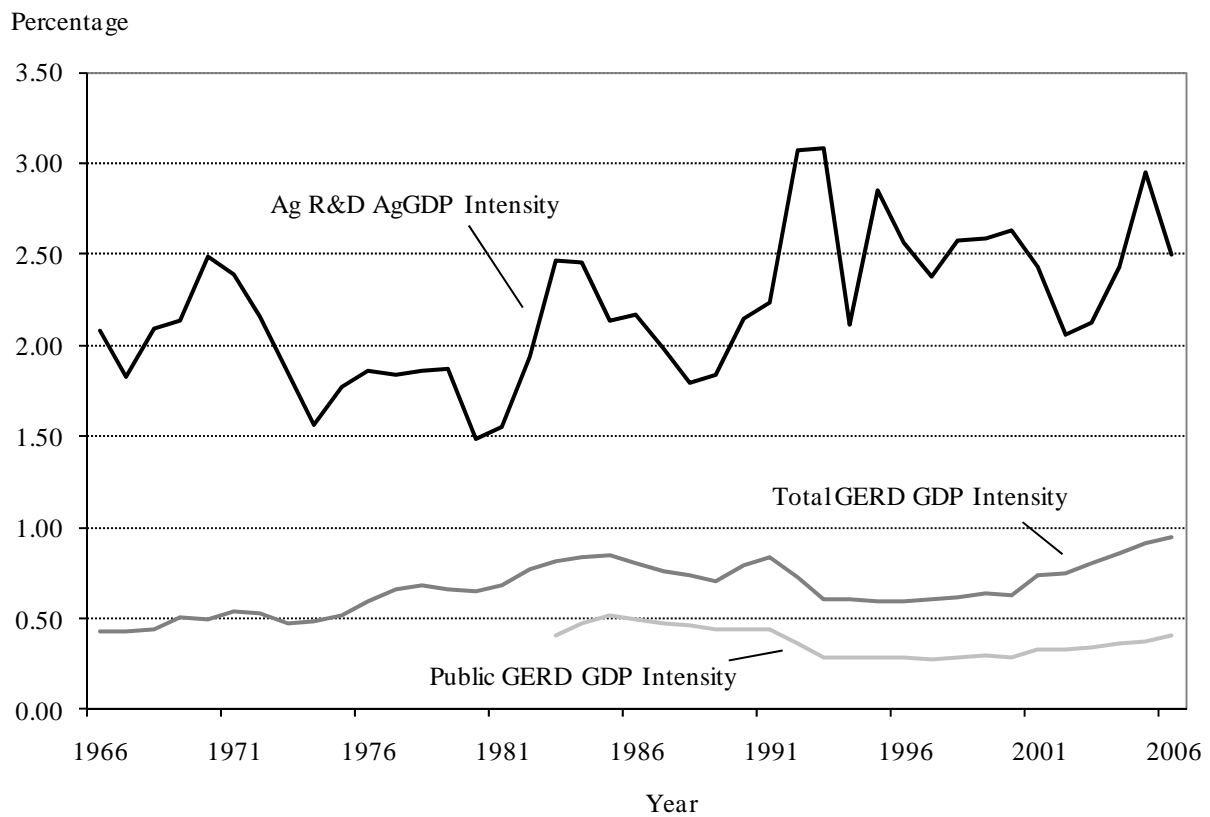
Expenditures (millions,
2000 international dollars)



Sources: CeSTII (various years) and Liebenberg (2010).

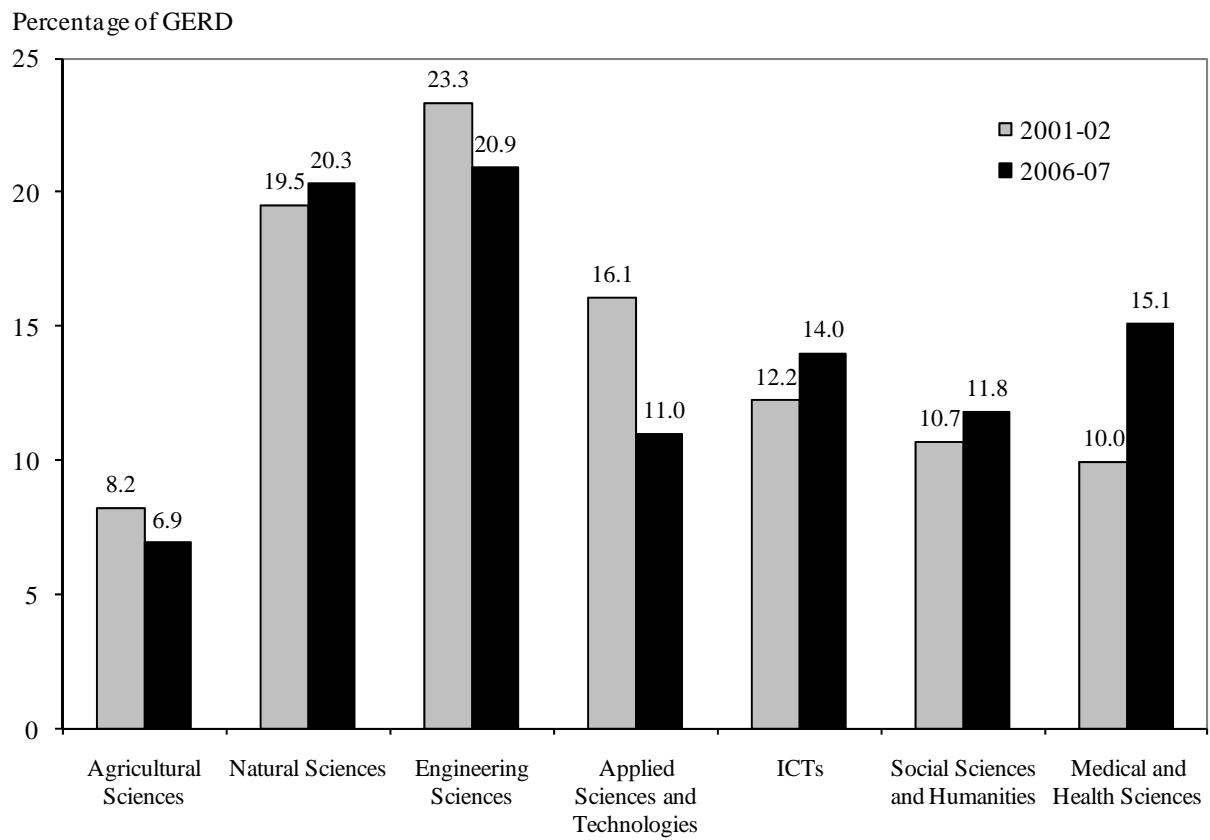
Notes: GERD data were reported bi-annually from 1966 to 1993, thereafter, in 1997, 2001 and from 2003 on an annual basis. Intervening years were derived by linear interpolation. Data were deflated using the GDP deflator from SARB (2009).

Figure 4: *Intensity of total and public GERD and public agricultural R&D, 1966-2006*



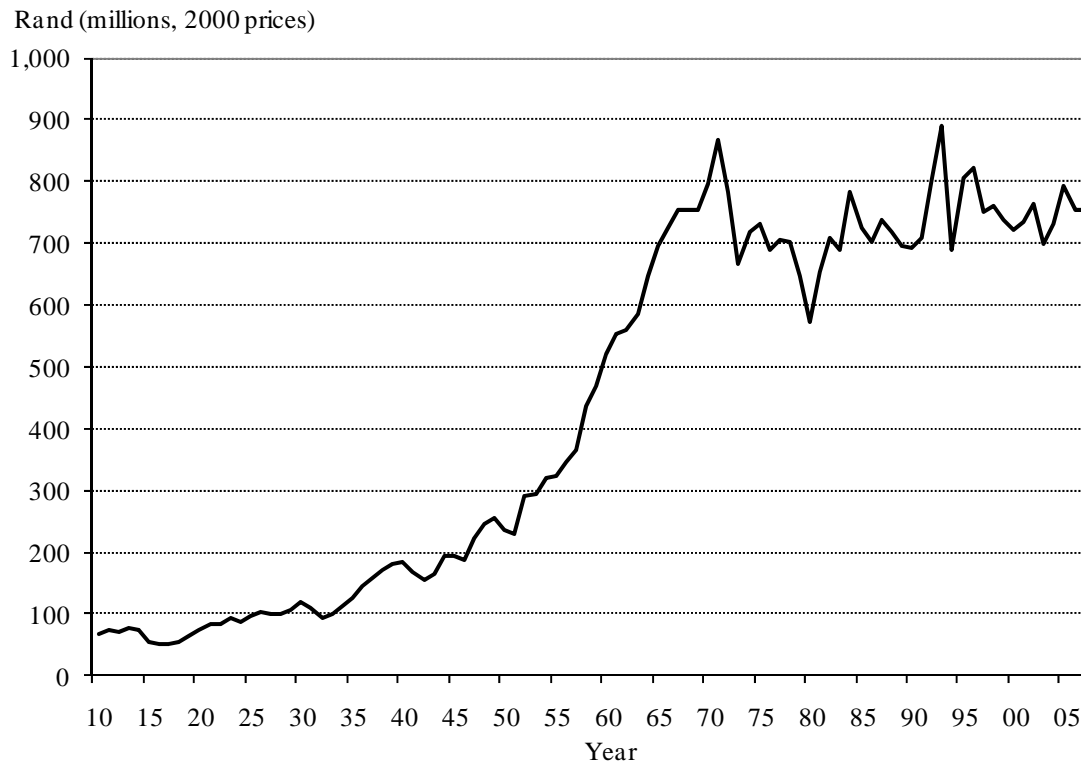
Sources: CeSTII (various years), SARB (2009), and Liebenberg (2010).

Figure 5: GERD spending by field of science, FY2002 and FY2006



Sources: CeSTII (2002 and 2009).

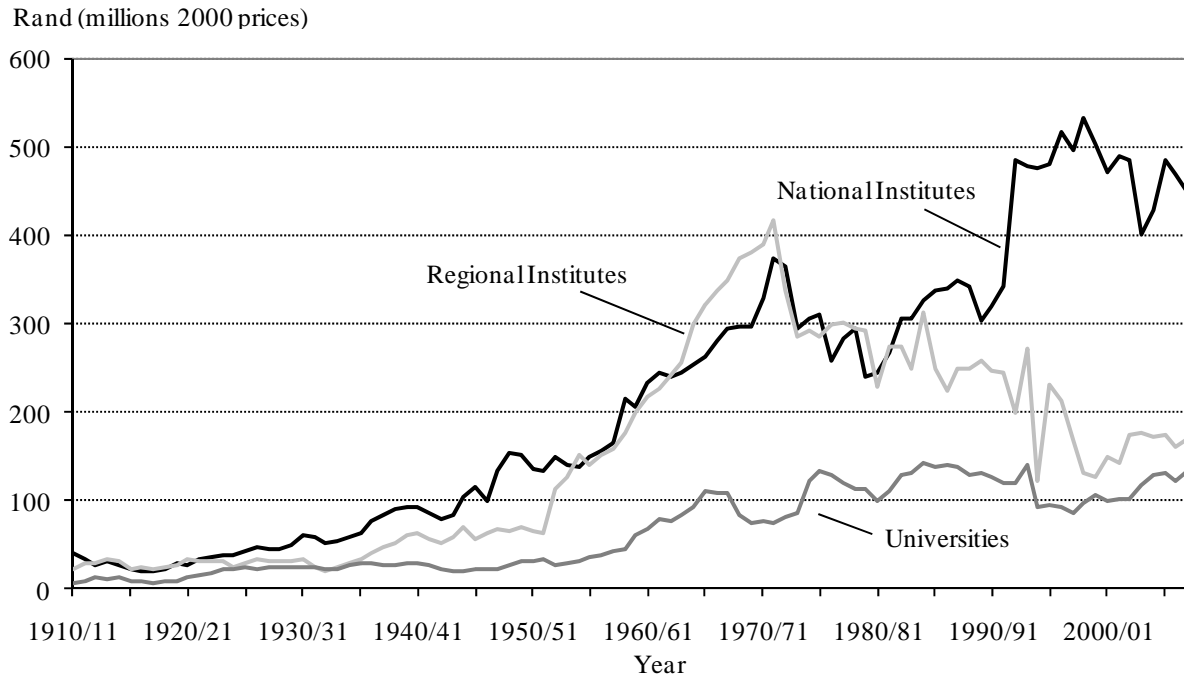
Figure 6: *Public agricultural R&D spending trends, 1910-2007*



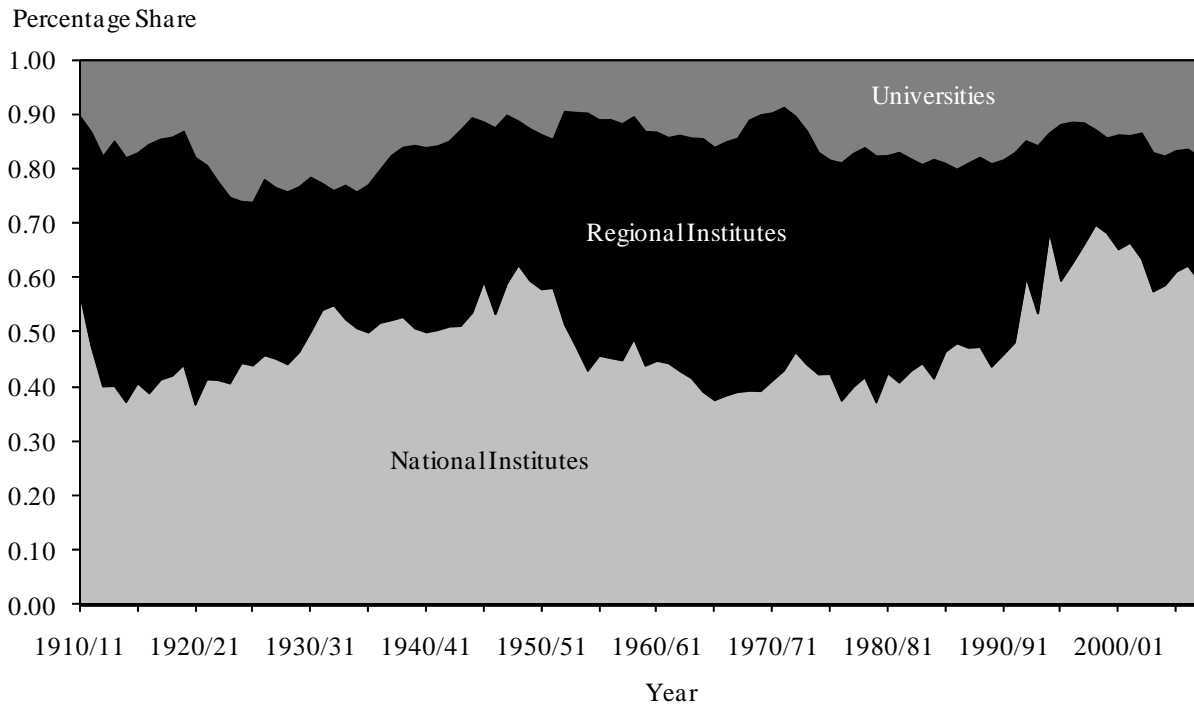
Sources: Union of South Africa (1910-1959), RSA (1960-2009), and ARC (1993-2009), SARB (2009).

Notes: A nominal agricultural R&D series was deflated using a GDP deflator derived from data provided by SARB (2009).

Figure 7: *Institutional structure of public agricultural R&D spending, 1910-2007*
 Panel a: Institutional orientation, 2000 prices

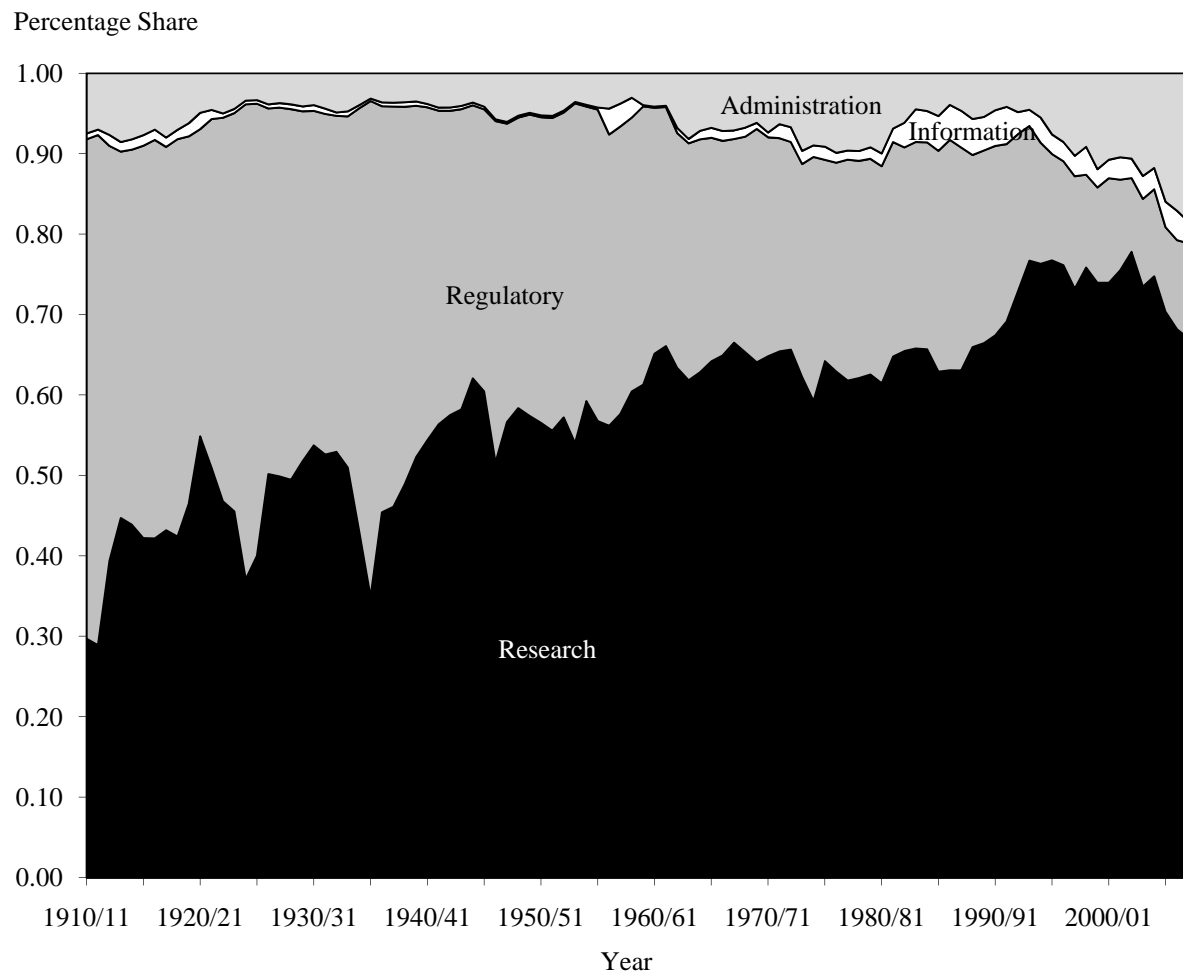


Panel b: Institutional spending shares



Sources: Union of South Africa (1910-1959), RSA (1960-2009), and ARC (1993-2009).

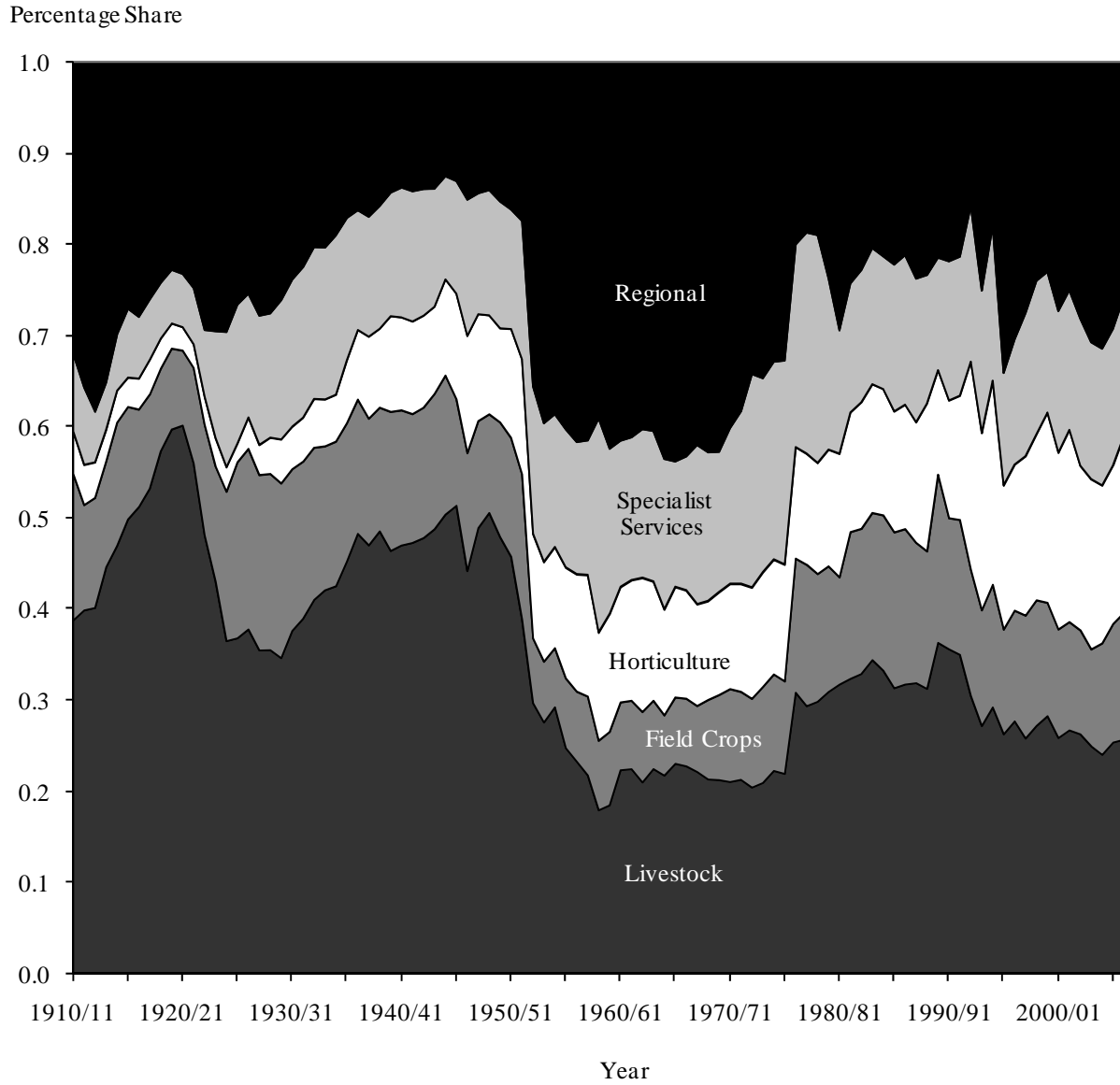
Figure 8: *Public funding of agricultural R&D and technology related services, 1910-2007*



Sources: Union of South Africa (1910-1959), RSA (1960-2009), and ARC (1993-2009).

Notes: Administration includes only central or corporate administration and overhead costs, as institute specific administration and overhead costs are embedded in the institute-specific expenditures that constitute the corresponding research, regulatory and information totals. Regulatory services refers to all functions and services performed by various entities within the Department of Agriculture that relate to setting and enforcing all production and marketing standards and quality controls, including on-site inspection services. Information includes expenditures on publications and computer services.

Figure 9: *Research focus of public agricultural R&D spending, 1910-2007*



Sources: Union of South Africa (1910-1959), RSA (1960-2009), and ARC (1993-2009).

Notes: “Specialist Services” refer to spending by the Institutes for Soil, Climate and Water; Plant Protection, and Agricultural Engineering. “Regional” refers in large part to the R&D conducted by the provincial departments of agriculture and the former Agricultural Development Institutes or regional research stations.

Table 3: *Alternative agricultural research intensity ratios, 1910-2007*

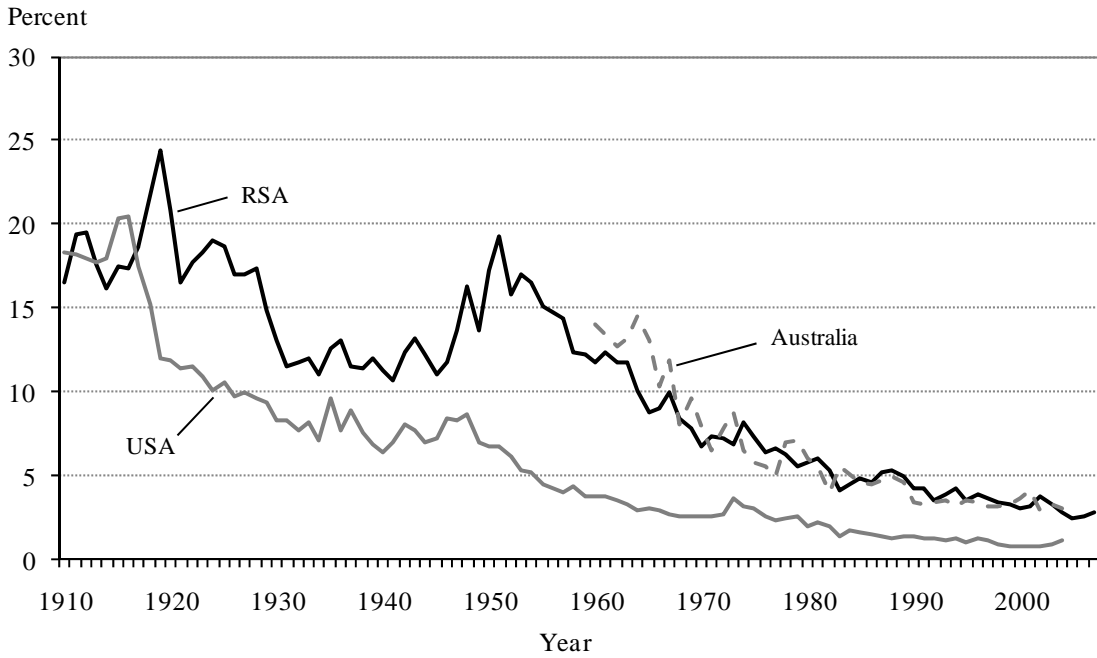
	1910	1930	1950	1970	1990	2000	2003	2004	2005	2006	2007
Relative to farm value added (percent)											
Research	0.59	0.93	0.82	1.06	1.46	1.37	1.19	1.35	1.45	1.22	1.01
Extension	0.56	10.96	2.38	1.19	0.22	0.12	0.09	0.12	0.17	0.14	0.10
Relative to Ag. GDP (percent)											
Research	0.67	1.27	1.01	1.89	2.53	2.61	2.13	2.44	2.95	2.49	2.15
Extension	0.64	15.05	2.94	2.13	0.38	0.22	0.16	0.22	0.35	0.28	0.22
Relative to farm numbers (real \$2000 per farm)											
Research	389	609	1,379	4,275	6,013	6,569	7,305	7,857	8,753	8,528	8,787
Extension	401	7,221	4,060	5,507	1,010	558	559	705	1,043	974	892
Relative to total population (real \$2000 per capita)											
Research	4.66	6.57	10.70	13.72	9.08	7.65	7.03	7.33	7.90	7.40	7.34
Extension	4.80	78.00	31.52	17.68	1.53	0.65	0.54	0.66	0.94	0.85	0.75
Relative to farm worker population (real \$2000 per capita)											
Research	64.60	74.44	166.36	244.86	333.90	245.29	364.87	441.99	527.60	421.26	456.27
Extension	66.58	883.34	489.92	315.42	56.09	20.82	27.94	39.65	62.86	48.13	46.31
Relative to total farm area (real \$2000 per ha)											
Research	0.39	0.73	1.76	3.93	4.31	4.01	3.88	4.07	4.41	4.18	4.18
Extension	0.40	8.67	5.17	5.06	0.72	0.34	0.30	0.36	0.53	0.48	0.42

Sources: BCS (1960), SARB (2007), DAS (1957-2009), Union of South Africa (1910-1959), RSA (1960-2009), and ARC (1993-2009).

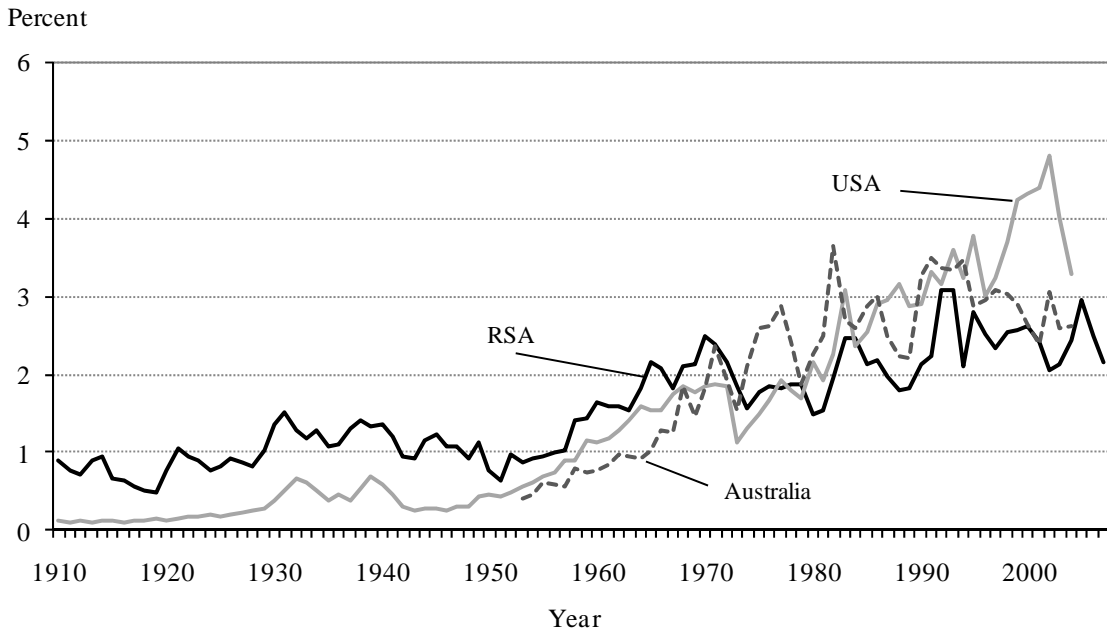
Notes: The establishment of an extension function within the Division for Education and Extension in 1925 was followed by a substantial increase in investments in agricultural extension services for the subsequent three decades, during which time the extension services were responsible for some research-related functions, such as the oversight and conduct of co-operative experiments. These arrangements and associated funding allocations) changed when the Department of Agriculture was restructured in 1952-1954 with the intent of giving a greater regional focus to the provision of agricultural R&D services.

Figure 10: Comparative intensity trends in the United States, Australia and South Africa, 1910-2007

Panel a: Agriculture as a share of GDP



Panel b: Public agricultural R&D spending as a share of agricultural GDP



Sources: Union of South Africa (1910-1959), RSA (1960-2009), ARC (1993-2009), Alston et al. (2010), Mullen (2010), US-BEA (2009), USDA (2009), and Australian Bureau of Statistics (2009).

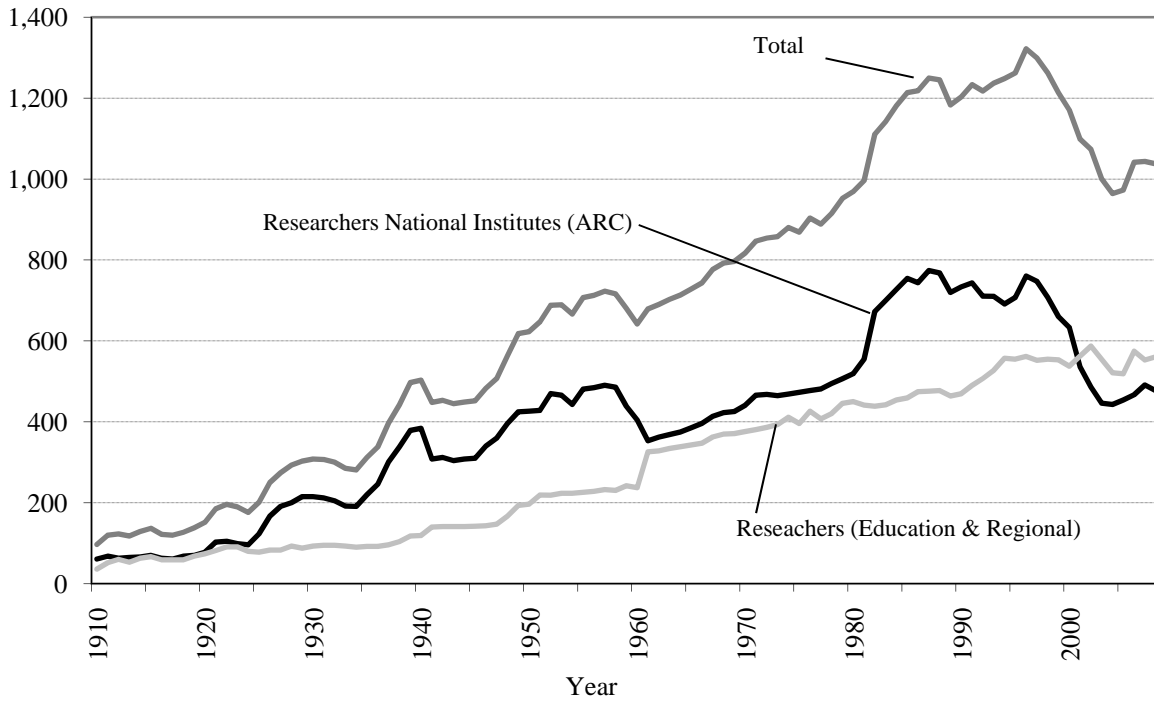
Table 4: *Degree status of university and national and regional institute personnel*

Agency	Degree	Share of Institutional Staff				Share of National Staff		
		1961	1993	2000	2006	1961	1993	2000
ARC	Phd	26.8	24.2	28.3	32.1	43.8	41.3	42.5
	MSc	25.6	34.8	44.1	49.5	42.9	55.8	60.4
	BSc	47.6	41.0	27.6	18.4	45.4	64.2	67.3
Regions	Phd	16.9	12.8	15.7	na	23.0	5.5	5.0
	MSc	29.9	47.9	51.5	na	41.7	19.3	52.5
	BSc	53.2	39.4	32.8	na	42.4	15.5	16.9
Universities	Phd	48.2	52.2	58.9	na	33.2	53.2	52.5
	MSc	21.6	26.0	30.2	na	15.3	24.9	24.7
	BSc	30.2	21.7	10.9	na	12.2	20.3	15.8

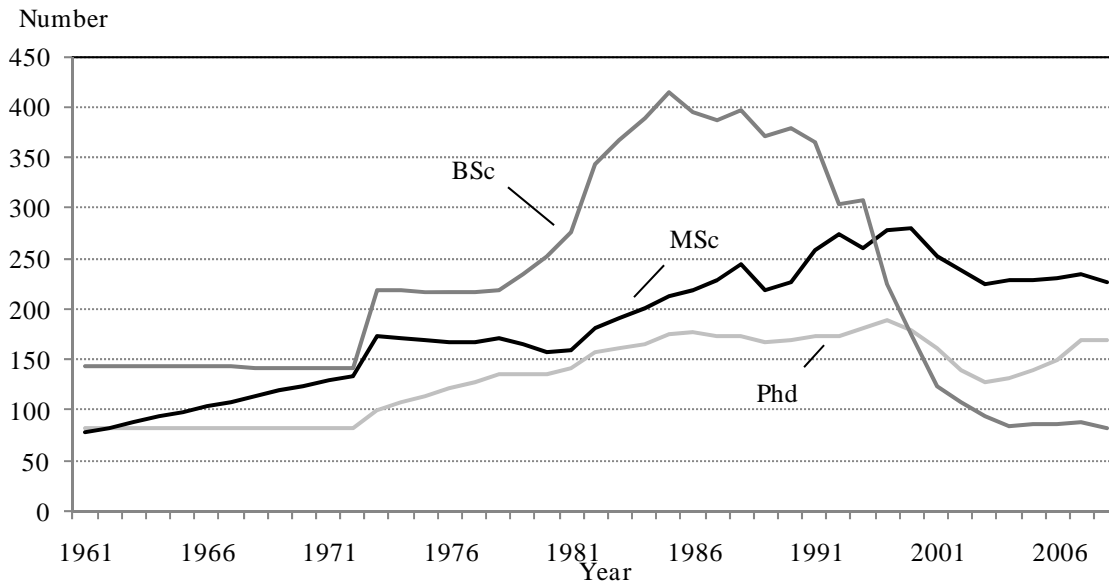
Sources: Roseboom et al. (1995), Liebenberg et al. (2004), and ARC (2009).

Figure 11: *Public sector agricultural researcher trends, 1910-2008*
 Panel a: National, regional and education researcher trends, 1961-2008

Number of Agricultural Researchers

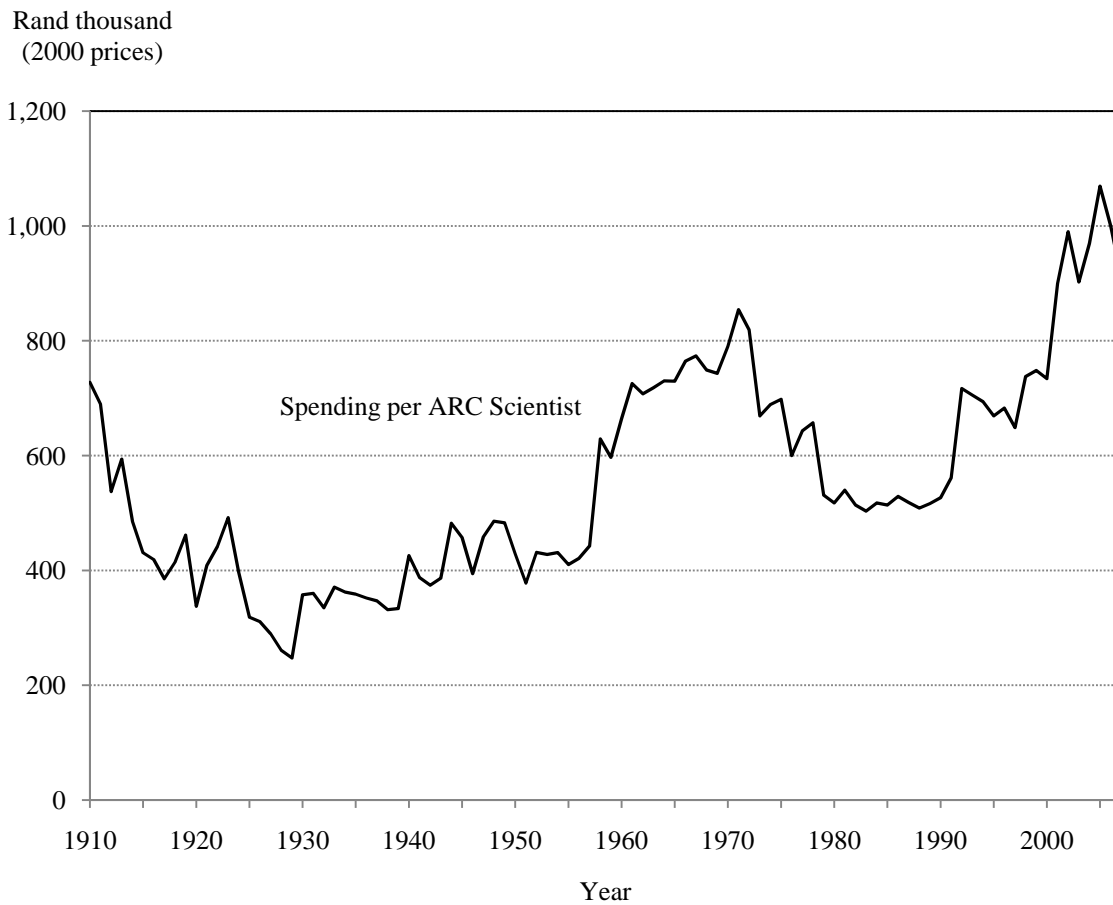


Panel b: Staff qualification of ARC researchers, 1961-2008



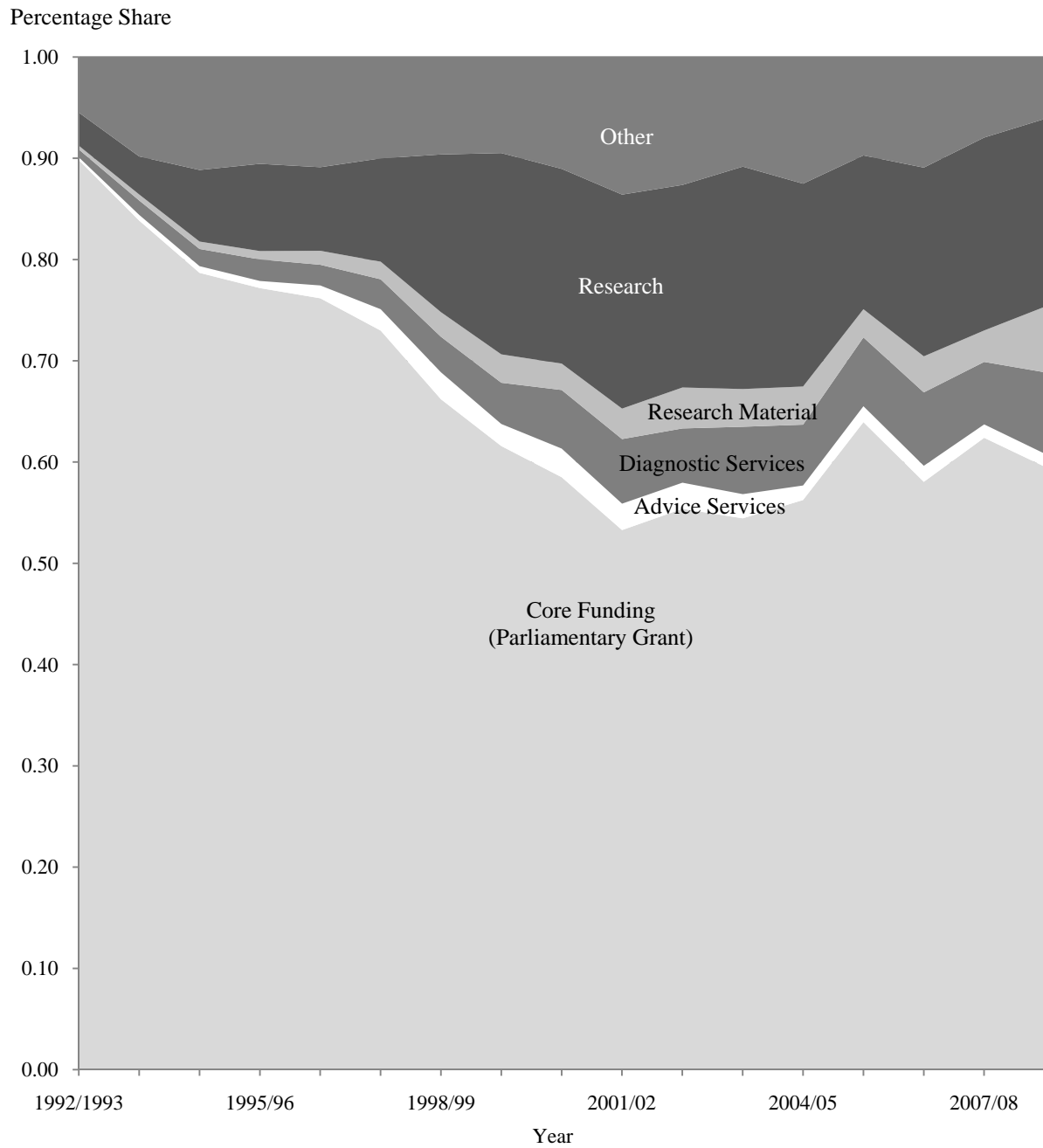
Sources: Dept of Finance (1910-1959), Republic of South Africa (1960-1976), Roseboom et al. (1995), Liebenberg et al (2004), ARC (various reports), and CeSTII (various reports).

Figure 12: *Real spending per ARC scientist, 1910-2007*



Sources: Republic of South Africa (1910-1959), RSA (1960-2009), and ARC (1993-2009), SARB (2009).
Notes: A nominal agricultural R&D spending per scientist series was deflated using a GDP deflator derived from data provided by the SARB (2009).

Figure 13: *Funding sources for ARC, 1992-2008*



Sources: ARC (2009).

Table 5: *Non-core sources of support for ARC institutes, various fiscal years*

Source	Institute												ARC Total
	Corporate	Grain Crops	Industrial Crops	Small Grains	Tropical & Subtropical	Infruitech	Vegetables & Ornamental Plants	Animal Products	Veterinary	Plant Protection	Soil, Climate & Water	Agricultural Engineering	
													Percentage
Share of External Income 1995/96													
Advice Services	0.0	0.4	0.0	0.5	5.3	1.5	3.6	4.3	2.0	1.3	3.1	78.1	3.4
Diagnostic Services	0.0	1.2	9.4	5.0	11.2	3.2	1.8	31.2	65.2	5.0	8.2	0.0	18.1
Farm Products	0.0	1.2	5.5	2.1	49.7	8.1	1.0	14.0	0.0	0.0	0.0	0.0	5.4
Personnel Services	4.0	0.0	22.3	0.7	14.6	7.6	11.8	3.7	6.4	0.4	0.0	20.3	5.1
Research Material	60.1	15.7	4.3	27.1	4.4	10.9	29.8	7.5	5.2	1.7	0.1	0.1	13.7
Research Services	14.5	79.5	58.5	63.3	13.2	67.0	52.5	33.5	19.9	91.0	87.7	0.0	45.6
Supporting Services	2.0	0.5	0.0	0.0	2.0	0.0	0.0	1.2	0.4	0.0	0.0	0.3	0.7
Other Income	19.3	1.3	0.0	1.3	-0.4	1.6	-0.6	4.5	1.0	0.6	0.9	1.2	8.1
Share of External Income 2002/03													
Advice Services	0.5	2.1	0.1	0.8	4.2	5.5	2.5	6.8	2.4	2.7	5.4	83.5	5.8
Diagnostic Services	0.0	4.7	4.5	3.8	8.4	2.1	0.9	12.2	47.1	1.6	10.6	0.0	12.0
Farm Products	0.0	13.2	7.3	3.7	21.4	6.4	0.9	11.6	0.0	0.0	0.0	0.0	6.0
Personnel Services	0.0	0.2	6.6	0.6	9.9	4.2	4.9	2.8	9.0	1.1	0.0	5.6	3.8
Research Material	0.0	2.7	7.8	21.1	5.1	11.2	13.1	21.5	2.6	1.9	0.0	0.0	9.1
Research Services	0.0	63.2	43.4	68.1	24.7	59.6	69.6	23.5	28.7	76.7	75.7	0.0	44.8
Supporting Services	2.7	0.2	0.0	0.0	0.7	0.0	0.0	0.1	2.1	0.0	0.1	0.1	0.5
Other Income	96.8	13.8	30.3	1.9	25.7	11.1	8.1	21.6	8.2	16.0	8.1	10.8	18.1
Share of External Income 2007/08													
Advice Services	0.0	0.4	0.0	0.5	5.1	1.5	3.2	4.3	1.7	1.2	2.9	73.4	3.4
Diagnostic Services	0.0	1.1	8.7	4.8	10.7	3.1	1.6	29.3	65.6	4.7	7.6	0.0	18.1
Farm Products	0.0	1.1	5.1	2.0	47.3	6.4	0.9	13.2	0.0	0.0	0.0	0.0	5.4
Personnel Services	4.8	0.0	20.6	0.7	13.9	7.5	10.5	3.5	7.6	0.4	0.0	15.4	5.1
Research Material	52.6	15.2	3.9	26.3	4.2	10.7	26.4	7.0	4.5	1.6	0.1	0.1	13.7
Research Services	16.7	74.6	54.0	61.3	12.6	65.5	46.5	31.9	16.6	86.2	84.7	0.0	45.6
Supporting Services	2.4	0.5	0.0	0.0	1.9	0.0	0.0	1.1	0.4	0.0	0.0	0.3	0.7
Other Income	23.5	7.0	7.7	4.4	4.4	5.3	10.8	9.7	3.5	6.0	4.7	10.9	8.1

Sources: ARC (2009).

Table 6: Annual contribution by commodity organizations to agricultural research, 1999-2008

Source	Contribution						
	1999	2000	2001	2002	2006	2007	2008
<i>Rands in millions</i>							
Trust contributions							
Crops	13.06	18.73	21.34	n.a.	n.a.	n.a.	n.a.
Horticulture	5.28	4.20	3.68	n.a.	n.a.	n.a.	n.a.
Livestock	3.58	3.47	7.22	n.a.	n.a.	n.a.	n.a.
Subtotal	21.92	26.40	32.25	n.a.	n.a.	n.a.	n.a.
Levy income							
Crops	11.19	11.49	12.34	n.a.	19.47	n.a.	23.20
Horticulture	19.16	25.67	27.52	n.a.	40.16	n.a.	46.22
Livestock	n.a.	n.a.	n.a.	n.a.	0.46	n.a.	1.26
Subtotal	30.35	37.16	39.86	38.41	60.09	74.42	70.68
Total contribution by commodity organizations							
Crops	24.25	30.22	33.68	n.a.	n.a.	n.a.	n.a.
Horticulture	24.44	29.87	31.21	n.a.	n.a.	n.a.	n.a.
Livestock	3.58	3.47	7.22	n.a.	n.a.	n.a.	n.a.
Total	52.27	63.56	72.10	n.a.	n.a.	n.a.	n.a.

Sources: Unpublished information provided by various trusts and commodity organizations (1999-2001) and NAMC (2007-2009).