R&D SURVEY

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SOUTH AFRICAN NATIONAL SURVEY OF RESEARCH AND EXPERIMENTAL DEVELOPMENT

BOOSTING R&D FUNDING IN SOUTH AFRICA IN THE CONTEXT OF REINDUSTRIALISATION

A Compendium of Analytical Briefs

Science, Technology and Innovation Statistics South Africa

HSRC Human Sciences Research Council

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- https://hsrc.ac.za/about-cestii/measuring-rd-activity-in-south-africa/

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Companion publications

- Centre for Science, Technology and Innovation Indicators (CeSTII). (2024). *South African National Survey of Research and Experimental Development: Statistical Report 2021/22.* Pretoria: Human Sciences Research Council (HSRC).
- Centre for Science, Technology and Innovation Indicators (CeSTII). (2024). *Main Trends in South African R&D 2021/22.* Pretoria: Human Sciences Research Council (HSRC).

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The data presented in this book is the result of a meticulously compiled time series, developed over many years, and is based on the South African National Survey of R&D panel. This extensive effort would not have been possible without the dedication and hard work of the HSRC-CeSTII project team of the South African National Survey of Research and Experimental Development. Their unwavering commitment to collecting and analysing this crucial data is invaluable. Special mention must go to the DSTI team that collaborated on producing projections of R&D intensity, contributing to the final brief in the monograph.

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ABBREVIATIONS

BERD	Business expenditure on R&D
BRICS	Brazil, the Russian Federation, India, China and South Africa
CeSTII	Centre for Science, Technology and Innovation Indicators
DSTI	Department of Science, Technology and Innovation
FTE	Full-time equivalent
GDP	Gross domestic product
GERD	Gross domestic expenditure on R&D
HSRC	Human Sciences Research Council
ICT	Information and communication technology
IMF	International Monetary Fund
NPO	Not-for-profit organisation
NSI	National system of innovation
OECD	Organisation for Economic Co-operation and Development
PPP	Purchasing power parity
R&D	Research and experimental development
RF	Research field
SIC	Standard Industrial Classification
SOE	State-owned enterprise
Stats SA	Statistics South Africa
STI	Science, technology and innovation
UIS	UNESCO Institute for Statistics
UNESCO	United Nations Educational, Scientific and Cultural Organisation

DEFINITION OF TERMS

Applied research is original investigation undertaken to acquire new knowledge. It is directed primarily towards a specific practical aim or objective.

Basic research is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view.

BERD refers to business expenditure on research and experimental development.

Biotechnology is an application of science and technology to living organisms, as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods and services.

Capital expenditure is the annual gross expenditure on fixed assets used repeatedly or continuously in the performance of R&D programmes for more than one year. Such expenditure is reported in full in the period in which it took place and is not registered as an element of depreciation. Capital expenditure includes expenditure on land, buildings, instruments and equipment.

Constant 2015 (Real) Rands is the value of goods and services of a given year using the prices of a determined base reference year, which is 2015 in this case. These values were obtained by deflating with the GDP deflator using data published in the Statistics South Africa GDP survey P0441, Fourth quarter 2021 (Stats SA 2021).

Current expenditure is composed of labour costs of R&D personnel and other current costs used in R&D. Services and items (including equipment) used and consumed within one year are current expenditures. Annual fees or rents for the use of fixed assets is included in current expenditures.

Experimental development is systematic work, drawing on existing knowledge gained from research and/or practical experience, which is directed to producing new materials, products or devices, to installing new processes, systems or services, or to improving substantially those already produced or installed.

Full-time equivalent (FTE) refers to the number of hours (person-years of effort) spent on R&D activities.

FTE per 1 000 in total employment is the number of professionals engaged in the conception or creation of new knowledge, products, processes, methods and systems, as well as in the management of these projects during a given year expressed as a proportion of 1 000 employed people. It is calculated by number of researchers during a given year divided by the total employed people and multiplied by 1 000.

Gross domestic product (GDP) is the total market value of all final goods and services produced in a country in a given year, equal to total consumer, investment and government spending, plus the value of exports, minus the value of imports.

Gross domestic expenditure on research and experimental development (GERD) covers all expenditures for R&D performed on national territory in a given year. It thus includes domestically performed R&D that is financed from abroad but excludes R&D funds paid abroad, notably to international agencies.

Headcount refers to the actual number of people directly involved in or supporting R&D (i.e. the total number of R&D personnel).

New materials refer to the technology and R&D activities of high-technology companies particularly in the aerospace, construction, electronic, biomedical, renewable energy, environmental remediation, food and packaging, manufacturing and motorcar industries. New materials include multi-functional materials, advanced materials, nanomaterials, nanocomposites and nanotechnology.

Other support staff includes skilled and unskilled craftsmen, secretarial and clerical staff participating in R&D projects or directly associated with such projects.

Research and experimental development (R&D) comprises creative and systematic work undertaken to increase the stock of knowledge—including knowledge of humankind, culture and society—and to devise new applications of available knowledge.

Researchers are professionals engaged in the conception or creation of new knowledge, products, processes, methods and systems, and in the management of the projects concerned.

Research field (RF) refers to a branch of science, either natural or social and humanities sciences.

R&D intensity refers to gross expenditure on R&D as a percentage of GDP.

R&D personnel include all persons (irrespective of nationality) employed directly on R&D activities, as well as those providing direct services, such as R&D managers, administrators, technicians and clerical staff. These include emeritus professors, honorary fellows and research fellows.[1]

R&D-performing sectors comprise the government, higher education, business and not-for-profit institutional sectors.

Standard Industrial Classification (SIC) are codes used by Statistics South Africa for all economic activities of industries.

State-owned enterprises (SOEs) are public corporations owned by government units mainly engaged in market production and sale of the kind of goods and services often produced by private enterprises.

Technicians and equivalent staff are persons whose main tasks require technical knowledge and experience in one or more fields of engineering, physical and life sciences, or social sciences, humanities and the arts.

Total employment is the total employment in the economy. This statistic is obtained from the Statistics South Africa Labour Force Survey series P0211 (Stats SA 2022), where employed persons are those aged 15-64 years who, during the reference week, did any work for at least one hour, or had a job or business but were not at work (temporarily absent).

Year-on-year changes are calculated as follows: (current year's figure - previous year's figure) / previous year's figure × 100%.

[1] Prior to 2016/17, emeritus professors, honorary fellows and research fellows were not required to be explicitly included in the estimates of R&D personnel.

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INTRODUCTION

The *Main Trends in South African R&D 2021/22* report provides a broad view of the national R&D landscape. In this companion publication we systematically explore specific issues related to R&D and innovation in South Africa in a set of analytical briefs.

These draw on academic literature and interrogate the data on R&D topics relevant to current policy priorities, research interests and the global economic situation. They aim to stimulate critical conversations, and inform policy discussion on future ways forward. The briefs adhere to rigorous scientific methods, and have undergone subject matter expert review but are tailored to be accessible to both subject matter experts and non-experts.

Innovation can exert a lasting influence on economic development, with R&D as a key innovation activity with potentially disruptive effects. However, the specific aspects of R&D that enable such impact, and the mechanisms and circumstances under which it occurs, remain unclear. Given South Africa's relatively low R&D performance and development, the briefs explore those factors that could transform this situation. We utilise available data and draw from academic literature to provide insights and suggest a way forward.

The first brief illustrates the capacity of public funding to spark and accelerate business sector investment in R&D. Using the well-known case of the USA, we seek to identify critical levels of public investment that are essential for inducing such investment.

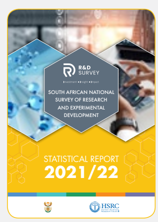
Recognising that post-WWII USA may not be an ideal comparator for 21st-century South Africa in all respects, the second brief explores countries with similar historical backgrounds, including both well-performing and under-performing nations to provide a comprehensive perspective.

The final brief utilises modelling data from the R&D Survey to explore the time and public funding needed to achieve South Africa's desired GERD/GDP target of 1.5%.

Accessing the R&D data and analysis

The **South African National Survey of Research and Experimental Development (R&D Survey) data** for the period 2001/02 to 2021/22 that is cited in this document was created by the Centre for Science, Technology and Innovation Indicators at the Human Sciences Research Council. Data is available for download and use by readers in different formats on the HSRC's website (https://hsrc.ac.za/about-cestii/measuring-rd-activity-in-south-africa/). For specialised data requests from CeSTII, visit https://data-request.hsrc.ac.za/

Also available on the HSRC website are the companion publications to the briefs presented here, which includes the *R&D Survey Statistical Report 2021/22* and *Main Trends in South African R&D 2021/22*.



1. FUNDING R&D IN A DEINDUSTRIALISING SOUTH AFRICA

N Mustapha

Introduction

Spending by firms on research and development acts as an investment to generate new technological knowledge, which in turn acts as a production factor to drive growth. Innovation economics contends that when the generated knowledge—an output of the R&D investment process—is deployed as a production factor, its contribution to productivity (and thus to higher GDP per capita in the long run) can be reasonably inferred.

Related is the generally accepted association between R&D intensity and economic wellness and the presence of a strong business sector. Robust industrial capabilities and technological infrastructure for both research and production, are essential to translate R&D investments into economic performance.

About this brief

This brief explores the current state of research and development (R&D) funding in South Africa and the need for increased investment to achieve the country's targets for R&D expenditure as a proportion of gross domestic product (GDP). It aims to show how South Africa can return to a pathway of high R&D intensity and suggests a benchmark value and approach to government funding of R&D to facilitate this.

Public authorities expect that increased investment in R&D will intensify technological progress and in turn, accelerate economic growth. As Jones and Williams (1998) assert, "The functional relationship between the social rate of return and the share of resources devoted to research depends only on the production possibilities of the economy."

This brief distinguishes between R&D activity, represented by R&D expenditure, and investment in R&D, represented by R&D funding, for reasons which we will discuss. In the business sector, these two indicators are almost identical as businesses primarily fund their own R&D. However, this is not the case for the government sector, which funds other sectors but performs little R&D itself.

In most countries, R&D funding is predominantly provided by government (including for higher education) and businesses, and this is essential to drive R&D activity. Nonetheless, the sector that performs the most R&D is not necessarily the biggest funder of it. The role of these funders of R&D seems to be determined by a country's stage of development. The public sector provides funding for most R&D activity in emerging economies, while the opposite is largely the case for developed economies.

This raises important questions including: What constitutes a healthy level of funding for R&D in South Africa? Is South Africa's funding of R&D adequate to meet the targets set by the National Development Plan 2030? What strategies can government use to shift from low levels of R&D intensity, with heavy reliance on government funding, to higher levels of R&D intensity with greater funding by the business sector?

A healthy level of funding for R&D

Healthy funding levels for a country's R&D depend on multiple factors. These include the size of the economy (GDP); fiscal policies that promote R&D; human capital, such as the number of researchers (Wang, 2010); openness to trade and knowledge sharing with other countries; tax relief instruments to promote R&D including government incentives, current sales and cash flow (Howe & McFetridge, 1976); and foreign direct investment. Additional factors include changes in capital stocks and employment levels, cyclical swings in the economy, growth in output, and shifts in relative prices (Nadiri, 1979). A healthy level of both public and private funding for R&D should enable a country to reach its R&D intensity targets. This, however, is not always the case, as the determinants of R&D intensity are not always well understood, and countries, including South Africa, repeatedly miss their set targets (Tudor & Sova, 2022).

R&D funds

"The source of R&D funds is the unit that provides the funds for R&D performance. Sources may be internal or external to the reporting unit. In surveys and data presentation, external sources are grouped by main sector and relevant subsectors. In broad terms, there are five main sources for R&D funding: Business enterprise, Government, Higher education, Private non-profit and the Rest of the world".

Source: OECD (2015) Frascati Manual 2015: Guidelines for Collecting and Reporting Data on Research and Experimental Development, Annexure 2, pg. 380.

Major funding sources for R&D

Investment in R&D is primarily provided by two sectors in an economy: business and government, with distinctive patterns evident for high-income and middle-income countries.

Business funding of R&D

The business sector is made up of enterprises that engage in professional, commercial, or industrial activities. Their purpose is to organise the economic production of goods or services with the aim of earning a profit. Most R&D activity in businesses takes place in high-income, research-intensive countries, with less in low- and middle-income countries.

Business is typically the largest funder of R&D in research-intensive countries. Countries that receive more than 60% of their R&D funding from the business sector include the U.S.A., Germany, South Korea and Japan. R&D spending is primarily devoted to the salaries and wages of highly educated scientists and engineers. As a result of their efforts, firms develop intangible assets, namely a knowledge base, from which profits will be made in the future (Hall, 2002). Knowledge may also be sourced from other areas, and a rich source of cutting-edge knowledge stems from basic research conducted at universities.

Government funding of R&D

Government employs two primary funding mechanisms for R&D: direct and indirect funding. Direct funding encompasses parliamentary grants allocated to government departments, as well as support programmes and innovation funds aimed at prioritised activities within the private sector. Indirect funding involves R&D tax incentives provided to businesses engaging in qualified R&D activities, subject to specific criteria. A country's government has a broader set of priorities than business. Government must regulate the country and is responsible for the protection and wellbeing of its citizens, instituting policies and legislation aimed at growing employment and providing education and health.

The government sector

In the case of South Africa, the government sector viewed as a performer of R&D includes national and provincial departments, research institutes, museums and municipalities. The national government also acts as the major funder to all of the spheres of government, and research organisations including science councils and all public universities.

R&D funding in the context of developed and developing economies

The R&D intensity of a country appears to be closely tied to whether R&D funding comes mainly from government or the business sector. Two scenarios can be applied to most countries in terms of R&D intensity.

Defining R&D intensity

"R&D intensity for a country is defined as the R&D expenditure as a percentage of GDP."

Source: Eurostat (2022) Statistics Explained, Glossary: R&D Intensity.

Scenario 1: Low R&D intensity with heavy reliance on government funding

Countries with low R&D intensity are characterised by limited investment in research and development activities, resulting in a lower capacity for innovation and technological advancement. Common characteristics include:

1. Limited funding for R&D: Governments often allocate a smaller portion of their budget to R&D, resulting in a lack of resources for scientists and researchers to innovate and develop new technologies.
2. Weak intellectual property protection: An absence of strong intellectual property laws can discourage innovation and R&D investments, as companies may be reluctant to invest in new ideas if they are not confident they can protect their intellectual property.
3. Poor education systems: Countries with low R&D intensity often have weak education systems, resulting in a smaller pool of skilled and educated workers to contribute to R&D activities.
4. Lack of collaboration: Countries with low R&D intensity may have limited collaboration between academic institutions, industry, and government, resulting in fewer opportunities to share knowledge and resources.
5. Limited private sector involvement in R&D activities, with companies preferring to focus on short-term profits rather than long-term R&D investments.

As there is limited funding of R&D by the business sector, government has to stimulate investment by subsidising the cost of R&D, promoting collaborations or through other support mechanisms.

Scenario 2: High R&D intensity with more business funding

Countries with high R&D intensity invest a significant number of resources, both public and private, in R&D activities. They tend to have these characteristics:

1. A highly skilled workforce with a strong emphasis on science, technology, engineering, and mathematics (STEM) education.
2. A supportive policy environment with government policies that promote and incentivise R&D activities, such as tax credits, grants, and subsidies.
3. Well-developed R&D infrastructure to support R&D activities, such as advanced laboratories, universities, and research institutions.
4. Strong collaboration between industry and academia, with universities and research institutions working closely with businesses and industry to develop new technologies and innovations.
5. High levels of innovation with very novel innovations and a strong focus on developing new products and technologies that can be commercialised and generate economic growth.
6. Strong business sector R&D activity. In all countries with high R&D intensity, the business sector is the largest contributor to R&D. Applied research is more common in these countries with a focus on developing practical applications and solutions to real-world problems; or in maintaining high-technology operations.

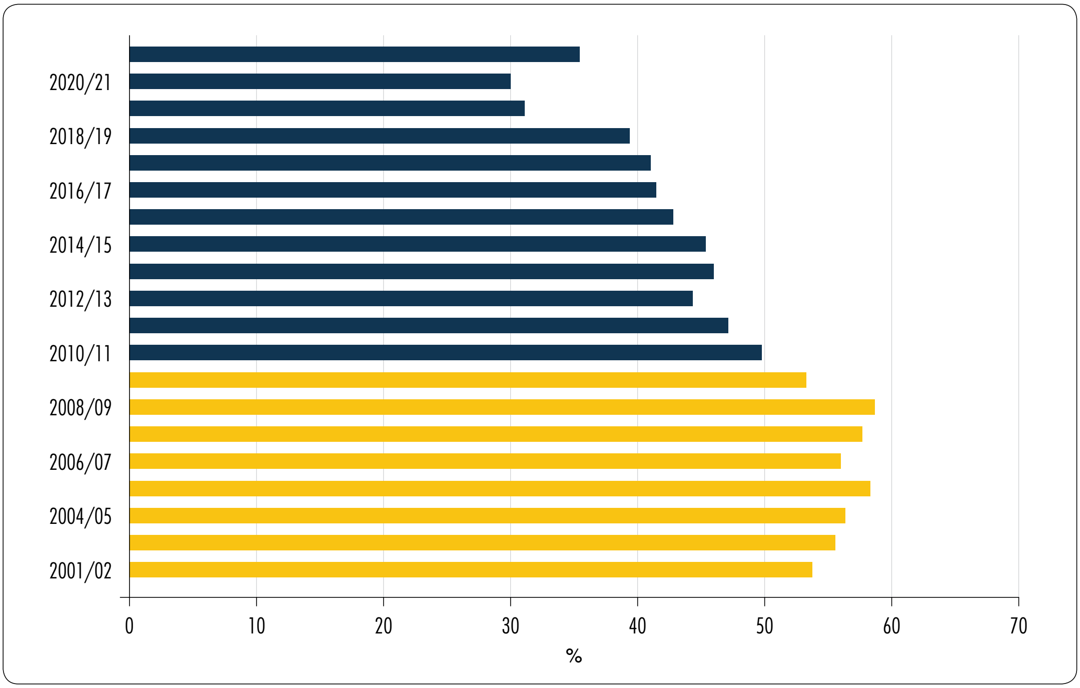
The ratio of R&D expenditure by the business sector (BERD) to a country's gross domestic expenditure on R&D (GERD) is the defining indicator of which source of R&D funding predominates. Countries with a BERD/GERD ratio of less than 50% are commonly MICs or LMICS (OECD, n.d.).

Reaching the National Development Plan 2030 target for R&D funding

South Africa's National Development Plan has set as a target spending 1.5% of the country's GDP on scientific and technological R&D. Achieving this will require a significant increase, with R&D investment currently standing at only 0.61% of GDP (2020/21). The indicator most pertinent for achieving this policy target is the contribution of business expenditure on R&D (BERD) to GDP over time.

Figure 1.1 shows that over the last 20 years South African business expenditure on R&D as a percentage of GDP (GERD) has regressed to low business expenditure levels typically associated with LMIC's. In contrast South African business expenditure on R&D as a percentage of GERD in the period 2001/2 to 2009/10 (the yellow bars) was comparable with countries enjoying a high R&D intensity as described in Scenario 2.

Figure 1.1 Business expenditure on R&D as a percentage of GDP on R&D in South Africa, 2001/02 to 2020/2021



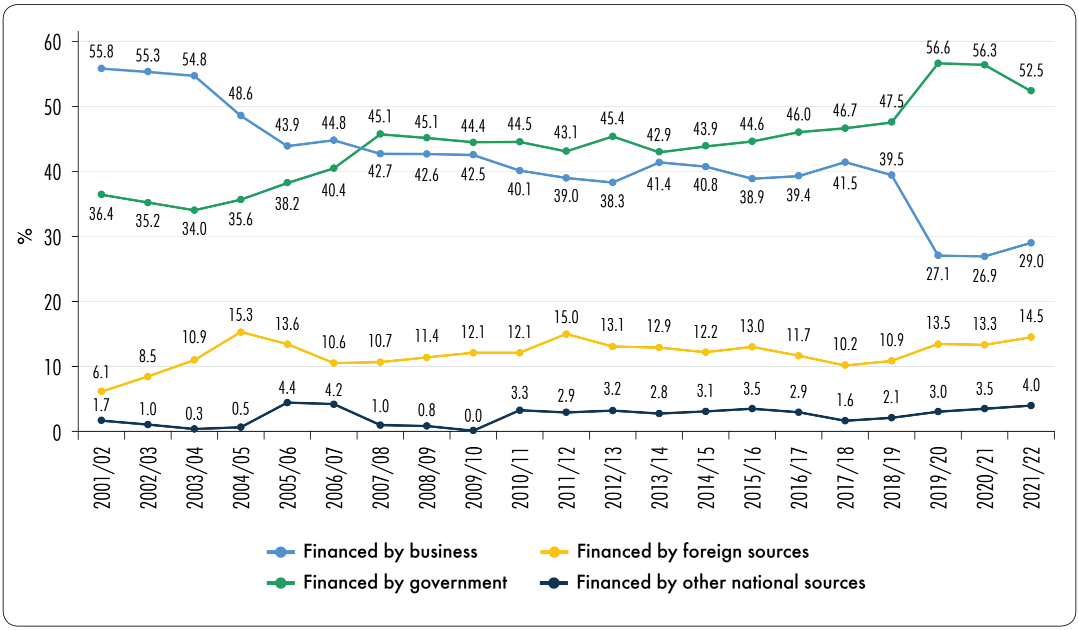
Source: South African National Survey of Research and Experimental Development, 2001/02 to 2020/21.

To address this the onus is on government to stimulate R&D activity in the business sector. This can be done by:

- funding R&D,
- incentivising business R&D,
- promoting collaboration,
- improving education systems,
- enhancing IP protection,
- and other means.

South Africa's annual national R&D survey provides data to analyse government funding of R&D by looking at historic trends in R&D investment. Government has contributed more funding to R&D activity than the private sector since 2007/08 as shown in Figure 1.2. In recent years, this disparity has grown even more.

Figure 1.2 Contribution to GERD by source of funds in South Africa, 2001/02 to 2021/22



Note: *Other national sources include contributions from higher education, not-for-profit organisations and individual donations.
**Government includes science councils.

Source: South African National Survey of Research and Experimental Development, 2001/02 to 2021/22.

However, the question still remains: Is there enough funding by government to steer South Africa back to a high R&D intensity scenario?

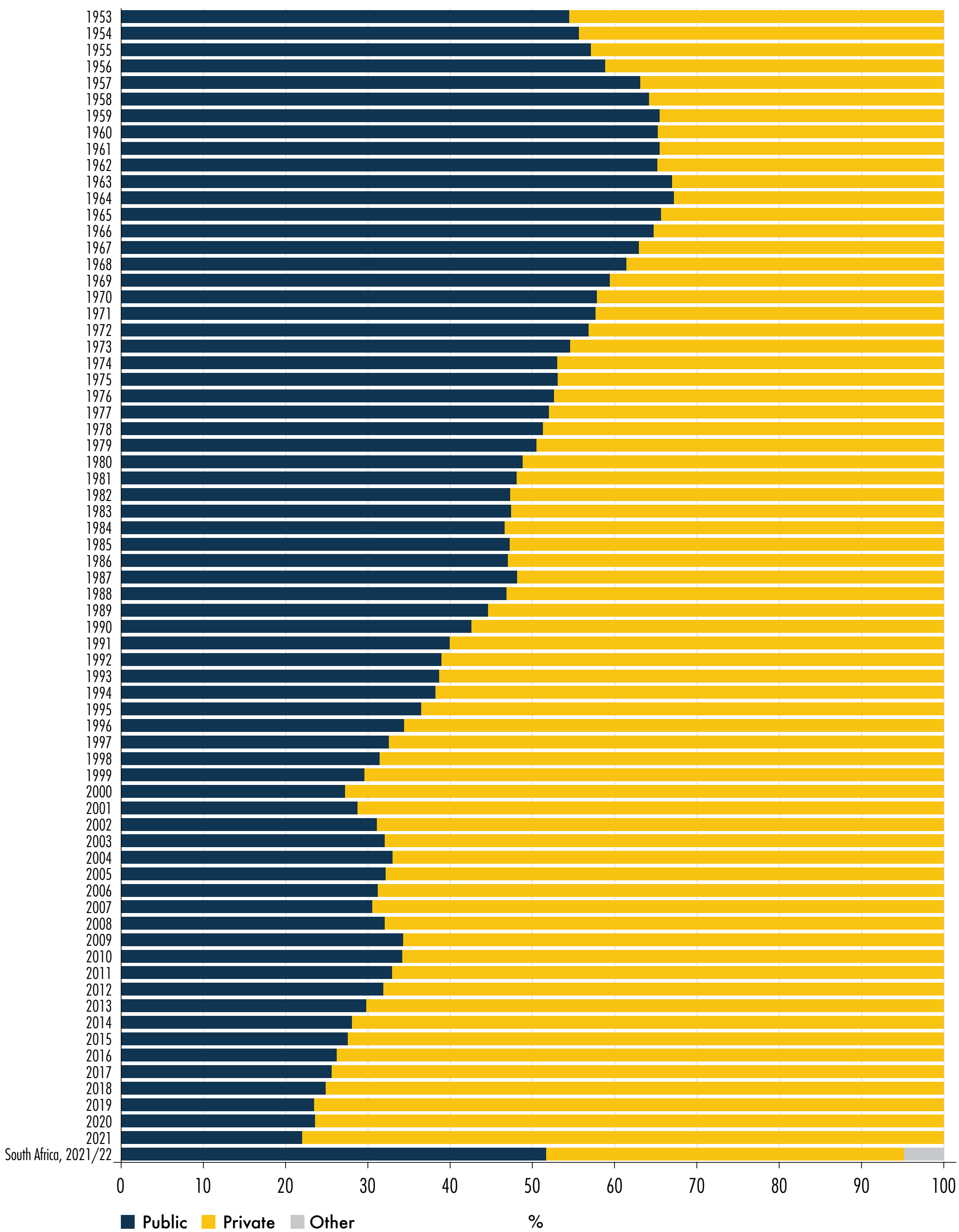
This may be partially answered by looking at the proportion of government funding in countries that have propelled themselves into high R&D contexts, such as the USA, South Korea and Japan, prior to achieving high-income status. Bear in mind that this indicator is not definitive, and there are myriad other economic circumstances that determine whether a country achieves a state of high R&D intensity.

How South Africa can change its R&D trajectory

Funding for R&D by the USA government post-World War II

The USA is often cited as a model for achieving high R&D intensity. In 1946, the U.S. government played a significant role in funding R&D, driven by the post-World War II economic boom and a commitment to advancing scientific and technological frontiers. This funding, estimated to constitute up to 80% of total R&D expenditure immediately after the war, supported diverse projects, including defence-related research, space exploration, and medical advancements. Over time, the proportion of government funding for R&D fluctuated, influenced by economic and political dynamics, while private sector and academic institutions also contributed to R&D endeavours. By 1953, the US had firmly established itself as a global technology leader, with government funding still accounting for 68% of R&D expenditure in 1964 (Figure 1.3). Subsequent years witnessed a gradual decline in government funding, accompanied by a rise in private sector investment. By 2020/21, US government funding of R&D had decreased to 22.9%, largely due to increased business expenditure on R&D (BERD). Presently, South Africa's R&D funding profile mirrors that of the US in 1973.

Figure 1.3 USA government funding for R&D (percentage), 1953 to 2021, and South Africa, 2021/22



Note: Other includes the contribution from higher education, not-for-profit organizations and individual donations.
Source: National Science Foundation (2023); South African National Survey of Research and Experimental Development: Statistical Report, 2020/21.

Considering this and South Africa's current status:

- The South African government needs to lift the R&D funding level, which was 56.3% in 2020/21.
- Post-WWII USA funding of R&D of around 70% gives a ballpark estimate of what is required in South Africa.

Following a similar trajectory as observed in the U.S.A., government has the potential to incentivise business investment in R&D by indirectly subsidising future technologies through the promotion of university research. The objective is to foster R&D activities at universities, anticipating that these innovations will eventually be commercialised in the business sector when economic conditions are conducive. However, it is important to recognise that this approach represents a long-term strategy.

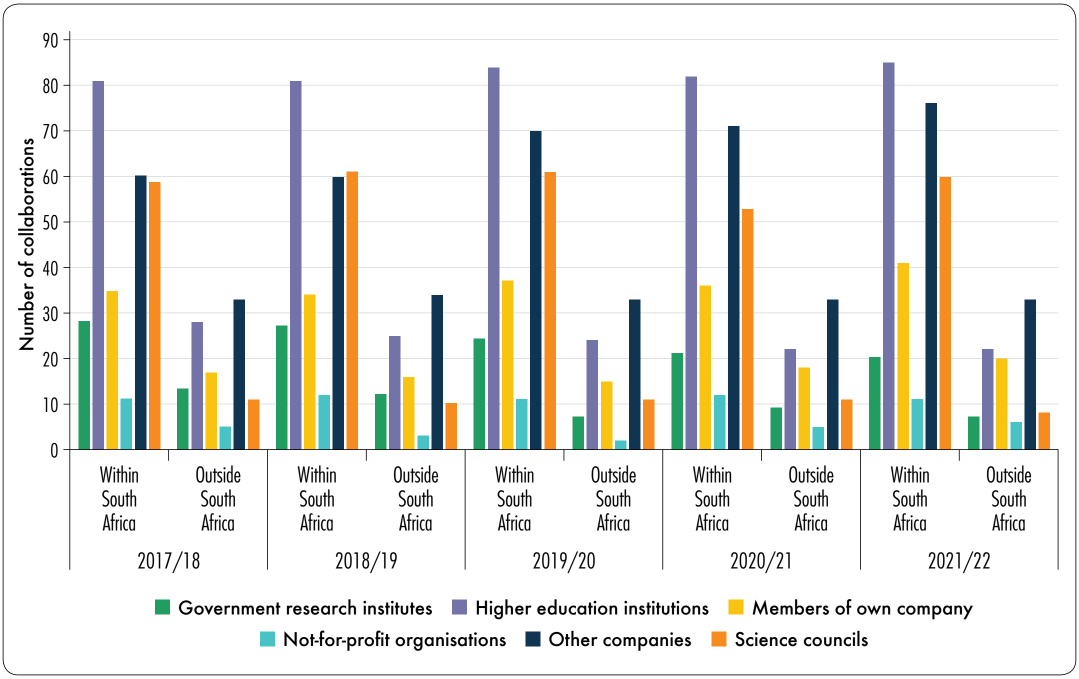
Another strategy employed by the South African government is the use of indirect incentives, such as the tax incentive scheme, which subsidises R&D conducted by businesses through tax rebates on such activities (Department of Science and Technology, 2002).

Promoting collaboration of business sector with other sectors

For a more immediate impact on R&D growth in the business sector, collaboration is a promising approach. Leveraging its influence and funding in various sectors, including universities, research institutes, science councils, and state-owned enterprises, government can incentivise the initiation of new R&D projects. This is particularly attractive as it allows government to prioritise funding in areas of high significance, thereby driving innovation and economic development more efficiently.

Figure 1.4 illustrates the frequency of collaborations between the business sector and various entities, including other businesses, universities, science councils, and government research centres over the past decade. These encompass partnerships, alliances, and formal collaboration. The interactions between businesses and institutions in higher education, science councils, and government research centres reflects the public sector's role in stimulating R&D activity by providing public funds. Some engagements extend to international partners outside South Africa. Notably, the number of collaborations has remained relatively stagnant in recent years, suggesting the potential for further stimulation, particularly collaborations with higher education institutions and science councils.

Figure 1.4 South African business sector R&D collaborations with other businesses, universities, science councils and government research centres, locally and internationally, 2017/18 to 2021/22



Note: Collaborative R&D entails partnerships, alliances and collaborations.
Source: South African National Survey of Research and Experimental Development, 2001/02 to 2020/21.

Targeting R&D intensity growth in an environment of deindustrialisation

South Africa exemplifies a deindustrialising country. Industrial activity has declined, reflected in reduced manufacturing output, reduced employment, and reduced investment in industrial sectors over recent decades. This has accompanied a shift to service-based industries resulting in significant structural changes in the labour market and posing challenges including decreased export competitiveness and the loss of skilled industrial jobs. Regional economic imbalances have also emerged, with certain areas more affected by the decline of traditional industries. The transition has strained social and economic systems as communities and workers struggle to adapt to these new economic realities.

Greater R&D intensity is necessary to facilitate the transition from a deindustrialised economy to a reindustrialised more modern one. However, R&D investment alone is insufficient. In the South African context, where the share of business sector R&D has been declining—an indicator of ongoing deindustrialisation—recommendations must first focus on building production capabilities. This ensures that investments in R&D generate technological knowledge that private firms in the industrial sector can exploit profitably, thereby enabling them to make their own R&D investments and support reindustrialisation.

The availability of a capable and skilled workforce is a critical component, with several key elements pertinent to South Africa. Firstly, a modernising economy requires a culture of continuous learning to develop both technical and soft skills development. Secondly, a healthy workforce needs institutional support to promote and support worker wellbeing. Lastly, high unemployment levels and challenges in education contribute to a shortage of employable workers with skills and experience in problem-solving and innovation.

Economic events that drive unemployment cause many South Africans to find work in the informal sector. This sector, despite its challenges, could potentially serve as an organically created incubator of the skills and capabilities needed to empower businesses and drive re-industrialisation. Since the 1970s, experts have examined the connections between the formal and informal sectors. Many view the informal sector as subordinate to the formal sector, but other perspectives explore why the informal sector grows even when income declines (Tokman, 1978). More recently, scholars like Mustapha et al. (2021) have described the informal sector as dynamic and driven by entrepreneurship and innovation. From an innovation systems perspective, the linkages between the formal and informal sectors provide learning pathways from the formal to the informal sector. This raises the intriguing question of whether the formal sector can also benefit from the learning occurring in the informal sector. The informal sector requires individuals to be resourceful, adaptable, and entrepreneurial—traits that are valuable in a reindustrialising economy. Workers in the informal sector frequently engage in diverse activities that can enhance their problem-solving abilities and innovation skills. Recognising and harnessing the potential of the informal sector could be a strategic approach to workforce development. By providing targeted support and integrating informal experiences into broader economic strategies, South Africa could develop a more skilled and capable workforce through improved linkages between the formal and informal sectors (Kruss, 2021). This, in turn, would facilitate the transition to a more industrialised economy and enhance the effectiveness of R&D and innovation initiatives.

Conclusion

The effectiveness of a country's R&D funding model is closely linked to the level of development of its economy. In middle-income countries such as South Africa, the public sector often bears a greater responsibility for R&D investment than the private sector. This contrasts with developed countries, where the private sector, driven by high levels of innovation in goods and services development, is typically the largest investor in R&D.

Despite this, the state can play a pivotal role in influencing private sector investment in R&D. Governments can incentivise R&D activities in the business sector through direct means, such as R&D tax incentives, or indirect means. In South Africa, the government has at least two tools at its disposal to encourage private sector R&D investment. In the long term, the state can subsidise the cost of developing future technologies by funding R&D at universities, which businesses can later commercialise. In the short term, the government can fund strategic projects within state institutions that collaborate with businesses, thereby stimulating private sector R&D activity. An example of this would be the Biovac Institute, which is a public-private partnership established to revive and enhance vaccine production in South Africa and the broader SADC region. This approach allows government to direct its spending on priority policy initiatives.

By fostering a productive private sector driven by capable and creative workers, government initiatives to promote R&D and innovation may have a greater impact. This approach can create conditions for a sustainable modern economy, where government investments in R&D do not exist in a void but rather contribute to a thriving, innovative industrial sector. The availability of skilled and capable workers is a challenge in a country with education shortcomings and high unemployment.

Finally, this brief suggests a proposed contribution to GERD that government can aim for, to help catalyse business expenditure on R&D, to achieve higher R&D intensity and less reliance on government funding in future. The figure was reached by comparing South Africa with the USA at an earlier developmental state in its R&D performance. The US government initially developed innovative technologies primarily for military purposes, which were later transferred to private industries. The strength of the private sector and its capacity to absorb and exploit these technologies is crucial for initiating its own R&D funding. Can South Africa emulate this strategy and its outcomes, without necessarily replicating the US focus on military or space technology? We acknowledge that areas of R&D that the USA directed the most funding to in the post-WWII years may not be the same areas that South Africa would want to concentrate on today. As such, this brief leaves open the question of which areas of policy attention are demanded by the current situation in South Africa, and which countries are better suited to compare South Africa to in terms of patterns of R&D funding. The latter is a subject for more comprehensive exploration in a companion brief.[2]

The **South African National Survey of Research and Experimental Development data** for the period 2001/02 to 2021/22 that is cited in this report was created by the Centre for Science, Technology and Innovation Indicators at the Human Sciences Research Council. Data is available for download and use by readers in different formats on the HSRC's website (hsrc.ac.za). For specialised data requests from CeSTII, visit https://data-request.hsrc.ac.za/

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2. COMPARING R&D: WHAT SOUTH AFRICA CAN LEARN FROM OTHER COUNTRIES

N Mustapha, J Borel-Saladin and M Clayford

Introduction

This brief looks at how South Africa compares to other countries that are active in research and experimental development (R&D). It aims to provide useful insights to South African policymakers by showing what has worked and what has not worked in other countries.

Understanding R&D in other countries can help South Africa improve its own efforts. When countries invest in R&D, they create new areas of expertise or strengthen existing ones, leading to the development of innovative products that can boost economic growth. Prominent examples include the surge in IT technology in the United States post-WWII and South Korea's ascent as one of the "Asian tigers" where a strategic emphasis on R&D fuelled its economic expansion.

What this brief provides

This brief explores which countries are best suited for comparison with South Africa in terms of patterns of R&D funding. It offers a bird's-eye view of the socio-economic and R&D landscapes of three other countries and highlights the importance of researcher intensity in transitioning to a developed economy. Socio-economic and STI indicators provide insights into how these areas may be related. The brief raises questions about the movement of researchers between sectors and its impact on R&D intensity and economic development.

The comparative analysis done in this brief aligns with modern theories of growth, which considers Research and Development expenditures as investments aimed at generating technological knowledge. This knowledge, cultivated through the R&D process, serves as a pivotal factor in production, as proposed in endogenous growth models. As a result, the contribution of this knowledge to long-term GDP per capita growth can be examined. The effectiveness of this process depends on the robust industrial capabilities of the workforce and its capacity to adapt to evolving technologies.

Herein lies the importance of a strong private sector equipped with industrial capabilities and adequate technological infrastructure, essential for translating R&D investments into economic performance. However, factors that contribute to successful R&D-driven economic growth are not straightforward and can vary widely. For instance, the South Korean government's systematic approach was pivotal in cultivating an innovative economy able to translate laboratory concepts into tangible products and industries. Also, cultural attitudes in South Korea are believed to foster innovation, as noted by Martin Hemmert (Dayton, 2020). But in a developing economy context, the paradigm in which R&D leads to innovation, which leads to productivity gains, falls short when providing empirical evidence which, at best, can be described as mixed (Fedyunina and Radosevic, 2022).

South Africa has been caught in a middle-income trap for decades, struggling to find a development pathway to higher income status. What lessons can we learn from countries with similar historical contexts that have successfully achieved this transition? Conversely, what can we learn from other countries that have not escaped the middle-income trap?

While innovation policy may help countries emerge from a middle-income trap, it cannot do so in isolation; and must be part of a larger economic and industrialisation strategy. This brief identifies successful strategies that South Africa can potentially adapt or adopt to stimulate new industries and expand into global markets.

Middle-income trap

When middle-income countries remain middle income for "too long" this is referred to as a middle-income trap. To move from this category, the economic growth rate must be high enough. This may depend on factors such as the changing structure of the economy, the role exports play, and the diversification of the economy (Felipe, et al., 2012).

The brief presents a comparative analysis of countries with similarities to South Africa, looking at their history, science technology and innovation (STI) profiles, and R&D efforts. The intention is to highlight data and indicators that are comparable using the international standard provided by the Frascati Manual (OECD, 2015).

Comparator country candidates

Due to the reliance on R&D and economic metrics, comparison is confined to a select group of nations with comparable statistical data and indicators. Table 2.1 compares South Africa's spending on R&D to that of other countries, using purchasing power parities (PPPs) to show how much R&D activity each country performs.

Table 2.1 Gross Domestic Expenditure on R&D for selected countries (millions in current price PPP$), 2018/19 to 2020/21

COUNTRY	2019	2020	2021
[1] Czechia	57 915	57 091	61 087
[1] Finland	8 126	8 643	9 569
[1] France	75 682	76 073	80 917
[1] Germany	153 293	150 789	161 232
[1] Italy	118 152	130 426	147 797
[1] Poland	17 830	19 080	21 869
[1,2] Russian Federation	47 413	50 746	-
[1] Spain	25 776	26 008	29 188
[2] China	545 461	607 601	701 115
[1] Japan	173 928	174 926	183 467
[1] South Korea	105 064	112 221	123 460
[1] Israel	6 880	6 680	7 120
Malaysia	-	15 127	-
[1] Türkiye	31 015	32 703	37 327
[1] United States	677 286	730 241	821 811
Mexico	7 493	7 361	7 562
Chile	1 684	1 646	-
Argentina	5 057	5 480	6 186
Egypt	2 646	3 389	3 653
Mauritius	470	490	457
[2] South Africa	4 881	4 627	5 177

Legend:
- Europe
- Asia and Middle East
- North, Central and South America
- Africa

Note: [1] OECD member states, [2] BRICS member/observer states.
Source: Czechia, Mexico, Egypt, Malaysia, Mauritius: The World Bank (n.d.); South Africa: South African National Survey of Research and Experimental Development: Statistical Report 2021/22; remaining countries: OECD (n.d.).

The selection of countries for comparison with South Africa includes African, Latin American, OECD and BRICS countries (Table 2.1). This includes middle- and upper-income countries, developed and developing countries, and world leaders in R&D performance. However, some countries lack comparable data based on Frascati standards e.g., India and Brazil in the BRICS grouping, while data for some countries is not available for certain years. Countries were selected based on the availability of data, but this begs the question: What are the most appropriate countries for comparison with South Africa in an evidence-led manner?

This is not easy to answer because of the many reasons why a country may or may not succeed in growing their R&D intensity to levels that are associated with economic success. Evaluating South Africa's advancement in STI against high-intensity R&D performers such as the United States of America (USA) or South Korea inevitably highlights our perceived shortcomings and underperformance. However, these nations may not serve as suitable benchmarks for various reasons. For example, while the USA is a significant trading partner for South Africa, the socio-economic challenges addressed through R&D

promotion in the USA differ significantly from those facing South Africa. Additionally, disparities in knowledge capabilities and economic standing exist, with South Africa largely reliant on imports, including high-tech goods. Similar considerations arise with China, and concerns regarding comparability extend to several Scandinavian countries. Are there more suitable comparator nations that offer insights into our emerging strengths and potential for upward progression? This brief attempts to shed light on this question by contrasting countries with similar histories to South Africa – that have experienced national challenges in the recent past – but with different economic outcomes. We have also selected science and technology indicators that are indicative of success in modernisation strategies and may be useful for benchmarking South Africa's national innovation system.

Histories and socio-economic factors in brief with a focus on STI policies

Argentina, Malaysia, and Czechia share several similarities with South Africa including the diversity of their economies, dependence on natural resources, and intended transitions toward more knowledge-based modes of production and products. Moreover, they have experienced significant socio-political events, including turbulent political changes.

Argentina

Until the mid-twentieth century, Argentina followed a development path similar to more developed countries. Its population density was relatively low and abundant natural resources enabled export-driven growth. However, since the 1930's Argentina experienced cycles of dictatorship and democracy, undermining institutional development and growth-enhancing economic policies, condemning Argentina to decades of stagnant productivity and poor economic growth (Spruk, 2019). Poverty rates are high and informal economic practices widespread in urban areas. In addition, education has been underfinanced and has lacked coherence for many years (Bertelsman Stiftung, 2024).

STI policies

Over the past two decades, Argentina has implemented various policies to promote STI with a focus on economic development. The foundation of Argentina's STI policies was established in 2001 with a framework to promote scientific and technological activities by integrating STI policies with national development plans, to enhance the country's technological competitiveness (Flanzbaum and Balbo, n.d.). Subsequently, the National Plan for Science, Technology, and Innovation (PNCTI) was launched in 2004, to boost Argentina's scientific capabilities and innovation systems. This plan emphasised the need for increased public and private investment in R&D, improvement of research infrastructure, and promotion of international cooperation (UNESCO, n.d.).

"In 2007, Argentina's System of Science, Technology and Innovation (STI) underwent a re-structuring process that resulted in the creation of the Ministry of Science, Technology and Productive Innovation (Ministerio de Ciencia, Tecnología e Innovación Productiva - MINCYT)" (UNESCO, n.d). This was integral in coordinating national STI policies, managing funding programmes, and strengthening the connection between scientific research and productive sectors.

In 2010, the Argentine Technology Fund (FONTAR) was created to provide financial support for technological innovation projects, particularly for small and medium-sized enterprises (SMEs), thereby encouraging private sector investment in R&D (UNESCO, n.d.). The same year, the Scientific and Technological Research for Strategic Areas (PICT) initiative was launched to support research in critical areas such as biotechnology and nanotechnology, aligning scientific research with national economic goals (UNESCO, n.d.).

STI Indicator trends

Argentina's expenditure on R&D, while lower than most developed countries, is greater than many other South American countries (except Brazil) and has increased resource allocation to R&D in the past several years. But, compared to its regional peers, Argentina spends less on private R&D. Labour productivity is also low (Arza et al., 2020). Argentina closely resembles South Africa in terms of the volume of their R&D activities, which are approximately equivalent (Table 2.1). Additionally, both countries boast workforces of around 20-25 million people. Of the three countries chosen for comparison, Argentina and South Africa exhibit the highest degree of similarity at a coarse-grained level.

Middle-income trap

Pessino et al. (2012) provide insights into Argentina's challenges with the middle-income trap, discussing how economic reforms aimed to address structural issues and promote sustainable growth amidst persistent income disparities and economic volatility. Argentina has remained trapped in a cycle of economic stagnation, characterised by macroeconomic instability and short-term populist policies, which hinder long-term growth and competitiveness (Levy Yeyati, 2021). Argentina's middle-income trap is further exacerbated by weak institutions, poor education and an underdeveloped financial sector, making it difficult to transition to a higher income level (International Growth Centre, 2017).

Malaysia

Malaysia, like South Africa, emerged from resource-based economic growth post-1900s as a former British colony. Post-World War II independence marked a period of significant economic change, with increased investment in infrastructure and human capital. Economic diversification since 1970 reduced poverty through labour-intensive manufacturing and urban service provision. Despite progress, Malaysia's growth was constrained by dependence on a few export sectors, limiting innovation-driven growth. After 2000, economic growth slowed due to export manufacturing competition from China. Malaysia has also been subject to declining labour productivity over the last decade.

STI policies

In the past decade, Malaysia initiated ambitious reforms through the Government Transformation Program (GTP) and Economic Transformation Program (ETP). Launched in 2010, the GTP aimed to enhance governance, targeting crime, corruption, educational improvement, poverty alleviation, rural infrastructure, and urban transport (Government of Malaysia, 2010). The Economic Transformation Program focused on restructuring Malaysia's economy across 12 areas to increase gross national income (GNI) per capita and create millions of jobs through public-private partnerships (Economic Planning Unit, 2010).

By the 2010s, Malaysia reported significant gains: improved crime rates, public transport, rural infrastructure, increased private sector investment, job creation, and global competitiveness (Malaysia Productivity Corporation, 2020). Challenges persisted, including governance issues and income disparities, prompting ongoing refinement and consolidation into the 2020s. The GTP focused on sustaining gains and enhancing public service delivery, while the ETP underwent evaluations to ensure economic resilience and equitable development (Government of Malaysia, 2021).

STI indicator trends

Over the past decade, Malaysia has shown a steady increase in research and development (R&D) expenditure, reflecting a commitment to enhancing its innovation capabilities. The Malaysian government played a pivotal role in funding R&D through agencies and initiatives aimed at fostering scientific research and technological advancements. Concurrently, there has been a notable rise in private sector investment in R&D, encouraged by government incentives and partnerships with academic and research institutions. Focus areas for R&D have included biotechnology, ICT, manufacturing technologies, and renewable energy, aligning with national strategic objectives (Malaysian Innovation Agency, n.d.). Moreover, Malaysia has increasingly engaged in international collaborations to leverage global expertise and resources (Tey and Idris, 2012), further enhancing its R&D capabilities.

Middle-income trap

To escape the "middle-income trap", Malaysia needs to increase funding for education, especially in science and mathematics, and innovation systems, including more funding for R&D (Sachs, n.d.).

Czechia

The 1990s represented a notable era of political transformation for Czechia, as the country shifted from its previous economic frameworks as part of the USSR to embrace greater openness to global corporations. This transition resulted in significant societal disruption. The peaceful split, often referred to as the "Velvet Divorce," led to the creation of two independent countries: the Czech Republic and Slovakia, effective January 1, 1993. This transition followed the end of Communist rule and the Velvet Revolution of 1989, which marked the end of the Communist regime in Czechoslovakia and ushered in a period of democratic reforms and economic transition (Kučera, 1993; Open Society Foundations, n.d.). This period was marked by economic restructuring, privatization, and the establishment of new political and social institutions. The challenges included high unemployment rates, inflation, and a sharp decline in industrial production, which affected the livelihoods of many citizens.

Historically, Czechia has had a well-educated, highly skilled labour force, with educational attainment among the highest in Europe (Novokmet, 2018). It has a long tradition of manufacturing across various industries. Initially, the economy was textile-based but later shifted to heavy industry and engineering, along with the development of commercial agriculture (Novokmet, 2018). By 1996, Czechia had established success in mining and manufacturing sectors such as steel, trucks, small aircraft, arms, electricity, cement, coal, oil refining, and shoes. Since then, it has grown its high-technology exports to be above the average for European Union countries in 2022 (World Bank, n.d.).

STI policies

Czechia has strategically directed its policy attention towards advancing STI to drive economic growth and competitiveness. The country has significantly increased its investment in R&D through public funding initiatives and incentives for private sector participation. This focus aims to stimulate innovation across various sectors and foster technological advancement. The development of innovation ecosystems has been a key priority, involving the establishment of technology parks, innovation hubs, and incubators. These initiatives support startups, facilitate collaboration between academia and industry, and accelerate the commercialisation of research outcomes. Investments in digital infrastructure and cybersecurity measures have enhanced the country's digital capabilities ensuring a secure environment for businesses and individuals. Additionally, education and skills development in STEM fields have received attention, with reforms aligning education curricula with industry needs. This strategic focus equips the workforce with necessary skills to thrive in the digital economy and support technological advancements. Sector-specific policies target key industries such as healthcare, renewable energy, manufacturing, and information technology, aiming to enhance their competitiveness through innovation-driven strategies and technological advancements (Goglio, 2006).

STI indicator trends

Czechia is classified as a moderate innovator compared to other European countries. It underperforms in intellectual assets, including patent, design, and trademark applications, venture capital investments, and opportunity-driven entrepreneurship relative to the rest of the EU. Innovation activities are highly concentrated, with a small percentage of R&D-performing enterprises accounting for the majority of expenditures. Czechia is also highly dependent on international funding for R&D.

Middle-income trap

The nation has exhausted previous growth factors and lost competitive advantages, falling into a "middle-income trap," characterized by long-term economic stagnation, slower wage growth, and declining living standards. Stronger support for higher value-added production could reverse this trend (Radio Prague International, 2023; Prague Forum, 2023).

Comparing key R&D indicators

This section analyses economic and STI indicators for Argentina, Malaysia and Czechia and identifies lessons from their STI performance and its correlation with economic development, in comparison to South Africa. Czechia shows progress towards a knowledge-based economy with significant exports of high-technology goods, contrasting with Argentina and Malaysia, which mirror South Africa's incomplete transformation in STI development. By analysing data for each country, we seek insights to guide South African policymakers and provoke questions to achieve STI-led growth.

GDP per capita is commonly used as a measure of socio-economic wellbeing. While all four countries had similar GDP per capita in the 1990s (Figure 2.1), Czechia's grew more rapidly than Argentina, Malaysia and South Africa from the early 2000s, when it joined the EU. By 2022, Czechia's GDP per capita was more than double that of Argentina, followed closely by Malaysia. South Africa's GDP per capita was less than half that of Argentina in 2022.

Czechia has historically had a higher GERD to GDP ratio than Argentina, Malaysia and South Africa (Figure 2.2), reaching 1.5% in 2011, continuing to increase to just under 2% in 2020. Malaysia's GERD to GDP ratio was the lowest of the four countries in the 1990s, but increased steadily to 1.5% in 2016, but declined to just below 1% by 2020. Argentina and South Africa have had significantly lower ratios of GERD to GDP than Czechia and Malaysia since the late 2000s.

In 2001, business expenditure on R&D as a percentage of GERD was above 50% in Malaysia, Czechia, and South Africa, whereas Argentina was below 50%, where it remained for the next 20 years (Figure 2.3). South Africa and Malaysia have had similar growth trends. Both started above 50% but dropped to below 50% by 2020. An interesting feature exhibited by Malaysia is the 2016 value of BERD/GERD, which was above 50%. Czechia's BERD to GERD ratio was consistently above 50%, with a value of 61% by 2020. A value above 50% is indicative of developed economies, and an indicator of economic wellbeing, such as GDP per capita.

The high R&D intensity (Figure 2.1) and high technology exports (Figure 2.5) that Czechia exhibits go hand-in-hand with a higher percentage of researchers per million than the other three countries (Figure 2.4). While the numbers of researchers grew slowly but steadily in Argentina and South Africa between the late 1990s and 2020, Malaysia experienced a rapid increase in the number of researchers from 2008 reaching a peak of 2,396 per million population in 2016 that coincided with the single value of BERD/GERD ratio of over 50%, but this was not sustained, and the number of researchers declined from that point.

High-tech exports

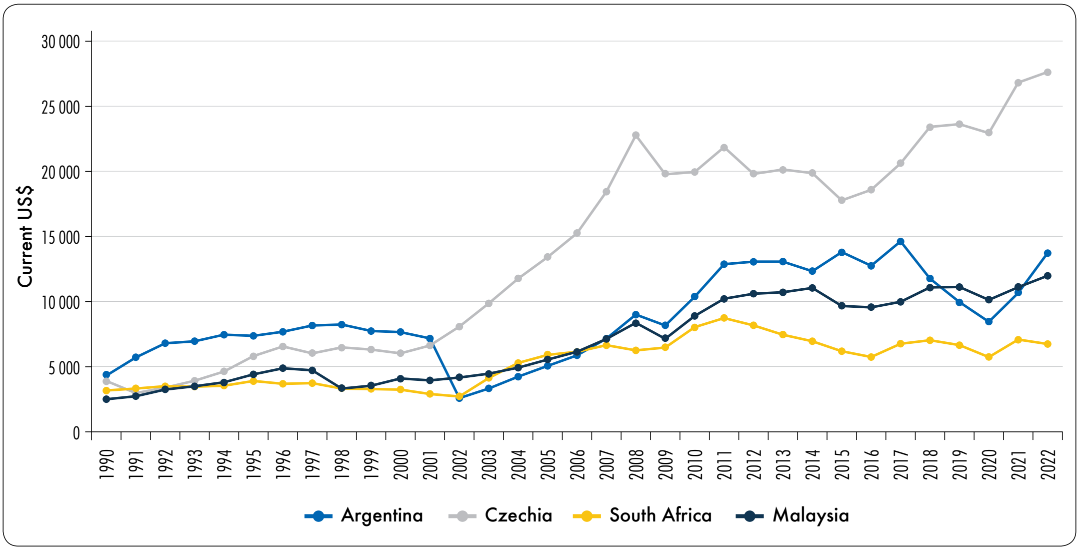
High-technology exports are products with high R&D intensity, such as aerospace, computers, pharmaceuticals, scientific instruments, and electrical machinery.

Source: World Bank (n.d.)

South Africa has had the least researchers per million of the four countries since the late 2000's—approximately 500 or fewer. It is interesting to note that, while Argentina has almost double the number of researchers per million than South Africa over the 20-year period, it has only recently exhibited higher R&D intensity. There appears to be a growing trend in BERD/GERD for Argentina starting in 2014.

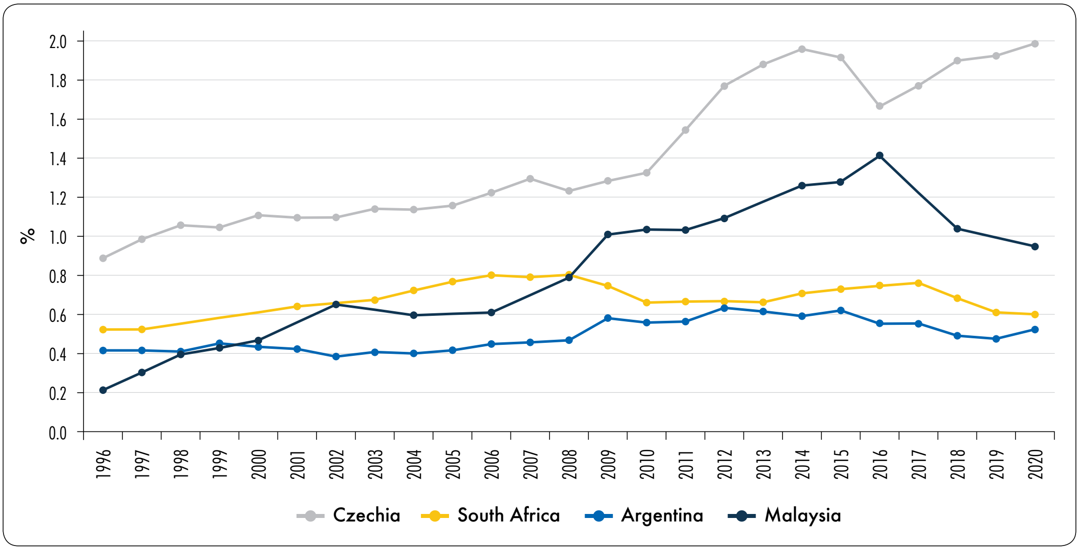
Although empirical analyses on these variables have not been conducted, preliminary data suggests a correlation between robust R&D capabilities and strong economic performance among South Africa's comparator countries.

Figure 2.1 GDP per capita (current US$) in South Africa, Malaysia, Argentina and Czechia, 1990 to 2022



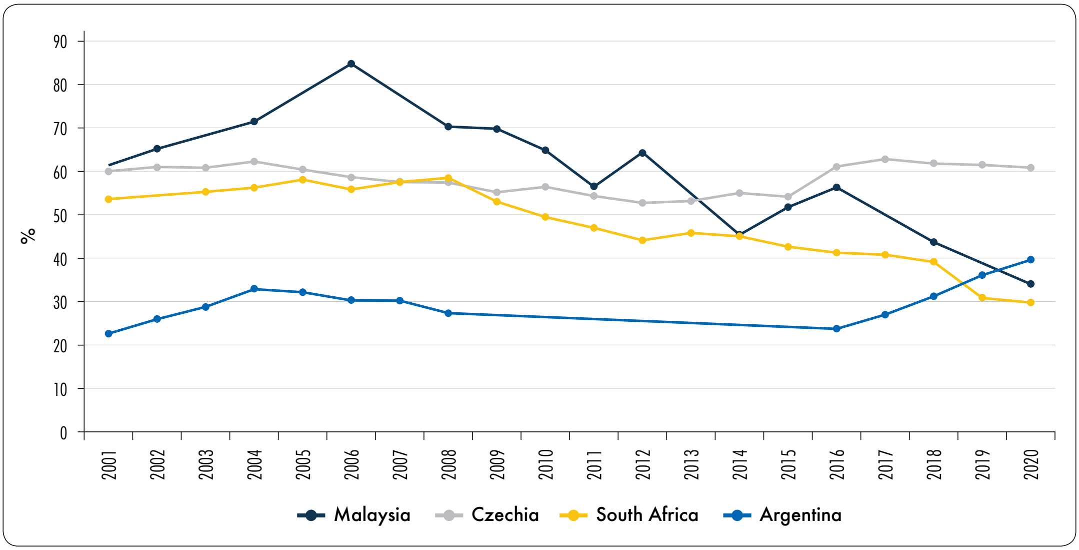
Source: OECD (n.d.); Stats SA (2023).

Figure 2.2 GERD as a percentage of GDP in Argentina, Czechia, Malaysia and South Africa, 1996 to 2020



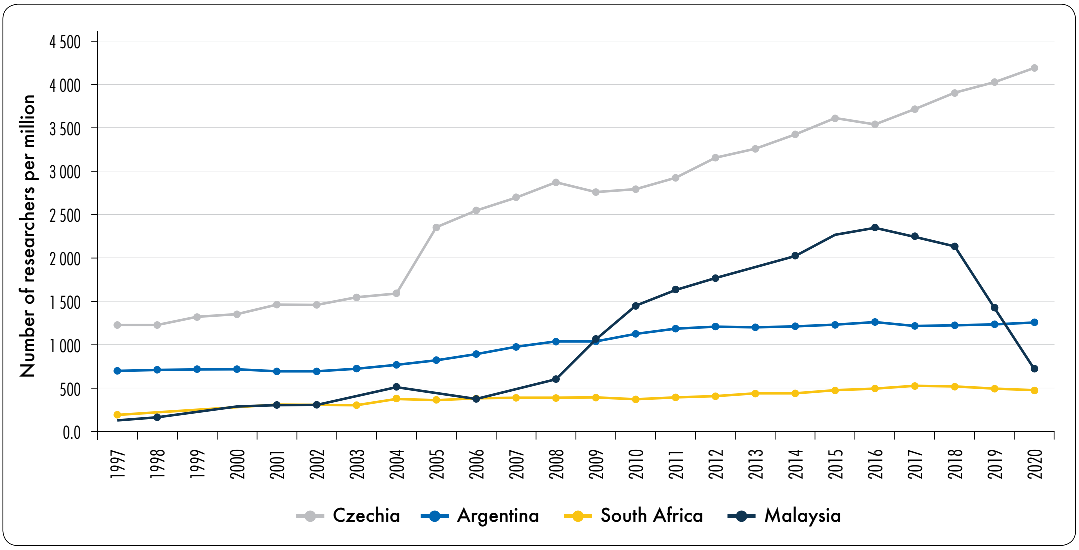
Source: World Development Indicators (n.d.); UNESCO Institute for Statistics (n.d.).

Figure 2.3 Business expenditure on R&D as a percentage of GERD in Argentina, Czechia, Malaysia and South Africa, 2001 to 2020



Source: OECD (n.d.); Knowledge Resource for Science and Technology Excellence, Malaysia (n.d.).

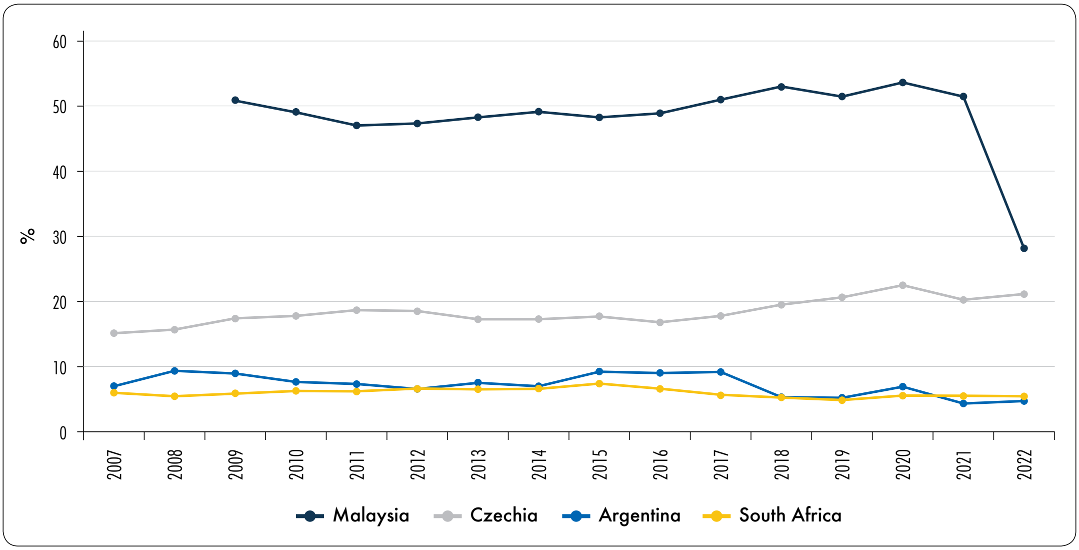
Figure 2.4 Researchers per million population in Argentina, Czechia, Malaysia and South Africa, 1997 to 2020



Source: World Development Indicators (n.d.); UNESCO Institute for Statistics (n.d.).

The data trend regarding high-technology exports as a proportion of manufacturing exports offers intriguing insights. Of the four countries, Malaysia stands out with the highest value in this metric, which may seem unexpected given its relatively low research and development (R&D) intensity. This anomaly becomes clearer when considering that a significant portion of Malaysia's high-tech exports is attributed to a single dominant player. The Electronics and Telecommunications (E&E) product group, "continued to be the top contributor to Malaysia's high-tech exports in 2022, amounting to USD96.38 billion or 77.08 per cent of export value" (MIGHT, 2023). High exports and low R&D might equate to dominance of assembling activity with a minimum of global R&D conducted in Malaysia (Letaba and Pretorius, 2021). Compared with South Korea, Malaysia gained comparative advantage in electronics only, whereas Korea had a comparative advantage in a significant number of sophisticated products and was well connected, demonstrating the importance of diversity in escaping the middle-income trap (Felipe et al., 2012).

Figure 2.5 High-tech exports as a percentage of manufactured exports, 2007 to 2020



Source: The World Bank (n.d.).

Moreover, the notable presence of high-tech exports in developing economies like Malaysia may be due to a statistical artefact. It's plausible that the majority of high-tech exports are linked to the international fragmentation of production value chains in the electronics sector (Srholec, 2007). That is to say, companies and countries specialize in particular segments of the production process where they have comparative advantages. For example, a country with advanced technology capabilities may focus on designing components, while another with lower labour costs may tend to handle assembly. On the one hand, the implication is that Czechia may be on the less valued end of such global value chains; that is the assembly end. On the other hand, Czechia demonstrates substantial proportions of high-tech exports in manufacturing alongside high researcher per population intensity values and R&D intensity values surpassing 1% of GDP. This suggests that Czechia's export performance manifests in export strength of *diverse* products, notwithstanding that the export dominance of its electronics sector may indeed be a statistical artefact due to international trade contributions to technology intensity in that sector.

Comparative Analysis of R&D Performance and Economic Indicators in Czechia, South Africa, Argentina, and Malaysia

Our intention is to open suggestions for further inquiry, rather than make definitive pronouncements.

Although all four countries had comparable GDP per capita figures in the 1990s and early 2000s, Czechia significantly outperformed the others since then. South Africa's GDP per capita growth appears to be like that of Argentina and Malaysia, although Argentina has shown a slight hint of an upward trend in the most recent two years (2021 and 2022) displayed. Moreover, the Business Expenditure on Research and Development (BERD) to Gross Expenditure on Research and Development (GERD) ratio for Argentina has been consistently increasing recently from 2017 to 2020.

Of the four countries, Czechia has consistently maintained the highest R&D intensity. Historically, countries with a GERD to GDP ratio of 1.5% or more have demonstrated greater competitiveness, leading to the production of high-value exports. Czechia was the only country among the four to reach this critical threshold (in 2011) and has continued to surpass it since. Additionally, a BERD to GERD ratio exceeding 50% typically indicates developed economies. By 2020, Czechia was the only country of the four to achieve this benchmark.

Table 2.2 Summary trends in STI indicators for South Africa, Argentina, Malaysia and Czechia between 2016 and 2020

COUNTRY	BERD/GERD		RESEARCHERS PER MILLION POPULATION		GERD/GDP	
	2016 BERD/GERD < 50%	2020	2016	2020	GERD/GDP < 1%	2020
South Africa	41%	30%	490	490	0.75%	0.60%
Argentina	24%	40%	1 260	1 230	0.56%	0.53%
	2016 BERD/GERD > 50%	2020	2016	2019	GERD/GDP > 1%	2020
Malaysia	57%	34%	2 350	1 430	1.42%	0.95%
Czechia	61 %	61%	3 620	4 030	1.67%	1.99%

Source: Authors' own calculations from data in the body. Numbers rounded to the nearest ten.

The inferences made in the ensuing analysis acknowledge that we have considered only a small sample. The four countries selected in this investigation all started the 1990s with a BERD/GERD value below 50%. The recent STI performance of the four countries can be summarised using several key indicators, as in Table 2.2. Notably among the four, when researcher intensity declined or remained stagnant, R&D intensity followed suit, and the same applied conversely. This behaviour persisted regardless of fluctuations in BERD/GERD. Furthermore, the number of researchers is notably higher in Czechia compared to the other countries and has been steadily increasing. In contrast, the numbers have seen sluggish growth in Argentina and South Africa and experienced a sharp decline in Malaysia in recent years.

Argentina and South Africa exhibit similar performance trends. Firstly, both countries have business expenditure on research and development (BERD) to gross expenditure on research and development (GERD) ratios below 50%. Secondly, their R&D intensities are notably below 1%. While Argentina's researcher intensity appears to be double that of South Africa, South Africa's unemployment rate is approximately double that of Argentina, suggesting similar researcher intensities when viewed in terms of the labour force instead of population size. These indicators reflect typical STI behaviours or outcomes for these countries. Interestingly, R&D intensity declined regardless of whether the business sector's contribution to R&D increased during the interval considered.

In contrast, Malaysia and Czechia stand out with recent BERD/GERD values exceeding 50%. Both countries boast significantly higher researcher intensities compared to South Africa, ranging from five to eight times larger. Most evident from the trend data between 2014 and 2020 is that Malaysia experienced growth and decline in BERD/GERD in tandem with increasing and decreasing researcher intensity, respectively. In contrast, Czechia distinguished itself by maintaining consistently higher levels of both researcher intensity and the BERD/GERD ratio compared to other countries. Associated with these indicators is a relatively higher level of high-tech export capacity (Figure 2.5). Malaysia's R&D intensity recently declined from 1.42% to 0.95% (Table 2.2) as its BERD/GERD ratio dropped below 50% (Figure 2.3), indicating that an R&D intensity of around 1% might not sufficiently be associated with substantial business sector-led R&D performance, whereas 1.5% appears to be a more robust indicator of such behaviour. Czechia's R&D intensity values fall between 1.5% and 2%, underscoring the importance of a robust business sector driving R&D performance. Note that, while Czechia has a GDP per capita level that's consistently higher than the other three countries (Figure 2.1), Malaysia is consistently at a level that compares with South Africa and Argentina, even though Malaysia has a high level of high-tech exports.

Taking all of this into account, it appears that growing researcher intensity is perhaps a necessary but not sufficient condition to transition from a developing to a developed economy. It is perhaps a result we expected, even though this may not be evident from the overall R&D intensity at first. Witness Argentina, which has a consistently low R&D intensity, but high researcher intensity (compared to South Africa) over many years (Figures 2.2 and 2.4). Even though its R&D intensity is low (relatively), in recent years its BERD/GERD ratio has been steadily climbing (Figure 2.3). Could it be that the overall researcher capability is not as important in this respect, but rather the movement of researchers between business sector and other sectors that matters more?

The data that we have examined do not make it clear if there is any one sector where researcher capabilities drive such a transition. However, the dominance of the business sector in R&D activity is naturally associated with a greater proportion of experimental development, which is expected to lead to novel products being generated in that sector, which in turn shows up in a greater number of high-tech exports. This is borne out for the four countries that we have selected.

Conclusion

In South Korea, government initiatives encouraged collaboration between industry and academia, positioning R&D as a catalyst for economic growth and societal change. Notably, Czechia's success can be attributed to strategies implemented since the 1990s. Like South Korea, Czechia leveraged its textile manufacturing industry with a skilled workforce. In contrast, Malaysia and South Africa, despite having strong textile manufacturing bases in the 1990s, have struggled to localise technological strength, remaining primarily in the assembly segment of global value chains for high-tech products. That is not to say that a history of textile manufacturing determines R&D driven growth performance. Rather the point is to illustrate the importance of leveraging the productive abilities of the economy, rooted in capabilities, as espoused in modern theories of economic growth as being driven by factors within the economy itself, such as innovation and human capital, rather than external forces.

Malaysia's economy continued to rely on a limited range of export sectors specifically electronics, potentially hindering self-sustaining innovation driven by science and technology. South Africa faced similar challenges immediately following the advent of democracy, marked by sluggish GDP growth, limited industrial competitiveness, and inadequate infrastructure funding, partially due to development under high tariff barriers and extensive apartheid-era subsidies. Adopting a neo-liberal trade policy akin to the Washington Consensus (Gantz, 2021), South Africa achieved export strength, notably in automotive manufacturing, but primarily through component assembly rather than indigenous technological advancement, similar to Thailand and Malaysia.

For the small set of comparator countries we have considered, we have confirmed that a high economic wellbeing (indicated simply by GDP per capita) is associated with a value above 50% for BERD/GERD. Furthermore, this is also associated with high values of R&D capability (proxied by researchers per million of the population). When we take the trend data into consideration, it appears that the growth in R&D intensity is associated with increasing the intensity of researchers.

Are South Africa's workforce and infrastructure sufficiently equipped to accommodate these changes if local production or strategic importation of technological knowledge proves successful? Is SA's economic strategy adequate to harmonise the various production factors, including the technological knowledge developed through R&D investments, in order to drive structural transformation and achieve a higher productivity capable of the economy from the middle-income trap? These are pertinent questions raised through such comparative analyses, which aid in identifying issues that South Africa, as well as other countries in the past, have encountered, and potential solutions to address them.

The **South African National Survey of Research and Experimental Development data** for the period 2001/02 to 2021/22 that is cited in this report was created by the Centre for Science, Technology and Innovation Indicators at the Human Sciences Research Council. Data is available for download and use by readers in different formats on the HSRC's website (hsrc.ac.za). For specialised data requests from CeSTII, visit https://data-request.hsrc.ac.za/

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3. PATHWAYS TO ACHIEVING SOUTH AFRICA'S R&D INTENSITY TARGET

N Mustapha and M Sithole

Introduction

This brief examines different pathways to achieve South Africa's R&D intensity target. It presents an optimistic outlook where research and experimental development (R&D) activity in the business sector is stimulated after significant government support and funding, and a pessimistic outlook where this fails to materialise, leading to continued government dominance in R&D performance while business sector investment declines.

A multinational analysis of countries has indicated that augmenting R&D expenditure by 1% leads to a corresponding 2.2% elevation in the actual growth rate of gross domestic product (Sokolov-Mladenović, Cvetanović & Mladenović, 2016).

African agreements codified in Agenda 2063 (AUC and AUDA-NEPAD, 2022) and STISA-2024 (AUC, 2014), require that governments in African countries consult with stakeholders within their R&D systems and clearly define the results they expect from R&D activities performed by public and higher education institutions, as well as the pathways to achieve the desired results.

About this brief

This brief provides two scenarios demonstrating the trajectory of growth in R&D activity required to reach the target R&D intensity of 1.5% by 2030. The first scenario is a pessimistic one, where government is the only actor that increases its investment in R&D; the other an optimistic one where the business sector increases its R&D investment in response to government efforts.

In South Africa, the 2019 White Paper on Science, Technology, and Innovation (DST, 2019) anticipates that gross expenditure on research and development (GERD) will increase to 1.5% of gross domestic product (GDP) by the year 2030. However, at the time of writing, the indicator remained stationary at around 0.6% of GDP. This brief looks at the investments in R&D that would be required to reach the policy target by considering scenarios modelling data up to 2030.

History shows that nations that have successfully restructured their R&D landscapes have typically undergone a phase where government funding has dominated in R&D endeavours.[3] Research shows that developed countries that invest a lot of money in research and development tend to be more innovative and successful. These investments come from both government and private companies with significant positive results (Soete, Verspagen & Ziesemer, 2022; Guellec & De La Potterie, 2001).

[3] A question explored in the companion brief, *Funding R&D in a deindustrialising South Africa.*

This stands in contrast to developing nations, where innovation and technological progress are hampered by limited expenditures on R&D activities.

Given that South Africa is comparable to countries that are in the development phase of knowledge-driven growth, large and persistent public funding of R&D is required to ignite the business sector, as argued in a companion analytical brief.[4] Such intensive government investment in R&D at the very least depends on sufficient public coffers, which in turn requires broadened tax revenues and most likely, improved economic activity over a long time period. The likelihood of such a growth regime, and favourable funding conditions, is outside the realm of this brief. Instead, the approach is, if we had such funds, what would it take to get to a business sector that dominates knowledge generation?

In the short term, governments can augment investment by subsidising R&D costs, fostering collaborations, or implementing other support mechanisms, given the limited funds allocated by the commercial sector for R&D within such growth environments (Mustapha et al., 2015).

The brief focuses on government strategy to make long-term direct investments in R&D through public sector institutions, including

R&D and innovation

The use of the terms R&D and innovation stem from the measurable approach used by statisticians and others engaged in country programmes to monitor and *evaluate the implementation of new ideas* in an *economic* context. This is designed to be consistent with the institutional sectors defined by the System of National Accounts (SNA) (European Comission et al., 2008). These are corporations (or business) sector, general government sector, non-profit institutions serving households (NPISHs) and households.

Research and experimental development

"R&D comprise creative and systematic work undertaken in order to increase the stock of knowledge – including knowledge of humankind, culture and society – and to devise new applications of available knowledge" (OECD, 2015: 28, para 1.32). R&D activity thus encompasses all actions deliberately undertaken by R&D performers to generate new knowledge (OECD, 2015: 46, para 2.12). The most common proxy used to describe R&D activity is R&D expenditure.

Innovation

"An innovation is a new or improved product or process (or combination thereof) that differs significantly from the unit's previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process)" (OECD, 2018: 60, para 2.99). Note that this definition applies to all four SNA sectors. Furthermore, "[r]esearch and experimental development … is one of a range of activities that can generate innovations (OECD, 2018: 46, para 2.14)".

[4] *Funding R&D in a deindustrialising South Africa*

government departments. While specific areas of focus are omitted from discussion, our primary concern lies in the long-term investment amount. The topic is multifaceted, and it is beyond the scope of this brief to address all its complexities.

Background

In another brief in this series,[5] the authors argued that a sustained, large amount of broad-based public funding of R&D to stimulate R&D activity in public research organisations, that may then be picked up and expanded on by the business sector, is needed to achieve the long-term R&D intensity target of 1.5%.

How much public funding is required to reach this level of R&D intensity by 2030? In this brief, we set out to answer this by looking at two scenarios using the following reasoning. For this target to be reached, an acceleration in R&D expenditure is require, because if current trends persist, R&D intensity will remain stagnant or decline further. Therefore, accelerated funding of R&D is required. In the absence of local business enterprises increasing R&D funding for their activities, this may be achieved, or made more achievable, by promoting foreign funding of R&D either by donors or multinational companies. However, government has little control over decisions made by private actors. What it does have control over is the allocation of resources to R&D for the public sector, i.e. universities, government entities, science councils, and state-owned enterprises.[6] History shows that consistent and strong support for R&D in public institutions can result in increased R&D by businesses that may benefit economic growth in the long run. The reason for such phenomena is still the subject of research, and the circumstances under which this occurs are not fully understood.

Looking at examples in history, a critical level of government funding appears to trigger a significant increase in business R&D spending, likely because it adequately prepares the foundation for further development. Presumably there are other factors that come together to spark such a response. A generally favourable economic cycle, well-functioning institutions and a permissive regulatory environment, a technological infrastructure suited to economic strengths, strong networks and partnerships, a leadership culture emphasising innovation, and a productive base fuelled by a sufficiently capable workforce come to mind.

Publicly funded research provides the foundation for greatly enhanced private sector investment and reduces the risk for private R&D investments. In this brief we consider what would happen if the value of public funding of R&D appeared to be around 70% of GERD as a starting point for scenario-building.

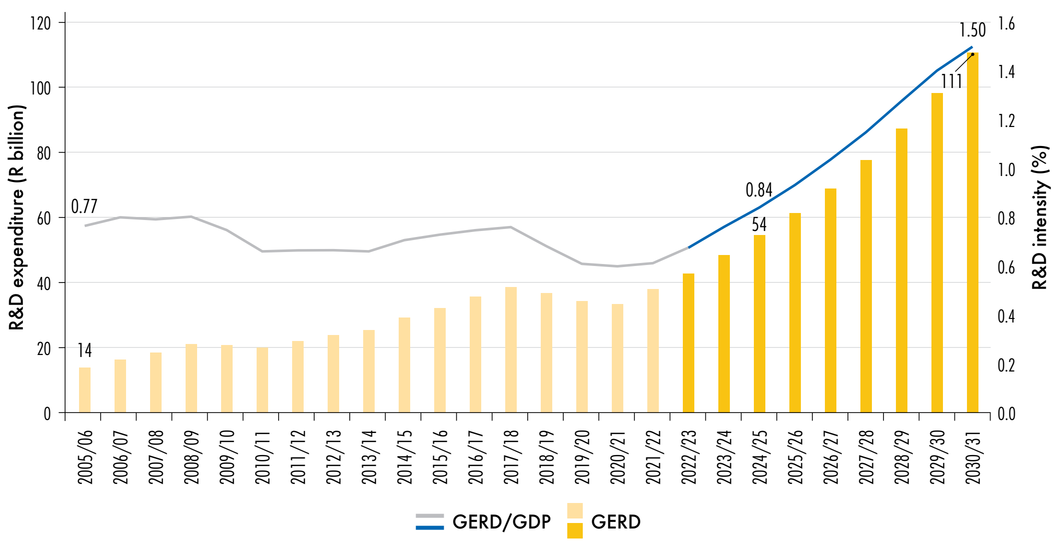
[5] *Funding R&D in a deindustrialising South Africa*

[6] Other controls that the government has are through incentives such as the R&D tax incentive programme and those offered within Special Economic Zones. For example, Malaysia, through its Government Transformation Programme, used SEZs to attract high technology multinational corporate brands (Medina, 2024).

A modelling approach

The data exploration considers how much funding will be required from the public to reach an R&D intensity of 1.5%, given forecasts of GDP (provided by the International Monetary Fund (IMF)) and assuming the gross domestic expenditure on R&D (GERD) trend persists geometrically into the future (Figure 3.1).

Figure 3.1 Nominal R&D expenditure and R&D intensity for South Africa from 2005/06, with values projected between 2022/23 and 2030/31 to achieve 1.5% R&D intensity



Source: South African National Survey of Research and Experimental Development, 2005/06 to 2021/22, and authors' own calculations.

The analysis draws heavily on trend data collected by South Africa's annual national R&D survey, and uses projections based on mathematical/statistical models.

There are two outlooks that may hold. The first looks at what funding is required from the public sector if business R&D activity continues to stagnate. The second considers the situation where the public sector increases the rate of funding (as in the first outlook), until a critical value of 70% publicly funded GERD is reached, whereupon the business sector starts to

How these scenarios were built

For readers who appreciate the technical aspects of creating forecasts and scenarios, the following describes the methodology used.

The GDP series from Stats SA was forecasted from 2022 to 2030 using growth indices by the IMF obtained from National Treasury. Inflationary indices were used to model growth in R&D expenditure such that the R&D intensity reached 1.5% by 2030. This determined the funding required to reach this level of R&D expenditure in 2030.

increase its rate of funding. Assuming that the threshold value of 1.5% R&D intensity is again reached by 2030, the savings to government is calculated, compared to the first outlook.

1. Pessimistic outlook
Continued stagnation in business sector R&D

The business sector trend of decreasing R&D persists until 2030. The government sector is compelled to increase its funding drastically to reach the target of 1.5% R&D intensity. This could be the case if medium-term interventions to promote R&D activity in businesses were ineffectual, for example, mechanisms to increase private-public collaborations. The level of funding required from the public sector (government, science councils and higher education) and the business and NPO sectors is displayed in Figure 3.2.

2. Optimistic outlook
Government support ignites business investment in R&D

In a situation where the government is the leading performer of R&D, the system relies on government to increase its funding of R&D, which in turn drives growth of R&D in the business sector. Under favourable conditions, growth persists until it reaches a critical point at which the business sector becomes the main funder of GERD, and eventually the major performer of R&D as well. In a previous brief, the level of government funding reached a maximum value at around 70%. For the purposes of exploration, we have used this critical value in the scenarios modelled. Under favourable circumstances, this tipping point is reached long before the target date of 2030, for South Africa's R&D intensity to reach 1.5% by 2030 (Figure 3.3). In less favourable circumstances, this could take longer.

What public sector funding does South Africa need to reach the R&D intensity target of 1.5%?

The first outlook, where business remains stagnant in growing R&D activity, allows for a straightforward estimation of the public sector funding of R&D needed to reach the policy target. Needless to say, the second outlook is preferable. This turns around the declining trend of R&D investment and activity in the business sector. For this to take place, we suggest that it would be necessary for the critical level of R&D investment to overlap with an existing culture of innovation and strong production capabilities in

Public sector and private sector

The public sector is composed of the government, science council and higher education sectors, plus state-owned enterprises within the business sector. The private sector is the business sector and NPO sectors, excluding state-owned enterprises. In this brief, we refer to the public sector interchangeably as the government sector consisting of government, science council and higher education sectors, without the SOEs. This is to simplify the discussions and modelling done.

the economy, as well as supportive policy actors. But we leave as open questions, the factors that are most important, and the confluence of factors that are potentially critical levers.

The timeline for achieving a turnaround will differ between countries, influenced by numerous factors, including changes in both internal and external framework conditions. For instance, a strong market for commodities over the next decade could ease fiscal constraints and lead to increased government support for research and development. However, the decision of domestic firms to adopt R&D as a business strategy is highly unpredictable.

The results from modelling

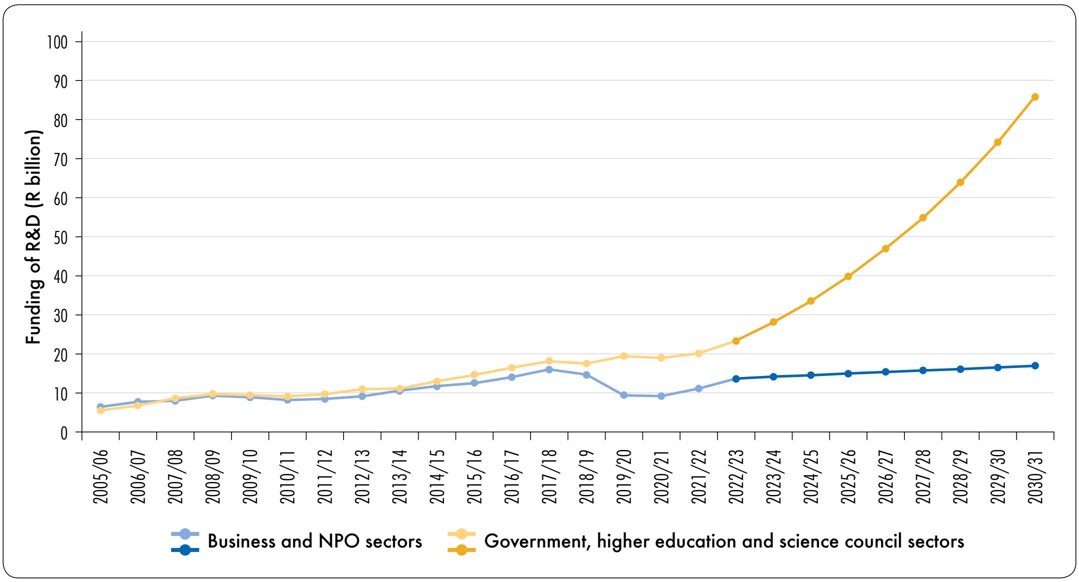
Pessimistic outlook

The amount of funding from the broader public sector (i.e. the government, science council and higher education sectors) required in the pessimistic scenario (Figure 3.2) is R450 billion from 2024 until 2030, an average of R50 billion per year.

Optimistic outlook

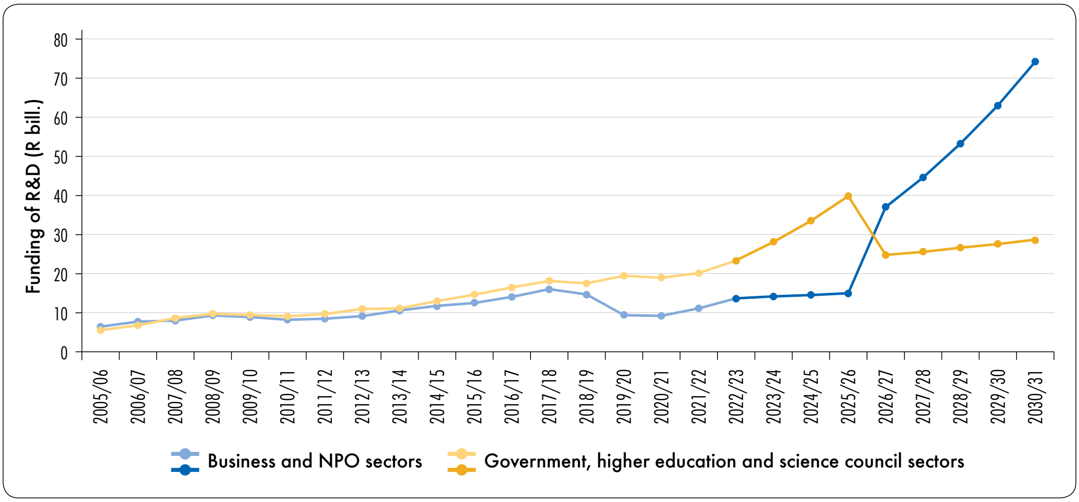
Funding from the public sector required in the outlook depicted in Figure 3.3 is R258 billion from 2024 until 2030, an average of R29 billion per year. That translates to a saving for the public purse of R21 billion every year between 2024 and 2030, a significant amount.

Figure 3.2 Funding required from the public sector and business and NPO sectors to reach the R&D intensity target between 2022 and 2030, where business R&D remains stagnant



Note: Foreign and other sources were projected using a linear growth trend.
Source: South African National Survey of Research and Experimental Development, 2001/02 to 2021/22, and authors' own calculations.

Figure 3.3 Funding required from the public sector and business and NPO sectors to reach the R&D intensity target, where business R&D activity picks up dramatically between 2022 and 2030



Note: Foreign and other sources of funding were projected using a linear growth trend.
Source: South African National Survey of Research and Experimental Development, 2001/02 to 2021/22 and authors' own calculations.

The steep slope of the projected curve in both scenarios suggests that a significantly accelerated funding regime would be required to achieve the 1.5% R&D intensity target by 2030. While reaching this goal is not impossible, the authors consider it unlikely. This outcome likely reflects the current maturity level of South Africa's National System of Innovation (NSI). In more mature NSIs, economic growth is often driven by outputs with high R&D intensity. At present, incremental innovation predominates in South Africa, and policy efforts are naturally focused on fostering an environment conducive to high R&D activity as a long-term objective. Therefore, the steep slope is not inherently negative but rather provides valuable insight that the 1.5% R&D intensity goal may realistically be achieved later than 2030.

Conclusion

The data exploration presented in this brief demonstrates that significant fiscal savings, amounting to an average of R21 billion over nine years in nominal terms, could be realised by fostering research and development (R&D) activities within the business sector, with the aim of achieving the 1.5% R&D intensity target by 2030. Attaining this target is expected to catalyse economic expansion through the production of knowledge-enriched goods and services. More-over, the steep slope of the projected R&D intensity curve highlights the need for accelerated funding to meet the 1.5% target by 2030. However, this challenge likely reflects the current maturity level of South Africa's National System of Innovation, where incremental innovation is prevalent. The analysis suggests that while achieving the target by 2030 may be unlikely, the slope provides valuable insight into the necessary long-term efforts required to create an enabling environment for high R&D activity, potentially delaying the target's attainment beyond 2030.

This brief, while addressing a long-term strategic policy objective, has also highlighted the potential benefits of near-term policy measures. These include fostering collaborations between the public and private sectors and implementing initiatives to stimulate R&D efforts within the business sector. It demonstrates how the fiscal burden could be lessened if the private sector assumes its role in increasing the funding for business R&D. Furthermore, it emphasises the importance of thoroughly understanding the essential framework conditions within the context of a national system of innovation (NSI) to integrate these efforts effectively.

The NSI framework views R&D actors and their interactions as drivers of economic growth, inherently involving a non-linear dynamic that suggests the possibility of critical behaviour. Consequently, the primary challenge is to identify the elements relevant to the South African context and leverage them effectively. This is crucial for successfully fostering an environment where both public and private sectors can collaborate and drive innovation, ultimately contributing to sustainable economic growth.

The **South African National Survey of Research and Experimental Development data** for the period 2001/02 to 2021/22 that is cited in this report was created by the Centre for Science, Technology and Innovation Indicators at the Human Sciences Research Council. Data is available for download and use by readers in different formats on the HSRC's website (hsrc.ac.za). For specialised data requests from CeSTII, visit https://data-request.hsrc.ac.za/

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