Universities are becoming major players in the national system of innovation

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Based on data from South Africa's research and development (R&D) surveys, the country's R&D expenditure has grown in real terms by 52% over the period 2001 to 2012. This growth has been driven by government funding, which rose from 34% of the total funding in 2003 to 45% by 2012. Much of the additional funding has been granted to universities, with government support of R&D in this sector rising 450% in nominal terms, or 250% in real terms, over the same period. This funding focus, indicative of a growing role for universities as R&D performers within the national system of innovation, follows a pattern set earlier in many developed countries and reflects a revision in the state's steering of knowledge creation. The R&D Survey also revealed a decline in the average cost of research, as expressed by expenditure per full-time equivalent researcher. This finding suggests that the researcher labour market is being better supplied and the constraints identified by earlier reviews are slowly being overcome. Both trends are highly positive for the research system. However, the 34% decline in business R&D expenditure since its peak in 2008 is a matter of concern and needs to be addressed. In particular, the level of state-industry embeddedness must be increased to encourage private investment and to overcome South Africa's present growth constraints in respect of developing competitive medium- to high-technology sectors.

Introduction

In South Africa, the Centre for Science, Technology and Innovation Indicators has undertaken and published a research and development (R&D) survey annually since 2003; other agencies undertook similar surveys at mostly biennial intervals over the period 1983 to 2001, apart from 1995, when no data were published.[1,2] Such surveys are rich in data that can inform policy and improve the overall performance of the R&D system. However, the link between survey data and policy appears to be made only sporadically, despite a number of recent reviews on science and technology policy.[3-5]

We attempt to stimulate a more regular policy discussion based on the results of the survey, especially the role of public-funded R&D in supporting the national system of innovation. We concentrate on three issues, namely the source and beneficiaries of the growth in South Africa's expenditure on R&D, changes in the R&D labour market, and the decline in business R&D expenditure. The trends are discussed within the context of previous studies on the R&D role of the state, including the need for a more focused and transformative innovation policy[3,4,6], constraints in R&D human resources[6-9], and business R&D performance[10]. The extent to which and the manner in which the state involves itself in R&D are important questions that can have significant consequences on overall economic performance. Facing multiple options and instruments, the state must act in a focused yet balanced fashion to address the key challenges, without disfavouring any particular sector.

Background literature

Research, development and economic growth

There has been a distinct, if not deliberate, change in the profile of public (government) funding for R&D in South Africa since 2003. This change reflects an international trend in the role of governments with regard to their support for R&D. To examine the significance of this change, an initial discussion of the theoretical basis for public funding of R&D is required.

Governments worldwide are major funders of R&D. This fact is justified initially on the basis that research is characterised by a market failure, in which business enterprises and private investors fail to invest at an optimal level in R&D because of the inherent uncertainty, indivisibility and inappropriability of the research sector.[11,12] Accordingly the role of the state is to fill this void and to supplement private R&D investment, thereby ensuring that its benefits are maximised. However, this perspective is by no means unchallenged. On the one hand, its neo-liberal opponents argue for reduced state involvement in the economy, based on the belief that state intervention is economically inefficient and therefore socially undesirable.[13] On the other hand, some scholars hold the view that the state must act not as a stopgap but as a leader working proactively.[14] The latter perspective recognises a more prominent role for public-funded R&D, in which funding creates opportunities for subsequent innovation, rather than simply attempting to support private-funded R&D or prevent the dissipation of previous investment by business enterprises.

Over the period 1980 to 2000, the neo-liberal position was popular, with the result that several developed countries decreased their levels of public R&D funding. In more recent years there has been a recovery in support for public R&D, based on new evidence from country-level studies. Beginning with Chalmers Johnson[15] who studied the history of modern Japanese industrial policy, followed by various other scholars in the developmental state school, new theories on the role of the state in enabling economic development have been proposed[16-21]. In a recent contribution that builds on these theories, Breznitz[22] offers a model of how developing countries can achieve economic transformation through state-led interventions that promote rapid innovation-based industries. This model is based on detailed case studies from Israel, Taiwan and Ireland. Breznitz[18] argues that there are three critical factors for productive interventions by the state, namely:

- a clear framework for how the state will acquire the necessary knowledge and skills to support such industries (including R&D)
- a set of policies to solve the inherent market failure of industrial R&D, including strategies to encourage private investment
- significant effort to nurture local competence and embed local firms in global production networks.

Breznitz[22] further noted that a plurality of solutions existed to the problem of developing rapid innovation-based industries in developing countries, within a context of globalisation and fragmented supply chains. However, the requirement for a close partnership between the state and business enterprise – referred to as 'embeddedness' – was universal.[18] Although Breznitz's work did not cover South Africa, it did cover countries of a similar size and stage of development in the 1970s and for which the source of economic growth had significant overlap. Furthermore the core recommendations of his work, namely that partnership, learning and skills development are crucial to successful transitions, accord with other studies on middle-income countries including Latin America. Raising levels of skills and technology transfer, nourishing local competitive firms, developing medium- and high-technology exports, and articulating a clear, simple industrial policy all underpin such transitions to a developed economy.[23,24]

Part of the confusion in the literature can be ascribed to the non-recursive nature of the variables. For example, economic growth is both caused by, and can in turn cause, an increase in knowledge production. Some authors have sought to examine these relationships in more detail. The nature and direction of causality between the accumulation of knowledge (principally through R&D) and economic growth has been studied using scientometric data and a bootstrap causality analysis.[25] The study concluded that the link between R&D and economic development is weak in developed countries that invest too little in basic research. A similar conclusion was reached in a separate study in the United Kingdom, in which the researchers argued that excessively short-term economic interests had led to the closure of the country's research laboratories, resulting in lower levels of technological innovation and ultimately less economic growth.[26] In South Africa, a positive correlation between academic research output and economic growth has been observed, indicating that such knowledge production has indeed benefited the economy.[27]

Nevertheless knowledge production, learning and skills development are not the only important factors; it is also critical that policies should identify areas of specialisation and incentivise specific sectors in which a country can establish its comparative advantage[28]. This imperative imposes on R&D policy and hence public R&D funding the need to facilitate not only human resource development, but also product or service development in sectors that can lead to significant economic growth.

Prior reviews of South Africa's R&D policy

The previous section briefly reviewed the variable nature of returns to R&D expenditure, how such returns can be measured, and the state's role in supporting R&D and ultimately facilitating economic development. We accepted the notion that the goal should be firm-level innovation, and that this outcome is linked at least partly to public expenditure on R&D; and we noted that South Africa has been characterised by a static level of innovation and economic activity in the important high-technology sectors[29]. Given these observations, the country's slow response to higher levels of public R&D funding has already been noted and studied. Prior reviews have considered this important issue and have identified several constraints. The first main constraint is the lack of focus or specialisation in R&D, and the second is a failure to provide sufficient R&D human resources.

Focus of South Africa's R&D

Concerns about a lack of focus within South Africa's R&D system and the small number of researchers spread over multiple projects have been raised in a number of reviews.[3,6] These concerns arose partly in response to growing evidence that specialisation is important in countries such as South Africa that are seeking to escape the middle-income trap.[30] Although a balanced and diversified R&D system might be the end goal for a developing country, the transition strategy requires a strong focus on specific sectors, which are then able to catch up with developed countries and build competitive local industries.

An attempt was made to address the issue of focus with the adoption in 2008 of the Ten-Year Innovation Plan.[27] This plan proposed five 'bold interventions in critical areas', labelled as grand challenges and covering the bio-economy, space science and technology, energy security, global change science with a focus on climate change, and human and social dynamics.[31] The Department of Science and Technology – and more broadly government in general – implemented the plan by directing at least a portion of the additional funding from National Treasury to large projects with close alignment to the grand challenges. These projects included the Karoo Array Telescope[32], the pebble bed modular reactor[33], the electric car (Joule)[34], and the development of a HIV microbicide (START trial)[35].

Unfortunately this focus has yet to yield measurable economic dividends. With the notable exception of Karoo Array Telescope, these projects were terminated without having reached their goals. Although failure is intrinsic to R&D, the high rate of failures is concerning. Furthermore it is claimed that the state's investment in innovation has been overly focused on big science projects, with insufficient attention to the priorities of business and social development.[36]

The debate about diversity versus focus within government-funded R&D is particularly an issue for small systems with limited resources. Options favouring diverse funding instruments and hence potential outcomes have the advantage of at least some measure of success, whereas overly focused programmes may all fail because of the inherently risky and unpredictable nature of R&D. This tension is at the core of portfolio management theory and the risk mitigation properties of a balanced portfolio.[37] However, small systems may fail to achieve critical mass in any particular area because of the inevitable dilution of available resources that accompanies diversity.

In this respect, criticism of resource allocation can always be made; only hindsight will identify the most perfect solution. Nevertheless there are suggestions that South Africa's choices for specialisation have been misguided. The present challenges are overly focused on long-cycle science-based sectors, instead of the recommended short-cycle technology-based opportunities. The latter category is more likely to yield the desired economic outcomes.[30]

Human resources for R&D

The severe shortage of human resources for R&D has been identified as a fundamental constraint to economic growth and R&D in every review since 1994. For example, the 2007 report by the Organisation for Economic Cooperation and Development (OECD) identified two looming crises: the engineering gap (deficit between supply of engineering and management skills or capabilities), and the limited supply of university graduates capable of undertaking research.[6] Similarly Kaplan[9] noted that any further expansion of the system will be 'predicated on a significant expansion in supply of skills' and that more resources devoted to R&D will have the effect of driving up unit costs and lowering productivity, rather than expanding output.[5] Likewise the 2012 Ministerial Review of Science, Technology and Innovation Landscape of South Africa noted that the 'biggest constraints are the stuttering pipeline of trained and knowledgeable people at all levels'.[36]

Seekings and Nattrass[38] highlight the deficiencies in the South African labour market as the key factor in the dual issues of employment and inequality. The market is characterised by a shrinking of low-wage formal employment opportunities and higher earnings or better working conditions for white- and blue-collar workers, as a result of an enduring skills shortage. The same diagnosis is reached by a separate study by the Reserve Bank, which concluded that the country needs to triple the growth rate of its skilled labour, thereby significantly increasing the pool of skilled workers and reducing their cost, so that firms can expand their skills base without bidding-up wages.[39] Based on an economic model, the latter study predicts that relieving the skills constraint would raise potential growth to 6.7% by 2025, but that this result would require long-term reform across the education and training spectrum.

The divergence between labour market conditions for unskilled versus skilled labour is an enduring feature of apartheid policies, which specifically sought to establish and preserve high wages and protected incomes for a minority group.[40] Policies such as trade liberalisation and the promotion of a high-productivity growth path have favoured capital-intensive firms over labour-intensive firms, resulting in rising real wages for employed people in 2014 compared with 1994.[40,41] As a result, the benefits of economic growth since 1994 have largely been experienced by the lower and upper middle classes, with the poor and unemployed being excluded.

The Ministerial Task Team summarised the problem in the 'stuttering pipeline' as being inadequate schooling and training systems, low university participation (admission) rates, high drop-out rates, minimal enrolments for advanced postgraduate study, an ageing research cadre, and high barriers to the expansion of the postdoctoral sector.[36] Proposed solutions included quadrupling the number of technical colleges, curriculum reform, improved functioning of post-graduate training programmes, and a new cohort of research institutes to undertake multi-focus high-level research.[36]

Given rising public expenditure on education and the long-standing nature of the problem, it is important to consider what progress has been achieved and whether the constraints are being eased by the various interventions. Unfortunately a number of surveys indicate little progress, especially at primary and secondary school level.[42,43] In terms of undergraduate education, the Council for Higher Education reported that only one in four students complete their degrees in regulation time, that 55% of students never complete their undergraduate studies, and that access/success rates are still racially skewed. The net result of the disparity is that less than 5% of African and coloured youth succeed in any form of higher education.[44] Participation, let alone achievement, remains a big challenge for higher education. The Department of Higher Education and Training plans to increase university enrolments to 1.5 million by 2030, and to increase the role and alignment with industry needs of technical and vocational education and training colleges. The department also plans to introduce foundation programmes at these colleges for additional instruction in mathematics and science, to prepare students for university. Further insight on changes in the human resource pipeline can be extracted from the R&D Survey.

Results of R&D Survey

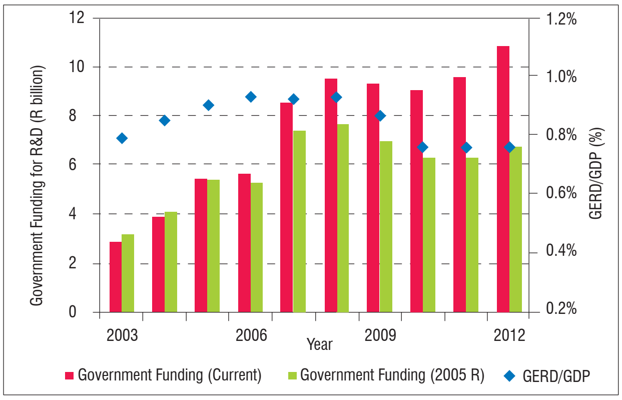
The report on the 2012/2013 R&D Survey covers a broad range of questions, including transformation, socio-economic objectives, R&D in key technology missions such as biotechnology, and regional disparities in R&D effort.[45] However, in this review of the results, only three themes will be covered as follows:

- increasing government budget appropriations or outlays for R&D, with much of the increases being allocated to universities
- increasing numbers of full-time equivalent (FTE) researchers, and declining expenditure per FTE
- declining business performance of R&D (BERD), measured as both performance itself and funding.

Government R&D expenditure and performance

Government is spending more on R&D than it did 10 years ago, with the increase in government budget appropriations or outlays for R&D over this period being 214% in real terms and 385% in nominal terms (Figure 1). Public funding of R&D has risen from 28% to 45% of gross domestic expenditure on R&D, and is now the dominant source of funds.

Much of the additional funding has been allocated to universities, whose R&D performance – as measured by higher education expenditure on R&D – has risen from R3.6 billion in 2007 to R7.3 billion in 2012. This marks an increase of 202% in 5 years (Figure 2). Universities now account for 34% of the total R&D performance, up from 19% in 2007.



Key: GERD – gross domestic expenditure on R&D

Figure 1: Government funding of R&D (2003 to 2012).

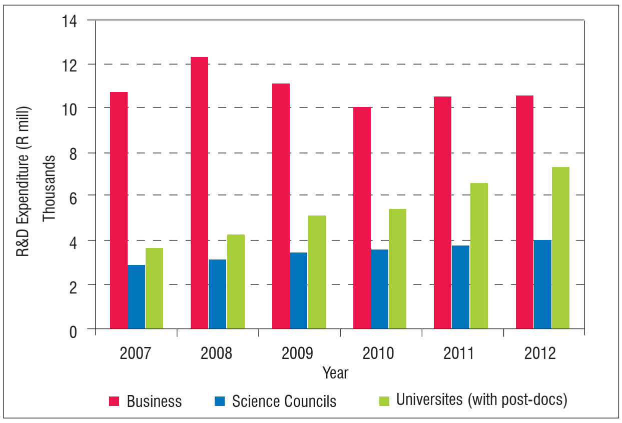
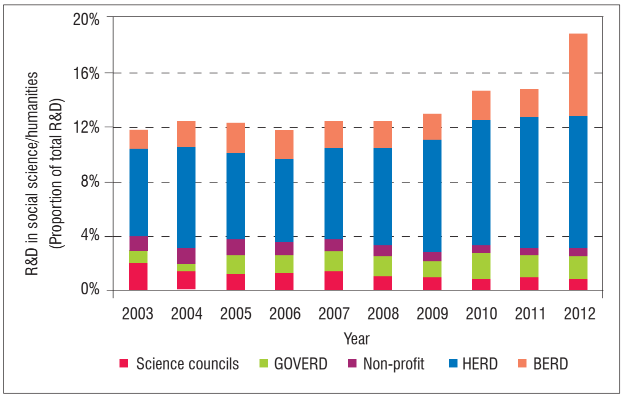


Figure 2: R&D performance by business, science and universities (2007 to 2012).

The growing role of universities in the overall R&D landscape reflects an international trend and aligns with the recommendations of the Ministerial Committee.[36] Universities in general have become more important actors within national systems, mainly as a consequence of the perceived lower social return from public research institutes.[46] Total public funding of universities has reached about 25% of gross domestic expenditure on R&D in OECD countries, or 0.43% of gross domestic product (GDP). Similarly, intramural expenditure on R&D by government, which measures R&D performance by government agencies, is declining in OECD as a percentage of GDP, and has now dropped to 0.27% of GDP.[47]

In terms of expenditure in different research fields, Kahn[48] previously pointed to the high proportion of South Africa's higher education expenditure on R&D devoted to the social sciences and humanities. Between 2002 and 2012 this proportion remained constant at 31%. However, the consequence of the growth in higher education expenditure on R&D as a proportion of total R&D expenditure, and certain structural changes to BERD, has been an increase in the overall ratio of spending on the social sciences and humanities (Figure 3). This proportion rose from 12% in 2002 to 19% in 2012. A corollary result was a decline in the proportion of experimental development from 38% to 28% over the same period. The latter is the Frascati[49] category, which records expenditure of development as opposed to research and is typically undertaken in the natural or engineering sciences on close-to-market R&D projects. The structural changes in BERD mentioned earlier are a decrease of R905 million in R&D relating to information, computer and communication technologies; and an increase of R972 million in R&D in the social sciences.



Key: GOVERD – government expenditure on R&D, HERD – higher education expenditure on R&D, BERD – business expenditure on R&D

Figure 3: Rising R&D expenditure in social sciences and humanities.

Disappointingly for the Department of Science and Technology, the ratio of gross domestic expenditure on R&D to GDP has not responded to the growth in the economy or the increase in government funding. It has instead remained at 2003 levels, as shown in Figure 1. The Department of Science and Technology's ten-year innovation plan set a target of 2% for this ratio, to be achieved by 2018, but South Africa is unlikely to achieve a figure of even half this value. Furthermore, limited economic growth, rising fiscal pressure and the low level of confidence within the private sector in the country's economic future suggest that the shortfall is unlikely to be met by either the public or the private sector. In the absence of significant re-allocations from other portfolios, the only alternatives for the Department of Science and Technology are to be more selective in its investments, to seek ways of achieving productivity increases and to more closely monitor the progress of its existing projects. Questions of specialisation and focus have already been discussed; it is likely that such questions will become even more relevant in the coming years.

Adjustments in the R&D labour market

Given the increase in funding, it is not unexpected that universities in South Africa have expanded in terms of the number of active researchers, with FTEs rising from 10 000 in 2007 to 13 744 in 2012 (Figure 4). However, the decline in the number of science council and business researchers, mainly because of the loss of 475 FTEs in science councils and 1 256 FTEs in business enterprises in a single year – 2010 – is of major concern.

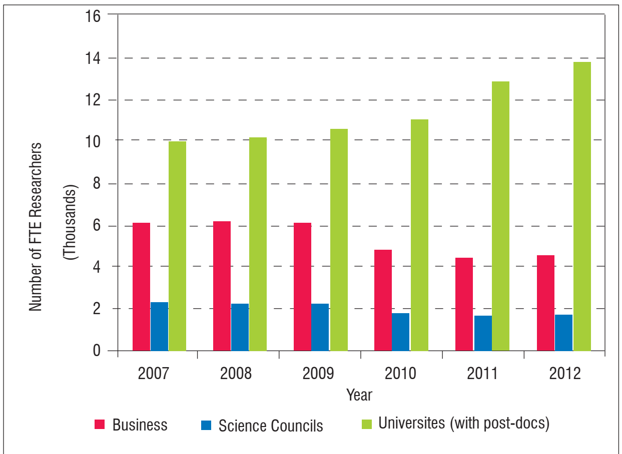


Figure 4: Trends in FTE researchers in the three R&D performance sectors (2007 to 2012).

The data indicate a recovery in the researcher labour market, despite concerns expressed in earlier reviews about labour market shortages and rising unit labour costs. Although the number of FTE researchers in universities has risen substantially, the unit costs per FTE have decreased over the same period, indicating that the R&D labour market conditions have eased at least for universities. Although R&D expenditure per FTE is only a proxy indicator for labour costs, it does provide some indication of what is happening in the market, because labour costs account for about 70% to 80% of total R&D expenditure. Notwithstanding this relaxation of labour market conditions, relative to their international peers and on a purchasing power parity basis, the average R&D spend per South African researcher is still higher than in some developed countries, and further adjustments in the labour market are necessary. The values in the graph shown in Figure 5 were calculated initially in USD purchasing power parity, and were then changed to 2005 constant ZAR using the purchasing power parity rate for 2005.

Figure 5: R&D expenditure per FTE for South Africa and comparator countries.

As predicted by Walwyn and Scholes[50], the cost of R&D in South Africa's public research institutions (known as science councils) has risen. Expenditure per FTE, which increased by 36% in real terms over the period 2007 to 2012, exceeded the value from the business sector for the first time in 2012 (Figure 6). These data reflect a growing equality in the market between R&D employment conditions in the public and private sectors, but could be indicative of the need for an adjustment to public research institutions' cost structures if these organisations are to compete more successfully against universities.

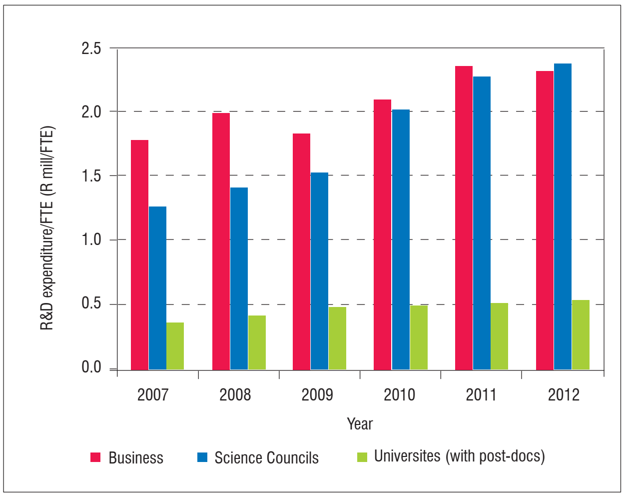


Figure 6: Trends in South Africa's R&D expenditure per FTE.

Business R&D

Of all the R&D metrics factors discussed in this article, the question of business funding for R&D is perhaps the greatest concern. (Note that business funding is different from business performance of R&D, where the latter is referred to as BERD within the R&D Survey's nomenclature, irrespective of source of funding). As shown in Figure 7, it is clear that both funding and performance of R&D in this sector has declined in real terms since its peak during 2006 to 2008 (a drop of 34% in real terms).[51] The data for performance are confounded by the funding for the pebble bed modular reactor, in which government invested R8.8 billion between 1999 and 2010.[52]

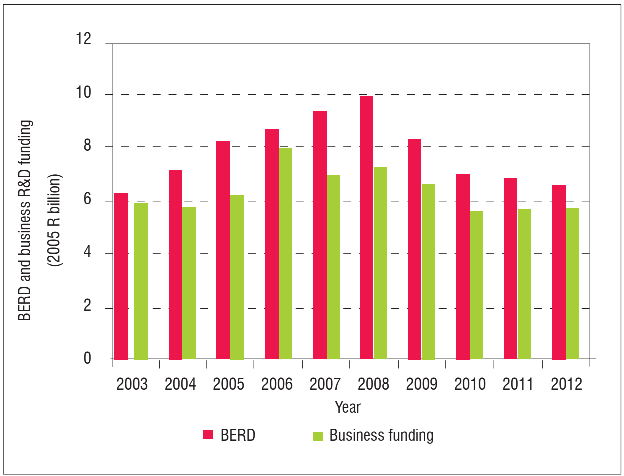


Figure 7: BERD and business R&D funding in constant 2005 R billion (2003 to 2012).

The decline in business funding for R&D would be even more severe if one were to exclude Sasol, whose funding for R&D rose from R376 million in 2002–2003 to R1.26 billion in 2012[53] and by 2012 constituted 12% of BERD in South Africa. A target or desirable value for BERD has been much debated over a long period, with proposed values ranging from 0.7% to 1.8% of GDP, or at a company level from 4% to 25% of revenue. Little agreement has been reached on the value with the highest return – or indeed even the methodology by which this value should be calculated.[54] In earlier work it has been suggested that South Africa's BERD should be about 0.9% of GDP (or about 3 times the present value of 0.34%); this figure was based on an analysis of the country's industry structure and benchmark values for each industry, as derived from an international comparison.[55]

A more recent approach to determining optimal R&D expenditure has followed the formulation of the Cobb-Douglas production function[56-58], as shown in Equation 1. The critical parameter for this discussion is the exponent y, which can also be expressed in the form of the Research Quotient (RQ). The latter is a normalised value calculated using the following equation:

$$RQ = y*181 + 81 \qquad \text{Equation 1}$$

Although the basis for the normalisation is not explained in the original paper[56], an RQ of 100 is understood to represent a breakeven point for companies. A value of less than 100 corresponds with y of less than 0.107, and implies that the firm (or country) destroys rather than creates value with its R&D efforts. We undertook a limited analysis on selected South African companies using this methodology. Encouragingly, the results showed at least one of the companies, Sasol, has a coefficient of 0.412 and hence an RQ of about 155. This figure is on par with the leaders in the sector (Table 1) and confirms the high added value of Sasol's R&D efforts.

Table 1: A comparison of Research Quotient (RQ) for Sasol and other leading international companies

Company	Sector	RQ
Sasol	Fuels and chemicals	155
Usec Inc	Chemicals	136
Medicines Co	Drugs	130
China Petroleum and Chemicals	Oil and gas	124
Amazon.Com Inc	Online retail	123
Salix Pharmaceuticals Ltd	Drugs	119

Source: http://www.amkanalytics.com/Pages/rq50 *for all companies except Sasol (RQ for Sasol was calculated in our study)*

The Sasol RQ result indicates the successful implementation of a strategy built on in-house R&D and technology management – an approach that has enabled the company to retain high levels of profitability. Sasol's revenue reached R181 billion in 2012, with an operating profit (gross earnings) consistently above 20% of revenue (Figure 8). Understandably these returns have been under pressure following the collapse of the crude oil price, although the most recent data on the company's performance are not yet publically available.

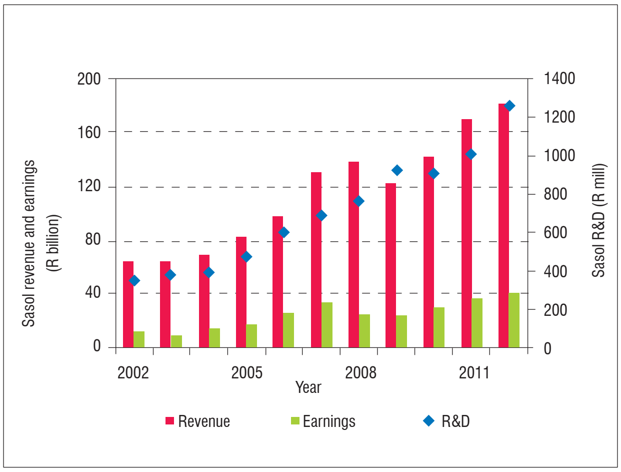


Figure 8: Sasol's revenue, earnings and R&D expenditure (2002 to 2012).

The initial results suggest that South African companies receive acceptable returns from their R&D expenditure. However, a perception remains that increased R&D is not judicious within the present business environment, and levels of BERD have continued to decline. The reasons for this decline might be complex, but appear to correlate with falling business confidence in the economy, which manifests in many ways – including reluctance to invest in R&D.

The economic upswing between September 1999 and November 2007 was the longest in South Africa's history[59] and was associated with growing business confidence, as indicated in Figure 9. During this period BERD also grew substantially, reaching a high of R10 billion (in constant 2005 rands) in 2008, before declining significantly between 2009 and 2012. The data indicate that BERD appears to track business confidence with a lag, not unexpectedly, of about a year. The implications of this correlation are discussed in the next section.

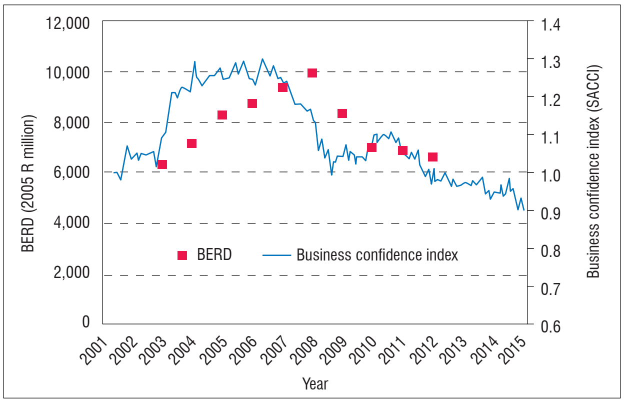


Figure 9: Trends in business confidence and business expenditure on R&D (2001 to 2015).

Discussion

Trends in R&D reveal interesting patterns in response to changes in the business environment, the policy context, social priorities, and advances in knowledge and technology. In this respect R&D is both a reflection of the past and a forecast of the future. The 2012/2013 R&D Survey illustrates several such trends, including an increasing role of universities in public-funded research, which follows an international trend of the movement of funds from public research institutions to universities. The preference towards universities or higher education institutions as performers of public-funded R&D has different drivers depending on specific national contexts. In South Africa, the trend can be ascribed to a number of overlapping and simultaneous adjustments within the system.

Firstly, universities have increased their activities in applied research. They have done so by establishing closer links with the private sector, setting up technology transfer offices, pursuing the registration and licensing of intellectual property arising from their R&D, and adopting the commercialisation of knowledge within institutions as a significant component of their mandates (in addition to teaching and research). Public research institutions, which have traditionally performed the role of adapting new knowledge for the development of novel products and services, are facing strong competition from universities in terms of access to competitive funding, networks with industry, sponsorship of specific research programmes and training of personnel in new technologies. In this competitive environment, universities have a strong cost advantage because of a rather loosely-applied notion of full cost and a generally lower cost per FTE researcher (Figure 6). The latter can be explained by the observation that much university R&D is conducted by doctoral or post-doctoral students, who are not remunerated by the universities except in unusual situations.

The second important aspect influencing the issue of universities and public research institutions is the implementation of new public management (NPM) and its effect within both institutions. NPM refers to the introduction of, firstly, a business-type managerialism adapted from the private sector. This management approach includes performance agreements, fixed-term contracts for senior managers, business planning, new financial techniques, full-cost accounting and greater autonomy for line managers. Secondly, NPM has introduced new institutional economics based on greater use of market mechanisms – including privatisation, removal of government subsidies, public choice, competition, quasi-markets, citizens as clients and customer satisfaction.[60] Although NPM was applied equally in both environments (universities and public research institutions), universities benefitted more in a financial sense from the change. For instance, an important consequence of NPM was the shift from block funding to competitive funding[47], with public research institutions having to compete for public funds alongside the universities. It has already been noted that universities have an inherent cost advantage in this contest for funding because of their use of indirectly-funded postgraduate students as researchers.

Rising levels of public-funded R&D within universities has the additional benefit of producing the necessary human resources to directly support the economy's transition from a resource-based to a knowledge-intensive structure. However, this link assumes requisite capacity within business enterprises to absorb these additional resources through intensification of business-supported R&D. As already noted, South Africa's development of this capacity has been slow and BERD has declined since 2008.

Furthermore, based on the trends in the South African Chamber of Commerce and Industry (SACCI) business confidence index, we predict that this decline has persisted since 2012/2013 (the most recent year for which R&D expenditure data are available) to the present, and will continue in the near future. In December 2015 the index reached a new low of 79.6, and the average in 2015 of 86.4 was the lowest since 1993 (when it was 81.3).[61] Assuming that this index is indeed predictive of business expenditure on R&D, as suggested by Figure 9, this trend does not auger well for BERD results in future years.

The situation presents an ongoing problem for government and requires a novel response. Its gravity can be appreciated even more profoundly if one considers the extent to which public policy has been reformed to support business R&D. For instance, government introduced a 150% R&D tax credit system in 2006; it provides financial support for technology entrepreneurs through the Technology Innovation Agency and the Support Programme for Industrial Innovation; it encouraged university-industry linkages through the Technology for Human Resources Programme; and through the Department of Science and Technology, government provides financial support for a wide range of R&D projects and collaborations. Given the disappointing outcome of these incentives, the South African government should consider other possibilities for productive interventions. These might include the three critical factors identified by Breznitz[22], the specialisation strategy proposed by Lee[62], and improved coordination between the Department of Science and Technology and other government departments to ensure more effective application of the various instruments. In particular, government needs to define a clear framework for how the state will acquire the necessary knowledge and skills to support new industries, how it will nurture local competence, and more importantly how it will embed local firms in global production networks.

The Department of Science and Technology also needs to clarify the mandates of its respective performance agencies, including the science councils, given the changes introduced by NPM and the new approaches to the commercialisation of university-based intellectual property. The role of science councils such as the Human Science Research Council and the Africa Institute of South Africa, which perform only basic and applied research (as defined by the R&D Survey), should be examined. There may be cost advantages associated with universities performing this type of research instead, and concomitant benefits of associated human capital development. In addition, the potential duplication of facilities and capabilities required for experimental development – and which already exist within public research institutions – should be avoided. Instead, government should seek to improve relationships between universities and science councils through a targeted instrument to support meaningful collaboration, especially in projects and areas that do not attract private sector interest.

The state's allocation of resources to support R&D is subject to various pressures, including the need to directly support business R&D, to grant more funding to universities and to sustain key infrastructure in the science councils. The final allocations must reflect at least a consideration of these priorities and a rational attempt to justify government decisions, based on a conscious logic model that articulates the relationship between funding and desired outcomes. Unfortunately such a model is complex and difficult to define. Many of the variables are non-recursive (bidirectional) and the relationship between them varies depending on the context. Assuming that South Africa is a middle-income country struggling to escape the proverbial trap of such countries, the need to pay more attention to learning and specialisation is appropriate, as it would in turn lead to gains in total factor productivity rather than factor accumulation. As a result, it could be argued that an increase in public funding for universities within the present context of overall human resource constraints is justifiable. Evidence for such a shift, as noted in our study, is aligned with innovation policy studies and could over time lead to the economic growth so urgently desired. However, this attention by the state to the human resource pipeline needs to be combined with strengthening the science councils to deliver on short-cycle technologies, as well as a large effort to ignite business R&D. Business R&D has fallen to low levels and this is becoming a major impediment to the potential for future economic growth in South Africa.

Conclusion

Investment in R&D is an important decision for all countries, but especially in countries with a appreciable set of structural and economic problems, such as South Africa. Returns from R&D are by no means guaranteed, and several studies have shown variable outcomes and weak causality. It is therefore critical that the country's R&D Survey results are critically analysed on a regular basis and research policy is continually adjusted based on the insights from such analysis.

In the most recent survey, it is apparent that South Africa's expenditure on R&D has grown in real terms by 52% between 2001 and 2012. This increase was driven by government funding, which rose from 34% of total R&D funding in 2003 to 45% by 2012. Much of the additional funding has been granted to universities, with government support of R&D in this sector rising 450% in nominal terms and 250% in real terms over the same period. The survey also reveals a decline in the average cost of research, as expressed by expenditure per full time equivalent (FTE) researcher. Although the latter is a crude measure, the decrease suggests that the researcher labour market is better supplied and the constraints identified by earlier reviews are being overcome slowly. Both trends (rising government funding and declining unit costs) are highly positive for the system. However, the 34% decline in business R&D expenditure since its peak in 2008 is a matter of concern and needs to be addressed. In particular, the levels of specialisation, state-industry embeddedness and effective incentivisation of BERD must all be increased if South Africa is to overcome its present growth constraints and develop a competitive high-technology sector.

Authors' contributions

The authors contributed equally to this paper.

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