

2022

# South African Science, Technology and Innovation Indicators Report

science & innovation
Department:
Science and Innovation
REPUBLIC OF SOUTH AFRICA

NACI
NATIONAL ADVISORY COUNCIL ON INNOVATION

The 2022 South African Science, Technology and Innovation Indicators report was compiled with the latest available data from a variety of organisations and institutions mandated to collect the data.

We welcome comments and suggestions that would enhance the value of the report. Please email such comments and suggestions to naci@dst.gov.za.

Report published by the National Advisory Council on Innovation

July 2022

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# 2022
# SOUTH AFRICAN SCIENCE, TECHNOLOGY AND INNOVATION INDICATORS REPORT

NATIONAL ADVISORY COUNCIL ON INNOVATION

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# List of Acronyms

| Abbreviation | Definition |
|---|---|
| AI | Artificial Intelligence |
| ARC | Agricultural Research Council |
| AUC | African Union Commission |
| BERD | Business Expenditure on Research and Development |
| BRICS | Brazil, Russia, India, China and South Africa |
| CREST | Centre for Research on Evaluation, Science and Technology |
| CSIR | Council for Scientific and Industrial Research |
| DHET | Department of Higher Education and Training |
| DSI | Department of Science and Innovation |
| DTIC | Department of Trade, Industry and Competition |
| DUT | Durban University of Technology |
| EIS | European Innovation Scoreboard |
| EPO | European Patent Office |
| ERRP | Economic Reconstruction and Recovery Plan |
| FTE | Full Time Equivalent |
| GDP | Gross Domestic Product |
| GEM | Global Entrepreneurship Monitor |
| GERD | Gross Expenditure on Research and Development |
| GII | Global Innovation Index |
| GIT | Georgia Institute of Technology |
| GVA | Gross Value Added |
| HEI | Higher Education Institution |
| HSRC | Human Sciences Research Council |

| Abbreviation | Definition |
|---|---|
| ICASA | Independent Communications Authority of South Africa |
| ICT | Information and Communication Technology |
| IMD | Institute for Management Development |
| IP | Intellectual Property |
| IPR | Intellectual Property Rights |
| IT | Information Technology |
| ITU | International Telecommunication Union |
| MHT | Medium and High Technology |
| MIMI | Municipal Innovation Maturity Index |
| NACI | National Advisory Council on Innovation |
| NDP | National Development Plan |
| NECI | National Entrepreneurship Context Index |
| NGO | Non-Governmental Organisation |
| NIPMO | National Intellectual Property Management Office |
| NPC | Not-for-Profit Company |
| NRF | National Research Foundation |
| NSC | National Senior Certificate |
| NSI | National System of Innovation |
| OECD | Organisation for Economic Cooperation and Development |
| PCT | Patents Corporation Treaty |
| PRI | Public Research Institutions |
| SA | South Africa |
| SAHPRA | South African Health Products Regulatory Authority |
| SAIS | South African Innovation Scorecard |

| Abbreviation | Definition |
|---|---|
| SAMRC | South African Medical Research Council |
| SAVCA | Southern African Venture Capital and Private Equity Association |
| SDG | Sustainable Development Goals |
| SEDA | Small Enterprise Development Agency |
| SET | Science, Engineering and Technology |
| SFP | Seed Fund Programme |
| SIC | Standard Industrial Classification |
| SME | Small or Medium Enterprise |
| SMME | Small, Medium or Micro-enterprise |
| SPI | Social Progress Index |
| SPII | Support Programme for Industrial Innovation |
| STA | Scientific and Technological Activity |
| STEM | Science, Technology, Engineering and Mathematics |
| STET | Scientific and Technical Education and Training |
| STI | Science, Technology and Innovation |
| STS | Scientific and Technological Services |
| TEA | Total Early-Stage Entrepreneurial Activity |
| THRIP | Technology and Human Resources for Industry Programme |
| TIA | Technology Innovation Agency |
| TIP | Transformative Innovation Policy |
| TT | Technology Transfer |
| TVET | Technical and Vocational Education and Training |
| UFS | University of Free State |

| Abbreviation | Definition |
|---|---|
| UJ | University of Johannesburg |
| UKZN | University of KwaZulu-Natal |
| UNCTAD | United Nations Conference on Trade and Industry |
| UNESCO | United Nations Educational, Scientific and Cultural Organization |
| Unisa | University of South Africa |
| Unizulu | University of Zululand |
| UP | University of Pretoria |
| USA | United States of America |
| USAf | Universities South Africa |
| USPTO | United States Patent and Trademark Office |
| VC | Venture Capital |
| WIPO | World Intellectual Property Office |
| Wits | University of the Witwatersrand |
| UJ | University of Johannesburg |
| UKZN | University of KwaZulu-Natal |
| UNCTAD | United Nations Conference on Trade and Industry |
| UNESCO | United Nations Educational, Scientific and Cultural Organization |
| UNISA | University of south Africa |
| UNIZULU | University of Zululand |
| UP | University of Pretoria |
| USA | United States of America |
| USAf | Universities South Africa |
| USPTO | United States Patent and Trademark Office |
| VC | Venture Capital |
| WEF | World Economic Forum |
| WIPO | World Intellectual Property Office |
| WITS | University of the Witwatersrand |

# CHAIRPERSON'S FOREWORD

I am pleased to present the 2022 South African Science, Technology and Innovation Indicators Report. The development of this tool for monitoring the national system of innovation was influenced by the South African Innovation Scorecard and the National Advisory Council on Innovation (NACI) Monitoring and Evaluation Framework, as well as the Covid-19 pandemic, and deepening economic, ecological and social crises.

Covid-19 created opportunities and challenges for the NSI. Many actors in the NSI worked collaboratively to deliver, and in spite of budget cuts, managed to do so, increasing the capacity of the public sector to provide testing services in various laboratories, as well as modelling the pandemic spread, identifying SARS-CoV-2 variants, and producing ventilators. Covid-19-related scientific publications increased from 400 in 2020 to almost 700 in 2021. Covid-19 also increased public recognition of the role of science, technology and innovation (STI) in healthcare, and inclusive and sustainable socio-economic development. A comprehensive and systematic analysis of the impact of Covid-19 on the NSI is still needed.

The pandemic also contributed to economic decline in South Africa, negatively affecting the NSI. Considering the low GDP, it is particularly concerning that gross expenditure on research and development (GERD) as a percentage of GDP declined to 0,62% instead of moving towards the 1,5% target. The share of the business sector expenditure on research and development (BERD) from GERD in 2019/20 was 31% (less than a third of the last figures reported). Ideally, BERD should contribute more than half of GERD. The information in this report suggests a need find new ways of reaching the required research intensity, perhaps through the Interministerial Committee on STI (IMC).

Changes in the levels of investment in research and development (R&D) affect innovation and economic performance. Reduced investments in R&D have resulted in fewer scientific publications, patents granted and receipts from the sale of South African intellectual property. The share of total scientific publications in Engineering and Technology decreased from 28,2% in 2019 to 22,2% in 2020, while social science publications decreased from 30,2% to 27,5% over the same period.

South Africa's medium and high technology manufacturing output decreased by almost 20% in 2020, while manufactured product exports declined by 10%. The number of total products export transactions fell by 9%, and the number of products exported by almost 2%. Formal employment in the manufacturing sector declined by 7% in 2020. During the same period, the proportion of people living in extreme poverty was estimated at 24%, with 33% of the population living below the lower-bound poverty line, and 45% below the upper-bound poverty line.

There have been changes in the demographic composition of the South African higher education and academic sector. A positive trend in the diversity of the population has been noted. The proportion of female academics at public universities increased from 46,40% in 2010 to 50,44% in 2019, and the racial breakdown of academics in 2020 was 45% African, 40% white, 8% Indian and 6% coloured.

The number of female professors increased from 22,05% in 2010 to 30,8% in 2019. Most professors are still white. There was slight increase in African female professors, from 1,51% in 2010 to 4,19% in 2019. These changes could be attributed to targeted programmes like the National Research Foundation's Black Academics Advancement Programme and the Department of Higher Education and Training's Future Professors Programme. An examination of the impact of skills development funds, particularly those in the sector education and training system, could prove useful.

During the 2015/16 to 2019/20 financial years, Gauteng had the highest R&D expenditure, followed by the Western Cape and KwaZulu-Natal. Gauteng also had the highest access to the Internet through all available resources (85,2%) and the Western Cape the second highest (80,9%). Mpumalanga followed at 77,6%. The provinces with the lowest access were the Eastern Cape (61,2%) and Limpopo (58,4%).

The NACI Council is grateful to the many stakeholders who provided the information we have used in the report.

We thank Dr P Letaba, Dr D Kaplan, Dr M Madikazela and Dr S Myeni for providing technical and intellectual support in the production of the report, under the leadership of Mr Dhesigen Naidoo, and the Secretariat, under the Acting CEO, Dr Mlungisi Cele, for the compilation of the report.

As always, the support of the Minister of Higher Education, Science and Innovation and the Director-General of Science and Innovation is appreciated.

We hope that all NSI stakeholders, including policy makers, the private sector, civil society and non-governmental organisations, will use the information in this report to improve the performance of the NSI and boost socio-economic growth and development.

**Dr Shadrack Moephuli**
**NACI Chairperson**

# 1. INTRODUCTION

The Science Technology Innovation (STI) Indicators Report seeks to provide information about the National System of Innovation (NSI) using the South African Innovation Scorecard (SAIS), which consists of the following elements:

i. Framework conditions-cover three innovation dimensions, i.e. human resources, attractive research systems and an innovation-friendly environment.

ii. Investments include public and private investment in research, development and innovation (RDI) and cover two dimensions, i.e. finance and support, and firm investments.

iii. Innovation activities-consisting of three dimensions, i.e. innovators, linkages and intellectual assets.

iv. Outputs-cover two dimensions, i.e. the economy (e.g. technology balance of payments, high technology exports and employment) and society.

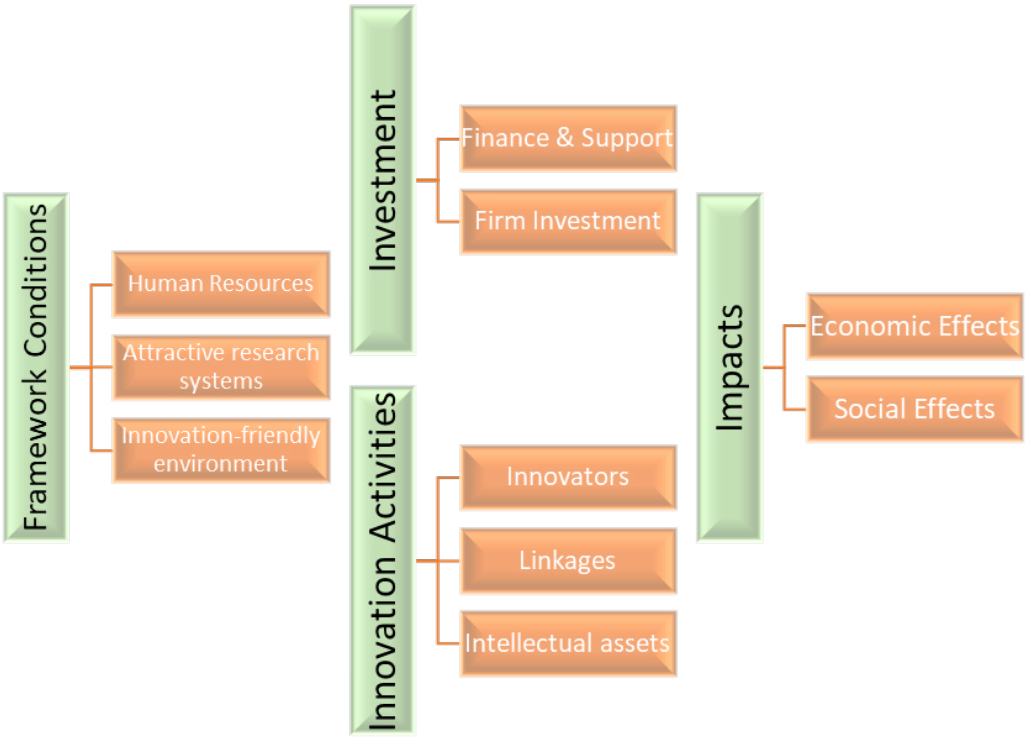



**Figure 1.1: South African innovation scorecard framework**

The Report also includes topical issues of COVID-19 pandemic and Climate Change as well as focus on the bio-economy sector and provincial innovation systems.

Overall, South Africa's innovation performance remains stagnant. There is a decline in almost all the four facets of SAIS. South Africa is falling behind other middle-income countries in respect of key outputs such as patents and high-technology exports, performing better in innovation inputs than innovation outputs.

# 2. SUMMARY OF THE KEY FINDINGS

This section provides a high-level summary of the STI indicators contained within this report. More detailed information can be obtained in various chapters of the report.

## 2.1 STI framework conditions

The 2019 White Paper on Science, Technology and Innovation includes several framework conditions for STI activities in South Africa, including a coherent and inclusive innovation system, increased human capital and an expanded knowledge enterprise, as well as the financing of STI activities. Although the coherence of the NSI is not the main focus of this report, it gives valuable information on the distribution and shifting of STI capacity across the business, higher education, science council, government and not-for-profit sectors. Inclusivity is measured mainly through racial transformation and gender parity among researchers, academic staff and SET doctoral graduates among other groups.

The following are key findings for the STI framework conditions:

- The number of researchers employed in R&D has been decreasing since 2018 (from 29 515 in 2017 to 28 358 in 2019), following a period (2010-2017) in which the number of researchers increased steadily, at an average of 6,8% each year.
- The number of technicians employed in R&D has been on the decline since 2015, with the proportion of technicians to researchers employed in R&D decreasing from 32,8% in 2014/15 to 24,3% in 2019/20.
- The proportion of female academic staff at the South African public universities increased from 46,40% in 2010 to 50,44% in 2019.
- The numbers employed in R&D in the business sector declined by just over one-fifth as compared with the previous year (2018/19). The numbers engaged in R&D in the business sector are lower than at any time in the last decade.
- Over the past decade, the country's publications per million population increased constantly, from 248 in 2011 to 505 in 2020. Overall, South Africa's scientific publications per million population are above the average for upper middle-income countries (452 in 2020).
- Nanotechnology's share of total South African publications has more than doubled, from 2,41% in 2011 to 5,48% in 2020. The country's share of world nanotechnology publications, while very small, also more than doubled over the decade, from 0,25% in 2011 to 0,57% in 2020.
- South Africa's digital competitiveness ranking improved slightly between 2016 and 2018, from 51 of 54 countries in 2016 to 48 in 2018. This was followed by a sharp decline in 2020 to 60 out of 63 countries – the largest decline by a country in that year's ranking. The percentage of individuals with access to the Internet is 62%. While about 70% of firms in manufacturing and services use email for conducting business, only 36% of firms have websites. A lack of digital skills is one of the main causes of this situation.
- South Africa's total early-stage entrepreneurial activity (TEA) is very low. The TEA measures the percentage of individuals between 18 and 64 years who are in the process of starting a business and those running businesses that are less than three and a half years old. The TEA rose gradually from 7% in 2014 to 11% in 2017 and then declined slightly to 10,8% in 2019. South Africa's low TEA indicates that there is a low motivation to start new businesses.

## 2.2 STI investments

The STI White Paper acknowledges that none of its policy intents can be achieved without sufficient funding. STI funding in South Africa is inadequate and not appropriately spread across the entire innovation value chain. The government is not the only stakeholder that funds STI. Other stakeholders like the business sector also play a role. Some of the STI investment indicators included in this report are government budget and funding of R&D, STI funding by specific government programmes (e.g. the Technology and Human Resources for Industry Programme, the Support Programme for Industrial Innovation, the R&D tax incentive and the Technology Innovation Agency's Seed Fund Programme), and business expenditure on R&D (BERD).

The following are some of the findings related to STI investments:

- Government expenditure on R&D has more than doubled in the past decade, increasing from R9 billion in 2010/11 to R19 billion in 2019/20. A minor dip in 2018/19 was followed by a significant increase in 2019/20 (11,1%).
- Over the years, more government funding of R&D has gone to the higher education sector, increasing from a share of 43,4% in 2010/11 to 58,6% in 2019/20.
- In 2019/20, R&D expenditure by the business sector was 29% lower than the previous year. This drop was far larger than the decline in aggregate private sector investment of 16%.
- The business sector's share of gross expenditure on R&D (GERD) has been decreasing consistently since 2010/11. There was a further significant decline in 2019/20 (from 39,3% in 2018/19 to 31,0% in 2019/20).
- While foreign funding of R&D in the business sector increased in 2019/20, this was from a very low base, following two years of significant decline. Foreign funding for business sector R&D in 2019/20 remains well below the levels of the last decade.

## 2.3 Innovation activities

In an attempt to embrace a broader conceptualisation of the NSI as envisioned by the STI White Paper, the innovation activities indicators covered in this report include the innovation practices of South African companies, co-publications (universities and industry, and universities and public research institutes), the commercialisation of public research, technology hubs and patenting. In this report, co-publications are used as a proxy for the linkages of universities with other actors within the NSI, and patents are used as a proxy for the level of inventiveness in South Africa. However, it should be noted that not all technological innovations are patented, as other means of intellectual property protection exist.

The following are some of the findings related to innovation activities:

- The innovation practices that score high (out of 100) for South African companies are mainly data-driven (71), hyper-relevant (71) and network powered (69). The hyper-relevant companies know how to be and stay relevant by sensing and addressing customers' changing needs.
- In the period 2016-2019, the University of Cape Town had the most co-publications with industry (5,2%), followed by the University of the Witwatersrand (5,1%) and the University of Pretoria (4,9%). Several universities experienced a decline in their share of scientific co-publications with the industry.
- The publications of most public research institutions (PRIs) are co-authored with at least one researcher from a South African university (90,56% in 2021). However, the co-publications between the universities and the PRIs constitute a small fraction of total university publications (6,43% in 2021).

- Domestic patents granted to South African residents declined by over 50% in 2020 (from 694 in 2019 to 313 in 2020), while patents granted to non-residents declined by 42% (from 5 468 in 2019 to 3 153 in 2020).
- South African patent registrations at the United States Patent and Trademark Office (USPTO) declined by 13%.
- Overall, the number of inventions coming from South Africa are very low. In 2020 the country had 25 patent applications per million population, whereas the average for upper middle-income countries in the same year was 641.
- Receipts from the sale of South African intellectual property declined by 16%.

## 2.4 The economic and social impact of innovation

The immediate goal of innovation is usually economic transformation and growth. The related policy intents of the STI White Paper include the exploitation of new sources of growth (e.g. emerging technologies, green technologies and digitisation) and the stimulation of innovation to revitalise existing economic sectors.

The socio-economic indicators presented in this report show a significant rise in deprivation, which reflects the impacts of the Covid-19 pandemic. There was a significant increase in the number of households living in poverty, including all poverty line indicators (lower-bound and upper-bound), such as minimum nutritional intake. Over the past decade, other forms of deprivation such as lack of access to clean water and sanitation, have remained unchanged.

It is difficult to estimate the causal effects of innovation on social outcomes. However, analyses of specific case studies of service delivery initiatives (e.g. on sustainable human settlements guided by transformative innovation policy and the Municipal Innovation Maturity Index), offer some insight into the social impacts of innovation. Innovative practices in the public sector can provide solutions to some socio-economic challenges.

The following are some of the indicators showing the impact of STI on the economy and society:

- Medium high and high technology manufacturing (MHT) output decreased by almost 20% in 2020.
- Manufacturing exports declined by a little over 10%. The percentage decline in MHT exports was somewhat higher (12,7%).
- The manufacturing sector shows no tendency towards higher technology intensity. In 2020, the country's high-technology manufacturing exports as a percentage of total exports was 5,6%. This is very low in comparison to the average for middle-income countries (23,4%), Brazil (11,4%), Malaysia (53,8%), China (31,3%) and Russia (9,2%).
- The total number of exporters increased marginally in 2020, but the number of export transactions fell by 9%, while the number of products exported declined by almost 2%.
- Formal employment in manufacturing declined by 7% in 2020. There were similar declines in MHT employment.
- The proportion of people living in extreme poverty was about 24% in 2020. Furthermore, 33% lived below the lower-bound poverty line and 45% below the upper-bound poverty line.
- Approximately 16% of the South African population lives in informal settlements.

## 2.5 Provincial systems of innovation

As an extension to the SAIS, this report assesses the performance of the provincial innovations systems. The distribution of provincial R&D expenditure in South Africa is concentrated mainly in Gauteng, the Western Cape and KwaZulu-Natal. Innovation support initiatives (e.g. incubators and technology stations, which are intended to improve the capacity of innovators and entrepreneurs) are also unevenly distributed, with most of them located in the same three provinces.

The following are some of the findings related to provincial systems of innovation:

- Between 2015/16 and 2019/20, Gauteng had the highest R&D expenditure, followed by the Western Cape and KwaZulu-Natal.
- In 2020, Gauteng had the highest level of learners obtaining National Senior Certificates (41,6%), followed by Kwa-Zulu-Natal (39,3%) and the Western Cape (37,5%).
- In 2021, the Western Cape had the best performance in Physical Science at National Senior Certificate level (78,3%), followed by the Free State (75,1%). The Eastern Cape (62,3%) and Mpumalanga (61,5%) were the poorest performers.
- In 2020, access to the Internet using all available means was the highest in Gauteng (85,2%), the Western Cape (80,9%) and Mpumalanga (77,6%). The provinces with the lowest access were the Eastern Cape (61,2%) and Limpopo (58,4%).

# 3. SCIENCE, TECHNOLOGY AND INNOVATION: TRENDS

The trends outlined below allow for an overall assessment of the national system of innovation. While Covid-19 is a current influence, trends are also shaped by past investments and policies. Despite the need to recover from the Covid-19 disruptions, the focus should remain on the country's pursuit of the long-term STI agenda.

## 3.1 Local trends in STI

This section explores the most important trends and emerging issues in STI in South Africa. Emphasis is placed on Covid-19 crisis and the immediate actions that were undertaken in STI. This section is based on early evidence; more comprehensive information is not yet available.

### *3.1.1 Funding for Covid-19-related research, development and innovation*

To respond to the pandemic, public research funders, private foundations and charities have set up an array of newly funded research initiatives. The South African government, recognising the importance of STI, set up a Ministerial Science Advisory Committee to provide scientific advice on Covid-19. The Department of Science and Innovation (DSI) mobilised resources for science-driven solutions. In January 2021, the DSI reported that it had invested R68,8m in the fight against the pandemic1[1]. This amount was reprioritised from the 2019/20 and 2020/2021 budgets. According to the South African Medical Research Council (SAMRC), over R500 million was raised and allocated to more than 60 Covid-19 research, development and innovation (RDI) projects. The Solidarity Fund, created in March 2020, supported various initiatives shown in Table 3.1. In total, R363,3 million was allocated to beneficiaries.

**Table 3.1: Amounts allocated from the Solidarity Fund**

| Description | Beneficiary | Funding allocated | Funding disbursed |
|---|---|---|---|
| Test kits | National Health Laboratory Service | R250,0 million | R245,6 million |
| Academic laboratory testing | South African Medical Research Council | R88,0 million | R56,5 million |
| Additional testing for healthcare workers | Independent Community Pharmacy Association | R25,3 million | R9,7 million |
| **Total Funding** | | **R363,3 million** | **R311,8 million** |

*Source: Solidarity Fund*

Unfortunately, the DSI's budget for 2020/21 was cut by 8% as the country prioritised measures to contain the Covid-19 pandemic. As shown in **Table 3.2**, the budgets of all the DSI's entities were cut, affecting their ability to carry out their mandates.

According to the DSI's 2020/21 Report on Government Funding for Scientific and Technological Activities Report (STA report), other significant cuts included R81 million from the Department of Small Business Development's Technology Business Incubator and Centre for Entrepreneurship Rapid Incubator.

[1] MRC 2021 Annual Report

**Table 3.2 Budget cuts among STI organisations**

| Name of organisation | Budget cut |
|---|---|
| Academy of Science of South Africa | R2,7 million |
| South African National Space Agency | R99,7 million |
| Human Sciences Research Council | R32,4 million |
| National Research Foundation | R96,6 million |
| South African National Space Agency | R18,2 million |
| Technology Innovation Agency | R45,5 million |
| **Total** | **R295,1 million** |

*Source: University World News, 2020*

### *3.1.2 Covid-19 response by public research institutions*

The Covid-19 pandemic triggered an unprecedented mobilisation of the scientific community. Public research institutions were involved in a wide range of activities in the fight against the virus. A 2020 report by Universities South Africa (USAf) revealed the extensive research contribution universities made to the fight against Covid-19. The report summarised the research efforts undertaken by 12 universities that responded to a survey.

The main activities that were undertaken at universities and science councils are shown in **Table 3.3**.

**Table 3.3: STI activities by public research institutions**

| Focus area | Activity | Expected outcomes |
|---|---|---|
| Safety and protective equipment | Development of protective equipment against covid-19 vaccines, production of sanitisers, and development of ventilators and components | Adequate supply |
| Surveillance and epidemiology | Genomic sequencing | Surveillance of the virus and detect emergence of new variants<br>Enhanced infection control practices in healthcare settings |
| Diagnostic tools | Development of diagnostic tools including wastewater testing for the presence of covid-19 mrna | |
| Digitilisation | Digital screening technologies | |
| Clinical trials | Testing of efficacy of vaccines | Efficacy and safety of vaccines, and access to J&J vaccine for healthcare workers |
| Vaccine manufacturing | Technology transfer to develop vaccine capacity based in mrna technology | Manufacturing of mrna-based vaccines |
| Manufacturing of vaccines | Filling and finishing the manufacturing of J&J vaccines by Aspen | Local vaccine manufacturing for covid-19 |

*Source: SAMRC 2020/21 Annual Report; USAf; DSI 2020/21 STA Report*

In 2020, as shown in **Figure 3.1**, South Africa had more than two vaccine studies, more than Australia, Japan, Brazil, the Netherlands and France, among others. As at 8 December 2020, about seven vaccine trials were being conducted in South Africa.

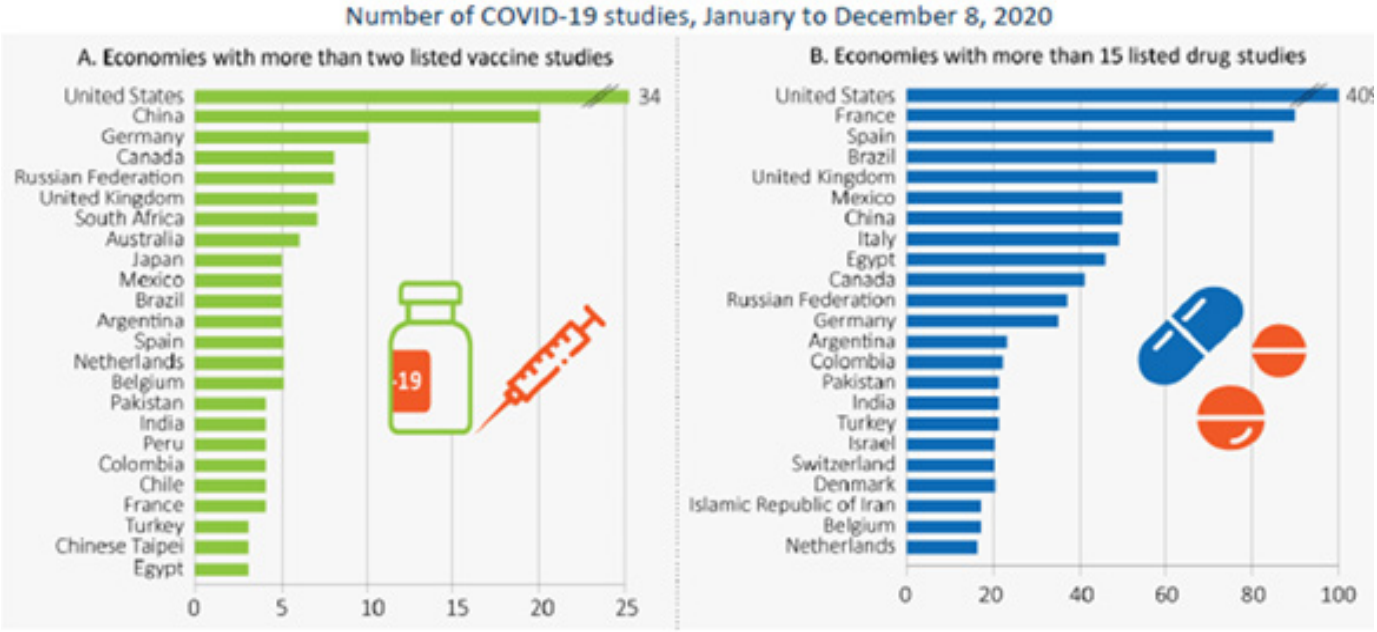



**Figure 3.1: Registered Covid-19 vaccine and drug studies by economy**

*Source: Organisation for Economic Cooperation and Development (OECD) STI Outlook 2021*

Because of its high incidence of TB and HIV, and work done to address this, South Africa had the capacity to mobilise vaccine trials at short notice. Covid-19 forced the South African Health Products Regulatory Authority (SAHPRA) to fast-track the approval process for such studies. SAHPRA also approved the emergency use of four vaccines from Moderna and Pfizer (United States of America), Sinovac (China) and Sputnik (Russia). It is interesting to note that no drugs for Covid-19 treatment were trialled in South Africa.

The National Treasury contributed R130,4 million to emergency funding to support the Sisonke study for the Johnson and Johnson (J&J) vaccine. The study was also supported by the Bill & Melinda Gates Foundation (R37,5m), the Solidarity Fund (R50m), the ELMA Vaccines and Immunisation Foundation (R40m) and the Michael & Susan Dell Foundation (R20m)[2].

In July 2021, a South African consortium and partners from COVAX established a technology transfer hub for mRNA vaccines in South Africa in order to help boost vaccine production in Africa.

### *3.1.3 Scientific publications and inventions related to Covid-19 response*

As result of the pandemic there was a rapid upsurge in coronavirus-related research. Covid-19-related scientific publications increased from 400 in 2020 to almost 700 in October 2021.

[2] The South African Medical Research Council's 2020/21 Annual Report

The World Intellectual Property Organisation (WIPO) made the suggested International Classification Codes for patents that relate to Covid-19 available. These are arranged in the categories shown in Table 3.4. The baseline used is 2019, i.e. before the outbreak of the Covid-19 pandemic. The inventions in these categories show areas in which there was a sudden high increase in inventions in 2020 and 2021. BRICS countries and others are used for comparative purposes. As shown, despite the lower number of patents from South Africa, its performance compares well with the other BRICS countries (except China), if the size of its population is taken into consideration.

An area in which the inventions in South Africa increased significantly from the 2019 baseline is medical facilities and transport. The six patents in this category (all published in 2021) relate mainly to the handling of sick and deceased persons in response to Covid-19.

**Table 3.4: Number of Covid-19 response-related patents**

| | Year | South Africa | Brazil | China | India | Russia | BRICS Total | World |
|---|---|---|---|---|---|---|---|---|
| Artificial respiration | 2019 | 2 | 1 | 32 | 7 | 3 | 45 | 8 265 |
| | 2020 | 0 | 2 | 73 | 4 | 2 | 81 | 10 549 |
| | 2021 | 2 | 3 | 87 | 15 | 4 | 111 | 12 036 |
| Diagnostics | 2019 | 15 | 26 | 1 176 | 118 | 41 | 1 376 | 141 525 |
| | 2020 | 10 | 29 | 1 472 | 96 | 46 | 1 652 | 153 197 |
| | 2021 | 12 | 30 | 1 731 | 117 | 61 | 1 948 | 152 945 |
| Disinfection | 2019 | 1 | 0 | 135 | 8 | 6 | 150 | 24 735 |
| | 2020 | 2 | 3 | 130 | 4 | 8 | 147 | 39 350 |
| | 2021 | 1 | 5 | 197 | 17 | 7 | 227 | 48 323 |
| Informatics | 2019 | 2 | 3 | 113 | 22 | 10 | 150 | 20 623 |
| | 2020 | 2 | 5 | 268 | 16 | 12 | 303 | 27 572 |
| | 2021 | 3 | 7 | 396 | 41 | 14 | 461 | 29 716 |
| Medical Equipment | 2019 | 12 | 21 | 855 | 95 | 36 | 1 019 | 116 347 |
| | 2020 | 10 | 23 | 1 110 | 71 | 29 | 1 243 | 128 553 |
| | 2021 | 10 | 23 | 1 322 | 95 | 45 | 1 495 | 130 015 |
| Medical facilities & transport | 2019 | 1 | 1 | 64 | 6 | 2 | 74 | 20 007 |
| | 2020 | 0 | 3 | 59 | 9 | 3 | 74 | 28 876 |
| | 2021 | 6 | 1 | 72 | 4 | 4 | 87 | 35 830 |
| Medical equipment | 2019 | 21 | 65 | 2 241 | 374 | 100 | 2 792 | 180 712 |
| | 2020 | 15 | 85 | 2 552 | 392 | 109 | 3 144 | 170 780 |
| | 2021 | 10 | 84 | 3 423 | 382 | 104 | 3 992 | 150 030 |
| Personal Protective Equipment | 2019 | 2 | 3 | 31 | 4 | 3 | 43 | 8 029 |
| | 2020 | 0 | 0 | 52 | 3 | 2 | 57 | 14 561 |
| | 2021 | 1 | 4 | 100 | 13 | 9 | 127 | 20 987 |

*Source: WIPO Patentscope Covid-19 Index*

### 3.1.4 Technology readiness index

The United Nations Conference on Trade and Development (UNCTAD) uses a technology readiness index to rank 158 countries in terms of their ability to use, adopt and adapt frontier technologies equitably. The index measures five categories, namely, ICT deployment, skills, R&D activity, industry activity and access to finance. As shown in Table 3.5, South Africa had the lowest technology readiness index of the BRICS countries in 2020. Its main weaknesses are in the areas of skills (where it ranks 84th of 158), industry activity (71st) and ICT deployment (69th). The availability of finance (13th) is an area of strength.

**Table 3.5: Readiness to use, adopt and adapt frontier technologies**

| Country name | Total ranking | ICT ranking | Skills ranking | R&D ranking | Industry ranking | Finance ranking |
|---|---|---|---|---|---|---|
| Brazil | 41 | 73 | 53 | 17 | 42 | 60 |
| China | 25 | 99 | 96 | 1 | 7 | 6 |
| India | 43 | 93 | 108 | 4 | 28 | 76 |
| Russia | 27 | 39 | 28 | 11 | 66 | 45 |
| **South Africa** | **54** | **69** | **84** | **39** | **71** | **13** |

*Source: UNCTAD, "Technology and Innovation Report 2021"*

### 3.1.5 Climate change trends in South Africa

This section communicates trends of climate change in South Africa. It also tracks progress that have been made in achieving the SDG13 and captures selected STI-related climate change indicators.

To provide context, this section references reports released by the Intergovernmental Panel on Climate Change's Working Group I[3] (which assesses the physical scientific basis of the climate system and climate change), Working Group II[4] (which assesses the vulnerability of socio-economic and natural systems to climate change) and Working Group III[5] (which assesses options for mitigating climate change through limiting or preventing greenhouse gas emissions) between August 2021 and April 2022.

The Working Group I Report made it clear that climate change is widespread, rapid, intensifying and unprecedented. It identified the Southern African region as a climate change hotspot. Some of the observed changes include a decrease in mean precipitation, observed increase in heavy precipitation and pluvial flooding, observed and projected increases in aridity, agricultural and ecological droughts, projected increases in dryness from 1.5°C, increasing probability of global warming, and projected increases in mean wind speed and fire weather conditions. As shown in Figure 3.2, part of South Africa is in the West Southern Africa region and part in the East Southern Africa region.

3 Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu and B. Zhou (eds.)]. Cambridge University Press. In Press

4 Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press. In Press

5 Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [P.R. Shukla, J. Skea, R. Slade, A. Al Khourdajie, R. van Diemen, D. McCollum, M. Pathak, S. Some, P. Vyas, R. Fradera, M. Belkacemi, A. Hasija, G. Lisboa, S. Luz, J. Malley, (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA. doi: 10.1017/9781009157926.001.

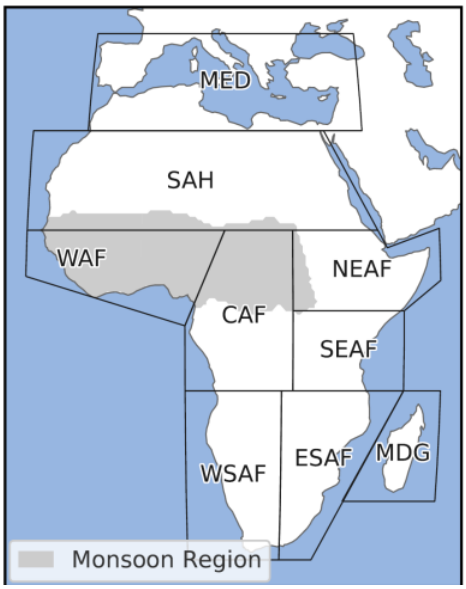



**Figure 3.2: Location of West and East Southern Africa regions**

*Source: IPCC, 2021*

The Working Group I reports are clear that the adverse impacts of climate change have been observed in all assessed regions. The impacts of weather and climate extreme have caused irreversible changes in some human and natural systems. It is projected that extreme weather events such as those recorded in KwaZulu-Natal in 2022 will become more frequent, and will have increasingly severe impacts. This has implications for South Africa's development aspirations, including employment creation, and poverty and inequality reduction.

The Working Group II report noted that "Climate change is a threat to human well-being and planetary health. Any further delay in concerted anticipatory global action on adaptation and mitigation will miss a brief and rapidly closing window of opportunity to secure a liveable and sustainable future for all". The need to build a climate-resilient society is urgent. South Africa has to respond to the current and projected impacts of climate change while transitioning to a just climate future. Investment in innovative mitigation and adaptation instruments to survive climate change and meet the Sustainable Development Goals is critical.

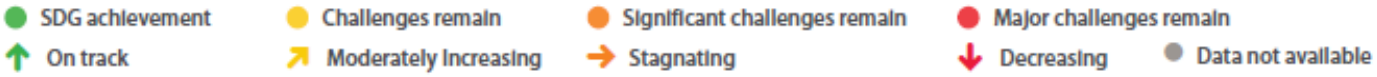
### *SDG climate change action*

South Africa's progress towards achieving the Sustainable Development Goals (SDGs) is summarised in **Table 3.6**. The main driver for global warming remains carbon dioxide, and South Africa is one of the top ten emitters of carbon dioxide in the world.

**Table 3.6: South Africa's performance under SDG13 (climate action)**

| | Value | Year | Rating | Trend |
|---|---|---|---|---|
| CO2 emissions from fossil fuel combustion and cement production (tCO2/capita) | 7.6 | 2020 |  |  |
| CO2 emissions embodied in imports (tCO2/capita) | 0.4 | 2018 |  |  |
| CO2 emissions embodied in fossil fuel exports (kg/capita) | 1 642.8 | 2020 |  | Information not available |

*Source: Sustainable Development Report, 2022*




The table shows that CO2 emissions from fossil fuels remain a major challenge and efforts to reduce emissions in South Africa are stagnant. However, the country continues its efforts to reduce imports that embody CO2 emissions. A just transition is critical in moving the country away from high emissions to ensuring a climate-resilient future.

## 3.2 Global trends in STI

The selected global STI trends that are included in this section are R&D expenditure, scientific publications, patent applications, innovation and economic transformation readiness, and social progress. Where relevant, a comparison is made with economies in other BRICS countries, and with low-income, lower middle-income, upper middle-income and high-income countries.

### *3.2.1 R&D expenditure*

R&D expenditure as percentage of GDP takes time to collect and verify, so it is impossible to know the exact impact of Covid-19 on investment in R&D yet. The trends in Table 3.7 show that before the outbreak of the pandemic, global R&D expenditure as a percentage of GDP was on the steady increase, with high-income and upper middle-income countries making the greatest contribution to this increase.

**Table 3.7: Global trends in gross expenditure on R&D as percentage of GDP**

| | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|---|---|---|---|
| ***World*** | ***1.62*** | ***1.64*** | ***1.65*** | ***1.66*** | ***1.68*** | ***1.69*** | ***1.69*** | ***1.71*** | ***1.73*** | ***-*** |
| ***Low-income countries*** | ***0.27*** | ***0.28*** | ***0.29*** | ***0.28*** | ***0.27*** | ***0.26*** | ***0.26*** | ***0.25*** | ***0.25*** | |
| Tajikistan | 0.09 | 0.12 | 0.11 | 0.12 | 0.12 | 0.11 | 0.11 | 0.12 | 0.10 | - |
| ***Lower middle-income countries*** | ***0.48*** | ***0.49*** | ***0.47*** | ***0.50*** | ***0.50*** | ***0.50*** | ***0.49*** | ***0.49*** | ***0.49*** | |
| Egypt | 0.43 | 0.53 | 0.51 | 0.64 | 0.64 | 0.72 | 0.71 | 0.68 | 0.72 | - |
| India | 0.79 | 0.76 | 0.74 | 0.71 | 0.70 | 0.69 | 0.67 | 0.67 | 0.65 | - |
| Tunisia | 0.69 | 0.71 | 0.68 | 0.67 | 0.65 | 0.63 | 0.60 | - | 0.60 | - |
| ***Upper middle-income countries*** | ***1.13*** | ***1.16*** | ***1.24*** | ***1.24*** | ***1.29*** | ***1.34*** | ***1.38*** | ***1.39*** | ***1.41*** | ***-*** |
| Brazil | 1.16 | 1.14 | 1.13 | 1.20 | 1.27 | 1.34 | 1.26 | 1.09 | 1.16 | - |
| China | 1.71 | 1.78 | 1.91 | 2.00 | 2.02 | 2.06 | 2.10 | 2.12 | 2.14 | 2.23 |
| Russia | 1.13 | 1.01 | 1.03 | 1.03 | 1.07 | 1.10 | 1.10 | 1.11 | 0.99 | 1.04 |
| **South Africa** | **0.66** | **0.67** | **0.67** | **0.66** | **0.71** | **0.73** | **0.75** | **0.76** | **0.69** | **0.62** |
| ***High-income countries*** | ***2.30*** | ***2.34*** | ***2.33*** | ***2.32*** | ***2.35*** | ***2.34*** | ***2.34*** | ***2.39*** | ***2.43*** | ***-*** |
| Singapore | 1.93 | 2.07 | 1.92 | 1.92 | 2.08 | 2.18 | 2.08 | 1.94 | 1.84 | - |
| South Korea | 3.47 | 3.74 | 3.85 | 3.95 | 4.08 | 3.98 | 3.99 | 4.29 | 4.52 | 4.64 |
| United Kingdom | 1.64 | 1.65 | 1.58 | 1.62 | 1.64 | 1.65 | 1.66 | 1.68 | 1.73 | 1.76 |
| United States | 2.74 | 2.77 | 2.68 | 2.71 | 2.72 | 2.72 | 2.79 | 2.85 | 2.95 | 3.07 |

*Source: UNESCO Institute for Statistics; OECD Main S&T Indicators; DSI/ HSRC 2019/20 R&D Survey Report*

The 2021 UNESCO Science Report notes that, of every five countries, four devote less than 1% of GDP to R&D. In the BRICS grouping, South Africa and India are struggling in this regard. After a recent rebasing of GDP, South Africa's R&D intensity value was revised downwards to 0,62% in 2019/20.

### *3.2.2 STI Human Resources*

The number of researchers involved in the R&D depends on the level of expenditure on R&D. High-income countries also lead in terms of the number of researchers per thousand in total employment (**Table 3.8**). South Korea has one of the highest R&D intensities in the world (second after Israel[6]) and this also applies to the researchers' intensity within that economy. According to the 2021 UNESCO Science Report, a 2017 evaluation by the Korean Ministry of Science, ICT and Future Planning and the Korea Institute of Science and Technology Evaluation and Planning estimated that investment in R&D contributed to about 40% of national GDP over the 2013-2017 period.

[6] 2021 UNESCO Science Report

**Table 3.8: Global trends in researchers per thousand in employment**

| | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|---|---|---|---|
| ***Low-income countries*** | | | | | | | | | | |
| Ethiopia | 0.1 | - | - | 0.1 | - | - | - | 0.2 | - | - |
| ***Lower middle-income countries*** | | | | | | | | | | |
| Egypt | 1.5 | 1.5 | 1.6 | 1.0 | 2.0 | 2.1 | 2.2 | 2.2 | 2.2 | - |
| India | 0.4 | - | - | - | - | 0.6 | - | - | 0.7 | - |
| Tunisia | 3.9 | 4.0 | 4.5 | 5.0 | 5.1 | 5.0 | 5.6 | - | 5.0 | - |
| ***Upper middle-income countries*** | | | | | | | | | | |
| Brazil | 1.4 | 1.5 | 1.6 | 1.7 | 1.8 | - | - | - | - | - |
| China | 1.5 | 1.7 | 1.8 | 1.8 | 1.9 | 2.0 | 2.1 | 2.2 | 2.3 | - |
| Russia | 5.8 | 5.9 | 5.8 | 5.8 | 5.9 | 6.0 | 5.7 | 5.5 | 5.4 | - |
| **South Africa** | 1.4 | 1.5 | 1.5 | 1.6 | 1.5 | 1.7 | 1.7 | 1.8 | 1.8 | 1.9 |
| ***High-income countries*** | | | | | | | | | | |
| Singapore | 10.5 | 10.7 | 10.5 | 10.9 | 10.8 | 11.2 | 11.1 | 10.9 | - | - |
| South Korea | 10.5 | 11.3 | 12.1 | 12.2 | 12.7 | 13.0 | 13.0 | 13.7 | 14.6 | - |
| United Kingdom | 7.9 | 7.7 | 7.8 | 8.0 | 8.2 | 8.4 | 8.5 | 8.4 | 8.9 | - |
| United States | 7.7 | 8.0 | 7.9 | 8.1 | 8.4 | 8.5 | 8.4 | 8.7 | 7.7 | - |

*Source: UNESCO Institute for Statistics; 2019/20 R&D survey report*

South Africa's number of researchers per thousand total employment is on a steady increase (from 1,4 in 2010/11 to 1,9 in 2019/20), although this is lower than Egypt and Tunisia (2,2 and 5,0 respectively, in 2018). However, South Africa has increasingly high unemployment rates, so the increase in its ratio does not necessarily mean that more researchers were employed.

### *3.3.3 Scientific publications*

The year 2020 shows the early impact of Covid-19 on global scientific publications. As expected, the rate of increase in publications slowed to the extent that the average global number of scientific publications per million population went up from 579 in 2019 to only 580 in 2020 (**Table 3.9**). High-income countries were the most affected by Covid in 2020, experiencing a decrease for the first time in 10 years. This may be a result of researchers seeking to address Covid-19 issues and often doing so in pre-print rather than peer-reviewed publications. The number of pre-print publications increased dramatically during the pandemic.

**Table 3.9: Global trends in scientific publications per million inhabitants**

| | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|
| ***Low income*** | ***10*** | ***10*** | ***11*** | ***12*** | ***16*** | ***16*** | ***20*** | ***20*** | ***24*** | ***28*** |
| Mozambique | 10 | 8 | 8 | 9 | 14 | 16 | 19 | 18 | 22 | 23 |
| ***Lower middle-income*** | ***48*** | ***52*** | ***58*** | ***64*** | ***85*** | ***94*** | ***103*** | ***110*** | ***119*** | ***130*** |
| Egypt | 100 | 111 | 121 | 135 | 177 | 196 | 200 | 221 | 253 | 296 |
| Eswatini | 51 | 43 | 52 | 38 | 70 | 79 | 120 | 137 | 138 | 160 |
| India | 49 | 54 | 62 | 71 | 93 | 100 | 101 | 105 | 111 | 123 |
| Lesotho | 13 | 15 | 16 | 19 | 27 | 30 | 33 | 30 | 40 | 50 |
| Nigeria | 19 | 18 | 18 | 21 | 30 | 33 | 38 | 42 | 49 | 59 |
| Tunisia | 372 | 401 | 468 | 520 | 656 | 704 | 765 | 708 | 730 | 681 |
| ***Upper middle-income*** | ***204*** | ***225*** | ***242*** | ***262*** | ***311*** | ***339*** | ***362*** | ***388*** | ***437*** | ***452*** |
| Botswana | 149 | 143 | 144 | 192 | 203 | 276 | 283 | 304 | 339 | 353 |
| Brazil | 237 | 253 | 266 | 276 | 348 | 362 | 383 | 402 | 432 | 452 |
| China | 196 | 221 | 242 | 264 | 293 | 324 | 347 | 380 | 446 | 469 |
| Russia | 251 | 253 | 267 | 306 | 436 | 513 | 569 | 630 | 671 | 633 |
| **South Africa** | **248** | **278** | **285** | **309** | **390** | **424** | **444** | **457** | **496** | **505** |
| ***High-income*** | ***1 712*** | ***1 783*** | ***1 849*** | ***1 930*** | ***2 129*** | ***2 212*** | ***2 247*** | ***2 293*** | ***2 430*** | ***2 395*** |
| Singapore | 2 759 | 3 064 | 3 290 | 3 476 | 3 902 | 4 103 | 4 164 | 4 269 | 4 424 | 4 531 |
| South Korea | 1 185 | 1 320 | 1 341 | 1 436 | 1 602 | 1 650 | 1 659 | 1 699 | 1 816 | 1 817 |
| United Kingdom | 2 897 | 2 984 | 3 143 | 3 182 | 3 646 | 3 747 | 3 822 | 3 856 | 4 130 | 3 972 |
| United States | 1 981 | 2 051 | 2 089 | 2 156 | 2 317 | 2 394 | 2 436 | 2 474 | 2 576 | 2 507 |
| ***World average*** | ***373*** | ***392*** | ***409*** | ***429*** | ***485*** | ***509*** | ***523*** | ***540*** | ***579*** | ***580*** |

*Source: Web of Science Core Collection*

In terms of scientific publications (**Table 3.10**), South Africa ranked 80th in 2019 and 2020. This is higher than the average for upper middle-income countries (88th in 2020).

Tunisia's 2020 publications ranking (70th) is better than the average ranking for upper middle-income countries, as well as all the BRICS countries (including South Africa). It is interesting to note that only the low-income countries' ranking improved, from 194th in 2019 to 190th in 2020. The high-income countries went down from 29th in 2019 to 32nd in 2020.

**Table 3.10: rankings in scientific publications per million inhabitants**

| | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|
| ***Low income*** | ***177*** | ***178*** | ***179*** | ***182*** | ***186*** | ***192*** | ***191*** | ***193*** | ***194*** | ***190*** |
| Mozambique | 176 | 184 | 189 | 188 | 188 | 192 | 193 | 196 | 196 | 194 |
| **Lower *middle-income*** | **122** | **117** | **118** | **121** | **126** | **125** | **136** | **135** | **140** | **141** |
| Egypt | 97 | 95 | 98 | 100 | 104 | 102 | 109 | 107 | 107 | 103 |
| Eswatini | 119 | 123 | 122 | 143 | 131 | 135 | 131 | 129 | 129 | 136 |
| India | 121 | 116 | 116 | 118 | 122 | 124 | 138 | 135 | 141 | 144 |
| Lesotho | 166 | 165 | 167 | 166 | 169 | 169 | 177 | 179 | 173 | 170 |
| Nigeria | 149 | 158 | 160 | 164 | 163 | 167 | 168 | 165 | 166 | 162 |
| Tunisia | 57 | 60 | 59 | 55 | 57 | 60 | 59 | 60 | 66 | 70 |
| ***Upper middle-income*** | ***76*** | ***75*** | ***78*** | ***81*** | ***83*** | ***82*** | ***83*** | ***85*** | ***87*** | ***88*** |
| Botswana | 85 | 89 | 93 | 88 | 96 | 90 | 95 | 95 | 99 | 97 |
| Brazil | 72 | 73 | 77 | 79 | 80 | 77 | 81 | 81 | 87 | 87 |
| China | 79 | 76 | 78 | 80 | 84 | 83 | 85 | 87 | 86 | 84 |
| Russia | 69 | 72 | 76 | 74 | 70 | 71 | 69 | 68 | 69 | 73 |
| **South Africa** | **70** | **68** | **73** | **73** | **73** | **74** | **73** | **74** | **80** | **80** |
| ***High-income*** | ***24*** | ***25*** | ***27*** | ***28*** | ***29*** | ***32*** | ***31*** | ***32*** | ***29*** | ***32*** |
| Singapore | 14 | 9 | 9 | 11 | 10 | 10 | 11 | 11 | 12 | 10 |
| South Korea | 35 | 33 | 34 | 36 | 38 | 40 | 40 | 38 | 38 | 40 |
| United Kingdom | 11 | 10 | 11 | 13 | 13 | 14 | 15 | 14 | 15 | 15 |
| United States | 22 | 22 | 23 | 23 | 26 | 29 | 27 | 27 | 26 | 30 |
| ***World average*** | ***57*** | ***61*** | ***62*** | ***61*** | ***68*** | ***72*** | ***71*** | ***72*** | ***72*** | ***74*** |

*Source: Web of Science Core Collection*

### *3.3.4 Intellectual property protection*

The patent applications per million inhabitants (**Table 3.11**) in high-income countries also decreased, from 1 315 in 2019 to 1 278 in 2020. The United Kingdom and United States of America were among the high-income countries affected. Singapore and South Korea, however, showed high resilience.

The United States has plans to improve its technology leadership. According to the 2021 UNESCO Science Report, these plans include enacting the Endless Frontiers Act, which will expand the mandate of the National Science Foundation (and rename it the National Science and Technology Foundation), and establish a new technology directorate in the foundation with a budget of $10 billion over five years to invest in research related to emerging technologies.

**Table 3.11: Global trends in patent applications per million inhabitants**

| | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|
| ***Low-income*** | ***18*** | ***19*** | ***4*** | ***4*** | ***3*** | ***3*** | ***3*** | ***4*** | ***3*** | ***3*** |
| Mozambique | 0,3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| ***Lower middle-income*** | ***28*** | ***28*** | ***28*** | ***28*** | ***29*** | ***29*** | ***30*** | ***30*** | ***32*** | ***31*** |
| Egypt | 9 | 9 | 9 | 10 | 9 | 11 | 12 | 12 | 12 | 12 |
| India | 13 | 14 | 16 | 17 | 18 | 20 | 21 | 22 | 25 | 27 |
| Nigeria | 0,5 | 0,3 | 0,4 | 0,0 | 0,0 | 1 | 1 | 2 | 2 | 2 |
| Tunisia | 14 | 18 | 20 | 16 | 19 | 24 | 16 | 17 | 0,0 | 0,0 |
| ***Upper middle-income*** | ***277*** | ***332*** | ***402*** | ***439*** | ***510*** | ***599*** | ***609*** | ***669*** | ***608*** | ***641*** |
| Botswana | 2 | 18 | 10 | 7 | 3 | 1 | 3 | 0,4 | 1 | 3 |
| Brazil | 32 | 33 | 34 | 33 | 32 | 35 | 36 | 33 | 35 | 34 |
| China | 324 | 415 | 539 | 611 | 732 | 906 | 935 | 1 041 | 943 | 1 021 |
| Russia | 220 | 243 | 237 | 198 | 235 | 221 | 192 | 212 | 206 | 210 |
| **South Africa** | **34** | **32** | **41** | **42** | **38** | **36** | **38** | **32** | **26** | **25** |
| ***High-income*** | ***1 217*** | ***1 261*** | ***1 282*** | ***1 286*** | ***1 297*** | ***1 297*** | ***1 294*** | ***1 290*** | ***1 315*** | ***1 278*** |
| Singapore | 884 | 923 | 1 017 | 1 085 | 1 119 | 1 203 | 1 239 | 1 315 | 1 294 | 1 398 |
| South Korea | 3 761 | 4 061 | 4 433 | 4 544 | 4 670 | 4 565 | 4 412 | 4 496 | 4 807 | 5 033 |
| United Kingdom | 804 | 812 | 801 | 815 | 821 | 808 | 815 | 846 | 820 | 790 |
| United States | 1 416 | 1 512 | 1 587 | 1 602 | 1 656 | 1 617 | 1 616 | 1 576 | 1 589 | 1 506 |
| ***World average*** | ***371*** | ***400*** | ***428*** | ***441*** | ***469*** | ***502*** | ***503*** | ***522*** | ***501*** | ***503*** |

*Source: WIPO IP Statistics Data Center*

As **Table 3.12** shows, South Africa ranked 76th in 2020, below all the other BRICS countries. For the first time in 10 years it is ranked lower than India (72nd) on patent applications per million population. China improved its ranking from 28th in 2011 to 21st in 2020, and is the best performing of the BRICS group of countries.

**Table 3.12: Rankings in patent applications per million inhabitants**

| | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|
| ***Low-income*** | ***75*** | ***78*** | ***101*** | ***110*** | ***113*** | ***123*** | ***125*** | ***122*** | ***112*** | ***119*** |
| Mozambique | 120 | 117 | 117 | 123 | 124 | 137 | 132 | 130 | 122 | 132 |
| ***Lower middle-income*** | ***68*** | ***70*** | ***71*** | ***74*** | ***71*** | ***76*** | ***74*** | ***73*** | ***70*** | ***71*** |
| Egypt | 91 | 88 | 92 | 97 | 95 | 101 | 94 | 96 | 90 | 94 |
| Eswatini | 94 | 54 | 126 | 71 | 89 | 149 | 146 | 147 | 134 | 140 |
| India | 82 | 83 | 83 | 84 | 79 | 89 | 82 | 81 | 75 | 72 |
| Lesotho | 129 | 126 | 126 | 137 | 140 | 149 | 146 | 127 | 126 | 140 |
| Nigeria | 114 | 122 | 118 | 137 | 140 | 138 | 137 | 126 | 116 | 124 |
| Tunisia | 80 | 79 | 79 | 88 | 78 | 81 | 89 | 86 | 134 | 140 |
| ***Upper middle-income*** | ***31*** | ***31*** | ***31*** | ***30*** | ***27*** | ***30*** | ***29*** | ***27*** | ***28*** | ***26*** |
| Botswana | 108 | 78 | 89 | 103 | 114 | 126 | 125 | 141 | 119 | 121 |
| Brazil | 67 | 65 | 68 | 69 | 68 | 72 | 71 | 71 | 69 | 67 |
| China | 28 | 27 | 27 | 26 | 23 | 24 | 24 | 22 | 22 | 21 |
| Russia | 34 | 33 | 34 | 36 | 32 | 37 | 39 | 38 | 42 | 39 |
| **South Africa** | **65** | **68** | **66** | **65** | **62** | **70** | **69** | **72** | **73** | **76** |
| ***High-income*** | ***24*** | ***16*** | ***16*** | ***16*** | ***16*** | ***16*** | ***16*** | ***19*** | ***18*** | ***18*** |
| Singapore | 20 | 20 | 19 | 20 | 16 | 17 | 16 | 17 | 18 | 17 |
| South Korea | 5 | 4 | 4 | 4 | 5 | 5 | 5 | 5 | 3 | 3 |
| United Kingdom | 21 | 21 | 21 | 23 | 22 | 26 | 25 | 24 | 23 | 24 |
| United States | 13 | 13 | 13 | 15 | 13 | 14 | 14 | 16 | 16 | 15 |
| ***World average*** | ***28*** | ***28*** | ***29*** | ***30*** | ***28*** | ***31*** | ***31*** | ***30*** | ***29*** | ***30*** |

*Source: WIPO IP Statistics Data Center*

Technological capability challenge in Africa extends to other African countries such as Botswana, Egypt, Tunisia and Nigeria. Tunisia approved the Start-Up Act in 2018 to remove several bureaucratic hurdles that innovative projects faced when creating new business structures[7].

7 https://www.atlanticcouncil.org/blogs/menasource/new-technologies-for-a-new-tunisia/

### 3.3.5 The Global Innovation Index

The GII aggregates most of the innovation inputs and outputs to show overall performance on innovation. As seen in **Table 3.13**, only the low-income countries improved their overall GII ranking in 2021 (118th in 2021 from 122nd in 2020), although this is from a low base. Most of this improvement comes from innovation outputs, as it is the case with Mozambique. The average ranking for lower middle-income countries in innovation outputs deteriorated, from 82nd in 2020 to 92nd in 2021. Nigeria is one of the countries most affected in this group of economies, going from 105th to 124th.

**Table 3.13: Global Innovation Index rankings**

| | Overall GII | | Innovation Inputs | | Innovation Outputs | |
|---|---|---|---|---|---|---|
| | 2020 | 2021 | 2020 | 2021 | 2020 | 2021 |
| | Ranking out of 131 and 132 countries (2020 and 2021 respectively) | | | | | |
| ***Low-income countries*** | ***122*** | ***118*** | ***124*** | ***122*** | ***122*** | ***113*** |
| Mozambique | 124 | 122 | 122 | 122 | 125 | 118 |
| ***Lower middle-income*** | ***92*** | ***96*** | ***99*** | ***99*** | ***82*** | ***92*** |
| Egypt | 96 | 94 | 104 | 102 | 82 | 86 |
| India | 48 | 46 | 57 | 57 | 45 | 45 |
| Namibia | 104 | 100 | 101 | 88 | 105 | 110 |
| Nigeria | 117 | 118 | 115 | 115 | 105 | 124 |
| Tunisia | 65 | 71 | 77 | 78 | 59 | 64 |
| Zimbabwe | 120 | 113 | 123 | 116 | 108 | 105 |
| ***Upper middle-income*** | ***66*** | ***66*** | ***69*** | ***70*** | ***61*** | ***65*** |
| Botswana | 89 | 106 | 84 | 97 | 104 | 109 |
| Brazil | 62 | 57 | 59 | 56 | 64 | 59 |
| China | 14 | 12 | 26 | 25 | 6 | 7 |
| Russia | 47 | 45 | 42 | 43 | 58 | 52 |
| **South Africa** | **60** | **61** | **49** | **55** | **68** | **68** |
| ***High-income*** | ***31*** | ***30*** | ***27*** | ***27*** | ***28*** | ***29*** |
| Singapore | 8 | 8 | 1 | 1 | 15 | 13 |
| South Korea | 10 | 5 | 9 | 9 | 10 | 5 |
| United Kingdom | 4 | 4 | 6 | 7 | 3 | 6 |
| United States | 3 | 3 | 4 | 3 | 5 | 3 |
| ***World average*** | ***55*** | ***57*** | ***59*** | ***60*** | ***59*** | ***57*** |

*Source: 2020 and 2021 Global Innovation Index reports*

Also, on the innovation outputs, the upper middle-income countries slipped from the equivalent ranking of 61st to 65th. South Africa, however, remained in 68th position. South Africa's ranking in terms of innovation inputs is far higher than in innovation outputs. This suggests that inputs in South Africa result in a lower yield of outputs than in other countries. It also dropped in innovation inputs, from 49th in 2020 to 55th in 2021.

**Table 3.14** gives a breakdown of the GII rankings for both inputs and outputs. Most of the data included as part of the GII 2020 will be for 2019. The GII 2021 therefore reflects the early impact of Covid-19 on the innovation ecosystems better.

**Table 3.14: Equivalent ranking of GII pillars by income group**

| | Innovation inputs | | | | | | | | | | Innovation outputs | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Institutions | | Human capital and research | | Infrastructure | | Market sophistication | | Business sophistication | | Knowledge and technology outputs | | Creative outputs | |
| | 2020 | 2021 | 2020 | 2021 | 2020 | 2021 | 2020 | 2021 | 2020 | 2021 | 2020 | 2021 | 2020 | 2021 |
| ***Low-Income*** | ***109*** | ***106*** | ***117*** | ***118*** | ***118*** | ***122*** | ***113*** | ***118*** | ***105*** | ***116*** | ***112*** | ***111*** | ***116*** | ***114*** |
| Mozambique | 127 | 127 | 108 | 112 | 83 | 77 | 125 | 126 | 124 | 127 | 122 | 116 | 122 | 115 |
| ***Lower middle-income*** | ***103*** | ***104*** | ***94*** | ***92*** | ***102*** | ***98*** | ***92*** | ***95*** | ***91*** | ***92*** | ***77*** | ***85*** | ***92*** | ***90*** |
| Egypt | 115 | 114 | 90 | 93 | 100 | 92 | 106 | 95 | 103 | 106 | 65 | 70 | 101 | 104 |
| India | 61 | 62 | 61 | 54 | 75 | 81 | 31 | 29 | 55 | 52 | 27 | 29 | 64 | 68 |
| Namibia | 69 | 73 | 114 | 57 | 112 | 112 | 103 | 92 | 111 | 112 | 127 | 119 | 79 | 105 |
| Nigeria | 110 | 109 | 121 | 121 | 124 | 120 | 102 | 102 | 75 | 77 | 120 | 123 | 110 | 116 |
| Tunisia | 75 | 75 | 38 | 35 | 74 | 89 | 112 | 98 | 110 | 115 | 52 | 55 | 63 | 79 |
| Zimbabwe | 128 | 129 | 93 | 88 | 131 | 128 | 84 | 64 | 108 | 100 | 101 | 109 | 112 | 101 |
| ***Upper middle-income*** | ***71*** | ***74*** | ***70*** | ***60*** | ***71*** | ***73*** | ***65*** | ***63*** | ***62*** | ***56*** | ***64*** | ***70*** | ***61*** | ***65*** |
| Botswana | 60 | 59 | 53 | 130 | 103 | 93 | 96 | 106 | 99 | 73 | 89 | 101 | 111 | 112 |
| Brazil | 83 | 78 | 49 | 48 | 61 | 69 | 91 | 74 | 35 | 34 | 56 | 50 | 77 | 66 |
| China | 62 | 61 | 21 | 21 | 36 | 24 | 19 | 16 | 15 | 13 | 7 | 4 | 12 | 14 |
| Russia | 71 | 67 | 30 | 29 | 60 | 63 | 55 | 61 | 42 | 44 | 50 | 48 | 60 | 56 |
| **South Africa** | **55** | **55** | **70** | **67** | **77** | **84** | **15** | **23** | **50** | **51** | **61** | **61** | **70** | **80** |
| ***Higher Income*** | ***28*** | ***30*** | ***31*** | ***31*** | ***27*** | ***30*** | ***27*** | ***32*** | ***29*** | ***29*** | ***27*** | ***29*** | ***28*** | ***28*** |
| Singapore | 1 | 1 | 8 | 9 | 13 | 15 | 4 | 5 | 6 | 3 | 14 | 13 | 18 | 17 |
| South Korea | 29 | 28 | 1 | 1 | 14 | 12 | 11 | 18 | 7 | 7 | 11 | 8 | 14 | 8 |
| United Kingdom | 16 | 15 | 10 | 10 | 6 | 10 | 5 | 4 | 19 | 21 | 9 | 10 | 5 | 4 |
| United States | 9 | 12 | 12 | 11 | 24 | 23 | 2 | 2 | 5 | 2 | 3 | 3 | 11 | 12 |
| ***World*** | ***58*** | ***59*** | ***59*** | ***56*** | ***62*** | ***68*** | ***62*** | ***64*** | ***49*** | ***42*** | ***54*** | ***54*** | ***57*** | ***55*** |

*Source: Global Innovation Index data*

The world average (equivalent ranking) shows that improvements in global innovation inputs between 2020 and 2021 have been in human capital and research (59th to 56th) and business sophistication (49th to 42nd). The improvement in human capital and research can mostly be attributed to the upper middle-income countries who improved their equivalent ranking from 70th to 60th. South Africa improved from the 70th to 67th. Botswana is the most notable exception among the upper middle-income countries in this category, dropping from 53rd in 2020 to 130th in 2021. A closer inspection of the indicators shows that this is due to a lack of data for Botswana on school and tertiary education (for use in GII 2021). The sudden improvement of Namibia in this category is also driven by data gaps. GII 2021 ranked Namibia 1st in terms of its school system, as only a few indicators in that category were used (education expenditure as % of GDP and pupil-to-teacher ratio).

### *3.3.6 Economic transformation readiness*

In its 2020 Special Report, the World Economic Forum changed its focus from ranking the competitiveness of countries to reviewing their competitiveness in terms of economic transformation readiness. However, this only covered 38 countries and only the scores are used (not ranked). The transformative change that is covered through this Special Report addresses not only the recovery from the adverse impact of the Covid-19 pandemic, but also the faultlines that existed prior to an outbreak of the pandemic.

As **Figure 3.3** shows, among the BRICS member countries, China scored highest in overall economic transformation readiness (65,5). Brazil was next highest at 51, and there was little difference between South Africa (50,4), Russia (50,4) and India (49,5).

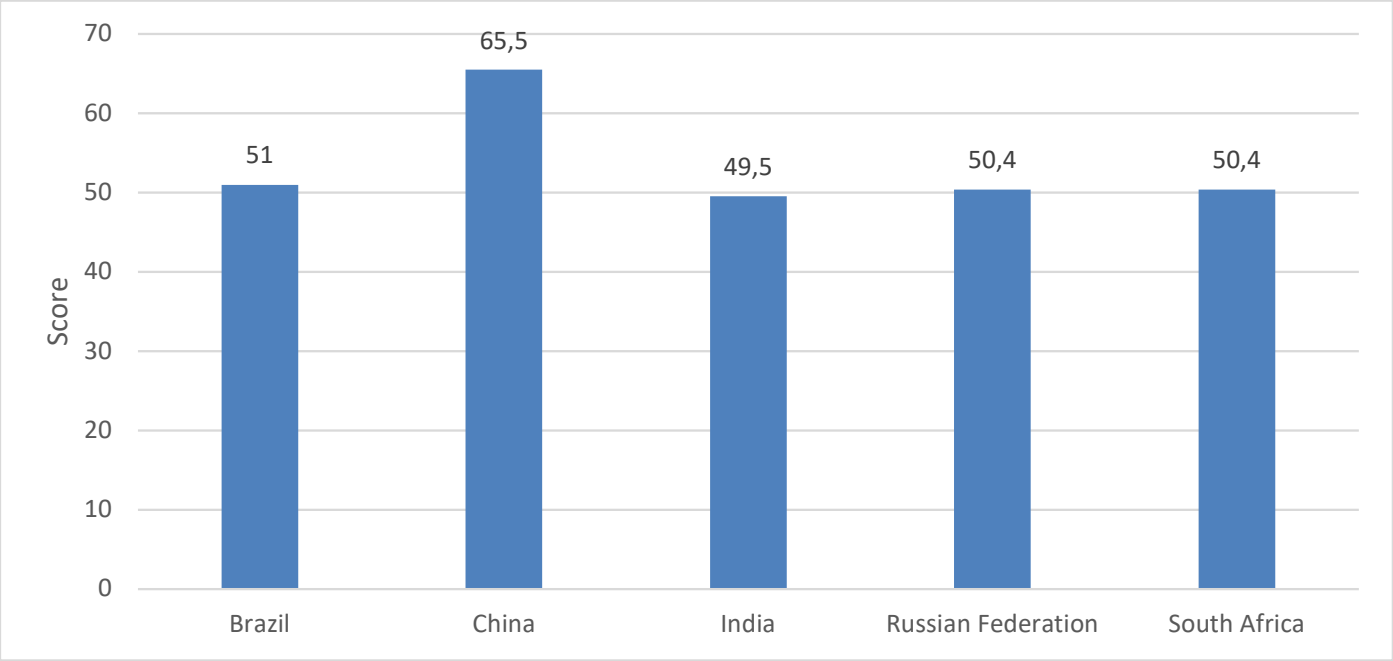



**Figure 3.3: BRICS performance in overall economic transformation readiness**

*Source: World Economic Forum Global Competitiveness Report: 2020 Special Edition*

South Africa's Economic Reconstruction and Recovery Plan (ERRP), introduced in October 2020, is intended to address, among other things, pre-pandemic issues such as a stagnant economic growth rate, high unemployment rate, poverty, inequality, disinvestment, etc. Some of the issues exacerbated by the Covid-19 are the significant reduction in gross fixed capital formation, drastic declines in capacity utilisation, job losses, loss of income, hunger, inequality and poverty.

As **Figure 3.4** shows, in terms of economic recovery readiness, most BRICS countries (including South Africa) score high in encouraging firms to embrace diversity, equity and inclusion to enhance creativity. Methods for better performance involve rethinking competition and anti-trust frameworks for the Fourth Industrial Revolution, thus ensuring local and international market access. This lever of economic transformation is critical, especially to ensure that the emerging technologies associated with the Fourth Industrial Revolution are nourished, protected and embraced.

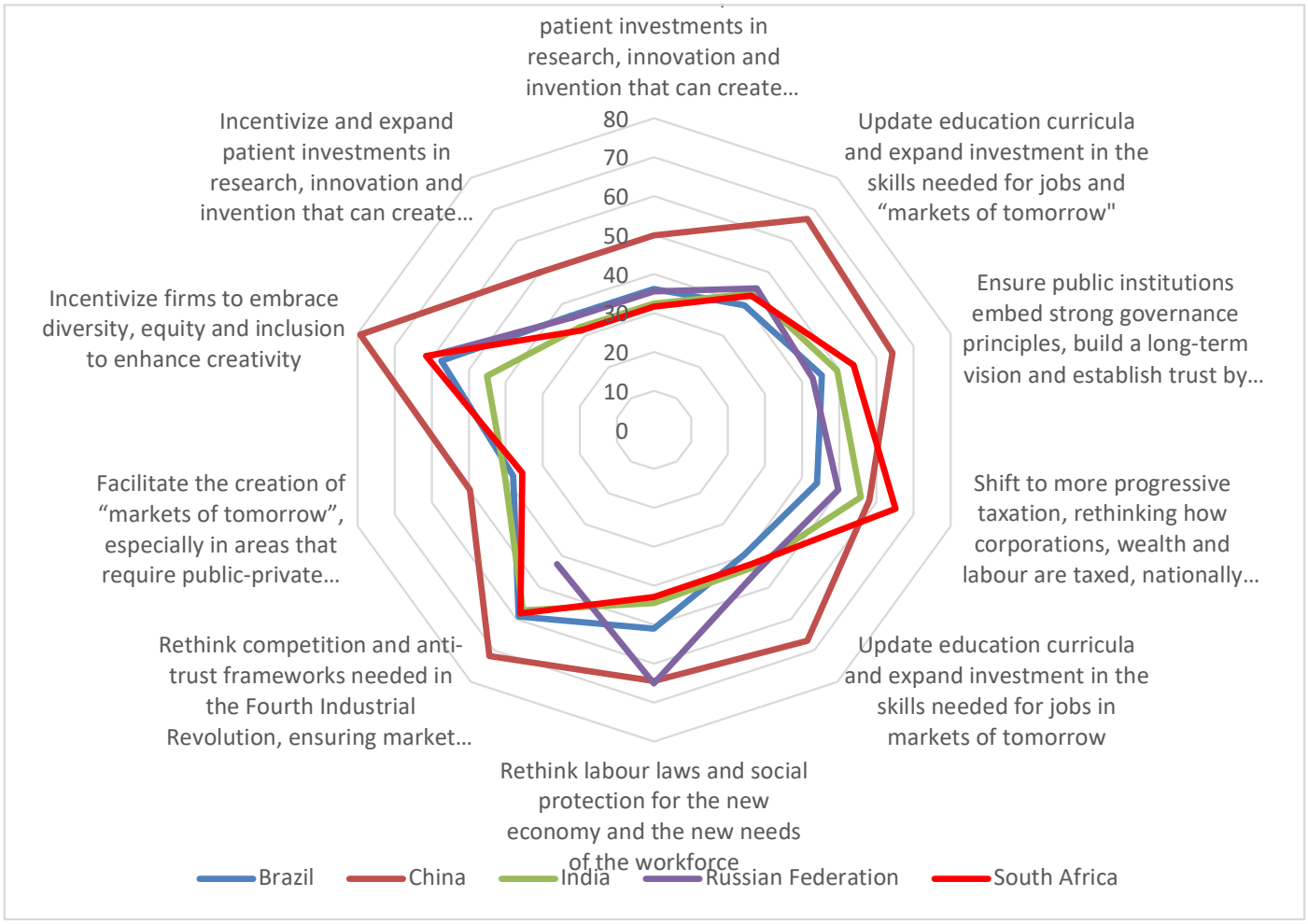



**Figure 3.4: BRICS performance in components of economic transformation readiness**

*Source: World Economic Forum's Global Competitiveness Report: 2020 Special Edition*

South Africa scored marginally higher than other BRICS member countries in shifting to more progressive taxation, rethinking how corporations, wealth and labour are taxed, nationally and in an international cooperative framework. However, the country scored lowest among the BRICS countries in incentivising and expanding long-term investment in research, innovation and invention that can create the "markets of tomorrow". South Africa's challenges in this regard are not only in respect of the research and technological system, but also weak public-private partnerships.

### *3.3.7 Social Progress Index*

The 10-year Social Progress Index (SPI) ranking trends shown in **Table 3.15** make it possible to assess Covid-19's disruption of the societal development trajectory. On average, social progress deteriorated in 2020 (100th equivalent ranking) and further in 2021 (102nd). The BRICS member countries such as South Africa were the less resilient in 2020 but have since shown some recovery.

**Table 3.15: Trends in equivalent rankings on the Social Progress Index**

| | South Africa | Upper middle income | BRICS | High income | Lower middle income | Low income | World |
|---|---|---|---|---|---|---|---|
| 2021 | 80 | 75 | 88 | 31 | 113 | 158 | 102 |
| 2020 | 82 | 74 | 90 | 30 | 114 | 158 | 100 |
| 2019 | 79 | 74 | 86 | 30 | 114 | 157 | 98 |
| 2018 | 85 | 73 | 86 | 29 | 113 | 157 | 100 |
| 2017 | 79 | 74 | 88 | 30 | 114 | 157 | 100 |
| 2016 | 80 | 74 | 86 | 30 | 115 | 155 | 101 |
| 2015 | 79 | 72 | 84 | 30 | 114 | 154 | 100 |
| 2014 | 82 | 73 | 83 | 30 | 114 | 155 | 100 |
| 2013 | 83 | 75 | 84 | 30 | 115 | 155 | 96 |
| 2012 | 83 | 76 | 82 | 29 | 114 | 154 | 95 |
| 2011 | 87 | 76 | 83 | 30 | 116 | 155 | 95 |

*Source: Social Progress Index*

A global deterioration in social progress around the world seems to have affected the categories of basic human needs and the foundations of wellbeing most (**Table 3.16**). Although the provision of shelter is deteriorating in equivalent ranking for the upper middle-income countries (from 92nd in 2019 to 93rd in 2021), South Africa experienced an improvement of ranking in this category, rising from 104th in 2019 to 96th in 2021. Since the start of the Covid-19 pandemic, government and civil society have made various efforts to provide shelter and take care of homeless people. South Africa also improved in health and wellness (109th to 102nd), environmental quality (85nd to 78nd) and personal rights (51st to 46th).

However, declining access to information during the pandemic is a concern. In South Africa, its position in terms of access to basic knowledge dropped from 86th to 93rd, and in terms of access to ICTs from 57th to 69th. This is in the context of the perception that Covid-19 has accelerated the adoption of digitisation. In South Africa, its ranking for access to ICTs dropped from 80th in 2019 to 86th in 2021.

**Table 3.16: Trends in equivalent ranking of SPI components and pillars**

| | | South Africa | Upper middle income | High income | Lower middle income | Low income | World |
|---|---|---|---|---|---|---|---|
| **Basic human needs** | **2019** | **116** | **83** | **30** | **119** | **153** | **108** |
| | **2021** | **117** | **86** | **30** | **120** | **153** | **110** |
| Nutrition and basic medical care | 2019<br>2021 | 112<br>112 | 87<br>88 | 31<br>31 | 121<br>119 | 152<br>152 | 105<br>105 |
| Water and sanitation | 2019<br>2021 | 115<br>115 | 81<br>82 | 42<br>42 | 118<br>117 | 153<br>152 | 112<br>112 |
| Shelter | 2019<br>2021 | 104<br>96 | 92<br>93 | 25<br>28 | 118<br>120 | 151<br>152 | 105<br>106 |
| Personal safety | 2019<br>2021 | 149<br>149 | 99<br>97 | 30<br>29 | 108<br>106 | 135<br>135 | 108<br>106 |
| **Foundations of well-being** | **2019** | **77** | **74** | **30** | **115** | **154** | **98** |
| | **2021** | **78** | **73** | **30** | **117** | **154** | **101** |
| Access to basic knowledge | 2019<br>2021 | 86<br>93 | 78<br>77 | 35<br>36 | 115<br>114 | 153<br>153 | 105<br>105 |
| Access to information and communication technologies | 2019<br>2021 | 57<br>69 | 83<br>83 | 25<br>24 | 117<br>116 | 151<br>150 | 80<br>86 |
| Health and wellness | 2019<br>2021 | 109<br>102 | 83<br>81 | 21<br>30 | 114<br>116 | 150<br>150 | 90<br>92 |
| Environmental quality | 2019<br>2021 | 85<br>78 | 90<br>89 | 37<br>38 | 121<br>123 | 117<br>118 | 141<br>139 |
| **Opportunity** | **2019** | **46** | **79** | **32** | **116** | **149** | **83** |
| | **2021** | **46** | **76** | **33** | **115** | **149** | **84** |
| Personal rights | 2019<br>2021 | 51<br>46 | 101<br>97 | 48<br>50 | 114<br>109 | 130<br>128 | 117<br>120 |
| Personal freedom and choice | 2019<br>2021 | 48<br>50 | 87<br>85 | 25<br>25 | 114<br>116 | 152<br>152 | 88<br>87 |
| Inclusiveness | 2019<br>2021 | 48<br>46 | 95<br>96 | 32<br>34 | 104<br>109 | 124<br>124 | 99<br>104 |
| Access to advanced education | 2019<br>2021 | 70<br>72 | 78<br>78 | 34<br>34 | 113<br>113 | 148<br>150 | 56<br>60 |

*Source: Social Progress Index*

# 4. SCIENCE, TECHNOLOGY AND INNOVATION FRAMEWORK CONDITIONS

The STI framework conditions that are discussed in this chapter are STI human capital, an attractive research system and an innovation-friendly environment. In the revised Conceptual Framework that is used for this report, digitalisation has been added as part of the innovation friendly environment.

## 4.1 Science, technology and innovation human capital

A critical component of a well-functioning innovation system is human capital across all the STI activities. This section assesses STI human resources development including gender and race transformation.

### *4.1.1 Researchers and technicians in research and development*

Previously, much of the focus was on researchers carrying out R&D activities in South Africa. However, technicians are important for the integration and translation of research ideas into demonstrators and other tangible R&D outputs. Hence, the number of researchers employed in R&D are analysed along with the technicians employed in R&D.

***Researchers employed in research and development***

There was a steady increase in researchers between 2010 and 2017. However, since 2017, the numbers have declined (**Figure 4.1**).

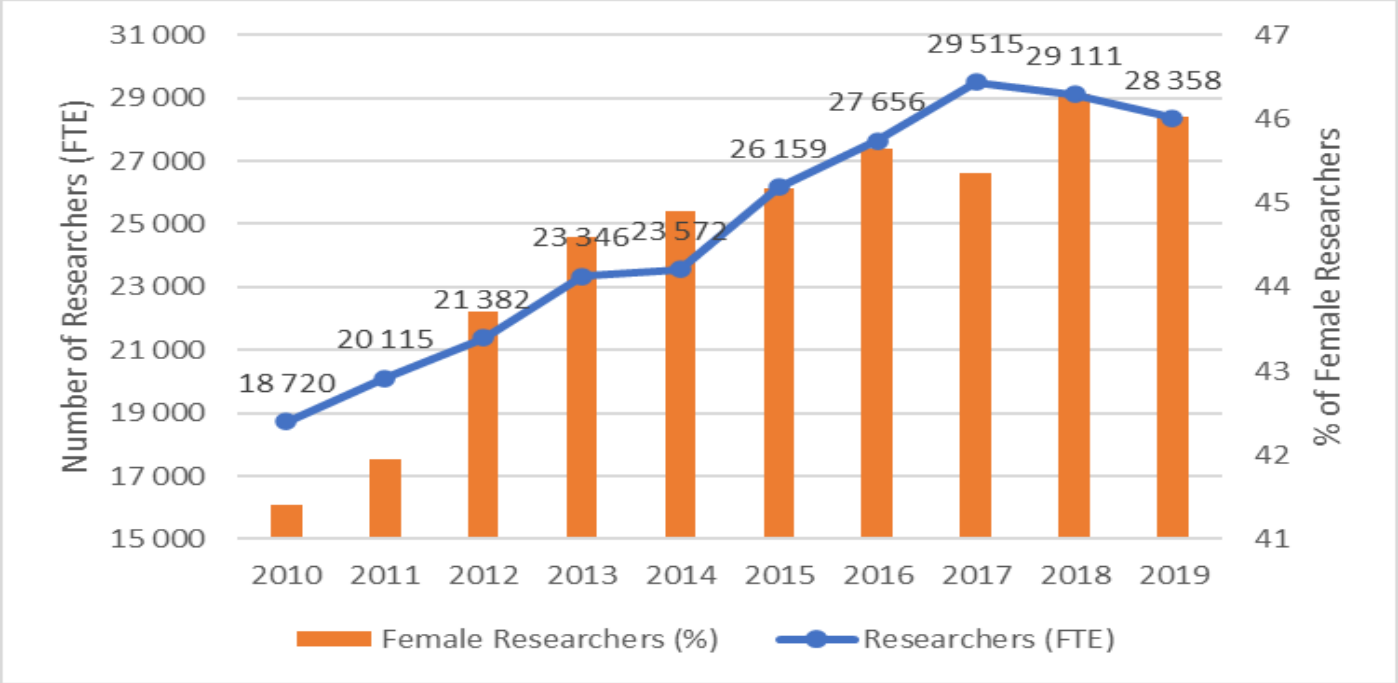



**Figure 4.1: Trends in number of researchers (total and by gender)**

*Source: 2019/20 National Survey of Research and Experimental Development*

South Africa's number of researchers in 2019 (28 358) was 51,5% more than in 2010 (18 720). The country needs to increase its number of researchers of all races to increase its innovation potential.

The increase of total researchers enabled the incorporation of more female researchers into the NSI. The proportion of female researchers has been on the increase since 2010, when they made up 41,41% of total researchers, to 2018, when they made up 46,30%. However, the proportion of female researchers decreased to 46,02% in 2019.

Another significant transformation taking place for the NSI in South Africa is the increase in the percentage of African researchers, from 26,7% in 2010 to 35,6% in 2019 (**Figure 4.2**). While the percentage of white researchers has been decreasing, the absolute number of white researchers was in fact on the increase (from 14 789 in 2010 to 15 795 in 2017). However, the numbers declined to 14 890 in 2018 and further to 14 224 in 2019.

The proportion of both coloured and Indian researchers increased marginally between 2010 and 2018, while the proportion of African researchers increased from 26,7% to 35,6%.

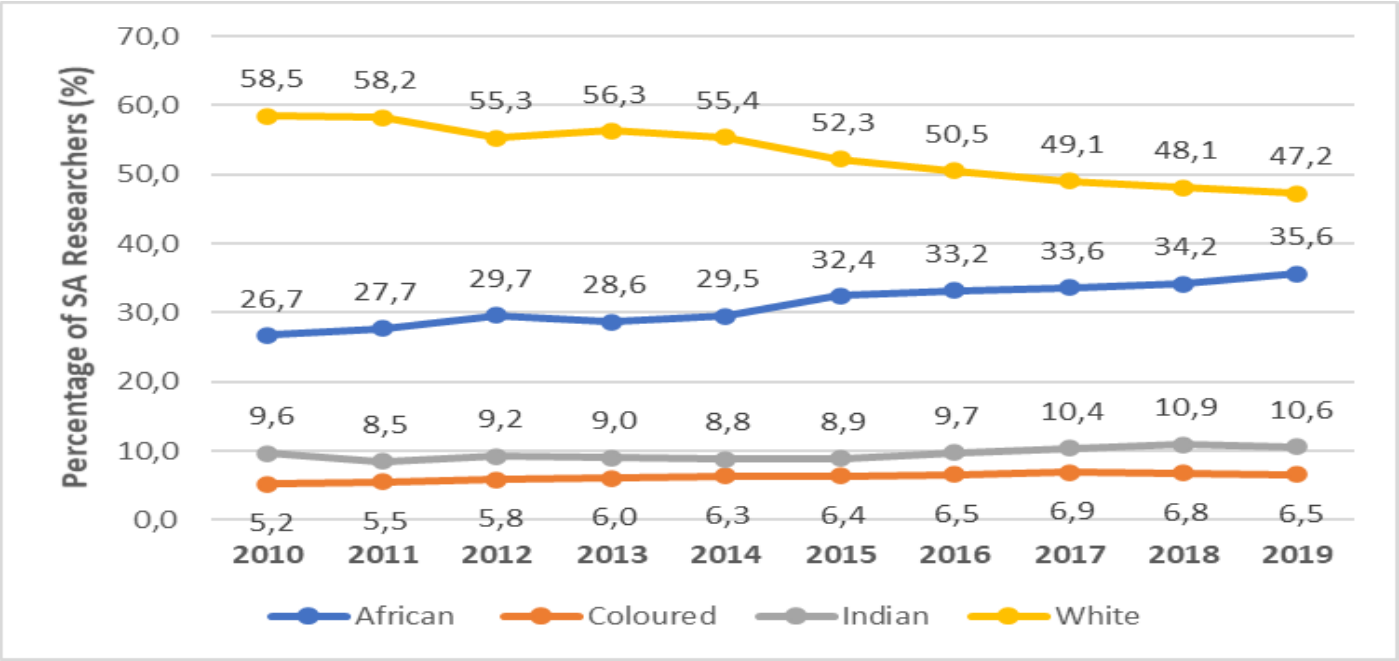



**Figure 4.2: Trend in proportion of researchers by race (head count)**

*Source: 2019/20 National Survey of Research and Experimental Development*

**Table 4.1** shows that the decrease in the number of researchers employed in R&D in 2018 and 2019 can be attributed to the business sector's shedding of 947 researchers in 2018 and a further 1 307 in 2019. During the past decade, the higher education sector has absorbed most of the researchers in the country.

**Table 4.1: Employment of South African researchers by sector (full-time equivalent)**

| | Business | Higher education | Science councils | Government | NGOs |
|---|---|---|---|---|---|
| 2010 | 4 804.0 | 3 613.7 | 1 777.3 | 874.2 | 196.2 |
| 2011 | 4 451.9 | 4 355.3 | 1 634.9 | 1 009.8 | 190.8 |
| 2012 | 4 555.9 | 4 700.6 | 1 697.1 | 1 091.4 | 294.5 |
| 2013 | 4 530.1 | 5 000.5 | 1 781.3 | 923.4 | 338.4 |
| 2014 | 4 636.2 | 5 097.7 | 1 765.4 | 970.0 | 396.0 |
| 2015 | 4 626.8 | 4 701.9 | 1 827.2 | 953.9 | 384.8 |
| 2016 | 4 777.3 | 5 220.4 | 1 940.5 | 969.1 | 340.5 |
| 2017 | 5 481.7 | 6 040.6 | 1 792.1 | 899.1 | 346.1 |
| 2018 | 4 535.1 | 6 007.2 | 1 697.0 | 920.8 | 367.3 |
| 2019 | 3 227.8 | 6 165.9 | 1 619.4 | 1 027.3 | 330.9 |

*Source: 2019/20 National Survey of Research and Experimental Development*

### *Technicians employed in research and development*

The number of technicians employed in R&D has been on the decline since 2015 (**Figure 4.3**). As a result, the proportion of technicians to researchers has decreased from a high of 32,8% in 2014 to 24,3% in 2019. The decline in the percentage and number of technicians employed in R&D should be interpreted in the context of the movement of R&D in South Africa from the business sector to higher education, with more focus on basic research.

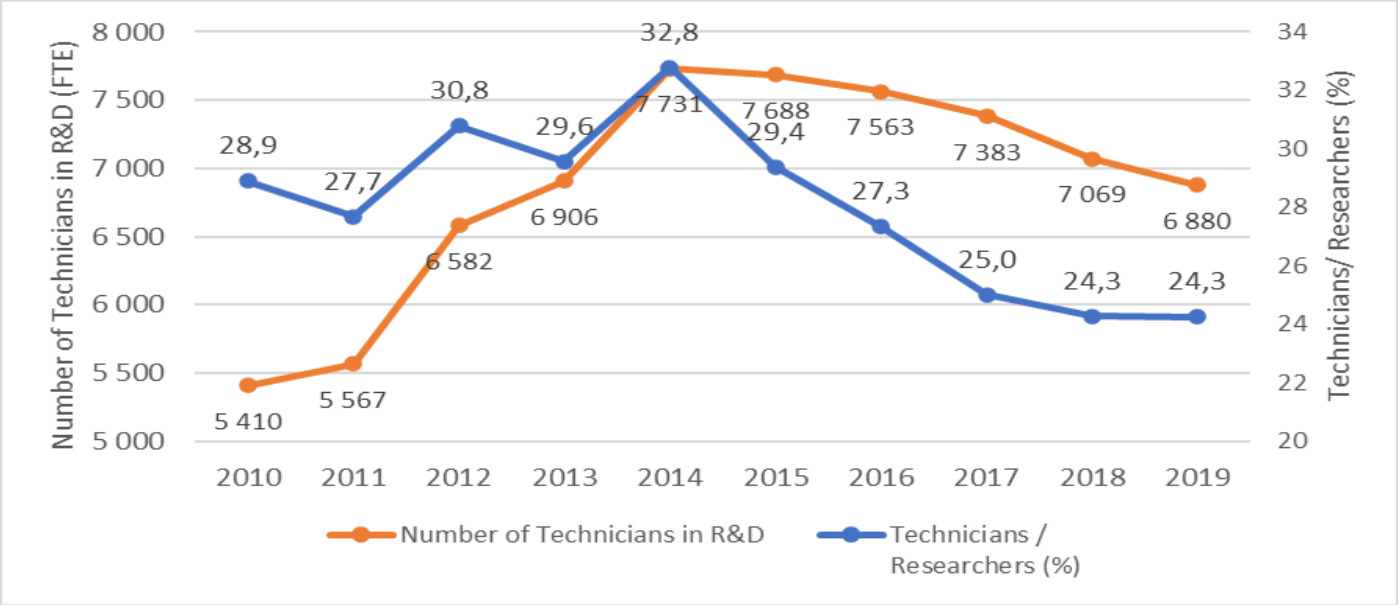



**Figure 4.3: Trend in the number of technicians in research and development**

*Source: 2019/20 National Survey of Research and Experimental Development*

**Table 4.2** shows a significant reduction in the number of technicians employed in the business sector since 2015. The numbers of technicians employed in R&D by the higher education sector is also very low.

**Table 4.2: Employment of South African Technicians in R&D by Sector (FTE)**

| | Business | Higher education | Science councils | Government | NGOs |
|---|---|---|---|---|---|
| 2010 | 3 328.7 | 543.9 | 1 155.5 | 252.9 | 47.6 |
| 2011 | 3 343.5 | 673.4 | 1 172.4 | 330.4 | 47.2 |
| 2012 | 4 065.5 | 737.3 | 1 279.6 | 385.8 | 114.2 |
| 2013 | 4 253.1 | 843.7 | 1 247.3 | 366.3 | 195.1 |
| 2014 | 4 494.4 | 857.3 | 1 686.2 | 337.9 | 355.5 |
| 2015 | 4 227.4 | 1 000.3 | 1 683.7 | 365.7 | 411.2 |
| 2016 | 4 149.4 | 804.2 | 1 676.0 | 357.9 | 575.6 |
| 2017 | 3 807.5 | 838.0 | 1 745.4 | 347.7 | 644.7 |
| 2018 | 3 546.9 | 924.5 | 1 579.6 | 324.9 | 693.2 |
| 2019 | 3 486.8 | 849.2 | 1 403.7 | 374.3 | 766.0 |

*Source: National Surveys of Research and Experimental Development*

### 4.1.2 Higher education academic staff profile

As **Figure 4.4** shows, the percentage of academic staff at South African public universities with PhDs remains low (47,53% in 2019), in spite of the 75% target for 2030 set in the National Development Plan (NDP). As alluded to by various policy documents, an achievement of this NDP target will provide the necessary supervisory capacity for postgraduate students and contribute to the socio-economic development of the country.

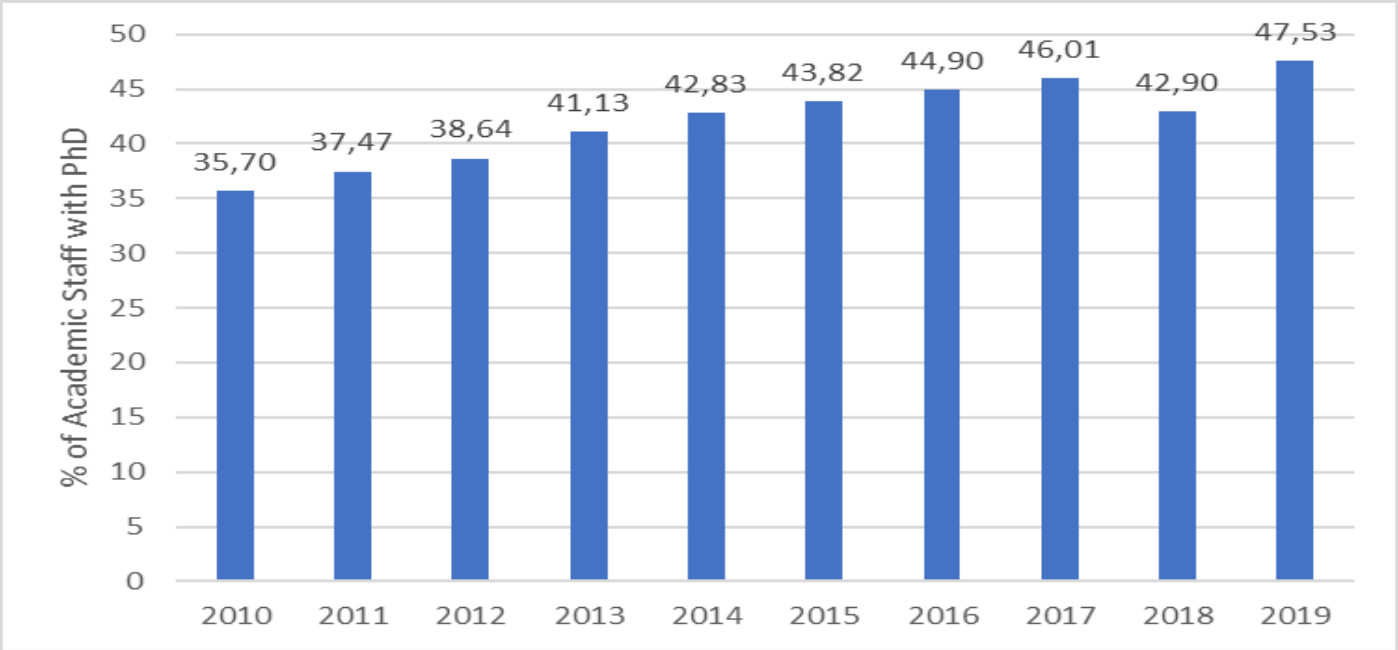



**Figure 4.4: Percentage of permanent academic staff with doctoral degrees**

*Source: NRF Information Portal*

Over the years, the higher education system has achieved gender parity in the composition of its academic staff. As **Figure 4.5** shows, the proportion of female academic staff at the public universities in South Africa increased from 46,40% in 2010 to 50,44% in 2019.

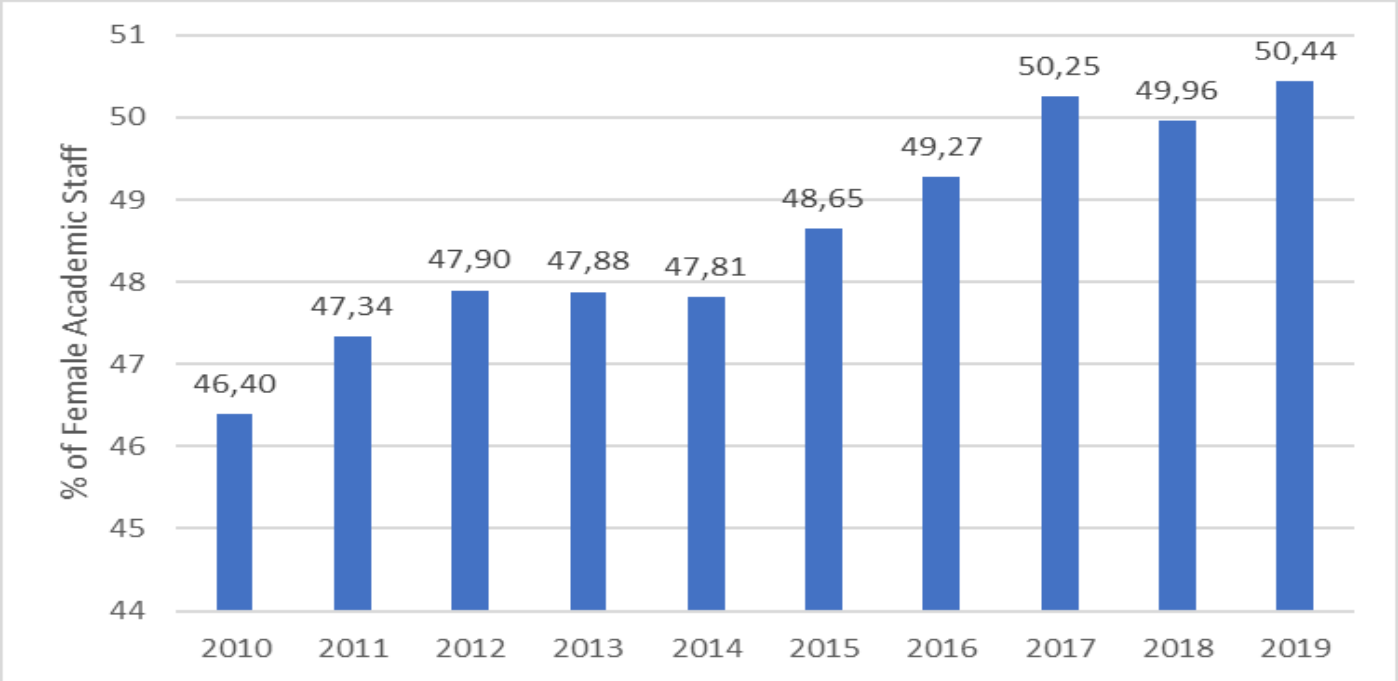



**Figure 4.5: Percentage of female academic staff at public universities**

*Source: NRF Information Portal*

Another key transformation taking place at the South African public universities is the increase in the proportion of African academic staff (**Figure 4.6**). Since 2017, Africans have made up the majority of academic staff (45% in 2019), followed by whites (40%), Indians (8%) and coloureds (6%). This trend resembles that of the profile of researchers in South Africa.

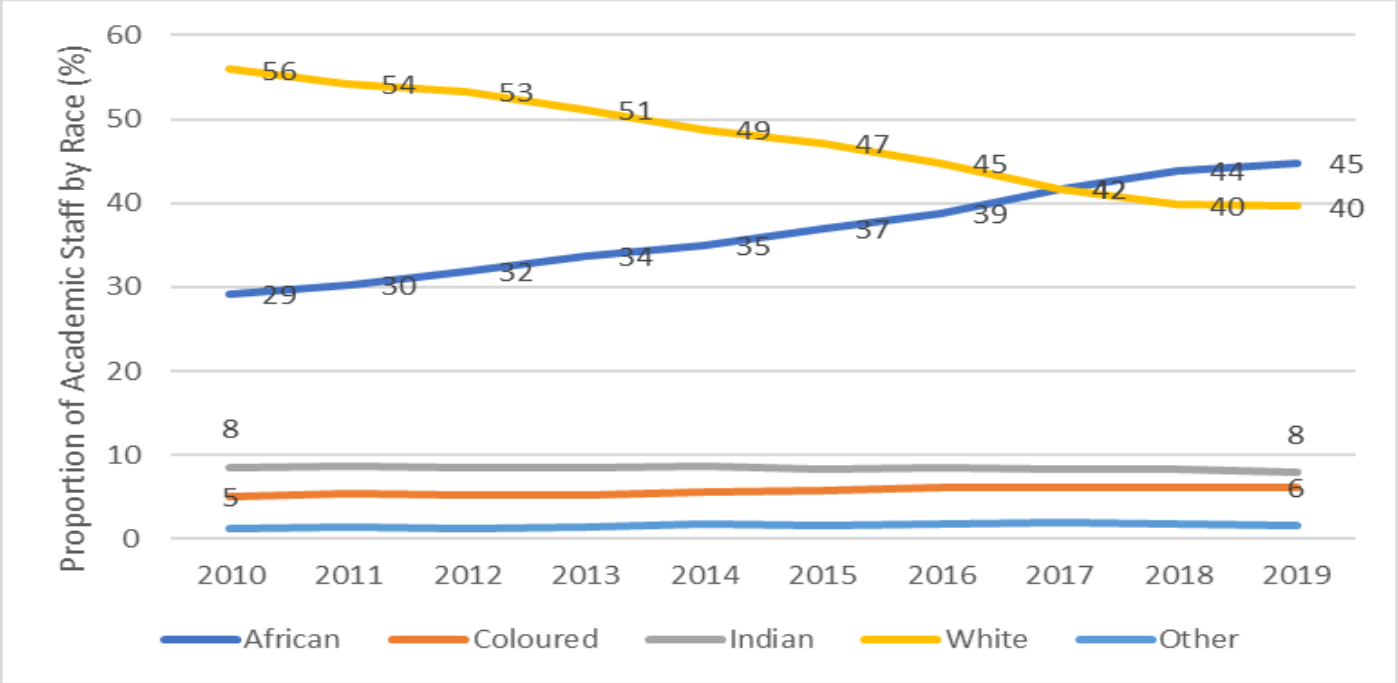



**Figure 4.6: Proportion of academic staff at public universities by race**

*Source: NRF Information Portal*

The higher education system has been successful in respect of increasing the number of female and specifically African female professors. As **Table 4.3** shows, the total share of female professors (of total professors) increased from 22,05% in 2010 to 30,8% in 2019. White females have the highest representation among professors, but there has been an increase in African female professors from a low of 1,51% in 2010 to 4,19% in 2019. There are programmes such as the National Research Foundation's Black Academics Advancement Programme and DHET's Future Professors Programme that can be used to grow the number of female African professors.

**Table 4.3: Proportion of female professors by race at public universities**

| | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|---|---|---|---|
| | % | | | | | | | | | |
| African female | 1,51 | 1,78 | 2,15 | 2,36 | 2,45 | 3,00 | 3,26 | 3,72 | 4,38 | 4,19 |
| Coloured female | 1,03 | 1,12 | 1,11 | 1,27 | 1,37 | 1,42 | 0,99 | 1,08 | 1,34 | 1,43 |
| Indian female | 1,07 | 1,04 | 1,11 | 1,24 | 1,23 | 1,76 | 1,77 | 1,92 | 2,24 | 2,53 |
| White female | 18,20 | 18,83 | 19,18 | 18,91 | 19,87 | 20,06 | 20,84 | 20,99 | 21,66 | 22,10 |
| Other female | 0,24 | 0,23 | 0,18 | 0,32 | 0,49 | 0,35 | 0,37 | 0,42 | 0,51 | 0,55 |

*Source: NRF Information Portal*

### 4.1.3 University SET graduates

The proportion of science, engineering and technology (SET) graduates remains low, especially for honours degrees (23,9% in 2020). As **Table 4.4** shows, SET graduation percentages decreased between 2019 and 2020. They remain high at doctoral and master's levels but, compared to 2011, the proportion of SET graduations at doctoral level decreased from 54,3% to 49,8% in 2020.

**Table 4.4: SET graduates as percentage of total graduates at public universities**

| | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|
| Bachelor degree | 32,4 | 31,9 | 31,7 | 31,5 | 27,9 | 26,8 | 27,7 | 27,5 | 27,7 | 27,6 |
| Honours degree | 23,3 | 24,6 | 23,9 | 25,3 | 25,5 | 26,9 | 25,4 | 24,3 | 24,5 | 23,9 |
| Masters degree | 42 | 42,2 | 43,7 | 43,3 | 45,7 | 44,6 | 46,4 | 47,6 | 46,9 | 46,7 |
| Doctorate degree | 54,2 | 52,4 | 52,5 | 50 | 49,9 | 49,5 | 52,0 | 49,9 | 53,5 | 49,8 |
| All Qualifications | 28,7 | 29,4 | 29,4 | 30 | 30,3 | 29,1 | 29,2 | 28,7 | 29,1 | 27,2 |

*Source: Department of Higher Education and Training*

A decline in the proportion of SET graduates at doctoral level is illustrated in **Figure 4.7**. It should be noted that this is taking place in the context of a constant increase in the annual number of doctoral graduates.

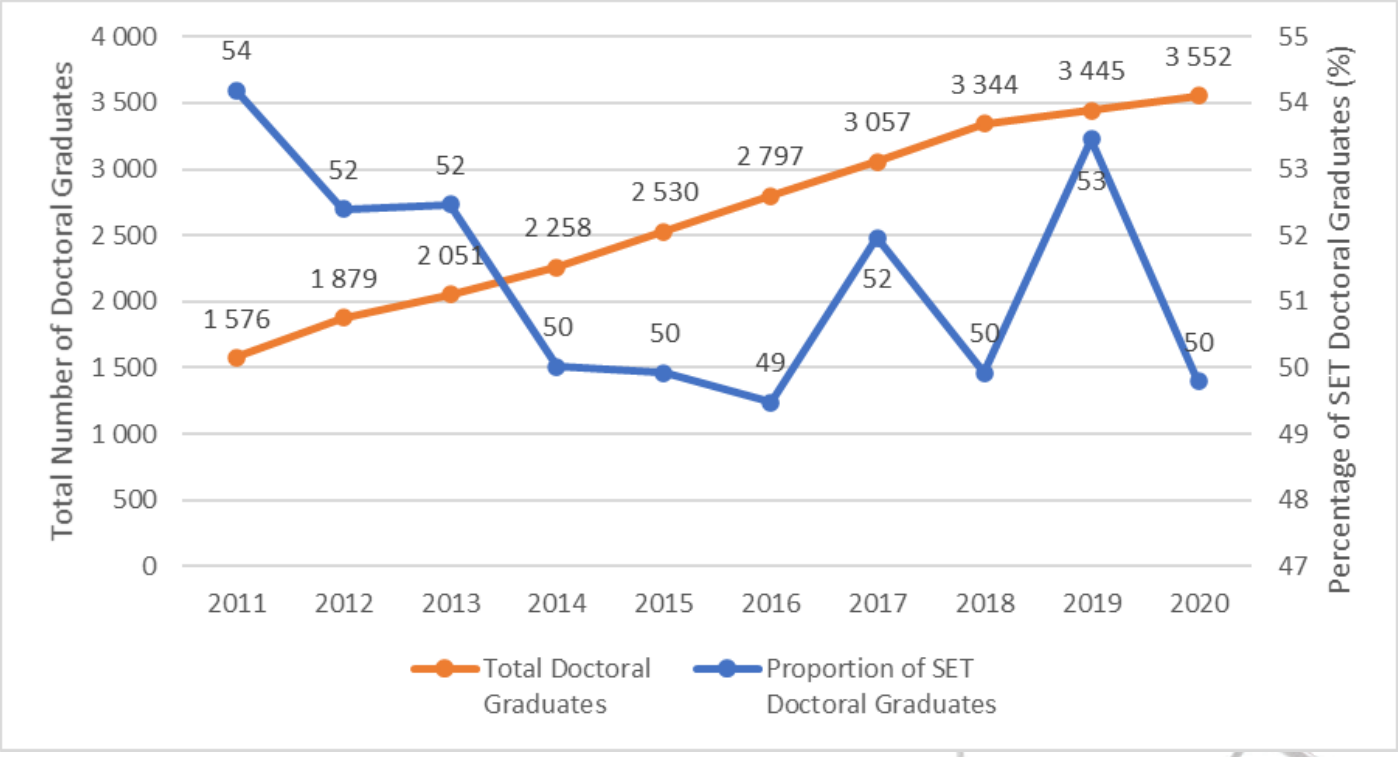



**Figure 4.7: Trend Trends in doctoral graduates and SET doctoral graduates**

*Source: Department of Higher Education and Training*

**Figure 4.8** shows that the decreased number of SET doctoral graduates also slowed the increase in the proportion of female doctoral graduates (from 40,87% in 2011 to 42,71% in 2020).

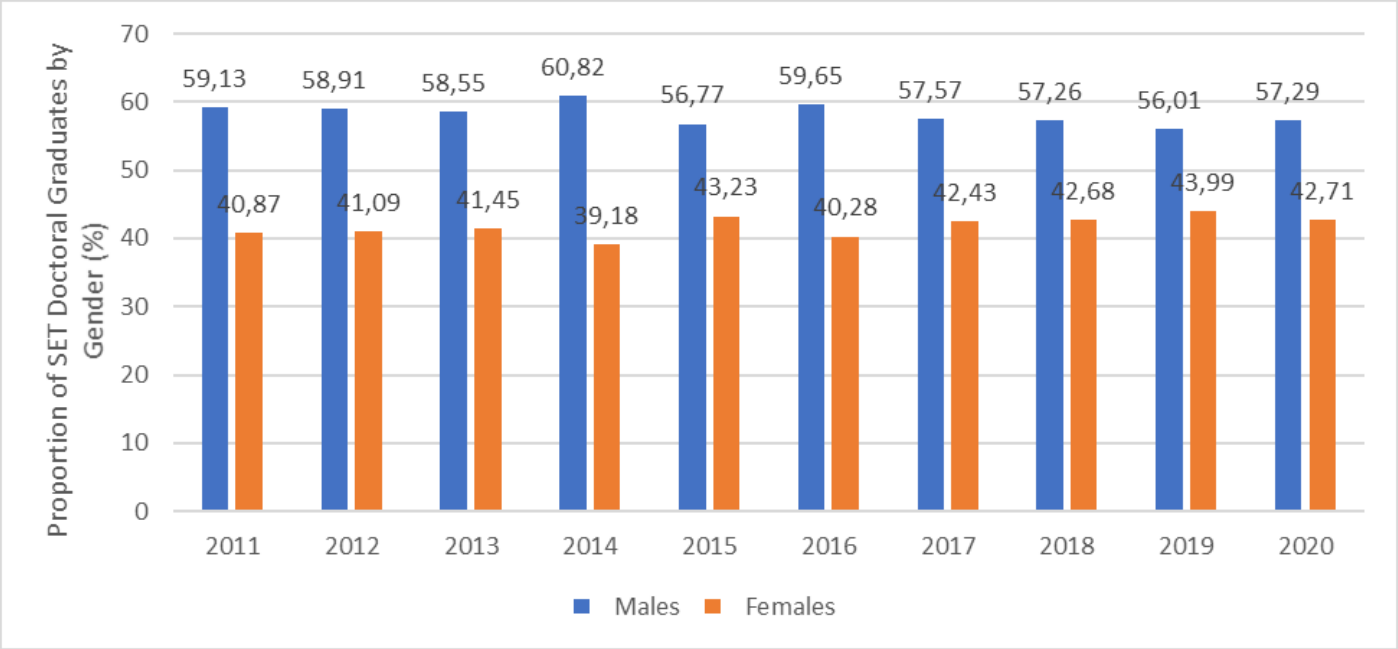



**Figure 4.8: Trend of SET Trends in SET doctoral graduates by gender**

*Source: Department of Higher Education and Training*

On a positive note, racial transformation continued. In 2020, the share of African doctoral graduates was 58,36%, up from 38,17% in 2011 (**Figure 4.9**). The proportion of Indian and coloured doctoral graduates is decreasing (from 8,43% and 4,80% in 2011 to 7,12% and 3,28% respectively in 2020).

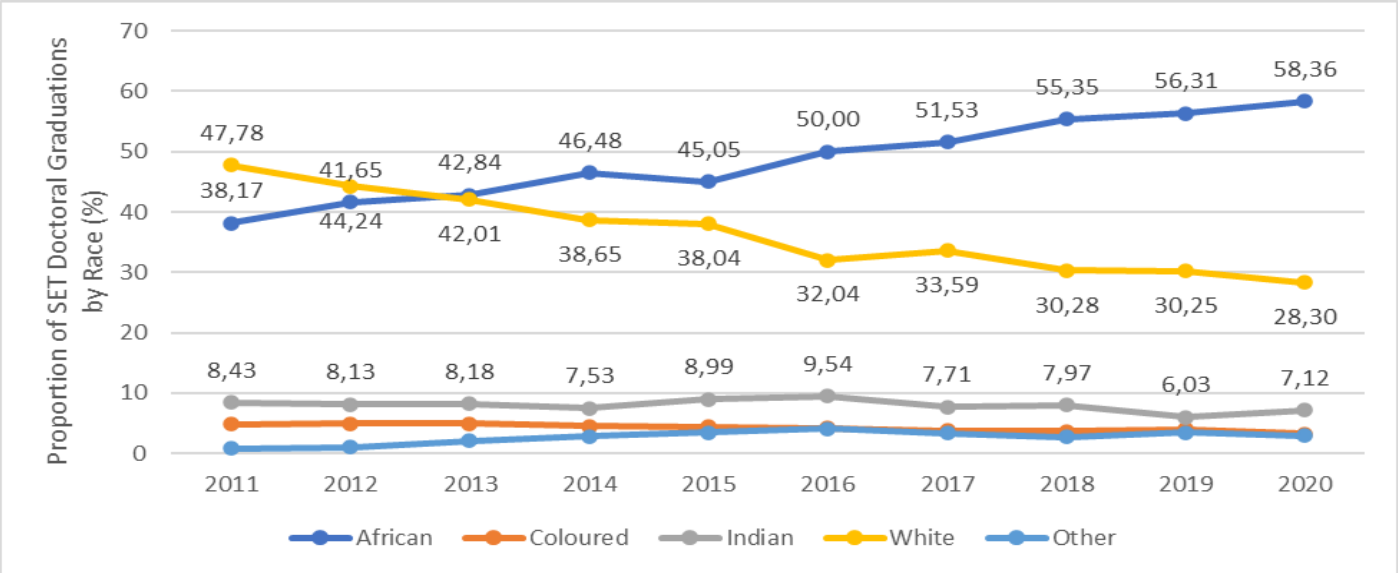



**Figure 4.9: Trend of SET Doctoral Graduates by Race**

*Source: Department of Higher Education and Training*

An increase in the total number of doctoral graduates translated to an increase in doctoral graduates per million population, from 30,31 in 2011 to 59,89 in 2020 (**Figure 4.10**).

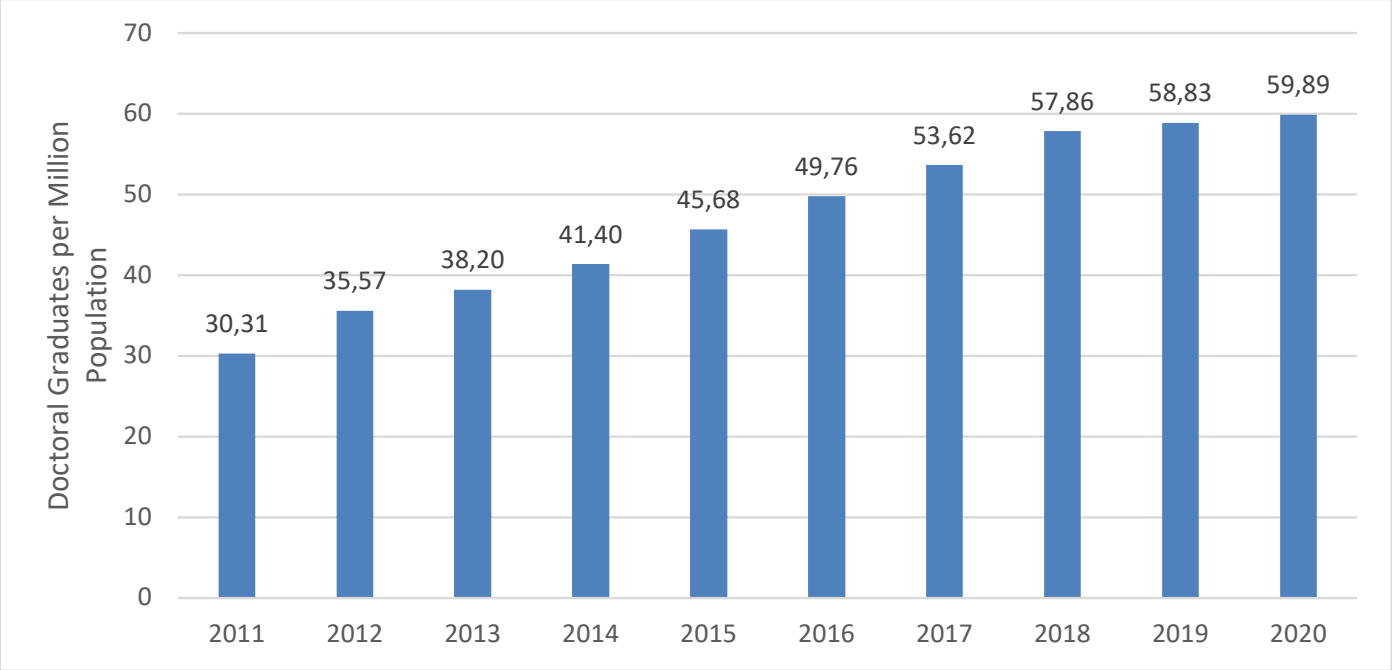



**Figure 4.10: Number of doctoral graduates per million population**

*Source: Department of Higher Education and Training*

The NDP target of producing 100 doctoral graduates per million population annually translates to 5 000 doctoral graduates annually by 2030. The total number of doctoral graduates in 2020 was 3 552.

### *4.1.4 Performance in Grade 12 maths, science and technical subjects*

***Mathematics***

As **Figure 4.11** shows, the proportion of national senior certificate (NSC) learners who passed Mathematics with 30% and above dropped from 54,6% in 2019 to 53,8% in 2020. The proportion of those who obtained distinctions in Mathematics increased from 2,0% to 3,2% over the same period. However, while the actual number of learners obtaining distinctions increased from 7 424 in 2020 to 7 725 in 2021, the proportion of all learners who wrote Mathematics decreased slightly, from 3,2% in 2020 to 3,0% in 2021. Although there is an increase in the proportion of learners passing Mathematics with 50% and above, this remained low in 2021 (23%).

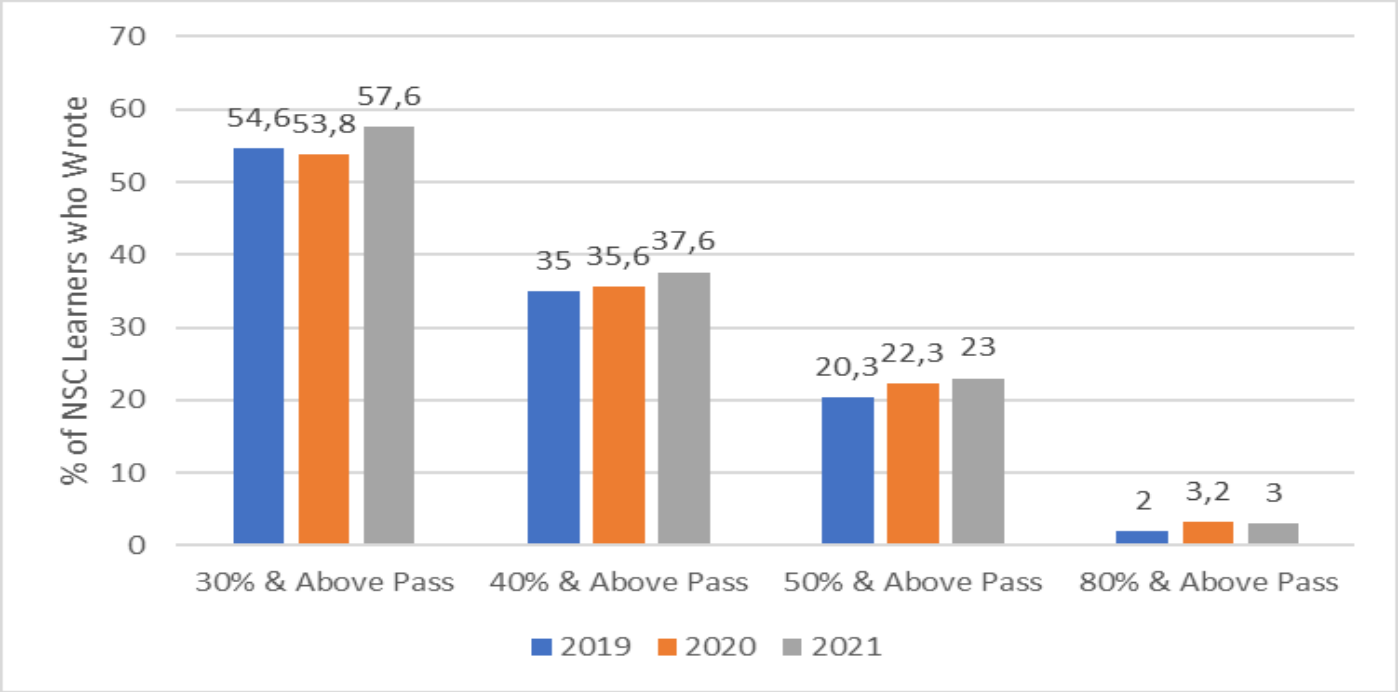



**Figure 4.11: Achievement at various levels for NSC Mathematics**

*Source: Department of Basic Education's 2021 NSC Examination Report*

***Physical Sciences***

At NSC level, Physical Science was more disrupted by the Covid-19 pandemic than Mathematics. As **Figure 4.12** shows, there was a drastic drop in the proportion of learners passing Physical Science at different levels in 2020, and 2021 percentages were still lower than the 2019 levels. The percentage of learners passing with distinctions for NSC Mathematics decreased from 3,7% in 2020 to 3,4% in 2021.

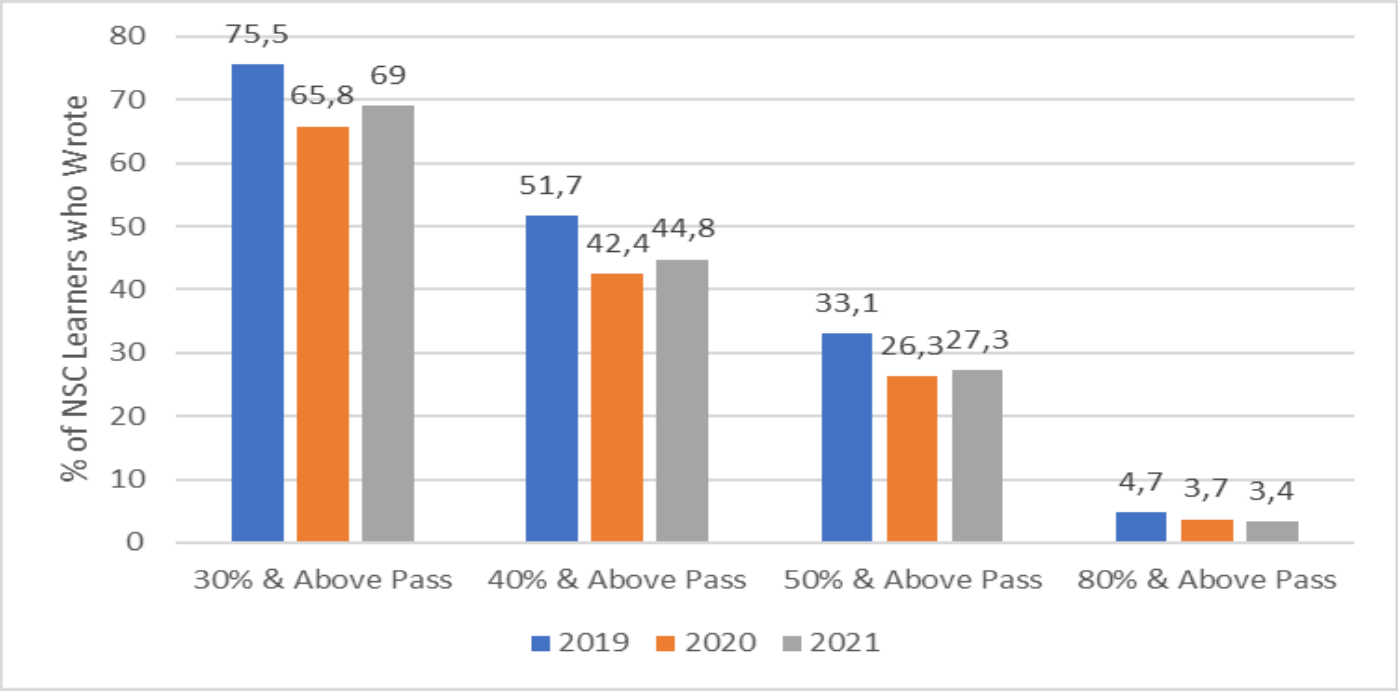



**Figure 4.12: Achievement at various levels for NSC Physical Science**

*Source: Department of Basic Education's 2021 NSC Examination Report*

***Technical subjects***

The technical subjects are important as they provide a pipeline of learners for technical and vocational training education (TVET) colleges and universities of technology. A pass rate for these subjects is very high, with most subjects at above 90% (see **Table 4.5**). Technical Mathematics is the only subject in which the pass rate is low. However, following a decrease in the pass rate for this subject in 2020, 2021 saw an impressive recovery, with a pass rate of 60,1%, up from 32,4% in 2020. The Technical Science pass rate also increased, from 80,4% in 2020 to 87,1% in 2021.

**Table 4.5: Pass rate on the national senior certificate technical subjects**

| | 2019 | 2020 | 2021 |
|---|---|---|---|
| Civil Technology (Civil Services) | 97.3 | 99.0 | 97.0 |
| Civil Technology (Construction) | 98.5 | 98.0 | 98.5 |
| Civil Technology (Woodworking) | 99.0 | 96.7 | 97.0 |
| Electrical Technology (Digital Systems) | 96.0 | 96.9 | 94.6 |
| Electrical Technology (Electronics) | 96.7 | 96.9 | 91.0 |
| Electrical Technology (Power Systems) | 95.6 | 94.9 | 94.4 |
| Mechanical Technology (Automotive) | 95.4 | 94.1 | 95.2 |
| Mechanical Technology (Fitting and Machining) | 97.7 | 96.8 | 97.1 |
| Mechanical Technology (Welding and Metal Works) | 92.3 | 88.8 | 90.6 |
| Technical Mathematics | 42.7 | 32.4 | 60.1 |
| Technical Science | 86.5 | 80.4 | 87.1 |

*Source: Department of Basic Education's 2021 NSC Examination Report*

## 4.2 Attractive research system

This section analyses the performance of the South African research system through the lens of scientific publications. Two emerging technologies, nanotechnology and artificial intelligence, are profiled in detail to assess the level of capability improvement taking place in the era of the 4th industrial revolution.

### *4.2.1 Scientific publications*

Although growth slowed in 2020, the number of scientific publications produced in South Africa increased. **Table 4.6** shows a breakdown of publications in the main fields of science. The fields in which the number of publications declined in 2020 are Social Sciences, Engineering and Technology, and Humanities. For the first time since 2013, the publication numbers for Social Sciences decreased. Most of the gain in the number of publications over the last year occurred in Natural Sciences (10,0%) and Medical and Health Sciences (9,4%).

**Table 4.6: Trends in scientific publications in various fields of science**

| | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|
| Natural Sciences | 8 525 | 9 045 | 9 923 | 11 207 | 11 207 | 12 932 | 13 589 | 14 268 | 15 499 | 17 056 |
| Medical and Health Sciences | 4 643 | 5 379 | 5 845 | 6 917 | 7 018 | 7 693 | 8 689 | 9 675 | 10 304 | 11 271 |
| Social Sciences | 2 927 | 3 723 | 3 368 | 4 115 | 4 346 | 5 209 | 7 711 | 7 784 | 8 779 | 8 217 |
| Engineering and Technology | 2 884 | 3 183 | 4 051 | 4 193 | 4 739 | 5 686 | 6 806 | 6 691 | 8 193 | 6 644 |
| Humanities | 951 | 958 | 1 018 | 1 121 | 1 302 | 1 486 | 2 391 | 2 152 | 2 437 | 2 319 |
| Agricultural Sciences | 843 | 696 | 982 | 779 | 863 | 911 | 951 | 1 102 | 1 171 | 1 216 |
| **Total publications** | **12 884** | **14 700** | **15 294** | **16 847** | **21 582** | **23 849** | **25 338** | **26 432** | **29 025** | **29 932** |

*Source: Web of Science Core Collection*

The decline in the number of scientific publications for Social Sciences and Engineering and Technology affected their share of total publications in South Africa. In Engineering and Technology, the proportion decreased from 28,2% in 2019 to 22,2% in 2020 (**Figure 4.13**). Social Sciences publications decreased from a share of 30,2% in 2019 to 27,5% in 2020.

Over a 10-year period, the fields that increased their share of South African scientific publications are Social Sciences (from 22,4% in 2011 to 27,5% in 2020), Medical and Health Sciences (from 36,0% to 37,7%) and Humanities (from 6,5% to 7,7%).

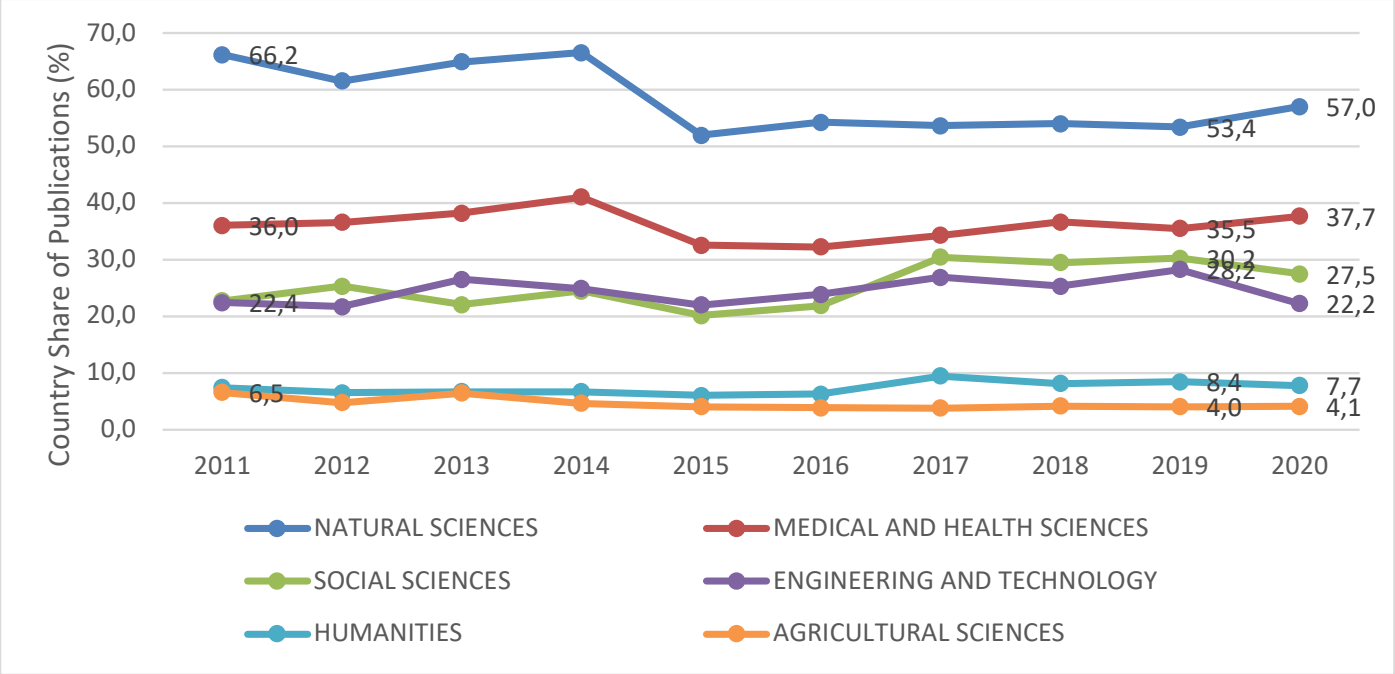



**Figure 4.13: Share of publications by scientific field**

*Source: Web of Science Core Collection*

### *4.2.2 Capability in emerging technologies*

To ensure South Africa's place in the 4th industrial revolution, scientific and technological advances in emerging technologies are required. The two prominent emerging technologies discussed here are nanotechnology and artificial intelligence.

### *Nanoscience and nanotechnologies*

South Africa's output of scientific publications on nanoscience and nanotechnology continues to grow in absolute terms, but also in terms of the world share of publications (**Table 4.7**).

**Table 4.7: Annual Nanotechnology Publications in South Africa**

| | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|
| Nanotechnology publications | 310 | 401 | 532 | 582 | 689 | 917 | 1 015 | 1 143 | 1 404 | 1 640 |
| % share of SA publications | 2,41 | 2,73 | 3,48 | 3,45 | 3,19 | 3,85 | 4,01 | 4,32 | 4,84 | 5,48 |
| % share of world nanotechnology publications | 0,25 | 0,29 | 0,34 | 0,33 | 0,35 | 0,42 | 0,42 | 0,44 | 0,49 | 0,57 |

*Source: Web of Science Core Collection*

Nanotechnology's share of total South Africa' publications more than doubled between 2011 (2,41%) and 2020 (5,48%). While very small, the country's share of world nanotechnology publications more than doubled over the same period, from 0,25% in 2011 to 0,57% in 2020.

As **Table 4.8** shows, in 2020 most nanotechnology and nanoscience publications were related to advanced manufacturing (50,85%), energy (37,87%) and waste and water (24,27%). South Africa's world share of nanotechnology and nanoscience publications was highest for mining and minerals (1,49%), followed by the chemicals industry (0,94%), construction (0,77%) and the medical and health sector (0,72%).

**Table 4.8: Nanotechnology publications by area of applications**

| | Number of publications | | World share (%) | | Share of SA nanotechnology publications | |
|---|---|---|---|---|---|---|
| | 2011 | 2020 | 2011 | 2020 | 2011 | 2020 |
| Advanced manufacturing | 169 | 834 | 0.33 | 0.63 | 54.52 | 50.85 |
| Agriculture and agroprocessing | 5 | 40 | 0.51 | 0.67 | 1.61 | 2.44 |
| Chemicals | 27 | 229 | 0.43 | 0.94 | 8.71 | 13.96 |
| Construction | 0 | 10 | 0.00 | 0.77 | 0.00 | 0.61 |
| Energy | 58 | 621 | 0.18 | 0.64 | 18.71 | 37.87 |
| Medical and health | 38 | 283 | 0.28 | 0.72 | 12.26 | 17.26 |
| Mining and minerals | 1 | 33 | 0.10 | 1.49 | 0.32 | 2.01 |
| Waste and water | 57 | 398 | 0.29 | 0.68 | 18.39 | 24.27 |

*Source: Web of Science Core Collection*

**Table 4.9** shows the leading institutions for nanotechnology and nanoscience publications in different target sectors. The University of Johannesburg leads in all areas except construction, in which Tshwane University of Technology makes the greatest contribution.

Other dominant institutions are the University of South Africa (2nd place for publications related to advanced manufacturing, energy and waste and water), the University of KwaZulu-Natal (2nd place for chemical industry-related publications) and the University of the Witwatersrand (2nd place for medical and health industry-related publications). The niche areas of agriculture and agroprocessing, construction, and mining and minerals are attracting other institutions, such as North West University, Durban University of Technology, Monash University, Nelson Mandela University and Vaal University of Technology.

**Table 4.9: Top 10 institutions for nanotechnology publications by application area, 2011-2020**

| | Advanced manufacturing | Agriculture and agroprocessing | Chemicals | Construction | Energy | Medical and health | Mining and minerals | Waste and water |
|---|---|---|---|---|---|---|---|---|
| University of Johannesburg | 849 | 12 | 126 | 7 | 408 | 155 | 35 | 390 |
| University of South Africa | 443 | 4 | 87 | 4 | 326 | 62 | 26 | 241 |
| University of KwaZulu-Natal | 402 | 6 | 105 | 3 | 280 | 125 | | 157 |
| University of the Witwatersrand | 483 | 2 | 40 | 5 | 218 | 126 | 29 | 106 |
| Council for Scientific and Industrial Research | 406 | - | 52 | 2 | 258 | 84 | 22 | 165 |
| University of the Free State | - | 2 | 29 | - | 175 | - | - | 100 |
| University of Pretoria | 273 | 3 | - | - | 293 | 34 | - | - |
| National Research Foundation | 265 | - | 45 | - | 169 | - | 6 | 88 |
| University of the Western Cape | 296 | - | - | - | 230 | 55 | 9 | 121 |
| Tshwane University of Technology | 196 | 2 | - | 19 | | 31 | 17 | 159 |
| iThemba LABS | - | - | 37 | - | 100 | - | - | - |
| Stellenbosch University | - | - | 41 | 5 | - | - | - | - |
| Rhodes University | 236 | 3 | 44 | - | - | 52 | 10 | 127 |
| Vaal University of Technology | - | - | - | - | - | | 7 | - |
| North West University | - | 7 | - | 2 | - | 53 | 16 | - |
| Durban University of Technology | - | 3 | - | - | - | - | - | - |
| Monash University | - | - | - | 2 | - | - | - | - |
| Nelson Mandela University | - | - | - | 2 | - | - | - | - |

*Source: Web of Science Core Collection*

### *Artificial Intelligence*

Artificial intelligence is a small but expanding area of research in South Africa. Its share of South Africa's scientific publications increased from 1,01% in 2011 to 2,5% in 2020 (**Table 4.10**). However, the pace for increase in the number of publications in this area is not fast enough to significantly increase the world share of publications (0,4% in 2011 and 0,5% in 2020).

**Table 4.10: Annual artificial intelligence publications in South Africa**

| | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|
| Artificial intelligence publications | 130 | 134 | 148 | 192 | 200 | 299 | 402 | 435 | 641 | 747 |
| % Share of SA publications | 1,01 | 0,91 | 0,97 | 1,14 | 0,93 | 1,25 | 1,59 | 1,65 | 2,21 | 2,50 |
| % Share of world AI publications | 0,40 | 0,37 | 0,37 | 0,42 | 0,39 | 0,49 | 0,51 | 0,42 | 0,48 | 0,50 |

*Source: Web of Science Core Collection*

*Note: The number of publications in artificial intelligence publication numbers in this publication are higher than those published in the 2021 report, as the expanded definition was used.*

In terms of discipline specialisation, in 2020 over 43% of SA publications were in machine learning. Machine learning complements big data generated daily around the world and connected devices (the Internet of Things) by enabling machines to learn and make certain decisions/predictions (using past data). Most of these disciplines complement one another. An example is knowledge-based/expert systems (with a world share of 3,88% in 2020), which can contribute to the capabilities of machine learning. Pattern recognition (with a world share of 0,66% in 2020) also goes along with computer vision and natural language processing.

**Table 4.11: Artificial intelligence publications by discipline**

| | Number of publications | | World share (%) | | Share of SA artificial intelligence publications | |
|---|---|---|---|---|---|---|
| | 2011 | 2020 | 2011 | 2020 | 2011 | 2020 |
| Knowledge-based systems | 14 | 43 | 1.50 | 3.88 | 10.77 | 5.76 |
| Machine learning | 6 | 324 | 0.13 | 0.46 | 4.62 | 43.37 |
| Robotics | 9 | 53 | 0.17 | 0.35 | 6.92 | 7.10 |
| Autonomous systems | 25 | 99 | 0.40 | 0.55 | 19.23 | 13.25 |
| Pattern recognition | 7 | 26 | 0.25 | 0.66 | 5.38 | 3.48 |
| Computer vision | 6 | 24 | 0.31 | 0.33 | 4.62 | 3.21 |
| Natural language processing | 0 | 13 | 0.00 | 0.35 | 0.00 | 1.74 |

*Source: Web of Science Core Collection*

As **Table 4.12** shows, South Africa's leading research institution in machine learning is the University of Cape Town (158 publications), followed by the University of KwaZulu-Natal (151) and the University of the Witwatersrand (122). The Department of Computer Science at the University of Cape Town was expected to introduce a master's degree in artificial intelligence from 2022. The Physics Department of the University of KwaZulu-Natal has taken machine learning to quantum level through research on quantum machine learning and quantum computing.

The University of Johannesburg leads on pattern recognition (32 publications), and is at third place in robotics, computer vision and natural language processing.

**Table 4.12: Top 10 institutions by artificial intelligence discipline publications, 2011-2020**

| | Knowledge-based systems | Machine learning | Robotics | Autonomous systems | Pattern recognition | Computer vision | Natural language processing |
|---|---|---|---|---|---|---|---|
| University of Cape Town | 13 | 158 | 40 | 90 | 31 | 8 | 5 |
| University of KwaZulu-Natal | 27 | 151 | 51 | 59 | 18 | 26 | 3 |
| University of Johannesburg | 21 | 109 | 39 | 48 | 32 | 19 | 6 |
| Stellenbosch University | 28 | 100 | 16 | 66 | 22 | 21 | 6 |
| University of Pretoria | 17 | 90 | 19 | 79 | 13 | 11 | 5 |
| University of the Witwatersrand | 21 | 122 | 20 | 39 | 10 | 12 | 6 |
| Council for Scientific and Industrial Research | - | 71 | 25 | 48 | 8 | 13 | 5 |
| University of South Africa | 26 | 39 | - | 34 | | | 7 |
| North West University | 17 | - | - | 32 | 8 | | 8 |
| Tshwane University of Technology | - | - | 21 | 32 | - | 8 | - |
| University of the Western Cape | - | 51 | - | - | - | - | 3 |
| National Research Foundation | - | - | 41 | - | 9 | - | - |
| University of the Free State | 13 | 32 | - | - | - | - | - |
| Nelson Mandela University | - | - | 18 | - | - | 3 | - |
| Rhodes University | 11 | - | - | - | - | - | - |
| International Centre for Genetic Engineering & Biotechnology | - | - | - | - | 4 | - | - |
| Central University of Technology | - | - | - | - | - | 4 | - |

*Source: Web of Science Core Collection*

## 4.3 Innovation-friendly environment

The innovation-friendly environment in South Africa looks at the environment in which enterprises operate using two indicators – broadband penetration among enterprises and opportunity-driven entrepreneurship – measuring the degree to which individuals pursue entrepreneurial activities as they see new opportunities, for example resulting from innovation.

### *4.3.1 Entrepreneurship*

Entrepreneurship is widely seen as an important driver of economic development, employment and innovations. However, it thrives in a favourable entrepreneurship ecosystem. This section summarises the level of entrepreneurship in South Africa by examining the National Entrepreneurship Context Index (NECI) and total early-stage entrepreneurial activity.

#### *The National Entrepreneurship Context Index*

In 2019, the Global Entrepreneurship Monitor (GEM) introduced the National Entrepreneurship Context Index (NECI), a single composite index that expresses the average state and quality of the entrepreneurial ecosystem of a country. As can be seen from **Table 4.13**, South Africa has the lowest NECI score of the BRICS countries.

South Africa's low NECI score means that the environment is not sufficiently supportive of entrepreneurship. Overall, South Africa has one of the lowest NECI indices of the 54 economies measured in 2018/19, and was ranked ahead of only Croatia, Guatemala, Paraguay, Puerto Rico and Iran. The report concludes that South Africa's entrepreneurial ecosystem shows little sign of improvement and in recent years has been declining.

**Table 4.13: NECI scores and ratings of BRICS countries in 2019**

| Name of Country | Brazil | Russia | India | China | South Africa |
|---|---|---|---|---|---|
| NECI score | 3,98 | 4,04 | 5,80 | 5,89 | 3,63 |
| Ranking | 43 | 41 | 6 | 4 | 49 |

*Source: Global Entrepreneurship Monitor report on South Africa, 2019*

*Note: The highest possible NECI score is 10.*

The main constraints and future areas of improving entrepreneurship that were identified in the report are summarised in **Table 4.14**. The GEM report on South Africa concluded that all the national framework conditions needed strengthening.

**Table 4.14: Top-ranked framework constraints and future focus areas for improving entrepreneurial activity**

| Current constraints on entrepreneurial activity | Future focus areas for improving entrepreneurial activity |
|---|---|
| 1. Government policies | 1. Education and training |
| 2. Capacity for entrepreneurship | 2. Government policies |
| 3. Financial Support for entrepreneurship | 3. Capacity for entrepreneurship |
| 4. Research and development transfer | 4. Market openness |
| 5. Education and training | 5. Cultural and social norms |

*Source: Global Entrepreneurship Monitor report on South Africa, 2019*

### *Total early-stage entrepreneurial activity*

A key indicator for entrepreneurship that is measured by the Global Entrepreneurship Monitor is total early-stage entrepreneurial activity (TEA). The TEA indicator provides a measure of the level of new enterprise creation in the economy. It measures the percentage of individuals between 18 and 64 years who are in the process of starting a business or who have been running businesses for less than three and a half years. **Table 4.15** compares South Africa's TEA with other BRICS member countries.

**Table 4.15: Comparison of South Africa's TEA with other BRICS countries**

| | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|
| Brazil | 17,2 | 21 | 19,6 | 20,3 | n/a | 23,3 |
| Russia | n/a | n/a | n/a | 6,3 | n/a | 9,3 |
| India | 14,2 | 10,8 | 10,6 | 9,9 | n/a | 15 |
| China | 15,5 | 12,8 | 10,3 | 9,3 | n/a | 8,7 |
| South Africa | 7 | 9,2 | 6,9 | 11 | n/a | 10,8 |

*Source: Global Entrepreneurship Monitor report on South Africa, 2019*

As is evident from the table, South Africa's TEA score is generally lower than other BRICS countries.

## *4.3.2 Digitalisation*

### *Digital competitiveness of South Africa*

The increasing digitalisation of the economy and society is changing the ways people act and interact. Digital capabilities are essential to ensure a country's growth and economic resilience. This section provides indicators for South Africa digital economy.

The Institute for Management Development (IMD) competitiveness reports analyse and rank the extent to which countries adopt and explore digital technologies leading to transformation in government practices, business models and society in general. In 2020, South Africa was ranked 60th of 63 countries in digital competitiveness (down from 48th in 2019) (**Table 4.16**). South Africa suffered the largest decline in relative ranking among the BRICS member countries in 2020's overall digital competitiveness ranking.

**Table 4.16: BRICS countries' digital competitiveness rankings**

| | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|
| Brazil | 54 | 55 | 57 | 57 | 51 |
| China | 35 | 31 | 30 | 22 | 16 |
| India | 53 | 51 | 48 | 44 | 48 |
| Russia | 40 | 42 | 40 | 38 | 43 |
| South Africa | 51 | 47 | 49 | 48 | 60 |

*Source: IMD Digital Competitiveness Reports*

To rank the competitiveness of countries, the IMD considers three factors, i.e. knowledge, technology and future readiness. As shown in **Table 4.17**, South Africa performed poorly in all three.

**Table 4.17: Digital competitiveness factor level performance of South Africa**

| | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|
| Knowledge | 49 | 49 | 52 | 54 | 60 |
| Technology | 51 | 53 | 52 | 51 | 55 |
| Future readiness | 47 | 42 | 43 | 44 | 57 |

*Source: IMD Digital Competitiveness Reports*

There was a significant decline in all the factors in 2020 compared to 2019, with future readiness displaying the largest decline.

***Broadband penetration***

According to the African Union Commission/OECD Africa's Development Dynamics report of 2021, 71% of firms in manufacturing and services in South Africa use email for conducting business. On the other hand, only 36% of firms have websites. Inadequate digital skills are the main reason for this. **Figure 4.14** compares the use of email and websites with other South African Custom Unions countries.

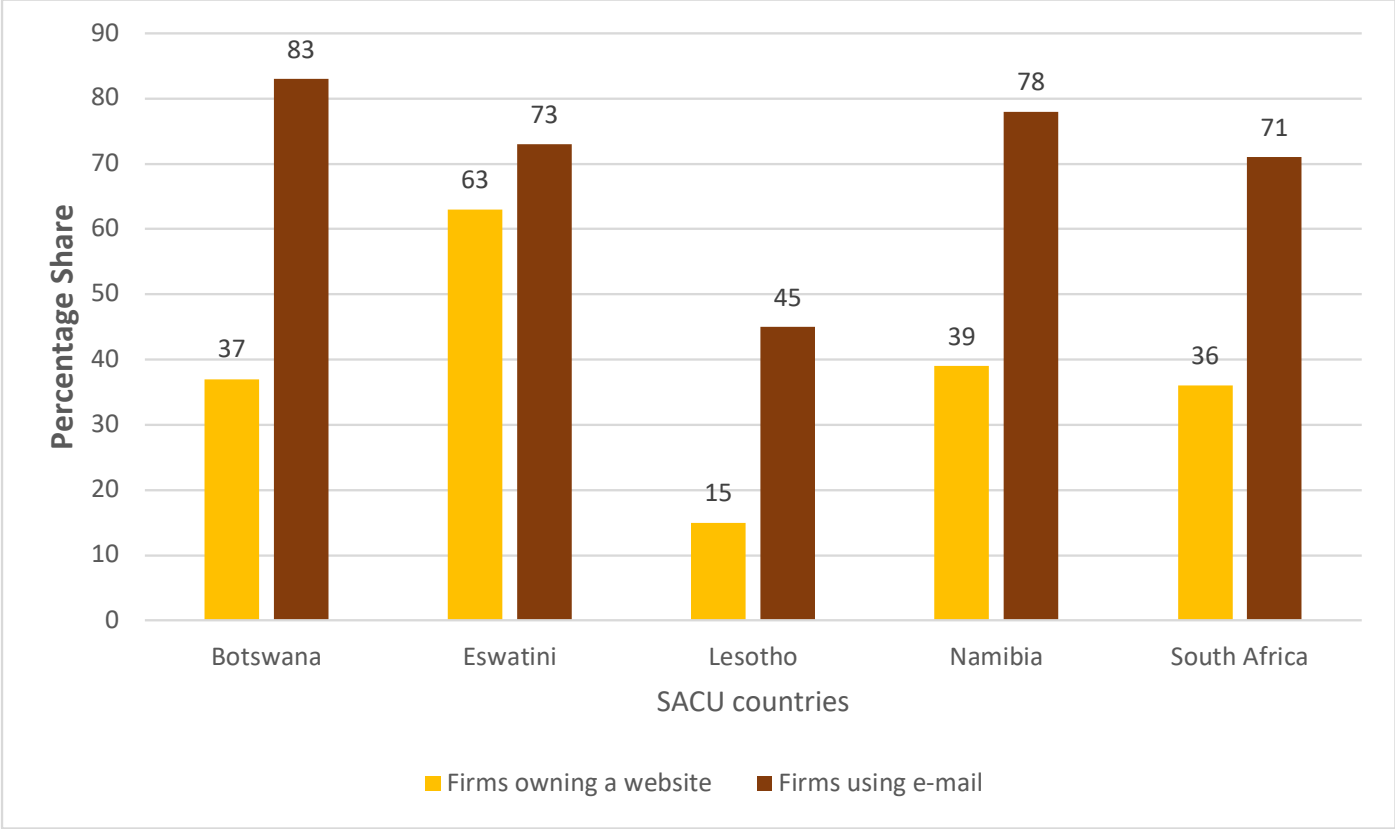



**Figure 4.14: Prevalence of digital adoption among manufacturing and service firms in Southern Africa**

*Source: AUC/OECD Africa's Development Dynamics 2021 Report*

**Figure 4.15** compares South Africa's fixed and mobile broadband speed with BRICS countries. According to the Independent Communications Authority of South Africa (ICASA) report of 2020, South Africa's speed was ranked at 96, the lowest in the group. However, South Africa's speed test ranking was the second best in the BRICS grouping at 60.




| | China | Russia | Brazil | India | South Africa |
|---|---|---|---|---|---|
| Fixed Broadband speed (rank) | 27 | 47 | 57 | 66 | 96 |
| Mobile speed (rank) | 6 | 96 | 77 | 128 | 60 |
| Fixed Broadband Download speed (Mbps) | 99,49 | 62,68 | 49,96 | 41,48 | 26,87 |
| Fixed Broadband Upload speed (Mbps) | 32,63 | 68,9 | 27,17 | 38,84 | 19,12 |
| Mobile Download speed (Mbps) | 68,21 | 20,43 | 24,45 | 11,58 | 31,36 |
| Mobile Upload speed (Mbps) | 19,04 | 9,79 | 9,12 | 13,5 | 9,41 |

**Figure 4.15: Speedtest benchmark of BRICS countries**

*Source: Ookla Speedtest Intelligence, 2019*

***Percentage of individuals with access to the Internet***

According to the International Technology Union (ITU), in South Africa 62% of individuals have access to the Internet, just under Botswana and Gambia (both at 63%).

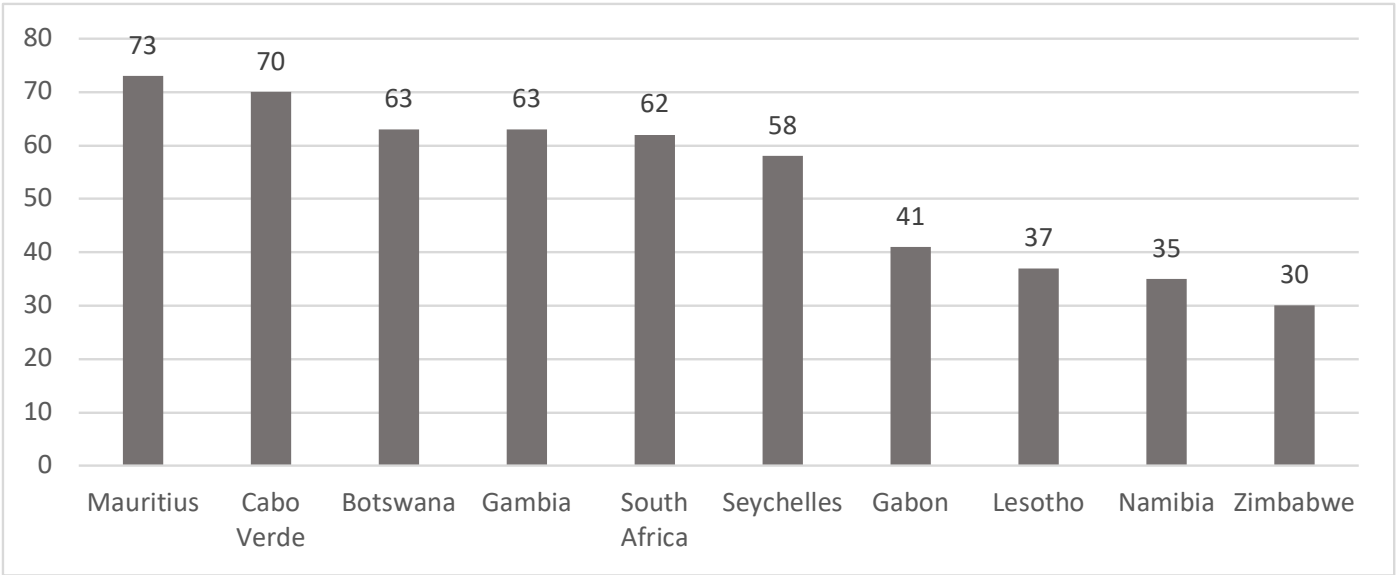



**Figure 4.16: Proportion of households with Internet access, Compound Annual Growth Rate 2017-2019**

*Source: ITU Report*

***Schools with access to ICT***

According to the ICASA's 2020 report on the State of the ICT Sector in South Africa, the total number of schools connected to the Internet based on universal service obligations imposed by ICASA was 6 949 as at 2019. As **Figure 4.17** shows, there has been a rapid increase in the number of schools with access to the Internet.

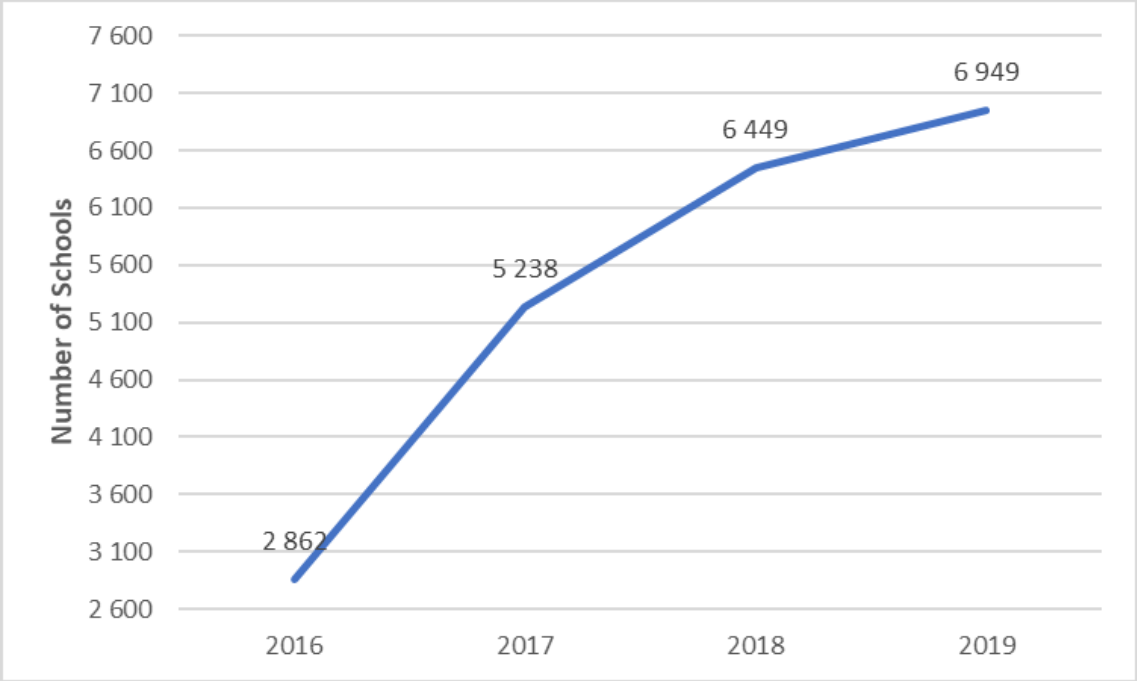



**Figure 4.17: Number of schools with Internet access in South Africa**

*Source: ICASA, 2020*

Access to the Internet is not an end goal to the school as its impact can be realised through the ICT skills of the educators and the digital structure within the school. **Figure 4.18** shows the average ICT maturity level of schools in South Africa per province. Level 1 is the lowest and level 5 the highest.

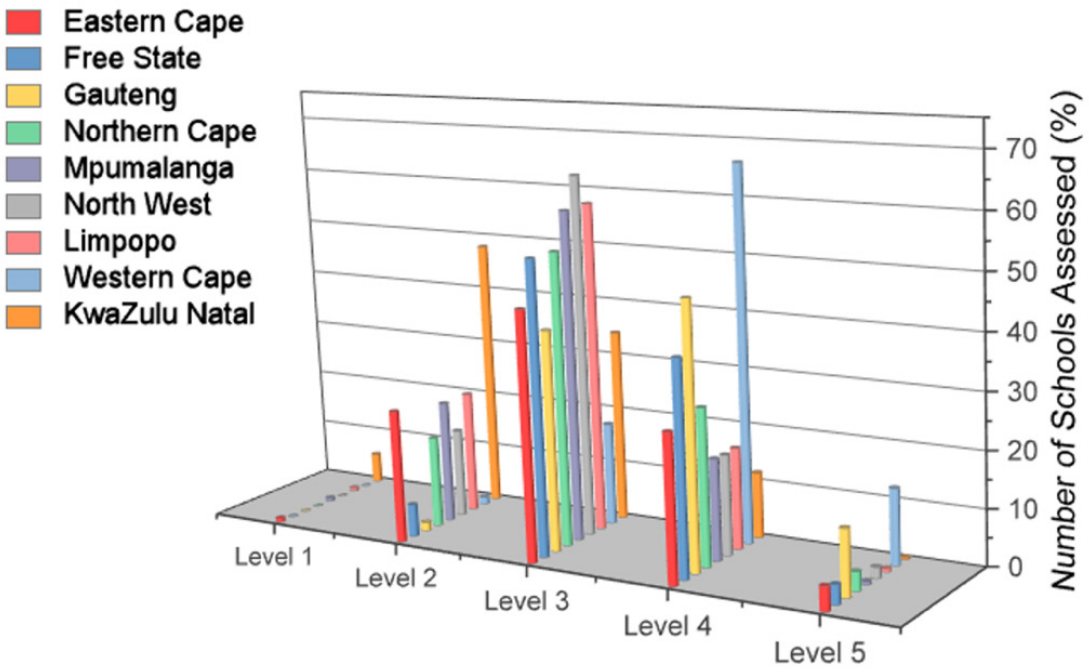



**Figure 4.18: Average ICT maturity level of schools in South Africa**

*Source: Department of Science and Innovation Schools eReadiness Assessment Report*

An average school in Gauteng and the Western Cape has level 4 ICT maturity, with several schools at level 5. Free State schools also have high level of ICT maturity, mainly level 3 followed by level 4. KwaZulu-Natal schools have on average ICT level 2 maturity, with relatively large number of schools at level 1.

# 5. SCIENCE, TECHNOLOGY AND INNOVATION INVESTMENTS

## 5.1 Science, technology and innovation funding and support

This section covers support instruments used by government to nurture, stimulate and promote innovation, specifically trends in government funding for R&D, and particular government programmes.

### *5.1.1 Government budget and funding for R&D*

In line with the guidelines provided by the OECD, the DSI annually compiles information about government's budget for funding scientific and technological activities (STAs). The three types of STAs are R&D, scientific and technical education and training (STET), and scientific and technological services (STS).

As **Table 5.1** shows, STA funding budget has been on the increase for the last four years. According to the DSI, the 2020/21 STA funding budget of R30,1 billion represents an increase of 6,95% from the previous year in nominal values and a decline of 5,14% in 2010 constant prices. The STS share of total STAs is increasing, but the other two categories (R&D and STET) are declining. The Covid-19 pandemic does not appear to have had any major impact on budget allocations for these three categories.

**Table 5.1: Government Budget on Scientific and Technological Activities**

| | STAfunding budget | R&D | STET | STS |
|---|---|---|---|---|
| | R billion | % share | | |
| 2016/17 | 23,4 | 57,5 | 17,8 | 24,7 |
| 2017/18 | 20,2 | 56,9 | 17,8 | 25,3 |
| 2018/19 | 26,0 | 53,5 | 16,9 | 29,6 |
| 2019/20 | 28,6 | 55,4 | 15,8 | 28,8 |
| 2020/21 | 30,1 | 55,3 | 15,6 | 29,1 |

*Source: Department of Science and Innovation's STA survey reports*

Some of the beneficiaries of STA funding are the science councils. **Table 5.2** shows the parliamentary grant allocations for the science councils in South Africa. It should be noted that different science councils have different funding models.

**Table 5.2: Parliamentary grant funding for the science councils, 2020/21**

| | Parliamentary grant (R' 000) |
|---|---|
| Academy of Science of South Africa | 27 783 |
| Agricultural Research Council | 965 279 |
| Council for Scientific and Industrial Research | 657 846 |
| Council of Geoscience | 253 693 |
| Human Sciences Research Council | 251 587 |
| Mintek | 276 236 |
| National Research Foundation | 859 469 |
| Necsa | 352 013 |
| South African Medical Research Council | 743 168 |
| South African National Biodiversity Institute | 1 373 |
| South African National Energy Development Institute | 80 471 |

*Source: 2020/21 Annual Reports*

The actual government funding of R&D is shown in **Figure 5.1**. This has more than doubled in the past decade, increasing from R9 billion in 2010/11 to R19 billion in 2019/20. A minor dip in 2018/19 was followed by a huge increase in 2019/20 (11,1%). The next R&D survey will show how Covid-19 affected government funding of R&D in South Africa.

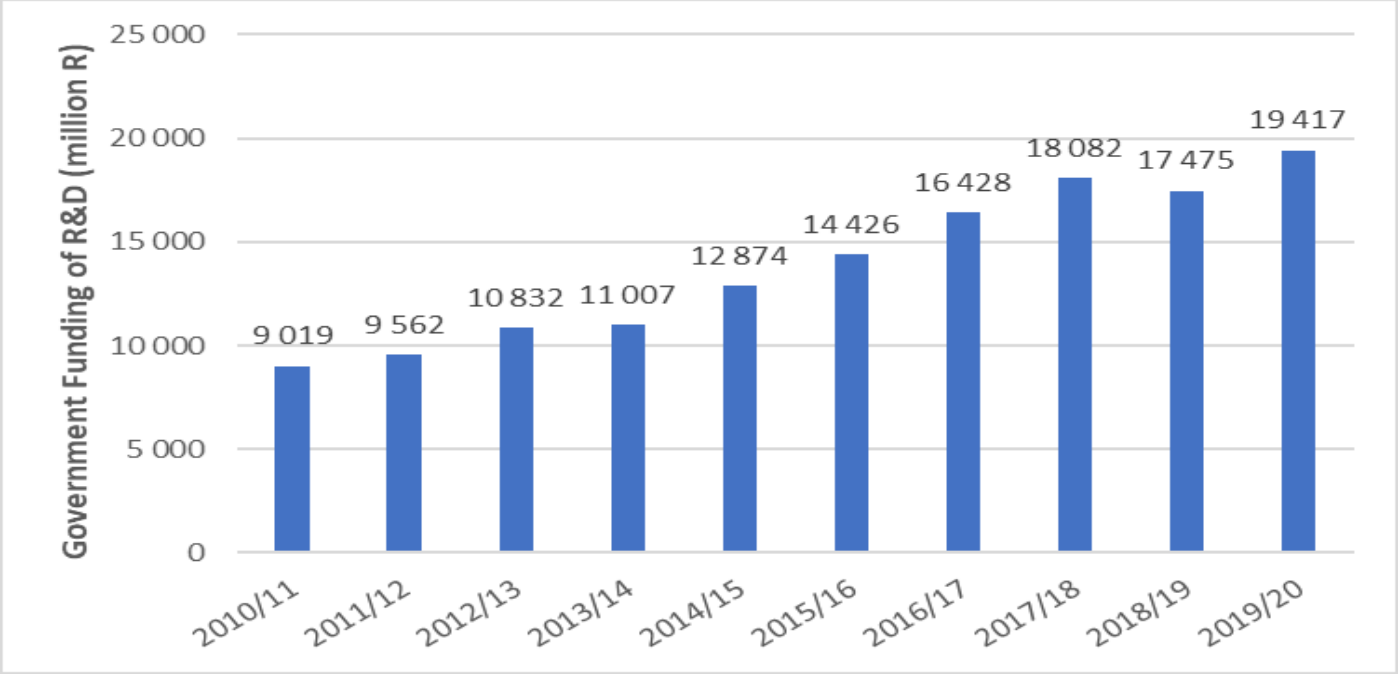



**Figure 5.1: Trends in government funding for research and development**

*Source: National Surveys of Research and Experimental Development*

**Table 5.3** shows a trend in government funding of R&D for various sectors, including the government's own public research institutes. Over the years, government's funding of R&D has been shifting towards the higher education sector, which has seen its share increase from 43,4% in 2010/11 to 58,6% in 2019/20. A large increase in business sector R&D funding in 2019/20 was very important as this sector has experienced a long-term period of significant loss of R&D funding from the government and other sources. This might be an early indication of an improved framework for STI budget coordination across government.

**Table 5.3: Government funding of R&D by sector**

| | Government | Science councils | Higher education | Business | Not-for-profit |
|---|---|---|---|---|---|
| | Million rands | | | | |
| 2010/11 | 990 | 2 932 | 3 918 | 832 | 38 |
| 2011/12 | 1 112 | 3 311 | 4 222 | 499 | 41 |
| 2012/13 | 1 269 | 3 369 | 4 598 | 684 | 114 |
| 2013/14 | 1 436 | 3 413 | 5 369 | 686 | 103 |
| 2014/15 | 1 712 | 4 319 | 6 021 | 690 | 131 |
| 2015/16 | 1 426 | 4 922 | 7 394 | 523 | 162 |
| 2016/17 | 1 531 | 5 077 | 9 222 | 454 | 144 |
| 2017/18 | 1 770 | 5 311 | 10 487 | 371 | 143 |
| 2018/19 | 1 898 | 4 644 | 10 501 | 215 | 217 |
| 2019/20 | 1 682 | 5 493 | 11 380 | 649 | 212 |

*Source: National Survey of Research and Experimental Development*

### 5.1.2 THRIP and SPII funding activities

***Technology and Human Resources for Industrial Innovation***

The Technology and Human Resources for Industry Programme (THRIP) promotes collaboration between industry and universities for technology transfer and human resources development. THRIP, a programme of the Department of Trade, Industry Competition (DTIC), was previously managed by the NRF and is now being managed directly by the DTIC.

Following this change, there were internal processes to optimise THRIP's impact on industry. This slowed the number of approvals from 25 in 2017/18 to only 8 in 2019/20 (see **Table 5.4**). The total grant amounts, projected investment/co-funding and students to be supported also decreased. A low number of THRIP grant approvals seem to have unlocked capacity for disbursements for previously approved applications.

**Table 5.4: Projects approved under THRIP**

| | Number of approvals | Grant amount (R million) | Projected investment (R million) | Disbursements | Students to be supported |
|---|---|---|---|---|---|
| 2017/18 | 25 | 208,1 | 298,7 | 20,1 | 135 |
| 2018/19 | 20 | 179,2 | 242,8 | 43,2 | 107 |
| 2019/20 | 8 | 92,2 | 128,2 | 52,6 | 47 |

*Source: DTIC 2019/20 Annual Incentive Report*

According to the DTIC, the eight approved projects in 2019/20 are distributed across Gauteng, KwaZulu-Natal and the Western Cape (based on the location of the industry partner). The four participating universities are North-West University, Stellenbosch University, the University of Pretoria and the University of Cape Town.

**Table 5.5** shows the sectoral distribution of projects approved by THRIP in 2019/20. Most of these are in the health sector.

**Table 5.5: Economic sectors funded through THRIP grants, 2019/20**

| Industry | Number of projects | Grant amount | Projected Investment (million R) |
|---|---|---|---|
| Agroprocessing | 1 | 8,4 | 9,1 |
| Health economy | 5 | 74,5 | 102,3 |
| Renewable energy | 1 | 5,2 | 7,0 |
| ICT services | 1 | 4,0 | 9,9 |
| **Total** | **8** | **92,2** | **128,2** |

*Source: DTIC 2019/20 Annual Incentive Report*

***Support Programme for Industrial Innovation***

The Support Programme for Industrial Innovation (SPII) is also located at the DTIC. SPII promotes technology development in various industries, with an emphasis on the creation of new and innovative products and processes.

Like THRIP, the number of projects SPII approved between 2017/18 and 2019/20 (see Table 5.6) decreased. Although SPII had a relatively large number of projects approved in 2019/20 (14), the total value of the grants approved was only R30,0 million, with industry co-funding of R55,0 million projected.

**Table 5.6: Approved projects under the Support Programme for Industrial Innovation**

| | Number of approvals | Grant amount (R million) | Projected investment (R million) |
|---|---|---|---|
| 2017/18 | 25 | 71,8 | 141,4 |
| 2018/19 | 18 | 40,9 | 76,8 |
| 2019/20 | 14 | 30,0 | 55,0 |

*Source: DTIC 2019/20 Annual Incentive Report"*

As **Table 5.7** shows, the approved projects in 2019/20 were based in Gauteng (6), KwaZulu-Natal (4) and Western Cape (4). Although the total value of approved grant funding for the Western Cape was only R10,5 million, the expected investment from the participating companies was R22,1 million.

**Table 5.7: Provincial distribution of projects approved for SPII, 2019/20**

| Province | Number of Approvals | Grant amount (R million) | Projected investment (R million) |
|---|---|---|---|
| Gauteng | 6 | 11,4 | 18,1 |
| KwaZulu-Natal | 4 | 8,1 | 14,9 |
| Western Cape | 4 | 10,5 | 22,1 |

*Source: DTIC 2019/20 Annual Incentive Report*

In terms of the industrial sectors, a huge share of SPII grant in 2019/20 (R14,9 million) was allocated to the electronics companies (**Table 5.8**). Transport equipment also had a relatively large allocation (R4,5 million).

**Table 5.8: Economic sectors funded through SPII grant, 2019/20**

| Industry | Grant amount (R million) | Projected investment (R million) |
|---|---|---|
| Health Economy | 1,8 | 2,1 |
| Electronics | 14,9 | 30,5 |
| Fabricated Metals | 0,8 | 0,9 |
| Non-metals | 2,0 | 2,5 |
| Transport Equipment | 4,5 | 9,9 |
| Veterinary Activities | 2,5 | 3,3 |
| Waste Recycling | 1,9 | 2,7 |
| Water Supply and Treatment | 1,6 | 3,1 |
| **Total** | **30,0** | **128,2** |

*Source: DTIC 2019/20 Annual Incentive Report*

### *5.1.3 TIA's Seed Fund Programme*

The Technology Innovation Agency's Seed Fund Programme (SFP) is a critical government funding instrument, which enables innovators in higher education institutions (HEIs), science councils and SMMEs to derisk research outputs for follow-on funding from the Technology Innovation Agency and/or other funders.

As shown in **Table 5.9**, during the period 2013-2020, a total of R361,3 million has been disbursed to the innovators based at HEIs and SMMEs. The percentage attributable to the HEIs over that period is 68,7%. As with THRIP and SPII, the funding for both the HEIs and the SMMEs is decreasing, possibly as a result of general budget constraints in government.

**Table 5.9: Seed Fund Programme disbursements**

| Year | HEIs | SMMEs | Total (SMME and HEIs) |
|---|---|---|---|
| 2013 | 45 941 858 | - | 45 941 858 |
| 2014 | 24 271 131 | 37 107 475 | 61 378 606 |
| 2015 | 44 871 839 | 23 000 000 | 67 871 839 |
| 2016 | 47 032 869 | 24 000 000 | 71 032 869 |
| 2017 | 33 292 862 | - | 33 292 862 |
| 2018 | 23 541 420 | 14 640 967 | 38 182 387 |
| 2019 | 22 006 651 | 9 774 273 | 31 780 924 |
| 2020 | 7 171 639 | 4 639 611 | 11 811 250 |
| **Total** | **248 130 270** | **113 162 326** | **361 292 597** |

*Source: Technology Innovation Agency*

The breakdown of disbursements by universities and science councils in Figure 4.2 shows that in the period 2013-2020, innovators who benefited most from the programme were based at the Stellenbosch University (R20,9 million), followed by the University of Cape Town (R16,6 million), Nelson Mandela University (R16,5 million), the University of KwaZulu-Natal (R15,6 million) and the University of Pretoria (R16,5 million).

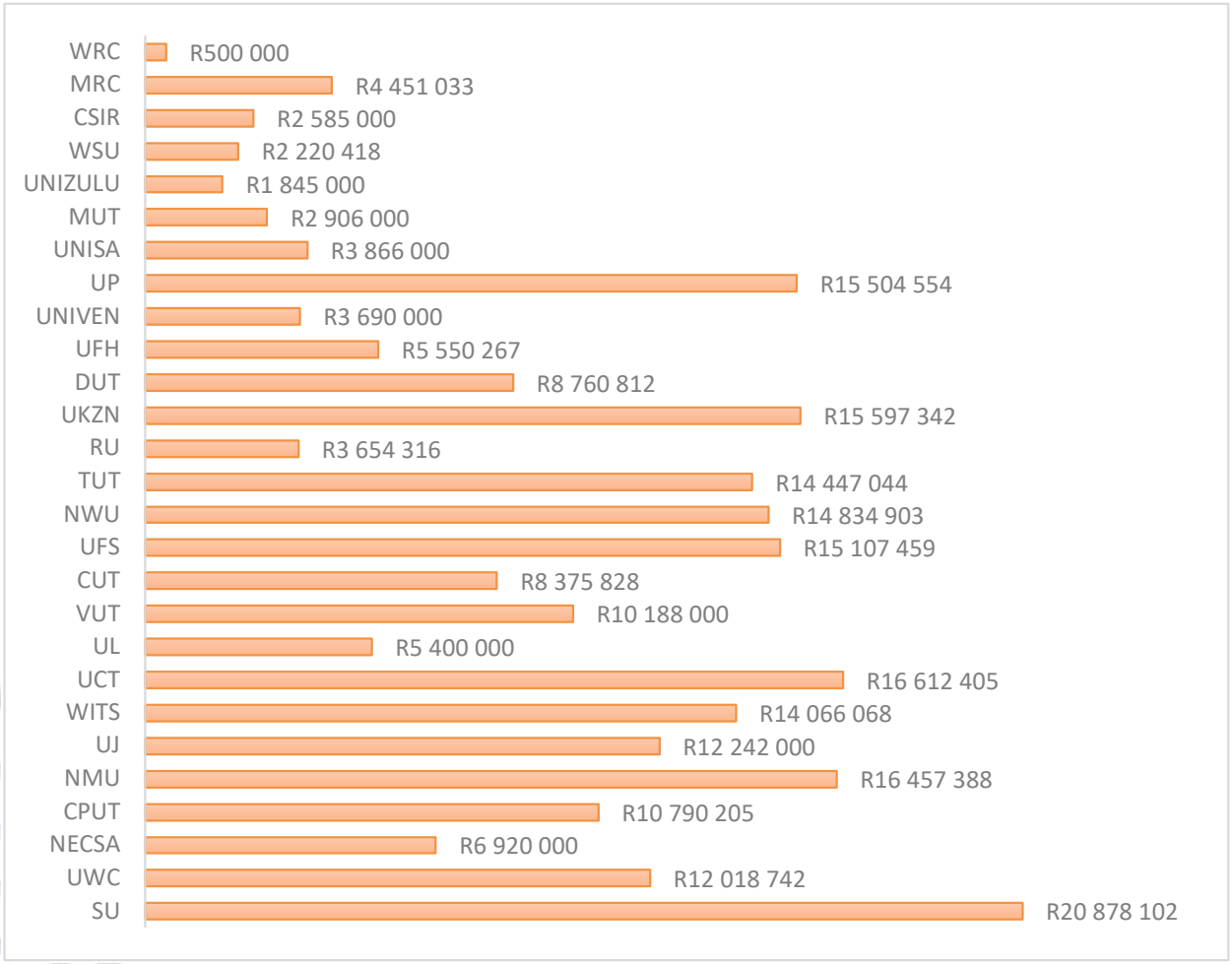



**Figure 5.2: Disbursements to higher education institutions and science councils, 2013-2020**

*Source: Technology Innovation Agency*

Among the science councils, most SFP disbursements went to innovators based at Necsa (R6,9 million), while the Water Research Commission received the lowest amount (R0,5 million).

**Figure 5.3** shows a breakdown of disbursements by different partners for the innovators based at the SMMEs. In the period 2014-2020, most disbursements were made by the Innovation Hub (R26,6 million), followed by the Craft and Design Institute (R21,8 million), SmartXchange (R17,3 million) and Invotech (R13,3 million).

The Innovation Hub, based in Pretoria supports the SMMEs in sectors such as smart industries (ICT and manufacturing), biosciences (health and industrial) and the green economy. The Craft and Design Institute is a not-for-profit company based in Cape Town which helps the SMMEs in the creative industry. SmartXchange, also called Durban Innovation Hub, is a Durban-based incubator. Lastly, Invotech is an incubator that is supported by the Durban University of Technology (DUT) and funded by the Small Enterprise Development Agency (SEDA).

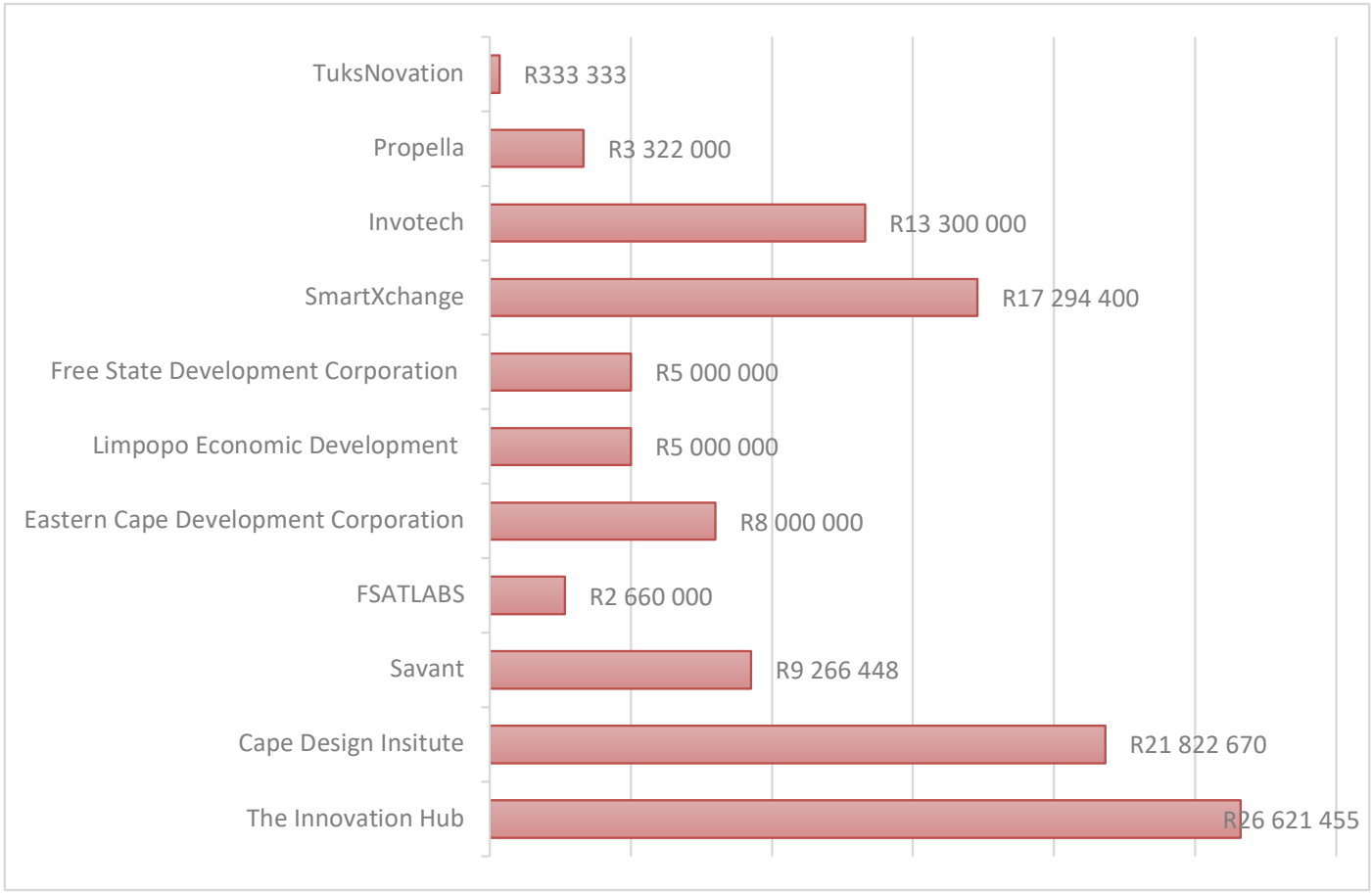



**Figure 5.3: Seed fund for SMMEs per implementing partner, 2014-2020**

*Source: Technology Innovation Agency*

**Figure 5.4** shows a breakdown of funding by sector for the higher education SFP portfolio. Most of funding share during 2013-2020 went to health (31%), followed by advanced manufacturing (19%).

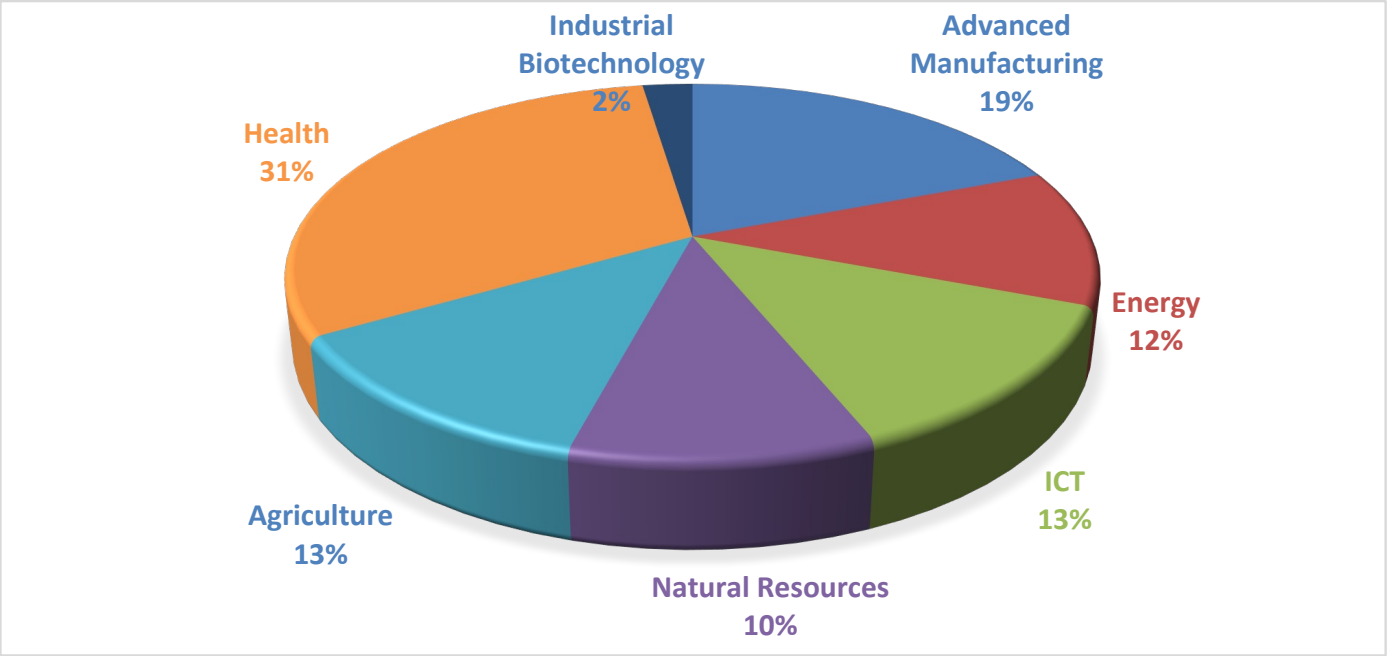



**Figure 5.4: Higher Education Seed Fund portfolio per sector, 2013-2020**

*Source: Technology Innovation Agency*

For the SMMEs, a large share of the SFP funding went to the ICT sector (47%), followed at a distance by advanced manufacturing (18%), health (12%), energy (10%) and agriculture (9%).

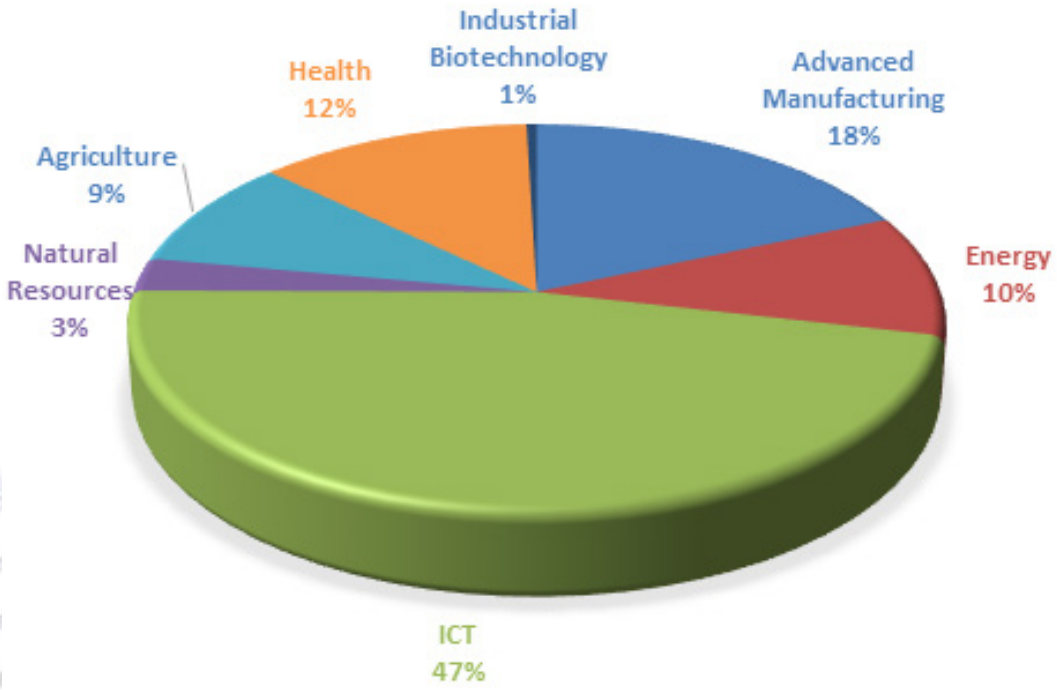



**Figure 5.5: SMME Seed Fund portfolio per sector, 2013-2020**

*Source: Technology Innovation Agency*

### 5.1.4 R&D tax incentive programme

The R&D tax incentive is a useful indirect government funding instrument for business sector R&D activities. Unlike the direct funding instruments, the programme allows companies to pursue the R&D priorities of their choice as long as criteria such as novelty are met. It was introduced in 2006, allowing companies to deduct 150% of approved R&D expenditure from tax due. The R&D tax incentive programme was revised on 1 October 2012, when the preapproval system was introduced as a condition for R&D expenditure tax deductions.

Tax forgone as a result of R&D tax incentive deductions is indirect government funding of business sector R&D. As **Table 5.10** shows, although the preapproval system was expected to remove uncertainties and increase R&D expenditure deductions, the amount of tax forgone fell, from R262 million in 2017/18 to R172 million in 2018/19. However, with a decrease in government funding of business sector R&D, this incentive is increasing relative to direct government funding of R&D (from 15,4% in 2007/08 to 80,2% in 2018/19).

**Table 5.10: Indirect government funding of business R&D through the R&D tax incentive**

| Reporting period | Tax revenue foregone (R'000) | Government funding of berd (R'000) | Tax forgone as % of government funding of business R&D |
|---|---|---|---|
| 2007/08 | 358 000 | 2 326 728 | 15,4 |
| 2008/09 | 594 000 | 2 567 140 | 23,1 |
| 2009/10 | 966 000 | 1 429 766 | 67,6 |
| 2010/11 | 1 216 000 | 832 173 | 146,1 |
| 2011/12 | 361 000 | 499 298 | 72,3 |
| 2012/13 | 197 000 | 683 669 | 28,8 |
| 2013/14 | 219 000 | 685 670 | 31,9 |
| 2014/15 | 207 000 | 690 396 | 30,0 |
| 2015/16 | 277 000 | 522 631 | 53,0 |
| 2016/17 | 233 000 | 453 958 | 51,3 |
| 2017/18 | 262 000 | 371 165 | 70,6 |
| 2018/19 | 172 000 | 214 541 | 80,2 |
| Information for 2019/20 and 2020/21 is not yet available. | | - | - |

*Source: 2020/21 R&D Tax Incentive Report to Parliament; R&D surveys*

Since the implementation of the preapproval system, the majority of approved applications for R&D tax deduction are in manufacturing, which has a 60,3% share of the approved R&D expenditure.

**Table 5.11: Estimated R&D expenditure on approved R&D tax incentive applications per industry sector (Oct. 2012 to Feb. 2021)**

| Sector | Number of approvals | Estimated R&D expenditure on approved applications | % Share of R&D expenditure |
|---|---|---|---|
| Agriculture, hunting, forestry and fishing | 79 | 11 712 360 348 | 14,6 |
| Mining and quarrying | 74 | 9 913 225 342 | 12,4 |
| Manufacturing | 581 | 48 223 287 056 | 60,3 |
| Electricity, gas and water supply | 20 | 1 583 099 760 | 2,0 |
| Construction | 8 | 79 500 000 | 0,1 |
| Wholesale and retail trade | 15 | 480 592 009 | 0,6 |
| Transport, storage and communication | 63 | 1 648 820 114 | 2,1 |
| Financial intermediation, real estate and business services | 185 | 6 226 373 345 | 7,8 |
| Community and social services | 4 | 94 751 633 | 0,1 |
| **Total** | **1 029** | **79 962 009 607** | **100.0** |

*Source: 2020/21 R&D Tax Incentive Annual Report to Parliament*

Although the financial intermediation, real estate and business services industry sector is second in terms of the number of approvals, it is the fourth in terms of a share of approved R&D expenditure for tax deduction. R&D activities in that sector are mainly geared towards the software-related innovations, which is less capital-intensive than agriculture, hunting, forestry and fishing, or mining and quarrying.

The preapproval system was introduced mainly to address the uncertainty about whether specific R&D activities qualified for tax deduction, especially with software development-related R&D activities. The sector with the highest percentage of non-approvals for tax deduction is the financial intermediation, real estate and business services sector. The Seed Fund information has shown that most SMMEs funded are those in the ICT sector. This is expected as South Africa is a service-based economy.

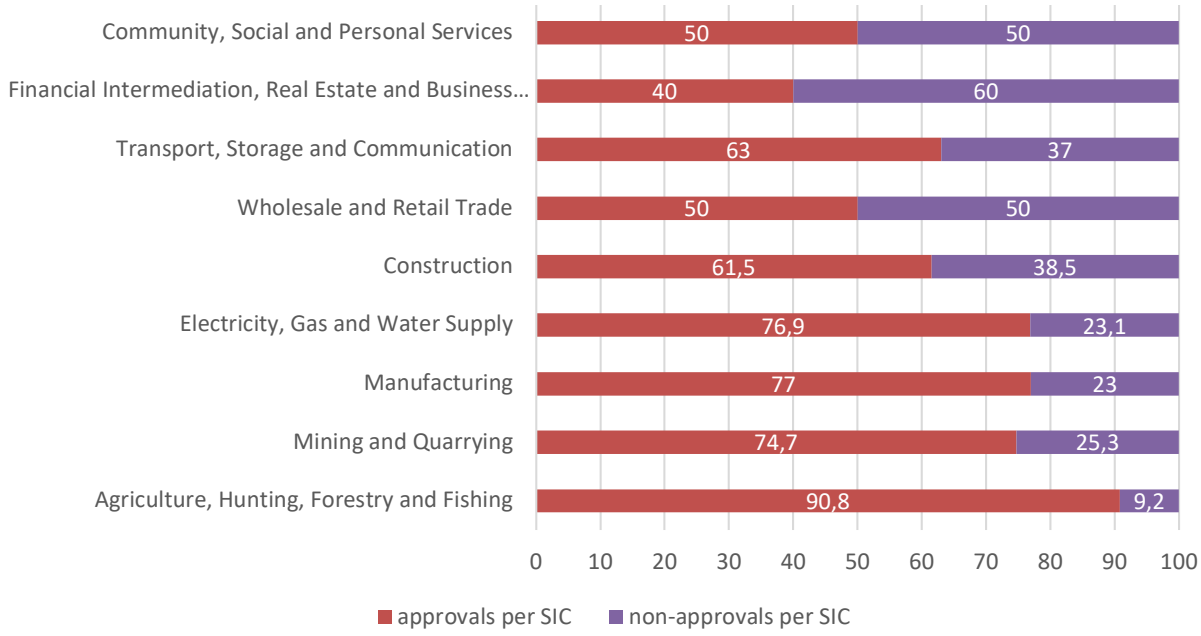



**Figure 5.6: Breakdown of approved and non-approved applications for R&D tax incentive per industry sector (Oct. 2012 to Feb. 2021)**

*Source: 2020/21 R&D Tax Incentive Annual Report to Parliament; R&D Surveys*

The industrial sectors with a higher percentage of approvals are likely to have R&D activities of unquestionable novelty. These are agriculture, hunting, forestry and fishing (90,8%), manufacturing (77,0%), electricity, gas and water supply (76,9%) and mining and quarrying (74,7%). Reviews of the R&D tax incentive programme in 2013, 2014 and 2016 were mainly aimed at removing uncertainty in terms of R&D definitions and qualification criteria.

**Table 5.12** shows the increase in proportion of very large companies (revenue of R100 million and above) participating in the R&D tax incentive programme following the implementation of the preapproval system. In 2021/20, they made up 38,5% of all participating companies, an increase from a cumulative value of 31,5% during November 2006-February 2021). The cumulative share during the period October 2012-February 2021 was 33,6%.

Companies with a revenue in the range of R10 million to R15 million were also well represented. However, these SMEs seem to have been negatively affected by the preapproval system as their cumulative percentage share for October 2012-February 2021 (24,1%) was lower than for November 2006-February 2021 (26,0%). In 2020/21, the share of companies in this revenue category participating in the programme was 17,3%.

The total share of all the participating 38 SMEs in 2020/21 was 36,5%. The 54 large and very large participating companies had a share of 52,0%. About 11,5% of participating companies in 2020/21 did not disclose their revenue. As the cumulative percentage share of participating SMEs during November 2006-February 2021 was 45,7%, one can deduce that the amendments to the R&D tax incentive brought more certainty to very large companies, they excluded some of the R&D activities of the SMEs.

**Table 5.12: number of companies participating in R&D tax incentive programme per turnover size**

| Turnover | Received in 2020/21 | | Cumulative (Oct. 2012 to Feb. 2021) | | Cumulative (Nov. 2006 to Feb. 2021) | |
|---|---|---|---|---|---|---|
| Turnover not indicated | 12 | 11,5% | 82 | 9,0% | 119 | 9,8% |
| R10m and below (SMEs) | 18 | 17,3% | 219 | 24,1% | 315 | 26,0% |
| R10m-R15m (SMEs) | 6 | 5,8% | 50 | 5,5% | 78 | 6,4% |
| R15m-R20m (SMEs) | 4 | 3,8% | 41 | 4,5% | 53 | 4,4% |
| R20m-R30m (SMEs) | 8 | 7,7% | 55 | 6,1% | 70 | 5,8% |
| R30m-R40m (SMEs) | 2 | 1,9% | 32 | 3,5% | 38 | 3,1% |
| R40m-R50m (large) | 5 | 4,8% | 33 | 3,6% | 41 | 3,4% |
| R50m-R100m (large) | 9 | 8,7% | 90 | 9,9% | 116 | 9,6% |
| R100m and above (very large) | 40 | 38,5% | 305 | 33,6% | 381 | 31,5% |
| **Total** | **104** | **100,0%** | **907** | **100,0%** | **1 211** | **100,0%** |

*Source: DSI 2020/21 R&D Tax Incentive Annual Report to Parliament*

## 5.2 Firm Investments

### *5.2.1 Venture capital investment*

Venture capital (VC) is an important source of funding to new enterprises, particularly innovative and technology-based small firms.

Seed and start-up capital represent the early-stage venture capital – the extent to which it supports new ventures. In 2020, seed and start-up capital made up 34% of investments by value of deals and 44,6% by number of deals (see Table 5.13). This was a lower share than in 2019, when seed and start-up capital made up 40,2% by value of deals and 53,8% by number of deals.

**Table 5.13: Venture capital investments contribution by stage of deal, 2020**

| | Investment by Value (%) | Investment by No. of Deals % |
|---|---|---|
| Seed capital | 3,8 | 8,9 |
| Start-up capital | 34,0 | 44,6 |
| Later-stage financing | 20,2 | 14,7 |
| Growth capital | 37,6 | 29,2 |
| Buyout capital | 1,5 | 1,3 |
| Rescue/turnaround | 2,8 | 0,9 |
| Replacement capital | 0,1 | 0,4 |

*Source: SAVCA 2020 Venture Capital Industry Survey*

As **Table 5.14** shows, there has been a steady increase in the value of investments and in the number of deals over the last decade, with the rate of growth rising most rapidly after 2015. While the growth rate slowed in 2020, the value of investments continued to rise, increasing by 13% in nominal terms from the previous year. The number of investments rose by 3% from 134 to 162. The number of fund managers investing rose from 69 in 2019 to 74 in 2020[8].

**Table 5.14: Venture capital investments per annum**

| | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|
| Investments per year – Value (R millions) | 211 | 288 | 183 | 273 | 372 | 933 | 968 | 1 067 | 1 230 | 1 390 |
| Investments per year- Number of deals | 11 | 8 | 19 | 67 | 69 | 116 | 147 | 134 | 162 | 167 |

*Source: SAVCA 2020 Venture Capital Industry Survey*

As shown in **Table 5.15**, in 2020 Manufacturing, Food and Beverage were the two leading sectors accounting for a little over one-quarter by value of all VC investments (25.2%) and 15.1% by number of deals. By number of deals, Business Products and Services (11.8%) and Software (11.6%) were the two leading sectors. Investments were widely spread over the other sectors.

8 Record investments show Covid – 19 has not dulled appetite for venture capital (Theunissen, 2021).

**Table 5.15: Number of venture capital investment deals by sector, 2020**

| | By value % | By no of deals % |
|---|---|---|
| Food and Beverage | 13,5 | 6,7 |
| Manufacturing | 11,7 | 8,4 |
| Fintech Specific | 8,8 | 11,2 |
| Consumer Products and Services | 8,8 | 7,5 |
| Medical Devices and Equipment | 7,8 | 5,9 |
| Agriculture | 7,5 | 9,6 |
| Software | 7,4 | 11,6 |
| Health | 7,2 | 5,6 |
| Business Products and Services | 5,4 | 11,8 |
| Energy | 4,9 | 2,9 |
| Telecommunications | 4,2 | 3,1 |
| Electronics/Instrumentation | 2,9 | 3,9 |
| Agriculture | 3,4 | 4,5 |
| Media/Entertainment/Gambling | 2,9 | 2,2 |
| eCommerce | 2,1 | 4,2 |
| Media/Entertainment/Gaming | 2,1 | 1,5 |
| eCommerce | 1,3 | 3,7 |
| Security Technology | 1,5 | 2,7 |
| Financial Services (non-Fintech) | 1,2 | 3,4 |
| Retailing/Distribution | 1,0 | 2,1 |
| Biotechnology | 0,9 | 0,7 |
| Mining, Minerals, Chemical Processing | 0,5 | 0,7 |
| Life Sciences | 0,4 | 1,2 |

*Source: SAVCA 2020 Venture Capital Industry Survey*

The percentage value of venture capital investments by sector in 2020 were largely the same as the previous year (**Table 5.16**). However, the share of business product services declined by more than half, from 10,9% in 2019 to 5,4% in 2020, and financial services (non-fintech) declined from 5,3% in 2019 to 1,3% in 2020.

The Western Cape has the highest number of venture capital firms. In 2020, a total of US$88 million was invested into tech start-ups in Cape Town. The Cape Town-Stellenbosch corridor is said to have 450 tech firms employing more than 40 000 people. This suggests that the Western Cape technology start-up ecosystem is larger than that of Nairobi and Lagos combined[9].

While the rate of increase of venture capital investments slowed somewhat in 2020, there was still an increase, even in a year in which private investment fell by 16%[10]. This suggests that there is continuing activity by new technology-based innovation firms and that this continues to attract investors.

9 Wesgro (2021)
10 Private investment declined from R 2 773 billion in 2019 to R2 323 in 2020, in constant (2021) Rand. Trade and Industrial Policy Strategies, The Real Economy Bulletin; 3rd quarter 2021:13.

**Table 5.16: Value of Venture Capital Investments by Sector**

| | 2019 | 2020 |
|---|---|---|
| | Share % | |
| Manufacturing | 13,8 | 11,7 |
| Food and beverages | 12,7 | 13,5 |
| Business products and services | 10,9 | 5,4 |
| Medical devices and equipment | 8,3 | 7,8 |
| Fintech specific | 6,9 | 8,8 |
| Software | 6,2 | 7,4 |
| Health | 6,2 | 7,2 |
| Consumer products and services | 6,1 | 8,8 |
| Financial services (non-fintech) | 5,3 | 1,3 |
| Energy | 4,6 | 4,9 |
| Electronics/instrumentation | 3,8 | 2,9 |
| Agriculture | 3,4 | 7,5 |
| Telecommunications | 2,4 | 4,2 |
| Life sciences | 2,2 | 0,4 |
| Electronic commerce | 2,2 | 2,1 |
| Media/entertainment/gaming | 1,3 | 2,2 |
| Biotechnology | 1,3 | 0,9 |
| Security technology | 1,1 | 1,5 |
| Retailing/distribution | 0,8 | 1,0 |
| Mining, minerals and chemical processing | 0,5 | 0,5 |

*Sources: SAVCA 2019 & 2020 Venture Capital Industry Survey*

The growth of venture capital investments should be seen in the context of the very low baseline from which the growth is measured (VC investments still have a very small share of total business investment and of business investment in R&D). Furthermore, VC investments have benefited from section 12J of the Income Tax Act. This section, introduced in 2008, offered South Africans a tax rebate if they invested in an approved venture capital company. Investors received an immediate tax deduction equal to 100% of the amount they invested. However, the incentive was discontinued in June 2021, which is likely to have a negative impact on VC investment going forward.

### *5.2.2 R&D expenditure and funding in the business sector*

There was a significant decline (29%) in R&D expenditure by the business sector in 2019/20 from the previous year (**Table 5.17**), far larger than the decline in aggregate private sector investment (16%).

**Table 5.17: R&D expenditure by the business sector**

| | BERD (R 000 in constant 2010 Rand values) |
|---|---|
| 2010/11 | 13 081 666 |
| 2011/12 | 12 894 165 |
| 2012/13 | 12 442 685 |
| 2013/14 | 13 103 667 |
| 2014/15 | 14 028 004 |
| 2015/16 | 13 814 995 |
| 2016/17 | 13 820 449 |
| 2017/18 | 14 058 812 |
| 2018/19 | 12 320 234 |
| 2019/20 | 8 735 099 |

*Source: National Surveys of Research and Experimental Development .*

As shown in **Table 5.18**, the share of the business sector in gross expenditure on R&D (GERD) has been declining consistently since 2010/11. There was a further very significant decline in 2019/20. The share of the business sector in GERD in 2019/20 was only 31%, down from almost half of GERD a decade earlier.

**Table 5.18: Business expenditure on R&D as % of GERD**

| | BERD as % of GERD |
|---|---|
| 2010/11 | 49,7 |
| 2011/12 | 47,1 |
| 2012/13 | 44,3 |
| 2013/14 | 45,9 |
| 2014/15 | 45,3 |
| 2015/16 | 42,7 |
| 2016/17 | 41,4 |
| 2017/18 | 41,0 |
| 2018/19 | 39,3 |
| 2019/20 | 31,0 |

*Source: National Surveys of Research and Experimental Development*

Business sector funding of R&D in government and higher education increased while business sector funding of R&D in the science councils and non-profit sector declined (**Table 5.19**).

**Table 5.19: Business-funded R&D by sector**

| | Total | Government | Science councils | Higher education | Business | Non-Profit |
|---|---|---|---|---|---|---|
| | R'000 | | | | | |
| 2010/11 | 8 128 246 | 2 406 | 198 206 | 367 340 | 7 528 667 | 31 627 |
| 2011/12 | 8 663 105 | 1 355 | 67 614 | 505 510 | 8 056 545 | 32 081 |
| 2012/13 | 9 152 042 | 11 552 | 135 729 | 577 527 | 8 402 340 | 24 894 |
| 2013/14 | 10 615 902 | 1 759 | 419 469 | 588 598 | 9 552 717 | 53 359 |
| 2014/15 | 11 981 974 | 290 | 222 892 | 885 280 | 10 810 428 | 63 084 |
| 2015/16 | 12 578 499 | 41 109 | 326 648 | 770 448 | 11 384 710 | 55 585 |
| 2016/17 | 14 045 892 | 1 261 | 483 166 | 906 651 | 12 586 109 | 68 705 |
| 2017/18 | 16 066 846 | 519 | 354 820 | 679 563 | 14 963 198 | 68 747 |
| 2018/19 | 14 534 123 | 4 614 | 206 648 | 463 413 | 13 787 512 | 71 937 |
| 2019/20 | 9 358 770 | 42 664 | 191 520 | 519 848 | 8 541 773 | 62 965 |

*Source: National Surveys of Research and Experimental Development*

Overall, business sector funding of R&D outside the business sector increased from R746,6 million in 2018/19 to R816,999 million in 2019/20 (a nominal increase of 9%).

Business sector funding for R&D is largely spent within the business sector (**Table 5.20**). In 2019/20 there was a decline in this share, but it remains above 91% and relatively unchanged over the decade.

**Table 5.20: Proportion of business funding for R&D by sector (%)**

| | Government | Science councils | Higher education | Business | Non-profit |
|---|---|---|---|---|---|
| 2010/11 | 0,0 | 2,4 | 4,5 | 92,6 | 0,4 |
| 2011/12 | 0,0 | 0,8 | 5,8 | 93,0 | 0,4 |
| 2012/13 | 0,1 | 1,5 | 6,3 | 91,8 | 0,3 |
| 2013/14 | 0,0 | 4,0 | 5,5 | 90,0 | 0,5 |
| 2014/15 | 0,0 | 1,9 | 7,4 | 90,2 | 0,5 |
| 2015/16 | 0,3 | 2,6 | 6,1 | 90,5 | 0,4 |
| 2016/17 | 0,0 | 3,4 | 6,5 | 89,6 | 0,5 |
| 2017/18 | 0,0 | 2,2 | 4,2 | 93,1 | 0,4 |
| 2018/19 | 0,0 | 1,4 | 3,2 | 94,9 | 0,5 |
| 2019/20 | 0,5 | 2,0 | 5,6 | 91,3 | 0,7 |

*Source: National Surveys of Research and Experimental Development*

As shown in **Table 5.21**, there has been a notable decline in the capacity of the business sector to attract foreign funding for R&D. A particularly significant decline in 2017/18 was followed by a further decline of 16% in 2018/19. In 2019/20, foreign-funded R&D in the business sector almost tripled. However, this increase comes after two years of significant decline. In real terms, foreign-funded R&D in 2019/20 was still substantially below that of a decade before. Foreign-funded R&D in the business sector was 220% more in 2009/10 than in 2019/2020.

**Table 5.21: Foreign-funded R&D in the business sector**

| | Foreign funding for business sector R&D (R'000) |
|---|---|
| 2009/10 | 1 538 917 |
| 2010/11 | 1 442 334 |
| 2011/12 | 1 562 277 |
| 2012/13 | 1 898 865 |
| 2013/14 | 1 226 966 |
| 2014/15 | 1 418 823 |
| 2015/16 | 1 532 766 |
| 2916/17 | 1 338 662 |
| 2017/18 | 474 762 |
| 2018/19 | 400 462 |
| 2019/20 | 1 168 659 |

*Source: National Surveys of Research and Experimental Development*

The business sector's share of foreign funding for R&D in South Africa (**Table 5.22**) has also declined since 2010/11. Whereas a decade ago some 60% of foreign funding for R&D in South Africa went to the business sector, in 2018/19 the sector received only 10%. In 2019/20, one-quarter of foreign-funded R&D was located in the business sector.

**Table 5.22: Proportional foreign-funded R&D in the business sector**

| | Business sector's share of foreign funding for R&D |
|---|---|
| 2010/11 | 59,0 |
| 2011/12 | 46,9 |
| 2012/13 | 38,2 |
| 2013/14 | 37,0 |
| 2014/15 | 39,8 |
| 2015/16 | 36,4 |
| 2016/17 | 32,1 |
| 2017/18 | 12,1 |
| 2018/19 | 10,0 |
| 2019/20 | 25,1 |

*Source: National Surveys of Research and Experimental Development*

There has been a steady increase in the business sector's share of R&D expenditure in financial intermediation, real estate and business services. In 2010/11, this sector accounted for a little more than one-third of all business expenditure on R&D (33,9%). By 2017/18, it accounted for nearly half. The shares of most other sectors in business expenditure on R&D declined. The steadily decreasing share of the manufacturing sector is particularly significant. In 2010, manufacturing received the highest share in business expenditure on R&D (35,7%), but in 2018/19 it received only 21,9%, less than half the share of financial intermediation, real estate and business services.

**Table 5.23: Proportional business sector R&D expenditure by industry**

| | 2010/11 | 2011/12 | 2012/13 | 2013/14 | 2014/15 | 2015/16 | 2016/17 | 2017/18 | 2018/19 | 2019/20 |
|---|---|---|---|---|---|---|---|---|---|---|
| Agriculture, hunting, forestry and fishing | 1,6 | 2 | 2,7 | 3,1 | 3,5 | 3,5 | 3,2 | 2,5 | 3,9 | 6,6 |
| Mining and quarrying | 10,5 | 12,9 | 14,7 | 14,2 | 10,1 | 8,8 | 7,2 | 6,9 | 12,1 | 6,4 |
| Manufacturing | 35,7 | 33,9 | 32,9 | 32,2 | 33,9 | 32,2 | 27,8 | 28,2 | 21,9 | 32,3 |
| Electricity, gas and water supply | 5,3 | 4,7 | 3,6 | 3 | 4,1 | 3,2 | 3,7 | 4 | 4,9 | 7,1 |
| Construction | 0 | 0,1 | 0,1 | 0,1 | 0 | 0 | 0 | 0 | 0,1 | 0,05 |
| Wholesale and retail | 6,2 | 5,2 | 1,7 | 0,9 | 0,6 | 0,3 | 0,4 | 0,5 | 0,7 | 0,8 |
| Transport, storage and communication | 3,5 | 4,6 | 4,4 | 3,8 | 4,8 | 6,5 | 10,4 | 6,2 | 7,7 | 4,7 |
| Financial intermediation, real estate and business services | 33,1 | 34,8 | 37 | 40,1 | 40,3 | 42,8 | 44,3 | 48,8 | 44,3 | 37,7 |
| Community, social and personal services | 4,1 | 1,6 | 2,8 | 2,6 | 2,7 | 2,7 | 2,9 | 2,8 | 4,4 | 4,3 |
| **Total** | **100** | **100** | **100** | **100** | **100** | **100** | **100** | **100** | **100** | **100** |

*Source: National Surveys of Research and Experimental Development*

2019/20 saw a reversal in these trends, with major declines in the share of financial intermediation, real estate and business services, mining and quarrying, and transport, storage and communications. The shares of manufacturing and agriculture, hunting, forestry and fishing increased significantly.

While R&D in high-technology manufacturing as a percentage of total R&D in manufacturing increased in 2018/19 (15,4%) and again in 2019/20 (15,6%), the general trend over the decade has been for this share to decline (Table 5.24).

More than two-thirds of manufacturing R&D goes to medium-technology sectors. This share increased to 68,5% in 2019/20. The most significant increase was in petroleum products, chemicals, rubber and plastics.

The share of the low-technology sectors in total manufacturing R&D has tended to increase over the decade. While the share of low technology sectors declined in 2019/20 by comparison with the previous year, its share remains above that of high technology sectors. Initially well below, low technology manufacturing now accounts for a larger share of total manufacturing R&D than is accounted for by high technology manufacturing.

Overall, R&D data for the manufacturing sector for the decade does not suggest that there is a tendency towards a higher technology intensity. Indeed, the tendency is the reverse.

**Table 5.24: Percentage share of R&D expenditure in the manufacturing sector by technology intensity**

| | 2010/11 | 2011/12 | 2012/13 | 2013/14 | 2014/15 | 2015/16 | 2016/17 | 2017/18 | 2018/19 | 2019/20 |
|---|---|---|---|---|---|---|---|---|---|---|
| **High technology** | **16,4** | **18,0** | **18,9** | **19,6** | **15,7** | **12,8** | **15,3** | **14,0** | **15,4** | **15,6** |
| Radio, television, instruments, watches and clocks | 16,4 | 18,0 | 18,9 | 19,6 | 15,7 | 12,8 | 15,3 | 14,0 | 15,4 | 15,6 |
| **Medium technology** | **72,8** | **69,5** | **67,7** | **66,4** | **71,2** | **73,7** | **73,8** | **72,7** | **65,1** | **68,5** |
| Petroleum products, chemicals, rubber and plastic | 33,3 | 38,9 | 32,8 | 33,1 | 40,8 | 40,5 | 41,3 | 37,8 | 25,3 | 33,7 |
| Other non-metal mineral products | 2,4 | 2,0 | 1,4 | 1,4 | 1,1 | 0,6 | 0,9 | 0,6 | 1,4 | 0,6 |
| Metals, metal products, machinery and equipment | 6,7 | 11,1 | 16,8 | 16,4 | 13,5 | 14,9 | 12,6 | 13,0 | 16,6 | 15,9 |
| Electrical machinery and apparatus | 5,8 | 8,7 | 9,0 | 6,7 | 6,7 | 8,6 | 11,1 | 14,2 | 11,8 | 7,3 |
| Transport equipment | 24,6 | 8,7 | 7,7 | 8,8 | 9,1 | 9,1 | 7,8 | 7,1 | 10,0 | 11,0 |
| **Low technology** | **10,8** | **12,5** | **13,4** | **14,1** | **13,1** | **13,5** | **10,9** | **13,3** | **19,5** | **16,0** |
| Food, beverages and tobacco | 6,2 | 8,0 | 9,2 | 9,0 | 8,1 | 8,5 | 8,0 | 10,2 | 15,7 | 13,1 |
| Textiles, clothing and leather goods | 0,1 | 0,0 | 0,1 | 0,8 | 0,8 | 0,2 | 0,2 | 0,5 | 0,4 | 0,3 |
| Wood, paper, publishing and printing | 3,0 | 2,3 | 1,5 | 1,6 | 1,6 | 2,2 | 2,1 | 2,0 | 2,4 | 2,3 |
| Furniture & other Manufacturing | 1,6 | 2,3 | 2,7 | 2,6 | 2,6 | 2,7 | 0,6 | 0,6 | 1,0 | 0,3 |

*Source: National Surveys of Research and Experimental Development*

### *5.2.3 R&D personnel in the business sector*

Reflecting declining expenditure on R&D in the business sector, the number of personnel employed in R&D in the business sector declined by a little more than one-fifth (20,44%) from the previous year (**Table 5.25**). This followed a decline of 9,7% in the previous year. There are fewer personnel engaged in R&D in the business sector than at any time since 2010.

As noted in last year's report, over the last decade business sector expenditure on R&D has stagnated, falling behind other sectors. The number of full-time equivalent (FTE) researchers has also stagnated. In 2018/19, both business sector expenditure on R&D and the number of FTE researchers employed in the business sector declined notably, and, in 2019/20, by more than a third, twice the decline in economy-wide private investment. The number of FTE researchers also decreased significantly, by more than 20%.

**Table 5.25: R&D Personnel Full Time Equivalents in the Business Sector**

| | Number of business sector FTE R&D personnel |
|---|---|
| 2010/11 | 10 205 |
| 2011/12 | 9 895 |
| 2012/13 | 11 322 |
| 2013/14 | 11 877 |
| 2014/15 | 12 928 |
| 2015/16 | 12 458 |
| 2016/17 | 12 549 |
| 2017/18 | 12 952 |
| 2018/19 | 11 691 |
| 2019/20 | 9 301 |

*Source: National Surveys of Research and Experimental Development*

In conclusion, in 2019/20, business expenditure on R&D and the number of researchers employed in the business sector both declined significantly. While foreign funding for R&D in the business sector increased, this was from a very low base, following two years of significant decline. Foreign funding for business sector R&D in 2019/20 remains well below 2010 levels.

Higher technology intensity shows no sign of increasing in the manufacturing sector. The share of lower-technology sectors in business sector R&D has risen, while the share of higher-technology sectors has decreased.

# 6. INNOVATION ACTIVITIES

Although the benefits of innovation are well known, its nonlinear complex pathways are often less understood. The innovation activities that are discussed in this chapter span across different sectors such as the higher education, public research institutions, companies and government.

## 6.1 Innovators

Accenture's 2020 Innovation Maturity Index shows how vulnerable South African industry is to disruptions. The disruption framework used incorporates components such as the presence and penetration of disruptors (high-technology start-ups, venture capital flows, etc.), the performance of established (incumbent) firms (profitability, bankruptcy rate, etc.), the ability to operate efficiently, innovation activities and investments (scale of innovation efforts, investment in new digital technologies and market perception of ability to innovate), and defences against disruption (brand dominance, openness of market and scale of trapped value).

**Figure 6.1** shows the current level of disruption and susceptibility to future disruptions of various industries. The 100 sampled companies were classified as vulnerable (62%), volatile (23%), durable (9%) and viable (7%).

The Covid-19 pandemic accelerated disruptions and the distribution of various industries in **Figure 6.1** nearly depicts the nature of the disruption in various industries. Some of the industries that were most affected by Covid-19 disruption were energy, chemicals, retail, banking, natural resources, capital markets and consumer goods and services. Essential service (e.g. utilities and health), high technology, and communications and media industries were more resilient.

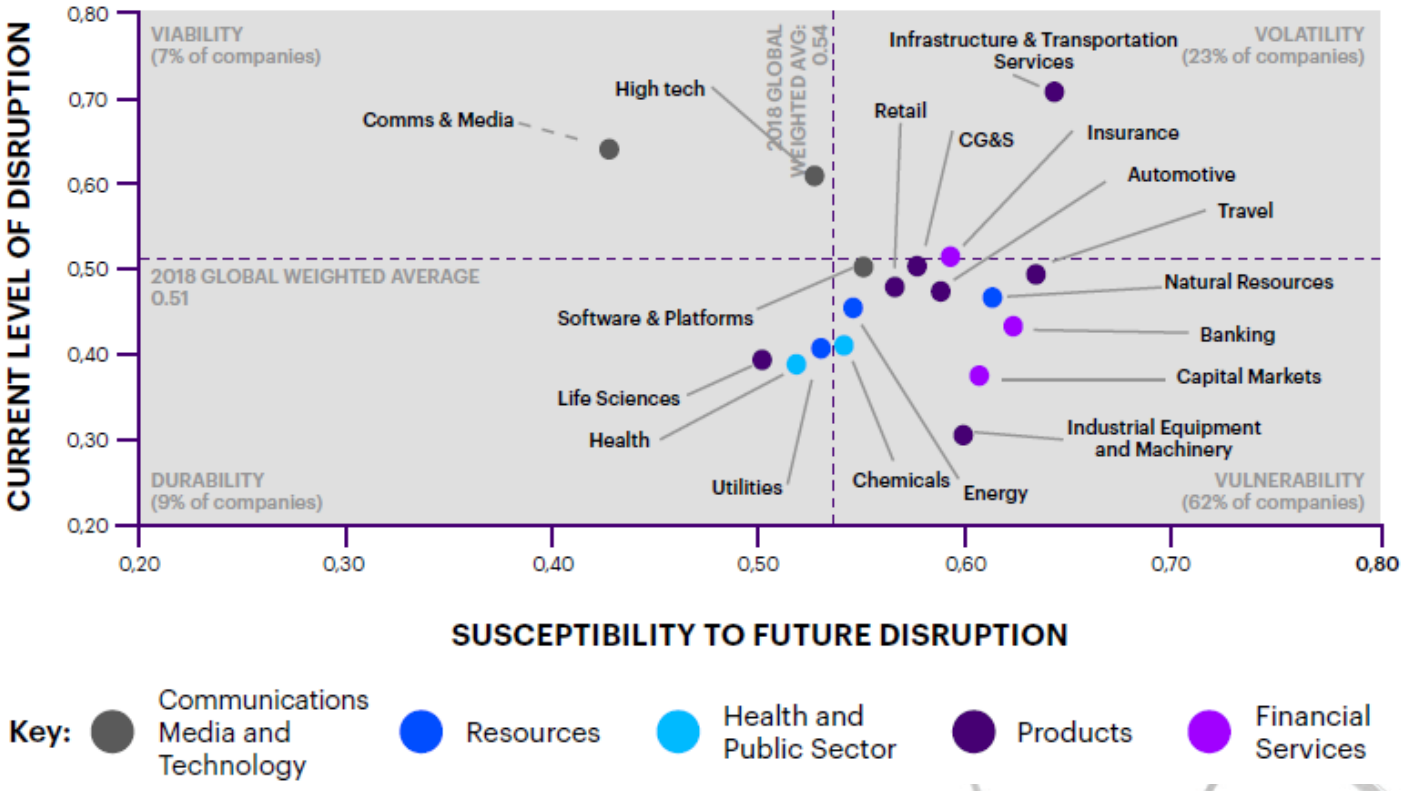



**Figure 6.1: South African industry exposure to disruptions, 2018**

*Source: Accenture's 2020 Innovation Maturity Index*

The 2020 Innovation Maturity Index score for innovation practices in South Africa compares the dominant innovation practices in South African companies with those of global innovation champions and the rest of the market (**Figure 6.2**).

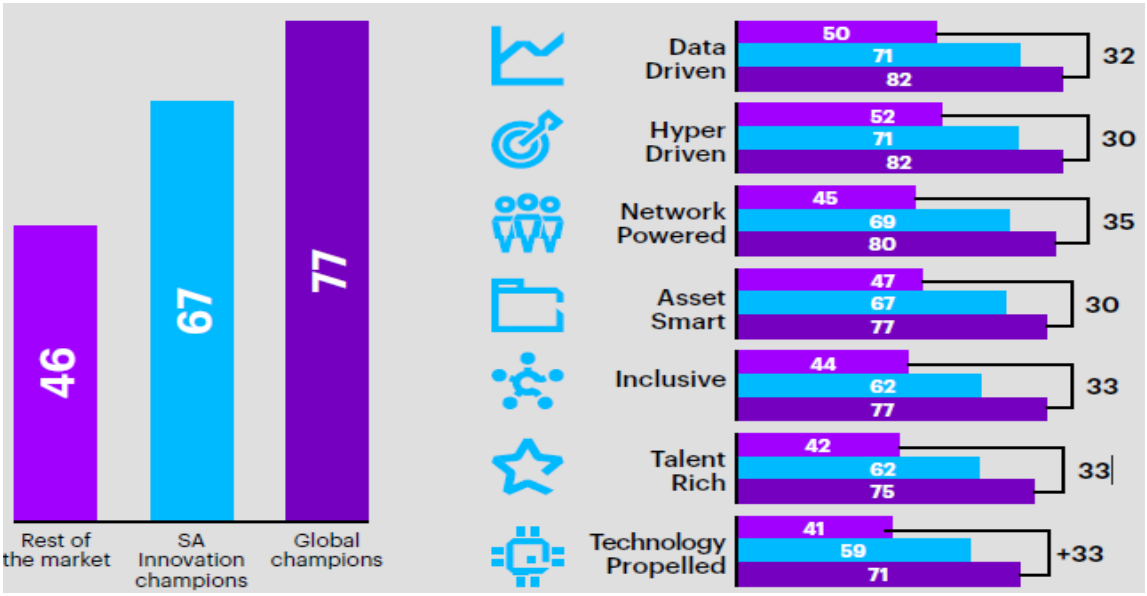



**Figure 6.2: Innovation practice scores (out of 100)**

*Source: Accenture Innovation Maturity Index, 2020*

The innovation practices in which South Africa scores best are mainly data-driven (71 out 100 score), hyper-driven (71) and network-powered (69). Data-driven activities entail the generation, sharing and deployment of data to deliver new product and service innovations safely and securely. Hyper-driven companies know how to stay relevant. South Africa's low score for technology-propelled practices (59) shows that mastering the leading-edge technologies that enable business innovation is not as much a priority for the country as it is a for global champions.

In comparison to the rest of the market, the global champions focus particularly on being network-powered (35 points above the rest of the market), followed by inclusive in terms of innovation and governance, and talent rich (both 33 points above).

## 6.2 Innovation linkages

This section shows various linkages within the NSI. Specifically, it covers university-industry co-publications, university-PRI co-publications, the commercialisation of public research and technology hubs. Links between universities and other sectors are important considering that university publications constitute about 83% of total South African scientific publications.

### *6.2.1 Co-publications between universities and industry*

The universities with a high share of research collaborations with industry (in the form of co-publications) are shown in **Table 6.1**. During the period 2016-2019, the University of Cape Town had the most co-publications with industry (6,2%), followed by the University of the Witwatersrand (6,1%) and the University of Pretoria (4,9%).

Several universities experienced a decline in their share of scientific co-publications with industry, namely, North-West University (from 10,4% in 2008-2011 to 4,1% in 2016-2019), the University of the Free State (from 5,9% to 4,6%) and the University of Johannesburg (from 3,9% to 2,2%).

**Table 6.1: Co-Publications between the Universities and Industry**

| | 2008-2011 | 2012-2015 | 2016-2019 |
|---|---|---|---|
| | % share of co-publications with industry | | |
| University of Cape Town | 5,1 | 4,7 | 5,2 |
| University of the Witwatersrand | 4,4 | 5,1 | 5,1 |
| University of Pretoria | 4,5 | 5,2 | 4,9 |
| Stellenbosch University | 4,3 | 4,3 | 4,7 |
| University of Free State | 5,9 | 4,7 | 4,6 |
| North-West University | 10,4 | 4,6 | 4,1 |
| University of KwaZulu-Natal | 3,5 | 3,3 | 3,7 |
| Rhodes University | 2,6 | 3,2 | 3,0 |
| University of Johannesburg | 3,9 | 2,6 | 2,2 |

*Source: CWTS Leiden Ranking*

Using the university with highest percentage of co-publications to benchmark South Africa with other countries shows that South Africa compares well with other BRICS members (**Table 6.2**). Only the China University of Petroleum, Beijing, had a higher share of industry co-publications (27,9%) than the University of Cape Town (5,2%) during 2016-2019. Several South African universities are leaders in Africa in terms of the proportion of their publications co-published with industry. A large percentage of co-publications with the industry seems to come from specialised universities, as it is a case with the universities such as the China University of Petroleum, Beijing, and the Colorado School of Mines.

**Table 6.2: Benchmarking of university-industry co-publications**

| | 2016-2019 |
|---|---|
| | % of co-publications with industry |
| University of Cape Town – South Africa | 5,2 |
| China University of Petroleum, Beijing – China | 27,9 |
| Universidade Federal do Rio de Janeiro – Brazil | 4,2 |
| Manipal Academy of Higher Education – India | 4,2 |
| ITMO University – Russia | 5,0 |
| Ain Shams University – Egypt | 3,3 |
| University of Ibadan – Nigeria | 4,0 |
| Université de Tunis El Manar – Tunisia | 1,5% |
| University of Strathclyde – United Kingdom | 13,3 |
| Colorado School of Mines – United States | 11,9 |

*Source: CWTS Leiden Ranking*

### 6.2.2 Co-publications between universities and public research institutions

Links between universities and public research institutions (PRIs) are an important part of ensuring that the scientific discoveries and ideas generated by the researchers based at the universities are translated into useful technologies, products and processes to meet government objectives and the socio-economic needs of the country.

As **Table 6.3** shows, there are strong linkages between universities and PRIs in terms of R&D activities. In 2021, the co-publications between these two sectors made up about 90,34% of total publications by the PRIs during that year, a significant increase from 79,17% in 2011. However, the co-publications between these two sectors constituted a small fraction of universities' total scientific publications (6,43% in 2021).

**Table 6.3: Scientific publications – Linkages between universities and PRIs**

| | PRI co-publications with universities as % of total PRI publications | University co-publications with PRIs as % of total university publications |
|---|---|---|
| 2011 | 79,17 | 6,74 |
| 2012 | 79,45 | 7,04 |
| 2013 | 76,71 | 6,71 |
| 2014 | 80,21 | 6,90 |
| 2015 | 83,81 | 7,41 |
| 2016 | 85,70 | 6,86 |
| 2017 | 83,73 | 6,53 |
| 2018 | 82,66 | 6,92 |
| 2019 | 86,67 | 6,88 |
| 2020 | 90,34 | 6,52 |
| 2021 | 90,56 | 6,43 |

*Source: Web of Science Core Collection*

### 6.2.3 Commercialisation of public research in South Africa

The transfer, exploitation and commercialisation of public research results is a critical area of science, technology and innovation policy in South Africa. Given their role in the creation and diffusion of new knowledge, public research institutions such as universities and science councils play a pivotal role in the innovation ecosystem.

The DSI supports the commercialisation of research results in various ways, through NIPMO, the Intellectual Property from Publicly Funded Research and Development Act and the offices of technology transfer, among others. The Centre for Science, Technology and Innovation Indicators (CESTII) has conducted two surveys to measure commercialisation from PRIs. This section gives an overview of the key trends identified through these surveys.

#### *Expenditure associated with technology transfer*

Public research institutions incur costs for technology transfer operations and activities such as the protection of intellectual property (IP). **Figure 6.3** shows this expenditure in various public research institutions.

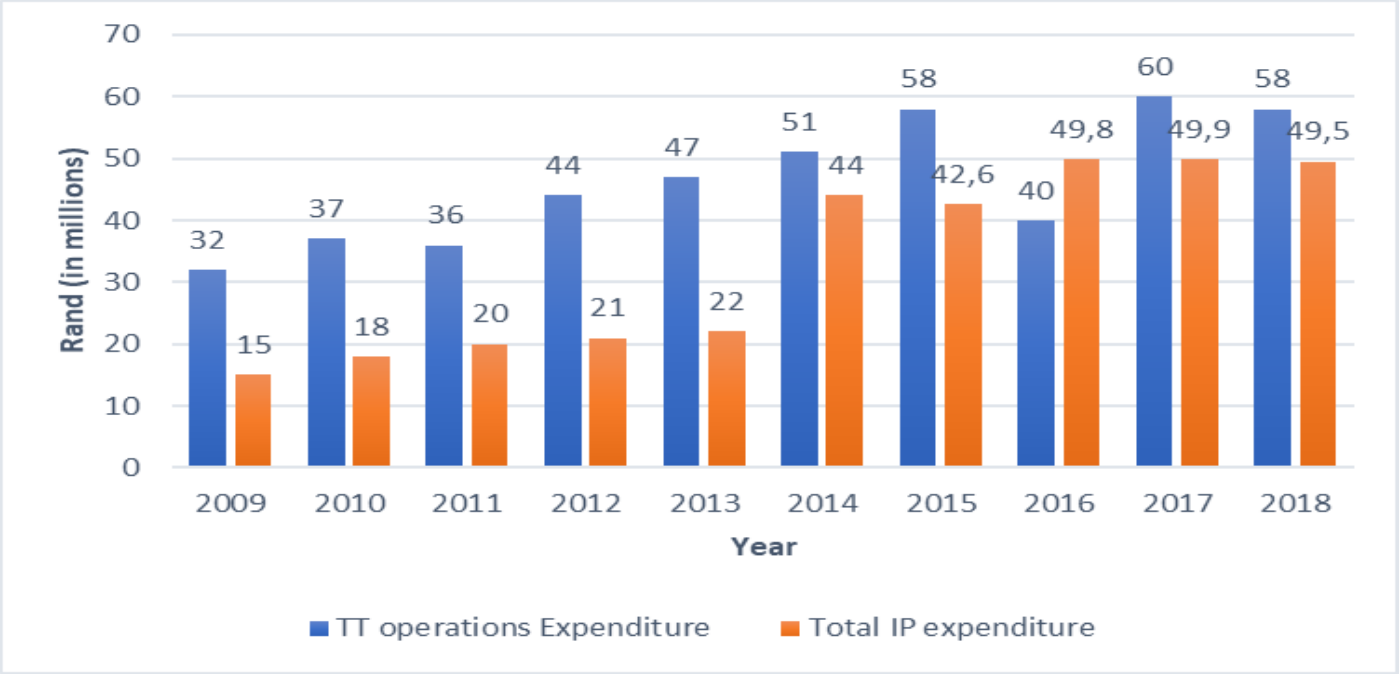



**Figure 6.3: Operational and IP expenditure at public research institutions**

*Source: IP & TT surveys 2008-2014 and 2014 – 2018*

*Note: Values for 2009 to 2014 (first survey) are 2010 constant prices and 2014-2018 (second survey) are 2014 constant prices.*

Between 2009 and 2018, a total of R794,8m was invested in supporting technology transfer functions and IP expenditure at public research institutions in South Africa.

### *Intellectual property portfolio*

**Table 6.4** shows IP how various institutions have protected IP. The data show that the IP portfolio has fluctuated year-on-year, for example, the number of patents that were granted increased from 2014 (95) to 2017 (234) and then declined in 2018 (229).

**Table 6.4: IP portfolio of public research institutions**

| | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|
| Patents granted | n/a | n/a | n/a | n/a | n/a | 95 | 130 | 225 | 234 | 229 |
| Trademarks | 9 | 15 | 35 | 20 | 14 | 22 | 88 | 83 | 44 | 57 |
| Registered designs | n/a | | 37 | 38 | 40 | 24 | 22 | 13 | 6 | 31 |
| Plant breeders' rights | n/a | n/a | n/a | n/a | n/a | 15 | 4 | 23 | 0 | 17 |

*Source: South African National Surveys of Intellectual Property and Technology Transfer at Publicly Funded Research Institutions (2008-2014 and 2014-2018) (IP and TT surveys)*

*Notes: Data for patents that were granted not available for 2008-2013*
*Data for plant breeders' rights not available for 2008-2013*
*Data for patents for 2009 to 2013 not available.*

### *IP Transactions and revenue*

To commercialise their IP, public research institutions enter into IP transactions in the form of licensing to other parties. As shown in **Figure 6.4**, the number of transactions executed increased from 10 in 2009 to 58 in 2018.

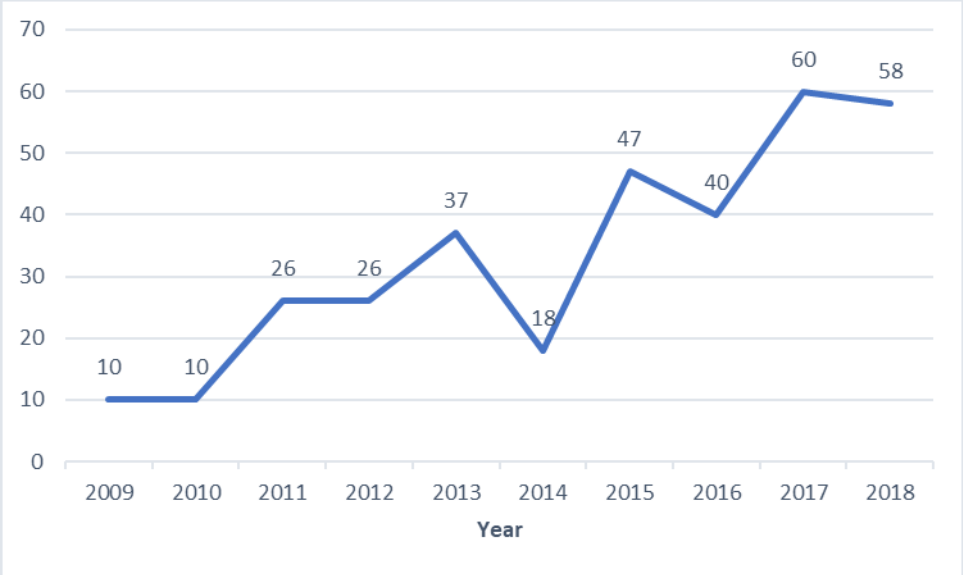



**Figure 6.4: Number of IP transactions executed**

*Source: IP and TT surveys*

The IP portfolio should result in commercialisation and generate revenues for the institutions. **Figure 6.5** shows the revenues that were generated by the various institutions between 2009 and 2018.

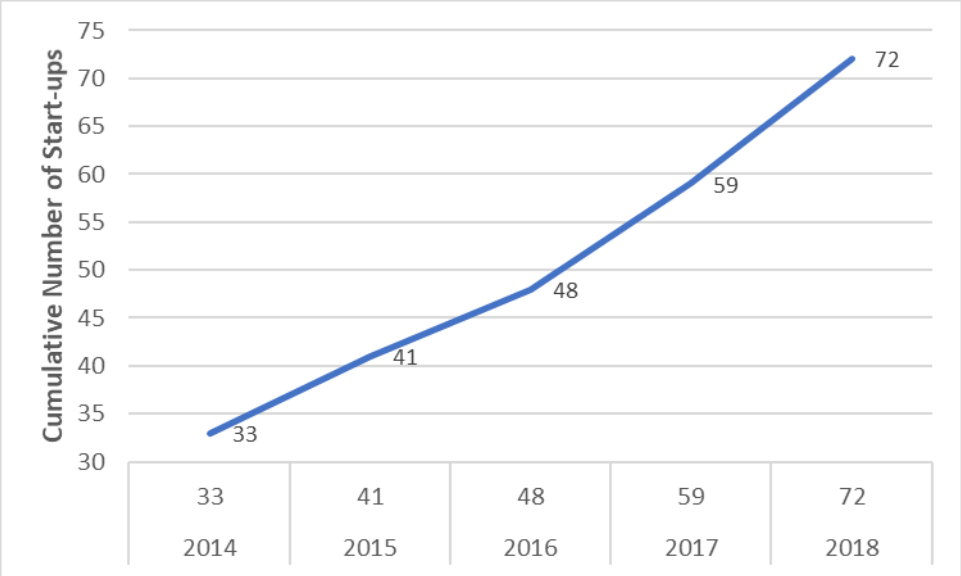



**Figure 6.5: Revenues generated from IP transactions**

*Source: IP and TT surveys*

***Number of start-ups from publicly funded research***

One of the aims of commercialising public research results is to create start-ups or spinoffs. As shown in Figure 6.6, 77 start-ups have been created since 2018.




**Figure 6.6: Number of start-ups created from public research IP**

*Source: IP & TT surveys*

The figure shows that the number of start-ups increased 64% between 2011 and 2017, although this was from a low base. According to the South African National Surveys of Intellectual Property and Technology Transfer at Publicly Funded Research Institutions (2008-2014 and 2014-2018), four universities were responsible for 70% of the spinoffs created between 2011 and 2014, and again between 2014 and 2018. Another important finding was the low contribution to start-ups by science councils (only three start-ups were created during 2014-2018).

Many start-up companies fail because of poor business models, a lack funding (especially for growth), management failures or competitive pressures. The 2014-2018 survey results show that the cumulative number of start-ups that were still in operation grew gradually from 33 in 2014 to 72 in 2018 as shown in **Figure 6.7**.

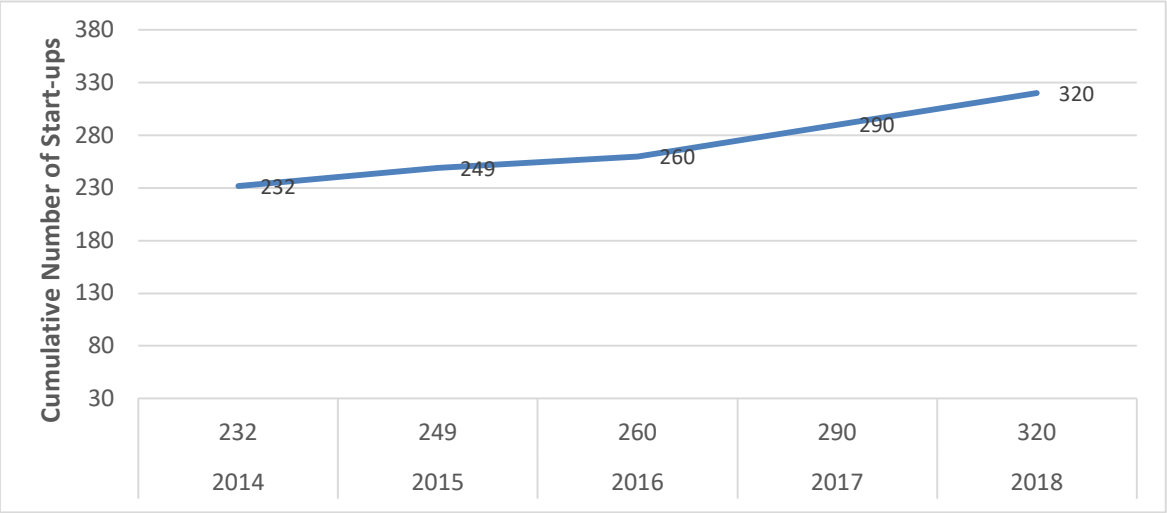



**Figure 6.7: Cumulative number of start-ups still in operation**

*Source: IP & TT Surveys*

*Note: Data for 2008 -2013 not available*

Start-ups are important for job creation and economic development. **Figure 6.8** shows the number of FTE staff who were employed in start-ups between 2014 and 2018.

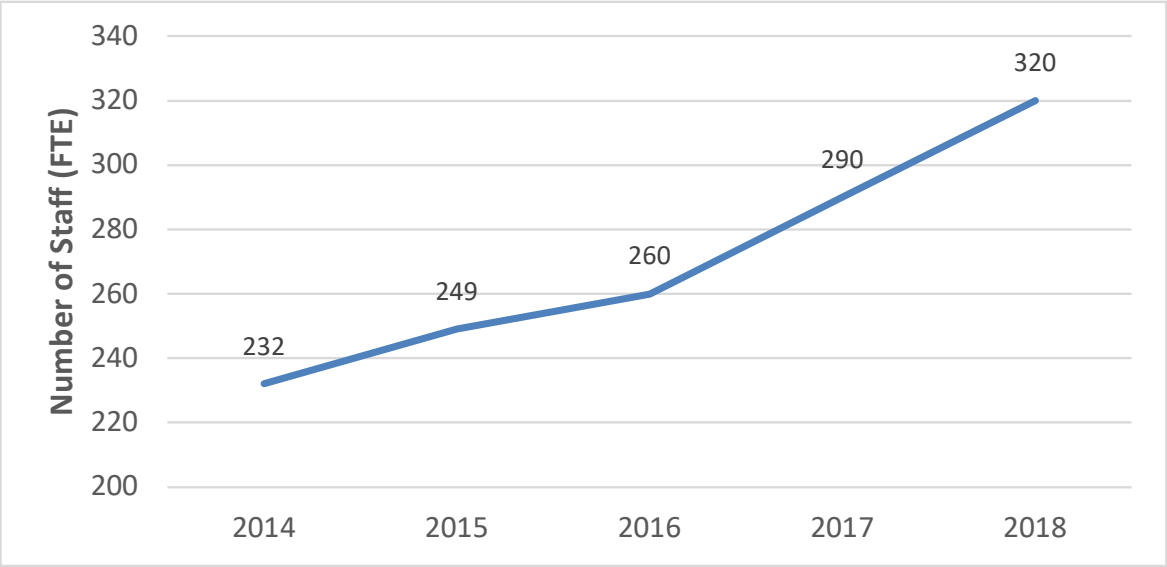



**Figure 6.8: Total FTE employment by start-up companies**

*Source: IP and TT Surveys*

*Note: Data for 2008-2013 period not available*

### 6.2.4 Technology hubs in South Africa

Technology hubs can be seen as interacting ecosystems or communities of researchers, software developers, digital makers, tech start-ups, small and micro-enterprises (SMEs), and corporate clients and investors in innovation. A hub is a centre, structure or network comprising of actors supporting or facilitating the development of an environment conducive to entrepreneurship or innovation. Hubs have become pervasive in regional development, innovation and local economic policy-making. The 2019 White Paper on STI proposed the development of innovation hubs in South Arica to stimulate local economic development.

As they are still a relatively new phenomenon, there are limited studies and information on technology hubs in South Africa. This section draws from studies on technology hubs in Africa that have been conducted by the World Bank, GSMA and AfriLabs and Briter Bridges.

#### *Spread of technology hubs in Africa*

The number of technology hubs in South Africa has been increasing gradually as shown in **Figure 6.9**. According to the AfriLabs and Briter Bridges Report, Nigeria had the highest number of technology hubs in Africa in 2021.

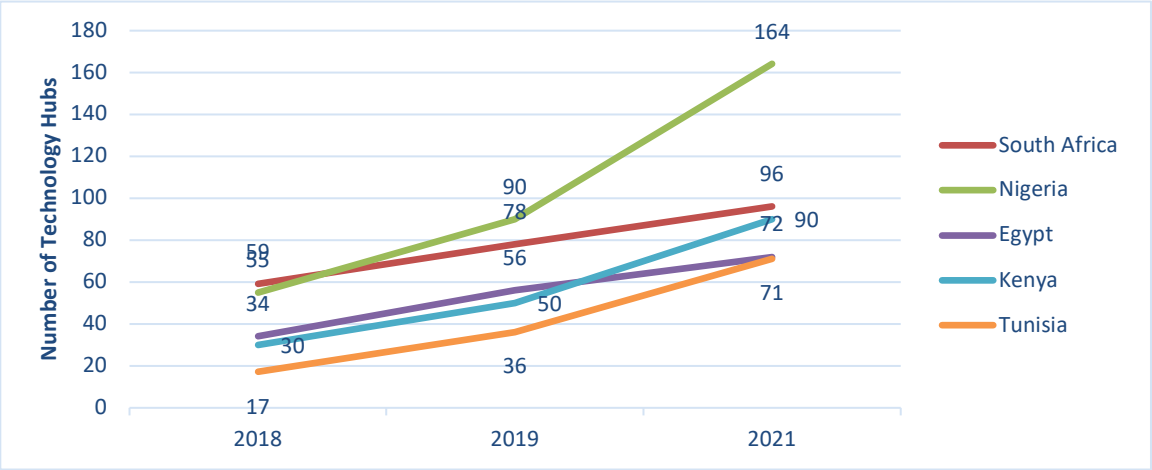



**Figure 6.9: Number of technology hubs in SA compared to selected African countries**

*Source: GSMA; AfriLabs and Briter Bridges Report*

*Note: data for 2020 is not available*

In Africa, the number of technology hubs increased from 443 in 2018 to 1 031 in 2021 across 53 countries[11]. This shows the growing importance of tech hubs as contributors to local economic development, job creation and supporting start-ups.

#### *Leading cities with technology hubs*

Technology hubs are generally located in major cities and economically active urban centres. As Figure 6.10 shows, in 2021 Lagos had at least 54 hubs, followed by Nairobi (51), Tunis (42), and Cape Town and Cairo (39 hubs each). The number of tech hubs in Cape Town grew by 33% between 2018 and 2021.

11 AfriLabs and Briter Bridges, 2021

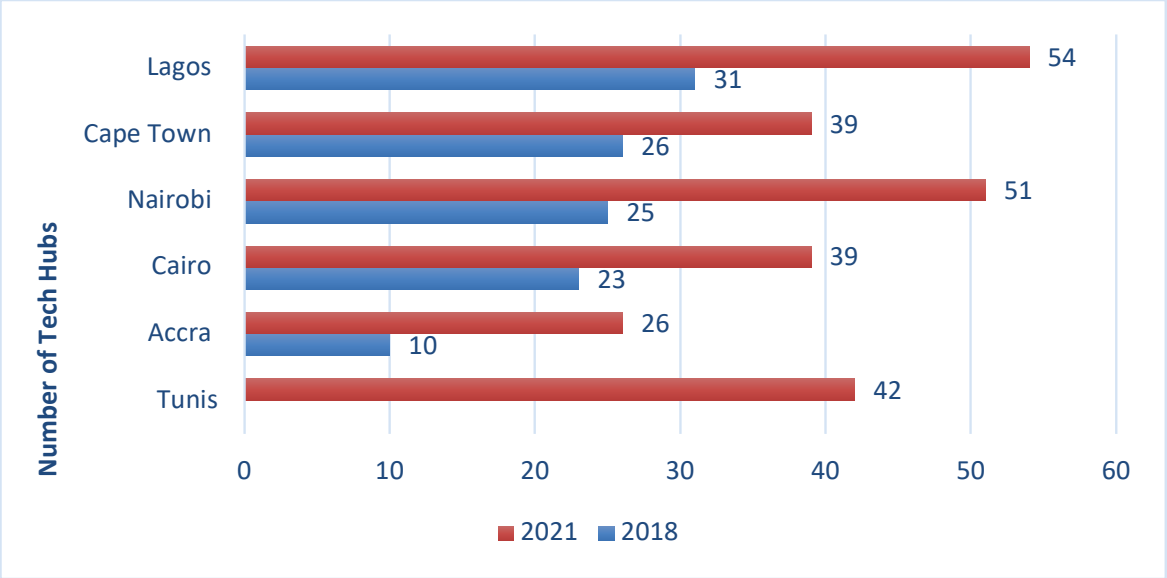



**Figure 6.10: Comparison of leading tech hubs in Africa**

*Source: GSMA 2018 and Briter Bridges 2021*

***Technology hubs by nature of service***

Hubs typically offer two types of support, co-working and community services, and support programmes offering training, financing and advice. **Figure 6.11** shows that South African hubs offer mainly support programmes. The number of organisations offering acceleration services, cohort-based programmes, mentoring and funding is growing.

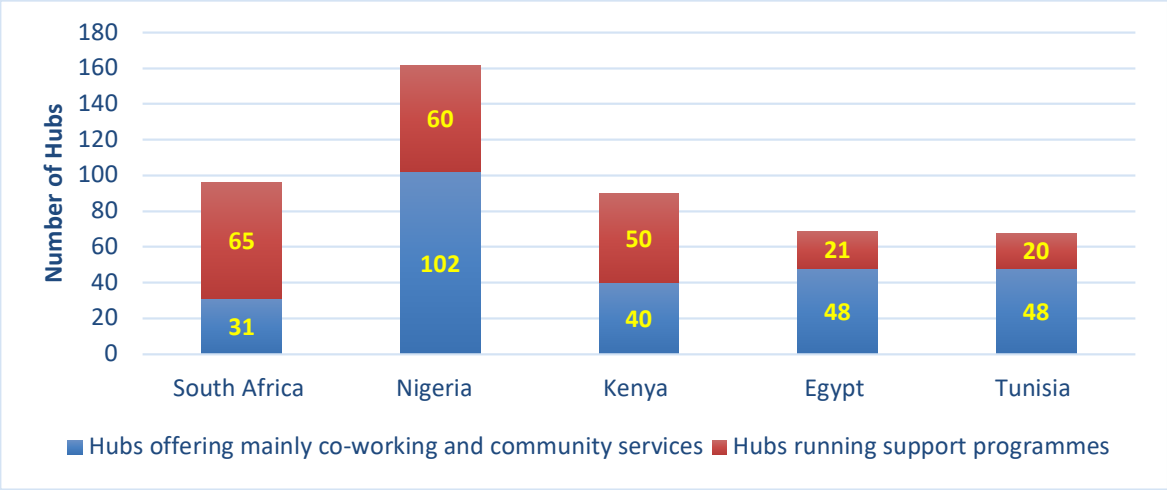



**Figure 6.11: Breakdown of leading tech hubs in Africa, including South Africa**

*Source: AfriLabs/Briter Bridges Report 2021*

## 6.3 Patents

The number of domestic patents granted to South African residents has been on a downward trajectory since 2010. However, patents granted to South African residents rose significantly in 2019, to 694 from 451 in 2018 (an increase of 54%). In 2020, patents granted to South African residents declined to 313 (by 55%).

**Table 6.5: Domestic patent grants, foreign and SA residents**

| | Resident | Non-Resident | Total | Resident % |
|---|---|---|---|---|
| 2010 | 822 | 4 509 | 5 331 | 15,4 |
| 2011 | 567 | 4 729 | 5 296 | 10,7 |
| 2012 | 685 | 5 520 | 6 205 | 11,0 |
| 2013 | 474 | 4 282 | 4 756 | 10,0 |
| 2014 | 445 | 4 620 | 5 065 | 8,8 |
| 2015 | 453 | 4 046 | 4 509 | 10,0 |
| 2016 | 403 | 3 852 | 4 255 | 9,5 |
| 2017 | 595 | 4 940 | 5 535 | 10,7 |
| 2018 | 451 | 4 295 | 4 746 | 9,5 |
| 2019 | 694 | 5 468 | 6 162 | 11,3 |
| 2020 | 313 | 3 153 | 3 466 | 9,0 |

*Source: WIPO Statistical Country Profiles*[12]

The number of patents granted to non-residents has shown no discernible trend over the past decade. As with patents granted to South African residents, there was a significant increase in 2019 (27%) and a sharp decline in 2020 (42%). The share of patents granted to South African residents has declined over the decade. In 2020, only 9% of patents granted in South Africa were to South African residents.

Regarding patents granted to South African residents abroad, **Table 6.6** shows the different types of patents granted to South Africans by the United States Patent and Trademark Office (USPTO) during the period 2010-2020.

Over the decade, there has been a generally rising trend in the total number of patents as well as in all the different classes of patents. However, there was a decline of 13% in the total number of patents granted in 2020; only plant patents increased.

Utility patents are the main patents granted to South Africans. The number of South African patents filed at the USPTO increased significantly in 2019 as compared with the previous year. However, the number of patents declined by 13% in 2020.

12 https://www3.wipo.int/ipstats/IpsStatsResultvalue

**Table 6.6: Different types of patents granted to South Africa by USPTO**

| Year | Utility | Design | Plant | Reissue | Total |
|---|---|---|---|---|---|
| 2020 | 155 | 27 | 12 | 1 | 195 |
| 2019 | 182 | 30 | 10 | 2 | 224 |
| 2018 | 145 | 23 | 4 | 1 | 173 |
| 2017 | 182 | 31 | 6 | 0 | 219 |
| 2016 | 181 | 21 | 13 | 0 | 215 |
| 2015 | 166 | 29 | 4 | 0 | 199 |
| 2014 | 152 | 26 | 2 | 1 | 181 |
| 2013 | 161 | 20 | 0 | 0 | 181 |
| 2012 | 142 | 14 | 1 | 1 | 158 |
| 2011 | 123 | 19 | 2 | 0 | 144 |
| 2010 | 116 | 23 | 2 | 1 | 142 |

*Source: USPTO databases*[13]

Almost 80% of total patents are utility patents. South Africa's share of all utility patents at USPTO is low and has generally been slowly declining. There was a further decline in South Africa's share in 2020.

**Table 6.7: South Africa's share of utility patent grants at USPTO**

| Year | Total | South Africa (count) | South Africa (%) |
|---|---|---|---|
| 2015 | 298 407 | 166 | 0,056 |
| 2016 | 303 051 | 181 | 0,060 |
| 2017 | 318 829 | 182 | 0,057 |
| 2018 | 307 760 | 145 | 0,047 |
| 2019 | 354 430 | 182 | 0,051 |
| 2020 | 352 010 | 155 | 0,044 |

*Source: USPTO database*

**Table 6.8** examines South Africa's share of utility patents granted to foreign (non-US residents) by USPTO. (Patent origin is determined by the residence of the first-named inventor listed on a patent.)

South Africa's share of utility patents granted to non-US residents at USPTO is very low and declined further in 2020. Both the number of South African patents and the percentage share of foreign patents declined in 2020. In contrast, all the other BRICS countries saw increases in both the number of their utility patents and in their percentage share of foreign patents in 2020.

13 https://www.uspto.gov/web/offices/ac/ido/oeip/taf/plant.htm#PartA1_1a

**Table 6.8: Selected countries by number of utility patents at USPTO**

| | Number of foreign utility patents | | Percentage share | |
|---|---|---|---|---|
| | 2019 | 2020 | 2019 | 2020 |
| **BRICS** | 25 816 | 28 162 | 13,8 | 15,0 |
| China | 19 209 | 21 428 | 10,3 | 11,4 |
| India | 5 378 | 5 861 | 2,9 | 3,1 |
| Russia | 622 | 677 | 0,3 | 0,4 |
| Brazil | 425 | 494 | 0,2 | 0,3 |
| South Africa | 182 | 152 | 0,09 | 0,08 |
| **High-income countries** | | | | |
| Japan | 53 542 | 51 619 | 28,5 | 27,5 |
| South Korea | 21 684 | 21 977 | 11,6 | 11,7 |
| Germany | 18 293 | 17 785 | 9,7 | 9,5 |
| **Total foreign** | **187 315** | **187 438** | | |

*Source: USPTO database*

Regarding plant patents, South Africa was ranked 16th in the list of countries that were granted plant patents in 2020. In 2019, South Africa ranked 13th, with 10 plant patents.

**Table 6.9: Ranking of countries by the number of plant patents, 2020**

| Rank | Country | Number of plant patents |
|---|---|---|
| 1 | Netherlands | 366 |
| 2 | Germany | 84 |
| 3 | United Kingdom | 56 |
| 4 | Denmark | 42 |
| 5 | France | 39 |
| 6 | Australia | 30 |
| 7 | Israel | 26 |
| 8 | Italy | 26 |
| 9 | Japan | 24 |
| 10 | Italy | 18 |
| 11 | Belgium | 19 |
| 12 | China | 16 |
| 13 | New Zealand | 16 |
| 14 | Spain | 16 |
| 15 | Thailand | 13 |
| 16 | South Africa | 12 |

*Source: USPTO database*

The number of South African patents granted at the European Patent Office has fluctuated over the decade. Unlike South African patents at USPTO, there was a significant increase of almost 14% in South Africa patents at the EPO, from 69 in 2019 to 80 in 2020.

**Table 6.10: South African patent grants at the EPO**

| | Number of Patent Grants |
|---|---|
| 2010 | 53 |
| 2011 | 53 |
| 2012 | 65 |
| 2013 | 54 |
| 2014 | 50 |
| 2015 | 59 |
| 2016 | 70 |
| 2017 | 50 |
| 2018 | 73 |
| 2019 | 69 |
| 2020 | 80 |

*Source: EPO database*

**Table 6.11** lists the top South African patent applicants under the Patent Cooperation Treaty (PCT). Patent applications at the PCT over the last three years have been dominated by the universities and the CSIR. In 2020, there were only three firms among the top applicants. Two of the firms, DetNet and Epiroc Holdings – the first and third ranked applicants – are in mining or mining-related industries.

**Table 6.11: Patent Cooperation Treaty top applicants**

| | 2018 | 2019 | 2020 |
|---|---|---|---|
| Detnet South Africa Pty Ltd | 6 | 1 | 11 |
| University of Pretoria | 4 | 5 | 9 |
| Epiroc Holdings South Africa (Pty) Ltd. | – | 2 | 8 |
| University of Johannesburg | 1 | 3 | 8 |
| University of Cape Town | 11 | 18 | 7 |
| CSIR | 8 | 9 | 6 |
| Stellenbosch University | 2 | 17 | 6 |
| Witwatersrand University | 0 | 3 | - |
| University of South Africa | 4 | – | 4 |
| Freddy Hirsch Group Proprietary) Ltd | 1 | – | 3 |

*Source: WIPO statistics database*

# 7. INNOVATION IMPACTS

The Covid-19 pandemic has renewed interest in the impact innovation has on the economy and society as various stakeholders raced to develop vaccines using some of the research and technological capabilities developed in the past. The crisis demonstrated the benefits of long-term fundamental research, and the need to respond to immediate challenges.

## 7.1 Innovation for economic impact

The proxy indicators used in this section for economic impact are the technology balance of payments, gross value added, outputs and exports.

### *7.1.1 Technology balance of payments*

South Africa's payments abroad for the use of IP have declined significantly since 2017 (see **Table 7.1**). This decline reflects lower levels of investment as economic growth has slowed. In 2020, these payments declined by 16,6%, following a decline of 12% in 2019. In 2020, receipts from the sale of South African IP declined by 16% from the previous year. This followed a similar decline in 2019.

**Table 7.1: Charges for the use of intellectual property**

| | Payments ($ billion) | Receipts ($ 000) |
|---|---|---|
| 2010 | 1,941 | 113 985 |
| 2011 | 2,118 | 139 891 |
| 2012 | 2,017 | 135 297 |
| 2013 | 1,937 | 135 485 |
| 2014 | 1,732 | 136 803 |
| 2015 | 1,641 | 126 114 |
| 2016 | 1,831 | 139 258 |
| 2017 | 1,883 | 157 684 |
| 2018 | 1,540 | 182 504 |
| 2019 | 1,356 | 150 760 |
| 2020 | 1,198 | 126 359 |

*Source: World Bank's World Development Indicators*

As **Table 7.2** shows, Brazil, Argentina and South Africa have all seen recent declines in their receipts from the sale of their IP abroad. But, for both Brazil and Argentina, in contrast with South Africa, receipts in 2020 were significantly higher than in 2015. Compared with all middle-income countries, South Africa's share of receipts declined significantly from 3% in 2015 to less than 1% in 2020.

**Table 7.2: Receipts on charges for the use of intellectual property, SA and selected countries**

| | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|
| | Current US$ | | | | | |
| Brazil | 581 080 500 | 650 833 689 | 642 157 301 | 825 475 487 | 641 114 074 | 634 291 803 |
| Argentina | 161 745 947 | 168 807 424 | 354 498 296 | 321 051 040 | 289 164 966 | 219 524 980 |
| South Africa | 126 114 070 | 139 258 220 | 157 684 448 | 182 504 287 | 150 760 778 | 126 359 274 |
| Middle-income countries | 4 252 | 4 278 | 8 752 | 10 263 | 11 278 | 13 674 |
| South Africa's share of middle income countries' receipts | 3,0% | 3,2% | 1,8% | 1,7% | 1,3% | 0,9% |

*Source: World Bank's World Development Indicators*

### *7.1.2 Gross value added by sector*

In 2020, gross value added (GVA) in manufacturing declined by a little over 12% from the previous year. High and medium-technology manufacturing GVA decreased more significantly, by almost 20%. High and medium high-technology manufacturing excluding motor vehicles declined by just over 18% in 2020. As a result, the percentage shares of manufacturing GVA for MHT and of MHT excluding motor vehicles declined further in 2020.

**Table 7.3: Manufacturing, medium and high tech manufacturing output (gross value added)**

| | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | R million (constant 2015 prices) | | | | | | | | | | |
| Manufacturing | 527 128 | 541 829 | 552 595 | 558 021 | 554 420 | 553 392 | 555 880 | 554 833 | 565 926 | 559 294 | 490 290 |
| MHT | 155 586 | 157 731 | 157 117 | 158 051 | 157 823 | 157 937 | 159 868 | 155 966 | 154 860 | 152 771 | 122 812 |
| MHT (excl. motor vehicles) | 136 441 | 138 046 | 136 739 | 137 019 | 136 459 | 13 024 | 138 400 | 134 757 | 132 021 | 130 003 | 106 222 |
| MHT | 29.52 | 29.11 | 28.43 | 28.32 | 28.47 | 28.54 | 28.76 | 28.11 | 27.36 | 27.31 | 25.05 |
| MHT (excl. vehicles) % | 25,88 | 25,48 | 24,74 | 24,55 | 24,61 | 24,58 | 24,90 | 24,29 | 23,33 | 23,25 | 21,67 |

*Sources: Quantec and Statistics SA*

Over the decade, the trend for the shares of MHT and MHT excluding motor vehicles in manufacturing GVA was to decline slowly, with a more pronounced decline from 2016.

Regarding the different sectors within high and medium-high technology manufacturing, percentage shares have generally been stable over the last decade (see **Table 7.4**). Special purpose machinery and motor vehicles saw a marginal increase in their shares of MHT value added. There are no sectors which show significant sustained increases over the decade.

**Table 7.4: Medium and high technology sectors output (gross value added; constant 2015 prices)**

| | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | R million (constant 2015 prices) | | | | | | | | | | |
| Basic chemicals | 14,20 | 12,95 | 11,49 | 11,71 | 12,27 | 12,49 | 14,21 | 13,39 | 12,75 | 12,48 | 12,61 |
| Other chemical products | 20,48 | 20,10 | 19,72 | 20,31 | 20,40 | 20,39 | 20,68 | 19,87 | 18,38 | 18,20 | 18,51 |
| General purpose machinery | 12,37 | 12,23 | 12,41 | 11,35 | 10,45 | 9,47 | 9,17 | 9,77 | 10,06 | 10,21 | 10,87 |
| Special purpose machinery | 13,20 | 13,31 | 13,65 | 13,89 | 13,64 | 13,30 | 12,67 | 13,75 | 14,13 | 14,20 | 14,56 |
| Household appliances | 1,81 | 1,75 | 1,82 | 1,77 | 1,84 | 1,71 | 1,52 | 1,59 | 1,67 | 1,76 | 1,78 |
| Office, accounting, computing machinery | 0,98 | 0,96 | 0,95 | 0,94 | 0,99 | 0,93 | 0,83 | 0,88 | 0,92 | 0,98 | 0,99 |
| Electric motors, generators, transformers | 1,27 | 1,51 | 1,77 | 1,83 | 2,01 | 2,03 | 2,26 | 1,99 | 2,09 | 1,97 | 2,08 |
| Electricity distribution and control apparatus | 1,26 | 1,31 | 1,29 | 1,33 | 1,19 | 1,25 | 1,22 | 1,35 | 1,31 | 1,32 | 1,20 |
| Insulated wire and cables | 1,38 | 1,44 | 1,44 | 1,42 | 1,37 | 1,36 | 1,38 | 1,48 | 1,50 | 1,51 | 1,53 |
| Other electrical equipment | 3,30 | 3,01 | 3,02 | 3,42 | 3,27 | 3,76 | 3,50 | 3,03 | 2,97 | 3,06 | 3,51 |
| Radio, television and communication apparatus | 0,97 | 1,08 | 1,19 | 1,26 | 1,54 | 1,43 | 1,65 | 1,60 | 1,42 | 1,41 | 1,57 |
| Professional equipment | 2,80 | 3,03 | 3,10 | 3,08 | 3,29 | 3,25 | 3,30 | 3,73 | 3,76 | 3,71 | 4,08 |
| Motor vehicles | 12,31 | 12,49 | 12,97 | 13,31 | 13,54 | 13,87 | 13,43 | 13,60 | 14,75 | 14,88 | 13,55 |
| Parts and accessories | 9,83 | 10,74 | 10,60 | 10,04 | 9,82 | 10,23 | 9,82 | 9,19 | 9,47 | 9,48 | 9,07 |
| Other transport equipment | 3,84 | 4,11 | 4,59 | 4,33 | 4,38 | 4,52 | 4,33 | 4,80 | 4,82 | 4,82 | 4,13 |

*Sources: Quantec & Stats SA*

### *7.1.3 Merchandise exports by technological intensity*

Manufacturing exports have tended to decline since 2015. Manufacturing exports declined by 2% in 2019. In 2020, manufacturing exports declined by a little over 10%. The percentage decline in MHT was somewhat higher (12.7%) than for total manufacturing exports so that MHT share of total manufacturing exports declined marginally. Exports of motor vehicles fell significantly in 2020, and if motor vehicles are excluded, the decline in MHT exports is significantly less (3%). As a result, the share of MHT (excluding motor vehicles) in total manufacturing exports increased.

**Table 7.5: Manufacturing exports, medium and high-technology exports**

| | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | R million (constant 2015 prices) | | | | | | | | | | |
| Manufacturing | 449 934 | 470 921 | 490 662 | 504 629 | 531 186 | 559 846 | 557 147 | 538 180 | 555 233 | 543 355 | 487 342 |
| MHT | 195 012 | 215 475 | 233 782 | 231 944 | 247 824 | 274 256 | 271 346 | 257 022 | 265 409 | 267 607 | 233 829 |
| MHT (excl. motor vehicles) | 143 271 | 160 539 | 170 969 | 172 873 | 179 361 | 184 711 | 185 345 | 175 756 | 179 380 | 182 747 | 176 760 |
| MHT | 43,34 | 45,76 | 47,65 | 46,83 | 47,40 | 48,99 | 48,70 | 47,76 | 47,80 | 49,25 | 47,98 |
| MHT (excl. motor vehicles) % | 32,05 | 34,04 | 34,80 | 34,36 | 33,72 | 32,99 | 33,27 | 32,66 | 32,31 | 33,63 | 36,27 |

*Sources: Quantec & Stats SA*

Focusing solely on high technology, there has been a steady decline in the value of South African high technology exports since 2015. The value of South Africa's high technology exports in 2019 was 10% less than in 2018. In 2020, the value of South Africa's high technology exports was similar to that of 2019. Since total manufacturing exports declined by 10% in 2020 (see above), the share of high technology exports in total manufacturing exports rose. Table 6.6: South Africa and Brazil High Technology Exports

**Table 7.6: South Africa and Brazil high technology exports**

| | South Africa | Brazil | South Africa% | Brazil% |
|---|---|---|---|---|
| | Value (US$ billion) | | Share of manufactured exports (%) | |
| 2010 | 2,5 | 8,8 | 6,2 | 12,3 |
| 2011 | 2,8 | 9,2 | 6,2 | 10,9 |
| 2012 | 2,9 | 9,5 | 6,9 | 11,5 |
| 2013 | 2,7 | 9,1 | 6,8 | 10,7 |
| 2014 | 2,8 | 8,8 | 6,7 | 11,7 |
| 2015 | 2,9 | 9,5 | 7,7 | 13,6 |
| 2016 | 2,4 | 10,4 | 6,7 | 14,8 |
| 2017 | 2,2 | 10,7 | 5,7 | 13,9 |
| 2018 | 2,1 | 11,1 | 5,3 | 13,4 |
| 2019 | 1,8 | 9,4 | 4,9 | 13,3 |
| 2020 | 1,8 | 5,9 | 5,6 | 11,4 |

*Source: World Bank's World Development Indicators*

Like South Africa, in 2019 Brazil saw the value of its high technology exports decline from 2018 (see **Table 7.6**). In 2020, there was a very significant decline in Brazilian high technology exports. By contrast, South Africa's high-technology exports in 2020 remained at the same level as in 2019. However, the share of South Africa's high technology exports in total manufacturing exports in 2020 is a little less than half of that in Brazil. By contrast with South Africa, the share of high technology manufactured exports in Brazil is higher than it was in 2010.

High-technology exports as a share of manufactured exports is significantly lower in South Africa than the world average, the average for middle income countries and for almost all other comparable countries.

**Table 7.7: Benchmarking of South African high-technology exports as % of manufactured exports, 2020**

| | Percentage |
|---|---|
| Malaysia | 53,8 |
| China | 31,3 |
| World | 22,2 |
| Middle Income Countries | 23,4 |
| Mexico | 21,5 |
| Brazil | 11,4 |
| Russian Federation | 9,2 |
| Chile | 15,8 |
| Portugal | 7,1 |
| Argentina | 6,1 |
| South Africa | 5,6 |

*Source: World Bank's World Development Indicators*

As with high technology manufactured exports, service exports have tended to decline since 2012. Service exports declined almost 5% in 2019. They declined further - by over 12% in 2020.

**Table 7.8: South African service exports**

| | (Current US$ billion) |
|---|---|
| 2010 | 107,6 |
| 2011 | 126,9 |
| 2012 | 117,8 |
| 2013 | 113,8 |
| 2014 | 110,5 |
| 2015 | 96,1 |
| 2016 | 91,1 |
| 2017 | 104,3 |
| 2018 | 111,3 |
| 2019 | 106,1 |
| 2020 | 93,2 |

*Source: World Bank's World Development Indicators*

### *7.1.4 Composition of exports*

**Tables 7.9** and **7.10** show export values; the number of exporters; the number of products exported; the number of export destinations and the number of export transactions.

**Table 7.9: Total export characteristics, excluding gold**

| | Value (US$) | Number of exporters | Number of products | Number of destinations | Number of transactions |
|---|---|---|---|---|---|
| 2010 | 75 015 618 849 | 32 666 | 4 247 | 218 | 856 857 |
| 2011 | 89 519 158 028 | 33 503 | 4 243 | 223 | 944 653 |
| 2012 | 81 477 002 781 | 39 377 | 4 234 | 218 | 1 036 806 |
| 2013 | 80 379 627 154 | 41 199 | 4 216 | 220 | 1057254 |
| 2014 | 77 538 185 918 | 41 328 | 4 219 | 226 | 1 089 767 |
| 2015 | 66 293 493 448 | 41 877 | 4 222 | 219 | 1 106 222 |
| 2016 | 62 266 265 394 | 42 172 | 4 217 | 220 | 1 111 175 |
| 2017 | 72 954 412 473 | 40 384 | 4 202 | 225 | 1 111 973 |
| 2018 | 77 320 210 944 | 37 428 | 4 199 | 223 | 1 091 335 |
| 2019 | 73 465 477 368 | 35 326 | 4 192 | 225 | 1 050 492 |
| 2020 | 71 297 209 036 | 35 666 | 4 178 | 218 | 961 052 |

*Source: Lawrence, Baduel and Engel (n.d.)*[14]

14 Lawrence, E., Baduel, B. and Engel, J. (n.d) The Evolution of South African Export Competitiveness from 2010: Analysis of Customs-Transaction-Level Data. Mimeo

**Table 7.10: Manufacturing export characteristics**

| | Value (US$) | Number of exporters | Number of products | Number of destinations | Number of transactions |
|---|---|---|---|---|---|
| 2010 | 39 638 889 313 | 30 555 | 3 529 | 217 | 773 097 |
| 2011 | 44 134 116 198 | 31 415 | 3 527 | 220 | 857 596 |
| 2012 | 41 754 205 817 | 36 629 | 3 518 | 215 | 935 223 |
| 2013 | 39 904 941 879 | 38 384 | 3 502 | 214 | 954 040 |
| 2014 | 40 808 339 551 | 38 586 | 3 505 | 221 | 985 647 |
| 2015 | 35 567 695 016 | 39 123 | 3 506 | 214 | 1 001 709 |
| 2016 | 32 535 154 836 | 39 269 | 3 501 | 216 | 1 006 221 |
| 2017 | 35 673 876 620 | 37 566 | 3 488 | 222 | 1 007 803 |
| 2018 | 38 090 094 108 | 34 874 | 3 487 | 218 | 990 581 |
| 2019 | 35 048 542 712 | 32 986 | 3 484 | 222 | 953 657 |
| 2020 | 31 868 009 041 | 33 321 | 3 470 | 217 | 868 767 |

*Source: Lawrence, Baduel and Engel (n.d.)*

Following the 2008 global financial crisis, the number of exporters expanded rapidly between 2010-2012. The rate of growth then tapered off and after 2016 the number of exporters declined. A small increase was registered in 2020. The number of exporters increased by 9% over the decade. The number of export transactions followed a similar trend – reaching a peak in 2017 and then declining. There was a significant decline (9%) in the number of export transactions in 2020 from 2019. The number of products, for both all exports and manufactures, has been on a slow declining trend over the entire decade. The number of export product manufactures is 1.7 % lower in 2020 by comparison with 2010 and 1.6% lower in respect of total exports.

From the perspective of innovation, the decline in the number of exporters and the decline in the number of export products is of particular concern. A rising number of exporters and of new export products would show increasing innovation.

Changes in exports can be divided into two categories. The first category, referred to as the intensive margin, relates to changes in the value of exports by established exporters exporting existing products to established markets. The second category, referred to as the extensive margin, relates to changes in the value of exports arising from the entry/exit of new exporters or continuing exporters, exporting new products, or exporting existing products to new destinations.

The intensive margin, the same firms exporting the same products to the same markets entails no additional innovation. By contrast, the extensive margin, new firms entering export markets and/or established exporters developing new export products and new export destinations are the outcome of innovation.

**Tables 7.11** and **7.12** break down the contribution of the extensive and intensive margin to changes in export values.

**Table 7.11: Breakdown of change in total exports: Extensive and intensive margins**

| | Extensive margins | Intensive margins | Total |
|---|---|---|---|
| 2010-2011 | 3,4 | 14,2 | 17,6 |
| 2011-2012 | 1,4 | -10,8 | -9,4 |
| 2012-2013 | -1,3 | -2,6 | -1,4 |
| 2013-2014 | 2,6 | -6,2 | -3,6 |
| 2014-2015 | -1,2 | -14,4 | -15,6 |
| 2015-2016 | -0,4 | -5,8 | -6,3 |
| 2016-2017 | 3,1 | 12,7 | 15,8 |
| 2017-2018 | -1,0 | 6,8 | 5,8 |
| 2018-2019 | -1,6 | -3,5 | -5,1 |
| 2019-2020 | -0,7 | -2,3 | -3,0 |

*Source: Lawrence, Baduel and Engel (n.d.)*

The intensive margin makes a far larger contribution to changes in export values throughout the decade. Established exporters, exporting established products to established markets dominate South Africa's exports. The contribution of new exporters and of established exporters exporting new products and entering new markets is very limited.

Over the decade, price changes accounted for some three-quarters of the annual growth in the intensive margin across the period 2011 to 2019. Growth in export volumes on the part of established firms exporting established products to established markets have only made a minor contribution towards aggregate growth in export value.

**Table 7.12: Breakdown of change in manufactured exports: Extensive and intensive margins**

| | Extensive margin % contribution to change in exports | Intensive margin % contribution to change in exports | Total % change in exports |
|---|---|---|---|
| 2010-2011 | 1,1 | 4,3 | 5,4 |
| 2011-2012 | 1,2 | -4,0 | -2,8 |
| 2012-2013 | 0,0 | -2,3 | -2,3 |
| 2013-2014 | 1,2 | -0,1 | 1,1 |
| 2014-2015 | -1,0 | -6,3 | -7,3 |
| 2015-2016 | -1,5 | -3,2 | -4,7 |
| 2016-2017 | 1,1 | 3,6 | 4,6 |
| 2017-2018 | 0,9 | 2,3 | 3,2 |
| 2018-2019 | -0,6 | -3,4 | -4,0 |
| 2019-2020 | -0,9 | -3,5 | -4,4 |

*Source: Lawrence, Baduel and Engel (n.d.)*

### *7.1.5 Medium and high technology employment*

Formal employment in manufacturing declined significantly in 2020, down 7% from 2019. There were similar declines in MHT employment (6,5%) and in MHT excluding motor vehicles (6%).

By contrast with overall manufacturing employment, over the decade, employment in MHT and in MHT excluding motor vehicles grown, however slowly. The share of MHT employment in manufacturing employment and of MHT excluding vehicles is marginally higher in 2020 than at the beginning of the decade.

**Table 7.13: Share of medium and high technology manufacturing employment**

| | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Manufacturing employment ('000) | 1 177 | 1 168 | 1 167 | 1 168 | 1 161 | 1 174 | 1 188 | 1 200 | 1 221 | 1 220 | 1 135 |
| MHT employment (R'000) | 339 | 348 | 353 | 360 | 355 | 354 | 365 | 369 | 384 | 385 | 360 |
| Share of MHT employment (%) | 28,78 | 29,79 | 30,30 | 30,79 | 30,60 | 30,17 | 30,68 | 30,74 | 31,41 | 31,51 | 31,76 |
| MHT employment, excl. motor vehicles (R'000) | 298 | 306 | 310 | 316 | 312 | 310 | 318 | 320 | 335 | 335 | 315 |
| Share of MHT employment, excl. motor vehicles (%) | 25,32 | 26,24 | 26,59 | 27,02 | 26,85 | 26,43 | 26,75 | 26,70 | 27,44 | 27,44 | 27,8 |

*Sources: Quantec and Statistics SA (Data for formal employment)*

Regarding the different sectors within MHT manufacturing, percentage shares of employment have been stable over the last decade. As shown in **Table 7.14**, the two sectors that had some growth in their shares of manufacturing output, namely special purpose machinery and motor vehicles, exhibit no significant change in their share of employment over the period.

**Table 7.14: Medium and high-technology sectors employment**

| | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Share of manufacturing employment (%) | | | | | | | | | | |
| Basic chemicals | 5,98 | 6,34 | 6,86 | 7,42 | 7,50 | 6,98 | 6,39 | 5,93 | 6,09 | 6,19 | 6,00 |
| Other chemical products | 14,08 | 14,49 | 14,60 | 14,82 | 15,37 | 15,39 | 16,02 | 15,97 | 16,63 | 17,67 | 17,78 |
| General purpose machinery | 12,71 | 12,75 | 12,58 | 12,71 | 12,80 | 12,54 | 11,89 | 11,83 | 12,19 | 12,43 | 12,52 |
| Special purpose machinery | 16,26 | 15,68 | 15,30 | 14,82 | 14,81 | 15,26 | 15,27 | 14,96 | 15,73 | 16,24 | 16,21 |
| Household appliances | 2,04 | 1,98 | 1,91 | 1,91 | 1,90 | 2,08 | 2,00 | 2,02 | 1,99 | 1,75 | 1,47 |
| Office, accounting, computing machinery | 1,88 | 1,83 | 1,64 | 1,57 | 1,44 | 1,24 | 1,15 | 1,22 | 1,23 | 1,18 | 1,06 |
| Electric motors, generators, transformers | 2,15 | 2,73 | 3,72 | 3,60 | 3,97 | 4,48 | 4,49 | 4,38 | 3,95 | 4,04 | 3,95 |
| Electricity distribution and control apparatus | 2,01 | 1,62 | 1,74 | 1,78 | 1,54 | 1,61 | 1,87 | 1,85 | 1,89 | 1,84 | 1,76 |
| Insulated wire and cables | 1,54 | 1,54 | 1,50 | 1,55 | 1,51 | 1,47 | 1,45 | 1,42 | 1,35 | 1,23 | 1,11 |
| Other electrical equipment | 5,16 | 5,30 | 5,31 | 5,11 | 4,98 | 4,68 | 4,59 | 4,54 | 3,04 | 3,57 | 5,75 |
| Radio, television and communication apparatus | 1,93 | 1,89 | 1,81 | 1,73 | 1,82 | 1,95 | 1,92 | 1,94 | 1,92 | 1,82 | 1,68 |
| Professional equipment | 2,88 | 3,06 | 2,99 | 3,05 | 2,97 | 3,00 | 2,96 | 3,11 | 3,28 | 3,29 | 3,23 |
| Motor vehicles | 11,92 | 11,98 | 11,87 | 12,19 | 12,19 | 12,19 | 12,33 | 12,75 | 13,09 | 12,53 | 11,99 |
| Parts and accessories | 14,73 | 14,03 | 13,74 | 13,57 | 13,23 | 13,00 | 13,40 | 13,55 | 13,09 | 11,87 | 11,08 |
| Other transport equipment | 4,73 | 4,77 | 4,42 | 4,19 | 3,97 | 4,13 | 4,28 | 4,55 | 4,53 | 4,38 | 4,42 |

*Sources: Quantec & Stats SA*

## 7.2 Social impact of innovation

South Africa is classified as a middle-income country, but still faces many socio-economic challenges, including poverty, high inequalities in income and wealth, and rising unemployment. For innovation systems to be embedded in the country's policy agenda, it has to come up with solutions to the country's problems. Globally, research and practice suggest that innovation is becoming an important pillar for social and economic development. Furthermore, the consensus is that Sustainable Development Goals (SDG) should be at the centre of innovation.

This section presents various socio-economic indicators and gives a glimpse of innovation projects that can be upscaled to provide solutions to some of the socio-economic problems facing South Africa. The focus of the section is on poverty and inequality, housing, water and sanitation and spatial integration. These challenges are at the centre of the international policy agenda, mainly the SDGs, and national development priorities as suggested by the NDP.

### *7.2.1 Poverty and inequality*

**Figure 7.1** shows the number of households living in different poverty lines, calculated from the General Household Survey.

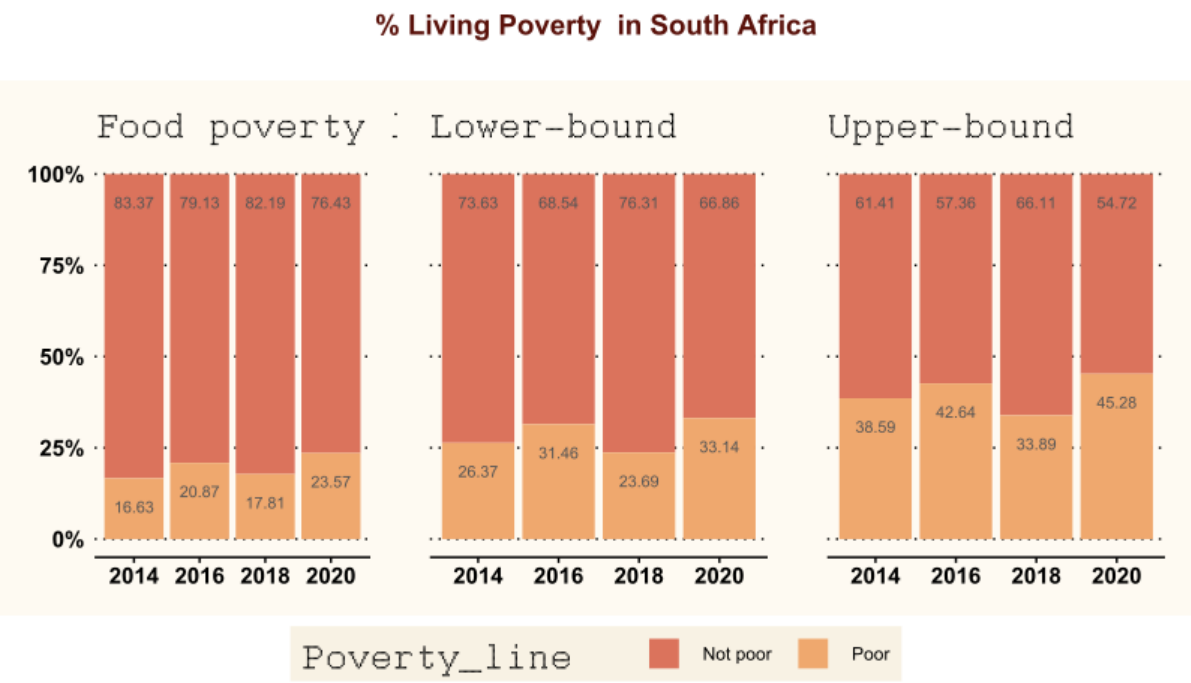



**Figure 7.1: Poverty levels in South Africa, 2014-2020**

*Source: General Household Surveys (Statistics South Africa, 2014-2020)*

South Africa has three poverty lines, defined by Statistics South Africa as follows:

- **Food poverty line**: This refers to the amount of money that an individual will need to afford the minimum required daily energy intake. This is also commonly referred to as the "extreme" poverty line.
- **Lower-bound poverty line**: This refers to the food poverty line plus the average amount derived from essential non-food items of households whose total expenditure is below but close to the food poverty line.

- **Upper-bound poverty line**: This refers to the food poverty line plus the average amount derived from non-food items of households whose food expenditure is equal to the food poverty line.

As shown in **Figure 7.1**, the proportion of people living in extreme poverty was about 24% in 2020. Furthermore, 33% lived below the lower-bound poverty line, and 45% lived below the upper-bound poverty line. However, higher poverty rates in all categories in 2020 can be attributed to the 2020 Covid-19 pandemic, resulting in the loss of employment and livelihoods (approximately 3 million were lost during the first lockdown[15]).

In addition to poverty, South Africa has the highest inequality in the world. Figure 7.2 shows the extent of inequality using the Gini Index, where 0 = perfect equality and 100 = perfect inequality. South Africa's Gini index is above 63%, the highest of the BRICS countries.

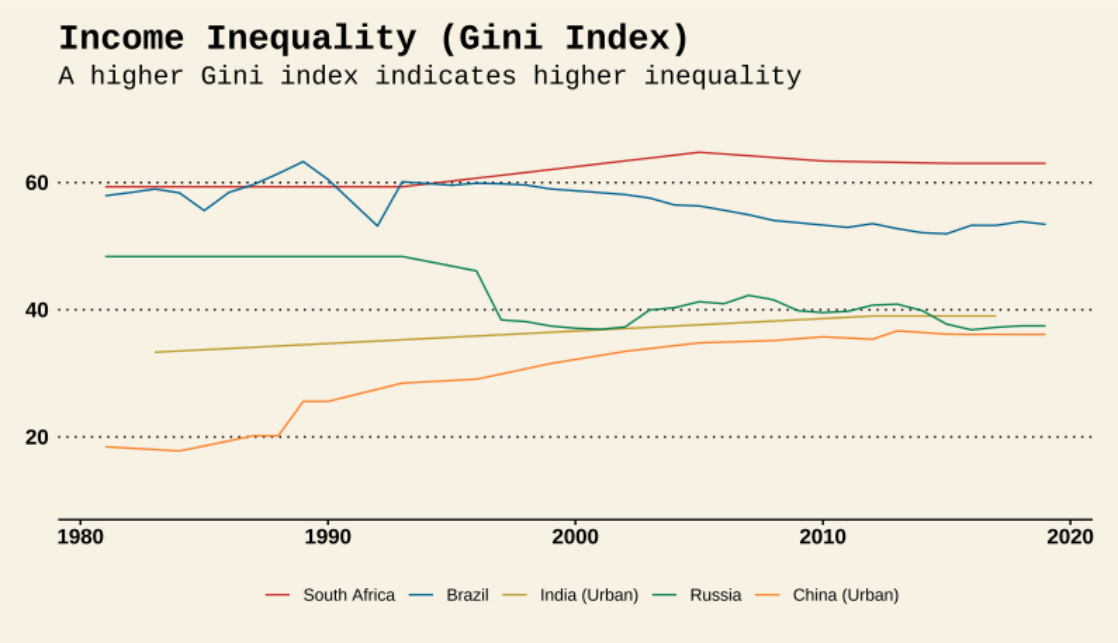



**Figure 7.2: Gini index of BRICS countries**

*Source: General Household Surveys (Statistics South Africa, 2014-2020)*

### *7.2.2 Availability of shelter*

South Africa has made progress in providing housing for the poor, but challenges remain. As indicated in **Figure 7.3**, 16% of households still live in informal settlements. Although the other proportion lives in formal settlements, housing structures are of low quality or households are excluded from socio-economic services and opportunities.

15 Spaull et al., 2020. The NIDS-CRAM Wave 1 Questionnaire. NIDSCRAM Technical Document A. (Online). Available: https://cramsurvey.org/reports/

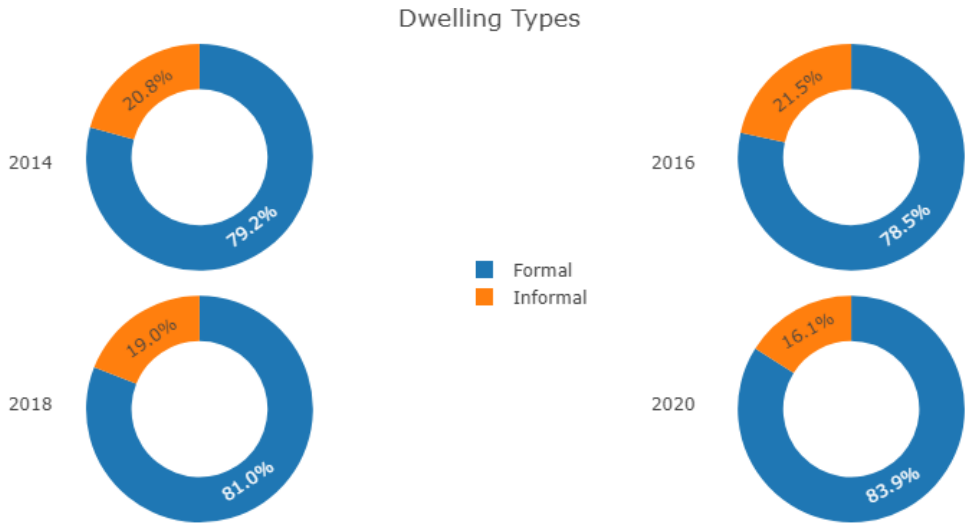



**Figure 7.3: Types of dwelling units in South Africa**

*Source: General Household Surveys (Statistics South Africa, 2014-2020)*

### *7.2.3 Water and sanitation*

Linked to human settlements is the pressing challenge of water and sanitation. SDG 6 is about "ensuring availability and sustainable management of water and sanitation for all". This is also one of the objectives of the NDP. As shown in **Figure 7.4**, about 35% of households do not use flush toilets or are not connected to the formal sewage system. This figure could be higher for rural households because of a lack of infrastructure.

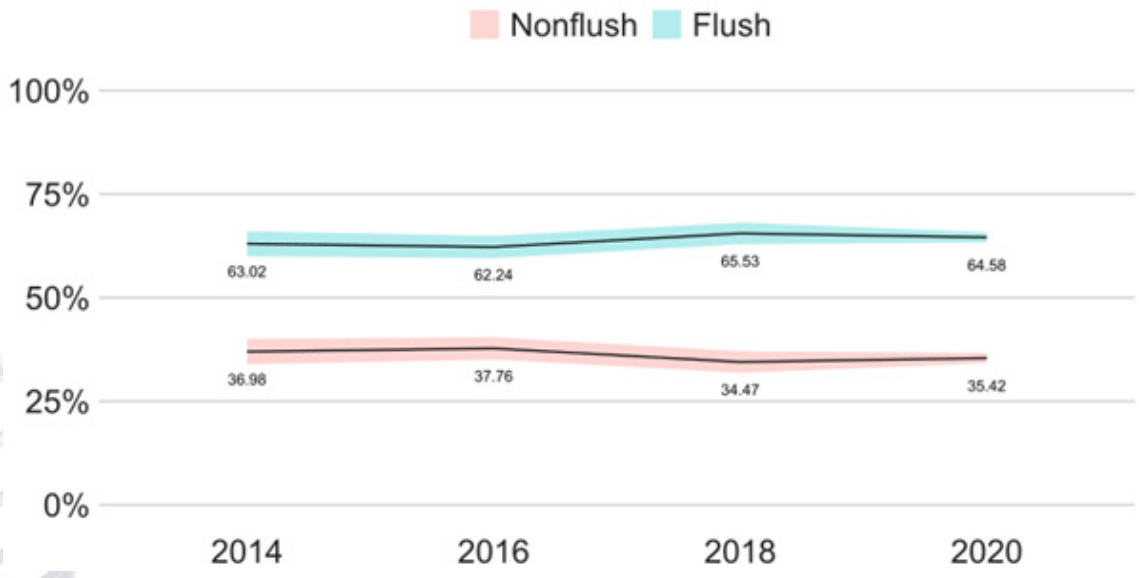



**Figure 7.4: Type of household toilet facilities**

*Source: General Household Surveys (Statistics South Africa, 2014-2020)*

Linked to sanitation is access to clean and safe water, which remains one of the greatest challenges faced by developing countries. Figure 5 shows that in 2020 a quarter of the country's households did not have piped water in the dwelling or yard.

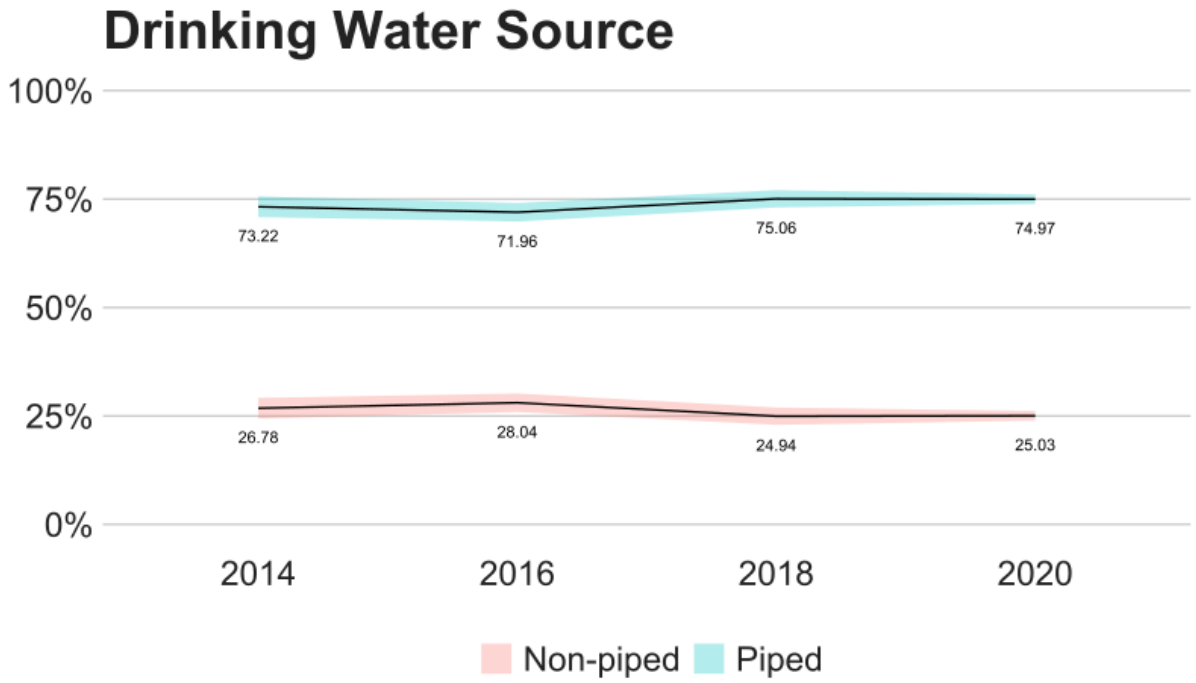



**Figure 7.5: Percentage of the South African households with running water**

*Source: General Household Surveys (Statistics South Africa, 2014-2020)*

### *7.2.4 Case studies of societal impact of STI*

The indicators presented above reveal the extent of the challenges the country faces. To succeed in South Africa, innovation needs to address poverty, unemployment and inequality directly. Fortunately, around the world, innovation is being used to address socio-economic challenges. For example, international organisations such as the OECD have embedded what they call "social innovation" within their institutional systems.

In South Africa, there are several case studies that have demonstrated the opportunities innovation offers, especially in relation to service delivery. Two of these are the Transformative Decision Support Tools in Human Settlements and the Municipal Innovation Maturity Index (MIMI).

These two case studies are part of the emerging trend towards a transformative innovation policy paradigm. Transformative innovation aims to use STI to address socio-economic and ecological challenges, and are thus in line with the SDGs. The intention is to use experts from government, universities and funding agencies to build capacity so that policy makers embed STI principles within their institutions while creating a space for learning from and cooperation with other global partners. It aims to use STI to bring transformative change to policy, society and the economy.

**Table 7.15: Framing of transformative innovation policy**

| Frame | Period | Focus | Actors | Scale |
|---|---|---|---|---|
| Frame 1: Research and development and regulation | 1960s-1990s | The focus was on how large firms and governments could apply science and technology to increase productivity and efficiency. | Governments, industry and scientists | National |
| Frame 2: National systems of innovation and entrepreneurship | 1990s (ongoing) | The focus is on promoting entrepreneurship and facilitating the creation of markets for innovative goods and services; improving business conditions for small and medium-sized enterprises and start-ups; using programmes to stimulate entrepreneurship and incubators; and enhancing skills development based on a proactive analysis of skill gaps | Government, scientists, industry, new technology-based firms | National and regional (centres of excellence and clusters of innovation) |
| Frame 3: Transformative innovation | Emerging | The focus is on solving social and environmental challenges, tilting the regulative playing field at global level and providing more space for experimentation with niche solutions at local level, enabling socio-technical systems change. | Government, science, industry, civil society, end-users and non-users | At various scales, as transformative innovation addresses transboundary challenges such as climate change and other SDGs |

*Source: Adapted from Transformative Innovation Policy Consortium, 2018*

The Transformative Innovation Policy Consortium is experimenting with various projects in various countries, including South Africa.

***Case Study 1: Transformative decision-support tools in human settlements***

The aim of the project, which ran from 2018 to 2019, was to explore how decision-support tools could be used in the human settlements value chain. The DSI commissioned the study after identifying a lack of coordination between various partners in the housing value chain, including between and within government (national, provincial, and local) and between various private actors (implementing agencies, contractors, engineers, etc.) There are various stages (planning, implementation and monitoring and evaluation) in government provision of housing, and different actors are tasked with different stages. The lack of communication and coordination between these actors results in inefficiencies in housing delivery.

The project aimed to find a decision-support tool that would address the above challenge. After an extensive process using mixed methods, including workshops and online surveys, the tool was selected. The selected tool was piloted, and the results were documented. These are described in **Figure 7.6**.

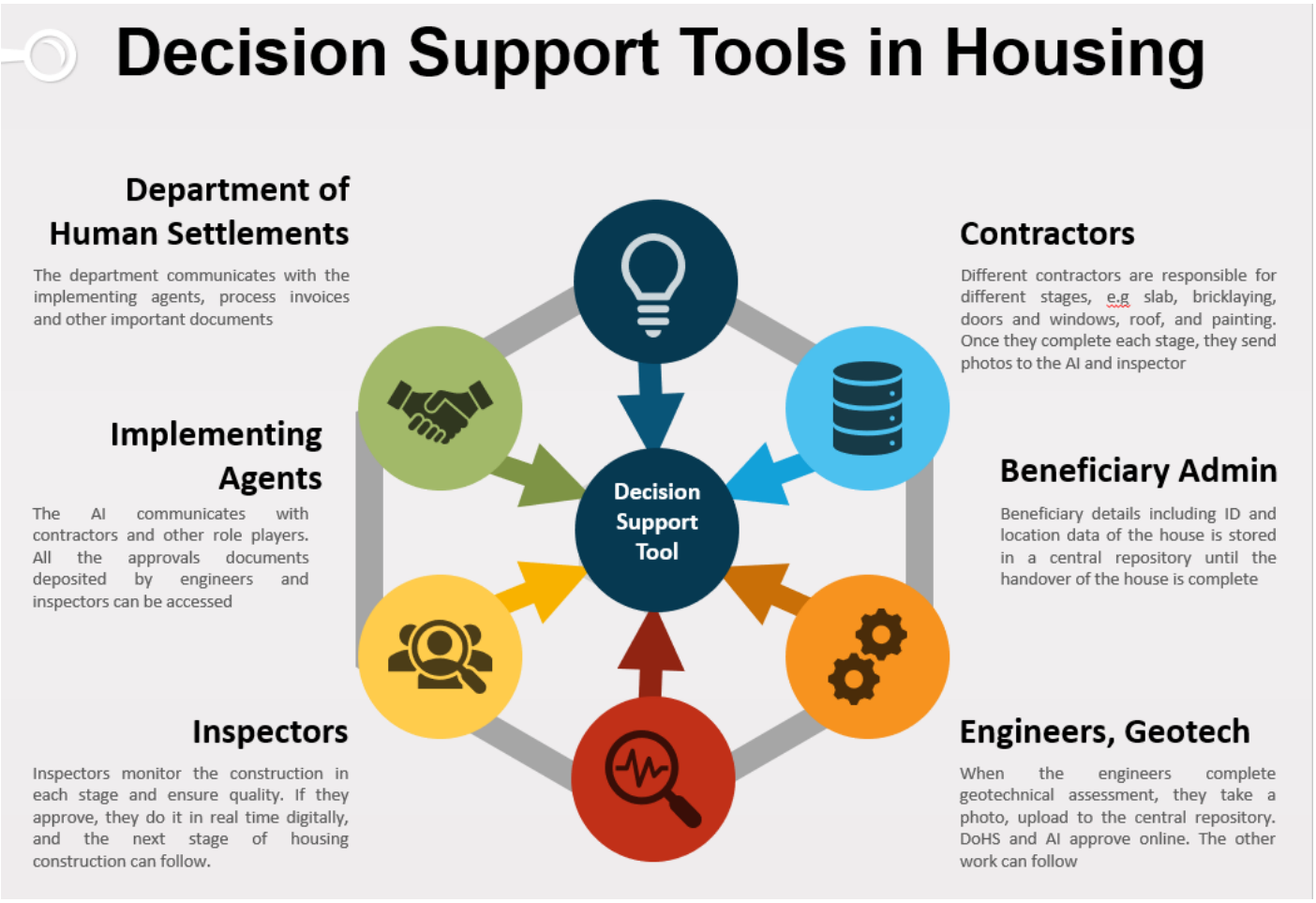



**Figure 7.6: The use of decision-support tools in human settlements**

*Source: Sustainable Human Settlement Decision-Support Tools Report, 2020*

The benefits of using decision-support tools were as follows:

- Digitisation of the housing provision process from planning to implementation. All documents are digital and stored in the central repository.
- Inspections and geotech completions are updated in real time online, fast-tracking the process.
- Transparency is enhanced.
- Mismatches between beneficiaries and housing can be identified.
- Only a smartphone is required.

***Case Study 2: Municipal Innovation Maturity Index***

MIMI is a decision-support tool that assesses the innovation capabilities, practices, and readiness of municipalities for improved service delivery. It assesses the capabilities of municipalities and their employees to learn, implement, adopt and institutionalise innovation. It measures and benchmarks the STI readiness of municipalities to ascertain their innovation maturity levels, and identify areas that require improvement to position municipalities on the path to higher innovation maturity levels. The MIMI framework applies six objective criteria for assessing the maturity of municipalities and their officials (**Table 7.16**).

**Table 7.16: Municipal Innovation Maturity Index (MIMI) levels**

| Level 1 | Level 2 | Level 3 | Level 4 | Level 5 | Level 6 |
|---|---|---|---|---|---|
| **Limited, if any** | **Defined** | **Applied** | **Managed** | **Entrenched** | **Share learnings** |
| There is limited, if any, innovation on the part of individual officials or the organisation. | Innovation is defined. Officials understand innovation principles and innovation strategies in place, but there is little, if any, evidence of implementation. | Innovation is applied. There is evidence of innovations being applied in certain departments of the municipality. Innovation is repeatable, but irregular. | Innovation is managed. There is ongoing innovation and processes in relation to this are managed well in the municipality. | Innovation principles and practices are entrenched throughout the municipality. Officials seek to optimise and evaluate solutions and improve on these continuously for internal benefit. | Innovation is open and outward looking. New knowledge is applied creatively, based on evidence, in different contexts and shared with others outside the organisation. |

*Source: MIMI Implementation Testing Report 2021*

Some preliminary MIMI results are reported in Table 7.17. In summary, MIMI seeks to measure innovation in municipalities, and also encourages institutions to embed innovation within their systems.

**Table 7.17: MIMI mean scores across provinces and municipalities**

| Provinces | Municipalities | Innovation maturity level | Municipal enablers of innovation | Management support for innovation | Individual innovation behaviour |
|---|---|---|---|---|---|
| Western Cape | Oudtshoorn Local Municipality | 2 | 3 | 3 | 2 |
| | Drakenstein Local Municipality | 3 | 3 | 3 | 3 |
| | Bergrivier Local Municipality | 3 | 3 | 4 | 3 |
| | Witzenberg Local Municipality | 3 | 3 | 2 | 3 |
| | City of Cape Town Metropolitan Municipality | 3 | 3 | 3 | 3 |
| | Cape Agulhas Local Municipality | 3 | 3 | 3 | 4 |
| | Swellendam Local Municipality | 3 | 3 | 3 | 3 |
| Gauteng | City of Tshwane Metropolitan Municipality | 3 | 3 | 2 | 3 |
| | Midvaal Local Municipality | 3 | 3 | 3 | 3 |
| | Sedibeng District Municipality | 1 | 1 | 1 | 1 |
| | West Rand District Municipality | 1 | 1 | 1 | 1 |
| KwaZulu-Natal | Msunduzi Local Municipality | 2 | 2 | 2 | 2 |
| | AbaQulusi Local Municipality | 3 | 2 | 3 | 3 |
| | eThekwini Metropolitan Municipality | 2 | 2 | 3 | 2 |
| Limpopo | Ba-Phalaborwa Local Municipality | 2 | 2 | 2 | 2 |
| | Waterberg District Municipality | 3 | 3 | 4 | 3 |
| Eastern Cape | Buffalo City Metropolitan Municipality | 2 | 2 | 2 | 2 |
| Mpumalanga | City of Mbombela Local Municipality | 2 | 3 | 2 | 2 |

*Source: MIMI Implementation Testing Report 2021*

# 8. SECTORAL AND PROVINCIAL SYSTEMS OF INNOVATION

## 8.1 Sectoral systems of innovation: The bioeconomy

The national Bioeconomy Strategy for South Africa was approved in January 2014 . To avoid annual fluctuations, the performance of the bioeconomy since the adoption of the strategy is assessed against a three-year average for the period 2013-2015.

The number of biotechnology publications has increased significantly since the adoption of the Bioeconomy Strategy. In 2019, publications went up 23% from 2018. Moreover, South Africa's global share of biotechnology publications also increased significantly. However, in 2020 there was a decline in the output and the world share of South African publications. Nevertheless, both the number and the world share of South Africa's publications in biotechnology have increased significantly since the adoption of the Bioeconomy Strategy.

**Table 8.1: South Africa's number and world share of biotechnology and applied microbiology publications (articles and reviews only)**

| Year | Number of Publications | World Share (%) |
|---|---|---|
| 2010 | 207 | 0,797 |
| 2011 | 252 | 0,897 |
| 2012 | 150 | 0,585 |
| 2013 | 187 | 0,653 |
| 2014 | 236 | 0,799 |
| 2015 | 178 | 0,591 |
| 2016 | 216 | 0,763 |
| 2017 | 228 | 0,760 |
| 2018 | 231 | 0,796 |
| 2019 | 267 | 0,899 |
| 2020 | 253 | 0,795 |
| Base: 2013 -15 | 200 | 0,681 |

*Source: CREST, Stellenbosch University*

South African biotechnology patents granted by the USPTO increased in 2019. However, as **Table 8.2** shows, the increase in patents in 2019 was a one-year increase following a general decline after the adoption of the Bioeconomy Strategy. The patents in 2019 were higher than the per annum average for the period 2013-15. However, the average number of patents granted annually in the period 2016-2019 was lower (5) than in the baseline years 2013-15 (6).

The Bioeconomy Strategy has three key economic objectives, namely, to increase the contribution of the bioeconomy to GDP through high growth, to create employment and to make the country more competitive. The data presented here are for what has been identified as the "core" of the bioeconomy, which consists of Standard Industrial Classifications 1, 30, 321-326, 391, 392, 395[16].

16 https://www.gov.za/sites/default/files/gcis_document/201409/bioeconomy-strategya.pdf

**Table 8.2: Biotechnology patents granted by USPTO**

| | Number of biotechnology patents |
|---|---|
| 2010 | 2 |
| 2011 | 2 |
| 2012 | 2 |
| 2013 | 3 |
| 2014 | 2 |
| 2015 | 7 |
| 2016 | 6 |
| 2017 | 3 |
| 2018 | 2 |
| 2019 | 8 |
| Base: 2013-15 | 6 |

*Source: USPTO*

Output declined by a little over 2% in 2020 from the previous year. This followed a similar decline in 2019. The bioeconomy has not grown its share of total South African output since the adoption of the Bioeconomy Strategy.

**Table 8.3: Bioeconomy GDP output and share of total South African GDP**

| | Bioeconomy GDP output (R million at constant 2015 prices) | Bioeconomy's share of total GDP (%) |
|---|---|---|
| 2010 | 300 221 | 8,31 |
| 2011 | 300 007 | 8,08 |
| 2012 | 305 325 | 8,07 |
| 2013 | 308 490 | 7,96 |
| 2014 | 319 083 | 8,11 |
| 2015 | 316 434 | 7,95 |
| 2016 | 311 091 | 7,75 |
| 2017 | 331 680 | 8,17 |
| 2018 | 336 146 | 8,16 |
| 2019 | 328 956 | 7,98 |
| 2020 | 321 536 | 8,29 |
| Base: 2013-15 | 314 669 | 8,00 |

*Source: Quantec and Statistics SA*

Employment in the bioeconomy has been declining consistently since 2015. In 2020, there was a decline of a little over 5% from 2019. The share of the bioeconomy in total South African employment in 2020 (10,7%) was marginally lower than the yearly average for the period 2013-2015 (10,9%).

**Table 8.4: South African bioeconomy sector employment+**

| | Bioeconomy employment | % total SA employment* |
|---|---|---|
| 2010 | 1 528 282 | 10,9 |
| 2011 | 1 480 064 | 10,3 |
| 2012 | 1 529 377 | 10,4 |
| 2013 | 1 612 396 | 10,7 |
| 2014 | 1 578 854 | 10,3 |
| 2015 | 1 828 822 | 11,6 |
| 2016 | 1 788 532 | 11,3 |
| 2017 | 1 756 935 | 10,9 |
| 2018 | 1 734 585 | 10,6 |
| 2019 | 1 727 305 | 10,6 |
| 2020 | 1 637 054 | 10,7 |
| Base: 2013 -15 | 1 673 357 | 10,9 |

*+ Total employment includes both formal and informal employment*

*Source: Quantec & Stats SA*

A key objective of the Bioeconomy Strategy is to increase exports and South Africa's competitiveness in global markets. In addition to increasing total bioeconomy exports, the strategy aims to increase the sophistication of exports and the unit value added of South Africa's bioeconomy exports. As a result of enhanced technological change and innovation, exports should be more sophisticated and hence of higher value.

In 2020, export figures remained about the same as the previous year. However, this followed a decline in exports in 2019 of almost 11%. Over the decade, there has been little increase the bioeconomy share of total South African exports. The bioeconomy share of total South African exports in 2020 (17,7%) was similar to that of 2013-2015 (17,5%).

More technologically advanced and innovative products show in a higher unit value price for exports. However, the unit value of bioeconomy exports (US$) has been declining since 2017 and in 2020 was lower ($0,76) than the average for 2013-15 ($0,84).

**Table 8.5: South African bioeconomy sector's exports**

| | Bioeconomy exports (Current US$ millions) | % of total SA exports | Unit value US$ |
|---|---|---|---|
| 2010 | 14 646 | 16,1 | 0.79 |
| 2011 | 16 799 | 15,6 | - |
| 2012 | 15 873 | 16,0 | - |
| 2013 | 16 362 | 17,2 | 0,78 |
| 2014 | 15 945 | 17,2 | 0,89 |
| 2015 | 14 526 | 18,0 | 0,85 |
| 2016 | 14 162 | 18,6 | 0,87 |
| 2017 | 15 971 | 18,0 | 0,88 |
| 2018 | 16 839 | 17,9 | 0,86 |
| 2019 | 15 048 | 16,8 | 0,75 |
| 2020 | 15 128 | 17,7 | 0,76 |
| Base: 2013-15 | 15 611 | 17,5 | 0,84 |

*Source: Quantec and Statistics SA*

In summary:

- The number of biotechnology publications decreased between 2019 and 2020. However, the number and world share of South Africa's publications in biotechnology have increased significantly since the adoption of the Bioeconomy Strategy.
- The number of bioeconomy patents increased between 2018 and 2019. The share of South African bioeconomy patents is similar to that in 2013-2015.
- Output in the bioeconomy decreased between 2019 and 2020. There is no trend showing an increase.
- Bioeconomy employment has been declining consistently since 2015. In 2020, there was a further decline of a little over 5% from 2019.
- There has been little change in the number and share of exports, or in the unit value of biotechnology. The unit value has been on the decline since 2017 and is currently below the 2013-2015 value.
- This strong performance in terms of science (publications) and moderate performance in terms of technology (patents) contrasts with the weak performance in economic indicators (output, employment, and exports). This contrast is mirrored in the performance of the business sector as a whole.

## 8.2 Regional systems of innovation

Regional innovations systems have gained prominence in recent years because of their importance in regional economic development. Since national systems of innovation are made up of regional systems of innovation, the regional systems are key building blocks for strong national systems. Regional innovation policies need to ensure a favourable environment for entrepreneurship and business growth to create jobs. This section communicates selected regional/provincial STI indicators in South Africa.

### *8.2.1 Provincial economic performance and industrial structure*

The sizes of the nine provincial economies in South Africa and their contribution to GDP differs considerably. As shown in **Table 8.6**, Gauteng dominates, contributing 38% of overall GDP for 2020, which is almost double the contribution of the second biggest contributor, KwaZulu-Natal. The Western Cape is the third biggest contributor to South Africa's GDP. Together, these three provinces accounted for 64% of the country's GDP in 2020.

**Table 8.6: Size of provincial economies in South Africa**

| | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|
| Eastern Cape | 324 | 331 | 336 | 338 | 341 | 344 | 346 | 350 | 349 | 330 |
| Free State | 214 | 220 | 225 | 228.5 | 228.7 | 228.9 | 231 | 233 | 232 | 217 |
| Gauteng | 1 430 | 1 470 | 1 511 | 1 538 | 1 557 | 1 576 | 1 591 | 1 620 | 1 628 | 1 514 |
| Limpopo | 277 | 281 | 287 | 290 | 296.1 | 296 | 299 | 303.5 | 303.3 | 287 |
| Mpumalanga | 283 | 289 | 294 | 301 | 302 | 303 | 306 | 310 | 309 | 290 |
| Northern Cape | 82 | 85 | 87 | 89 | 90.7 | 90.3 | 92 | 93 | 92.8 | 89 |
| North West | 247 | 245 | 252 | 245 | 254 | 248 | 252 | 255 | 254 | 236 |
| KwaZulu-Natal | 661 | 678 | 696 | 709 | 717 | 723 | 734 | 745.8 | 745.5 | 696 |
| Western Cape | 578 | 595 | 610 | 621 | 631 | 638 | 646 | 656 | 657 | 618 |
| South Africa | 4 099 | 4 197 | 4 302 | 4 363 | 4 420 | 4 450 | 4 501 | 4 568 | 4 573 | 4 279 |

*Source: Quantec at constant 2015 2015 prices, seasonally adjusted and annualised*

**Table 8.7** shows the sectors which contribute the most to the GDP of the various provinces. The provincial economies that contribute the most to South Africa's GDP are dominated by finance, real estate and business services. The biggest sectors in provinces with small economies, except for the Eastern Cape, are mining and quarrying. This disparity in economic contributions and economic structures has a bearing on the provincial innovation systems.

**Table 8.7: Sectors contributing the most to GDP in each province**

| Province | Sector | Percentage contribution |
|---|---|---|
| Eastern Cape | General government services | 20,8 |
| Gauteng | Finance, real estate and business services | 24,8 |
| Free State | Trade, catering and accommodation | 16,4 |
| KwaZulu-Natal | Finance, real estate and business services | 16,9 |
| Limpopo | Mining and quarrying | 25,4 |
| Mpumalanga | Mining and quarrying | 23,1 |
| Northern Cape | Mining and quarrying | 26,5 |
| North West | Mining and quarrying | 27,6 |
| Western Cape | Finance, real estate and business services | 28,3 |

### 8.2.2 *Indicators for provincial innovation systems*

This section presents input indicators for the regional innovation systems. These include R&D expenditure and human resource development, including NSC performance in Mathematics and Science.

Investment in research and development is an important input and contributes to provincial economic development. **Table 8.8** shows provincial R&D expenditure for the nine provinces between 2015/16 and 2019/20. In this period Gauteng had the highest R&D expenditure, followed by the Western Cape and KwaZulu-Natal. The provinces with the highest R&D expenditure have the high numbers of leading PRIs and universities, high-technology industrial activities and/or knowledge-based services, which attract new start-ups and highly qualified personnel.

**Table 8.8: Provincial R&D expenditure trends**

| | 2015/16 | 2016/17 | 2017/18 | 2018/19 | 2019/20 |
|---|---|---|---|---|---|
| | R'000 | | | | |
| GERD | 32 336 679 | 35 692 973 | 38 724 590 | 36 783 968 | 34 484 862 |
| Eastern Cape | 2 142 919 | 2 206 473 | 2 300 631 | 2 211 524 | 2 091 071 |
| Free State | 1 778 469 | 1 834 572 | 2 149 267 | 1 976 953 | 1 711 039 |
| Gauteng | 14 666 111 | 16 421 582 | 17 319 635 | 15 767 101 | 14 385 849 |
| KwaZulu-Natal | 3 335 141 | 3 639 100 | 4 172 713 | 4 074 154 | 3 629 403 |
| Limpopo | 627 125 | 728 874 | 854 885 | 806 624 | 772 074 |
| Mpumalanga | 791 248 | 699 720 | 715 616 | 853 859 | 841 877 |
| Northern Cape | 660 963 | 532 530 | 576 963 | 905 844 | 900 545 |
| North-West | 1 209 434 | 1 298 778 | 1 306 478 | 1 682 406 | 1 700 184 |
| Western Cape | 7 125 269 | 8 331 345 | 9 328 402 | 8 505 504 | 8 542 820 |
| **Total (GERD)** | **32 336 679** | **35 692 973** | **38 724 590** | **36 783 968** | **34 484 862** |

*Source: National Surveys of Research and Experimental Development*

Figure 8.1 shows proportional R&D expenditure trends. Although Gauteng has the highest proportional expenditure, there has been a decline since 2017/18. In 2019/20, R&D expenditure declined in all provinces.

The data illustrates the significant disparities in R&D expenditure among the provinces. The R&D expenditure is concentrated in three provinces – Gauteng, the Western Cape and KwaZulu-Natal. This unbalanced R&D landscape has implications for innovation performance since R&D intensity is frequently used as a measure to determine an economy's creative/innovative capacity.

**Figure 8.1** shows that in 2020 the R&D expenditure of Gauteng, the Western Cape and KwaZulu-Natal was almost 75% of national R&D expenditure.

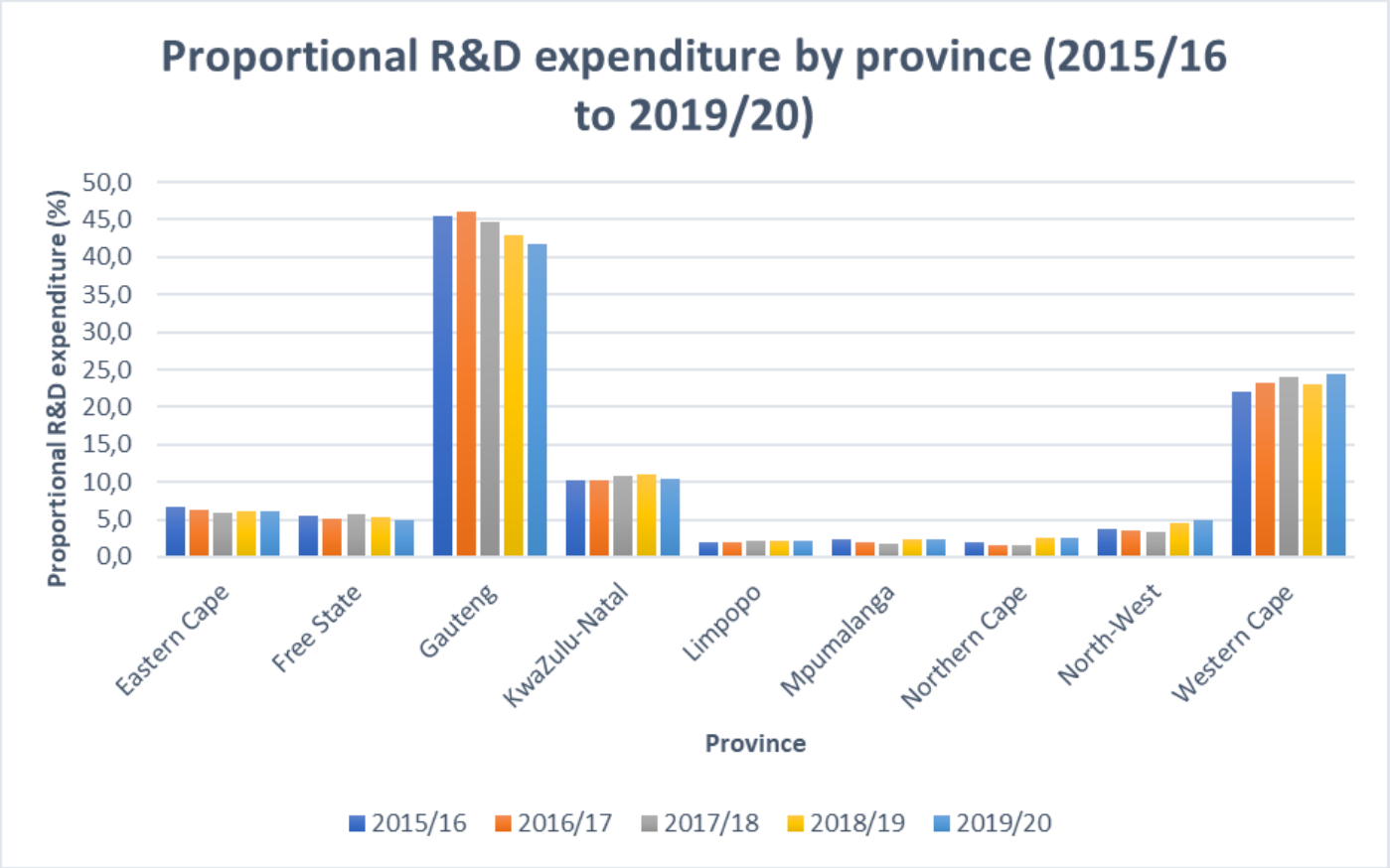



**Figure 8.1: Proportion of R&D expenditure by province**

*Source: National Surveys of Research and Experimental Development*

The following sections present the contributions of business, government and higher education sectors to R&D at provincial level.

**Table 8.9** shows business expenditure for each province between 2015/16 and 2019/20.

**Table 8.9: Business sector R&D expenditure by province**

| Province | 2015/16 | 2016/17 | 2017/18 | 2018/19 | 2019/2020 |
|---|---|---|---|---|---|
| | R'000 | | | | |
| Eastern Cape | 651 533 | 690 478 | 707 348 | 674 516 | 439 537 |
| Free State | 1 124 042 | 1 060 177 | 1 105 873 | 991 206 | 694 454 |
| Gauteng | 7 183 557 | 7 876 139 | 8 285 425 | 7 617 873 | 5 447 407 |
| KwaZulu-Natal | 1 436 737 | 1 553 130 | 1 679 718 | 1 446 281 | 1 193 914 |
| Limpopo | 145 736 | 171 567 | 223 014 | 184 199 | 78 484 |
| Mpumalanga | 339 985 | 284 655 | 304 990 | 392 986 | 370 695 |
| North-West | 451 891 | 526 962 | 565 486 | 601 653 | 566 308 |
| Northern Cape | 206 786 | 49 508 | 60 007 | 50 561 | 39 576 |
| Western Cape | 2 274 728 | 2 568 653 | 2 927 324 | 2 488 558 | 1 874 107 |
| **Total** | **13 814 995** | **14 781 270** | **15 859 185** | **14 447 833** | **10 704 481** |

*Source: National Surveys of Research and Experimental Development*

As expected, the business sector in Gauteng has the highest R&D expenditure of the provinces, followed by the Western Cape. Overall, there has been a sharp decline in R&D expenditure in all the provinces, which can be attributed to the Covid-19 pandemic.

**Figure 8.2** illustrates the percentage proportional trend of business R&D expenditure among the provinces. The trend shows that business expenditure in R&D in Gauteng, the Free State and Limpopo declined slightly. The proportion of business expenditure in the rest of the provinces increased marginally. Despite the Covid-19 pandemic, overall business expenditure was stable.

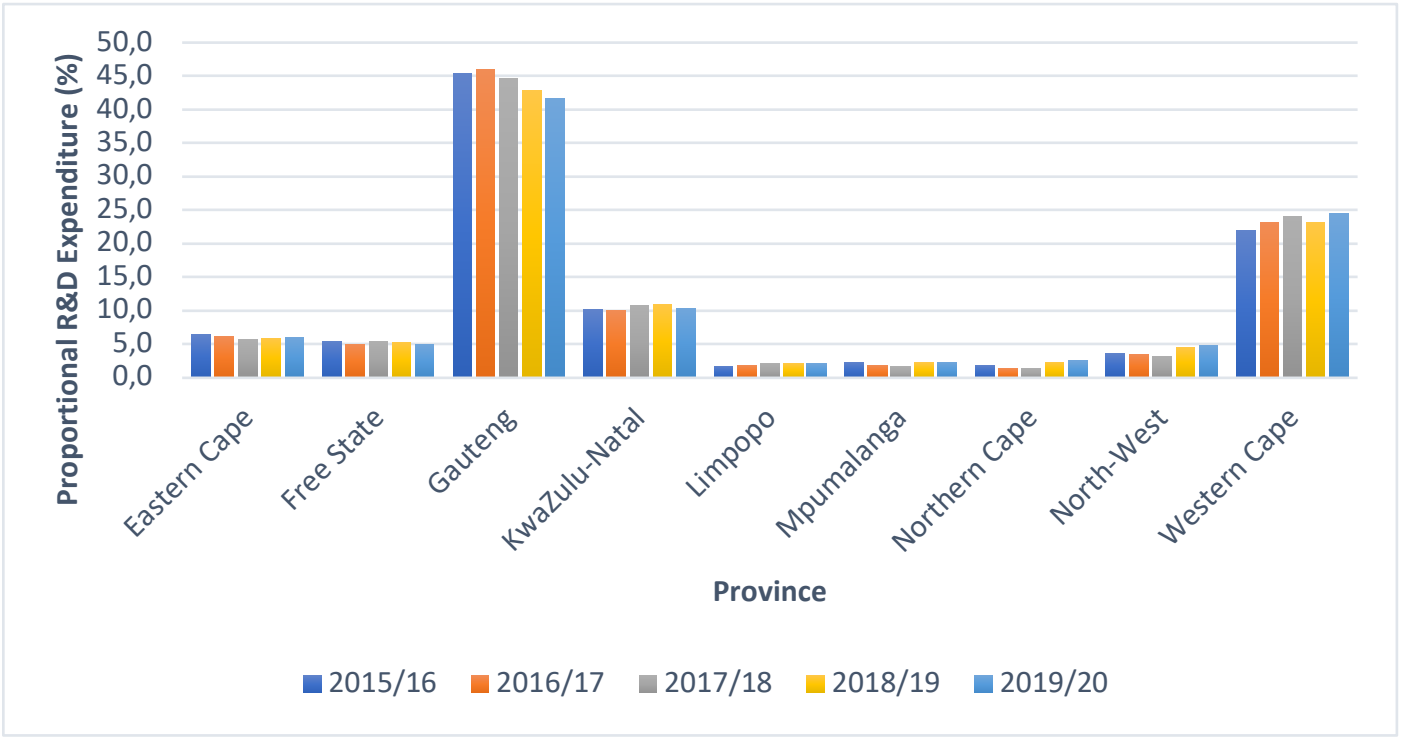



**Figure 8.2: Proportional business sector R&D expenditure by province**

*Source: National Surveys of Research and Experimental Development*

Government supports R&D expenditure through various programmes and funding instruments. **Table 7.10** displays government expenditure among the provinces between 2015/16 and 2019/20. As data shows, Gauteng province again has the highest expenditure followed by Western Cape and Eastern Cape-which is slightly higher than KZN.

**Table 8.10: Government Sector R&D Expenditure by Province**

| Province | 2015/16 | 2016/17 | 2017/18 | 2018/19 | 2019/2020 |
|---|---|---|---|---|---|
| | R'000 | | | | |
| Eastern Cape | 225 603 | 222 456 | 281 201 | 305 629 | 301 816 |
| Free State | 61 802 | 81 957 | 81 890 | 59 694 | 45 660 |
| Gauteng | 832 397 | 885 142 | 974 192 | 836 827 | 581 945 |
| KwaZulu-Natal | 187 088 | 172 655 | 206 551 | 236 602 | 205 503 |
| Limpopo | 84 232 | 76 541 | 86 876 | 89 889 | 81 308 |
| Mpumalanga | 112 173 | 107 237 | 104 154 | 88 922 | 83 648 |
| North-West | 61 815 | 57 994 | 60 594 | 66 727 | 57 423 |
| Northern Cape | 69 174 | 66 200 | 94 659 | 88 575 | 525299 |
| Western Cape | 378 737 | 428 465 | 435 757 | 450 560 | 483 841 |
| **Total** | **2 013 021** | **2 098 646** | **2 325 875** | **2 223 426** | **1 893 543** |

*Source: National Surveys of Research and Experimental Development*

**Figure 8.3** shows that government's proportional expenditure in Gauteng declined from 37,6% in 2018/19 to 30,7% in 2019/20. During the same period, the proportional government expenditure in the Western Cape increased from 20,5% to 25,6%. As the graph shows, the Eastern Cape and KwaZulu-Natal have enjoyed modest proportional increases. The proportional expenditure in the Eastern Cape rose from 13,7 % in 2018/19 to 15,9% in 2019/20. On the other hand, proportional expenditure in KwaZulu-Natal increased from 9,4% in 2014/15 to 10,6% in 2018/19.

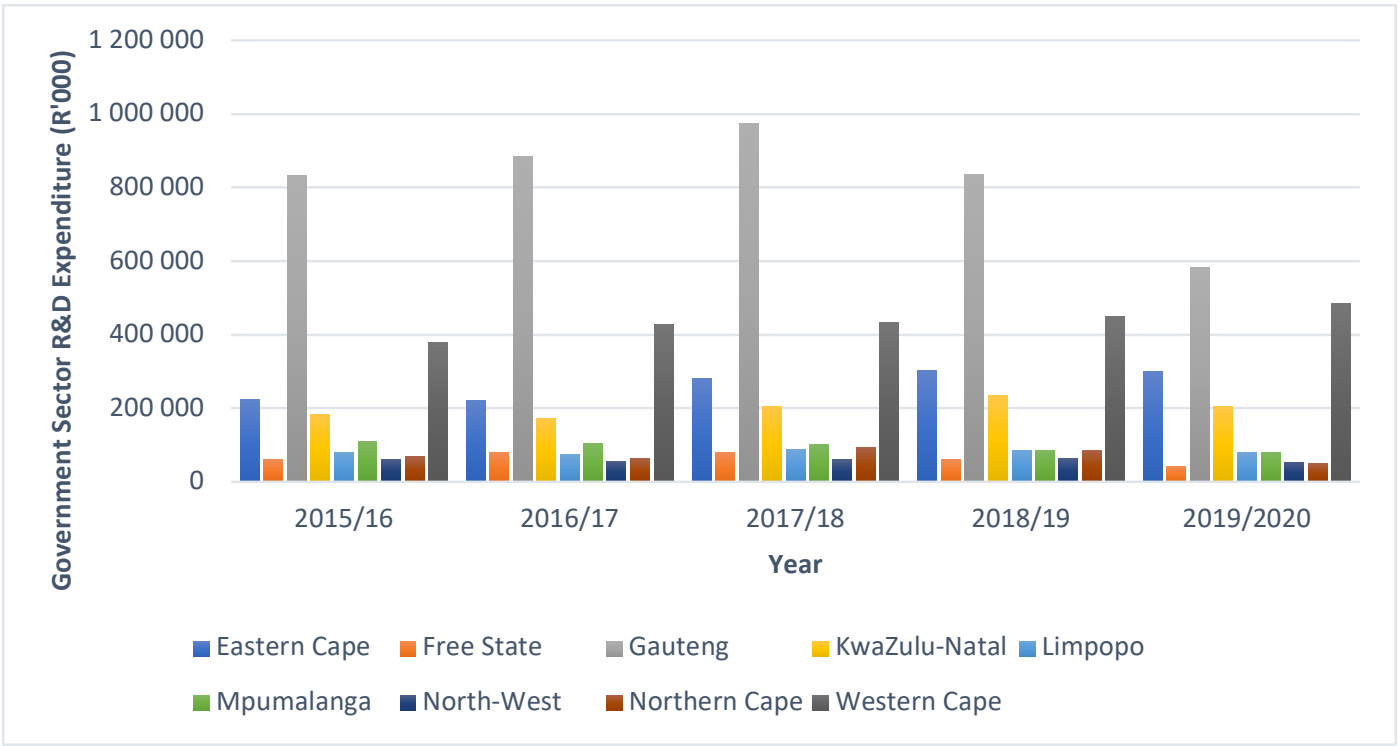



**Figure 8.3: Proportional government sector R&D expenditure by province**

*Source: National Surveys of Research and Experimental Development*

At regional level, higher education institutions are key actors in the regional innovation system. The presence of universities who are strong R&D performers provides regions with access to knowledge assets and technological knowledge. Knowledge can be transferred to local businesses or start-ups can be created.

The level of investment in research and development by the higher education sector in the provinces is shown in Table 8.11.

**Table 8.11: Higher education sector R&D expenditure by province**

| Province | 2015/16 | 2016/17 | 2017/18 | 2018/19 | 2019/20 |
|---|---|---|---|---|---|
| | R'000 | | | | |
| Eastern Cape | 975 099 | 1 002 978 | 1 017 383 | 1 027 996 | 1 123 901 |
| Free State | 523 782 | 625 646 | 894 118 | 803 727 | 847 104 |
| Gauteng | 3 305 576 | 4 105 237 | 4 269 020 | 3 730 236 | 4 188 428 |
| KwaZulu-Natal | 903 664 | 1 157 722 | 1 428 653 | 1 646 915 | 1 514 301 |
| Limpopo | 229 364 | 301 809 | 358 543 | 384 346 | 466 703 |
| Mpumalanga | 190 716 | 148 981 | 155 430 | 170 553 | 213 914 |
| North-West | 444 135 | 469 171 | 449 196 | 833 635 | 856 833 |
| Northern Cape | 164 487 | 188 515 | 180 632 | 161 714 | 169 999 |
| Western Cape | 3 139 800 | 3 659 198 | 4 256 902 | 4 423 997 | 4 797 779 |
| **Total** | **9 876 623** | **11 659 258** | **13 009 876** | **13 183 119** | **14 178 960** |

*Source: National Surveys of Research and Experimental Development*

The data in the table shows that expenditure in the Western Cape (R4,7bn) is the highest. The Western Cape has a high concentration of leading universities. These universities are able to attract not only talent but also research funds, both domestic and international. Gauteng has the second highest expenditure in R&D by higher education (R4,2bn). The rest of the provinces are far behind.

The Western Cape's proportional expenditure was 33,8% in 2019/20, compared to Gauteng's, at 29,5%. It is worth noting that Gauteng's portion increased from 28,3% in 2018/19 to 29,5%% in 2019/20.

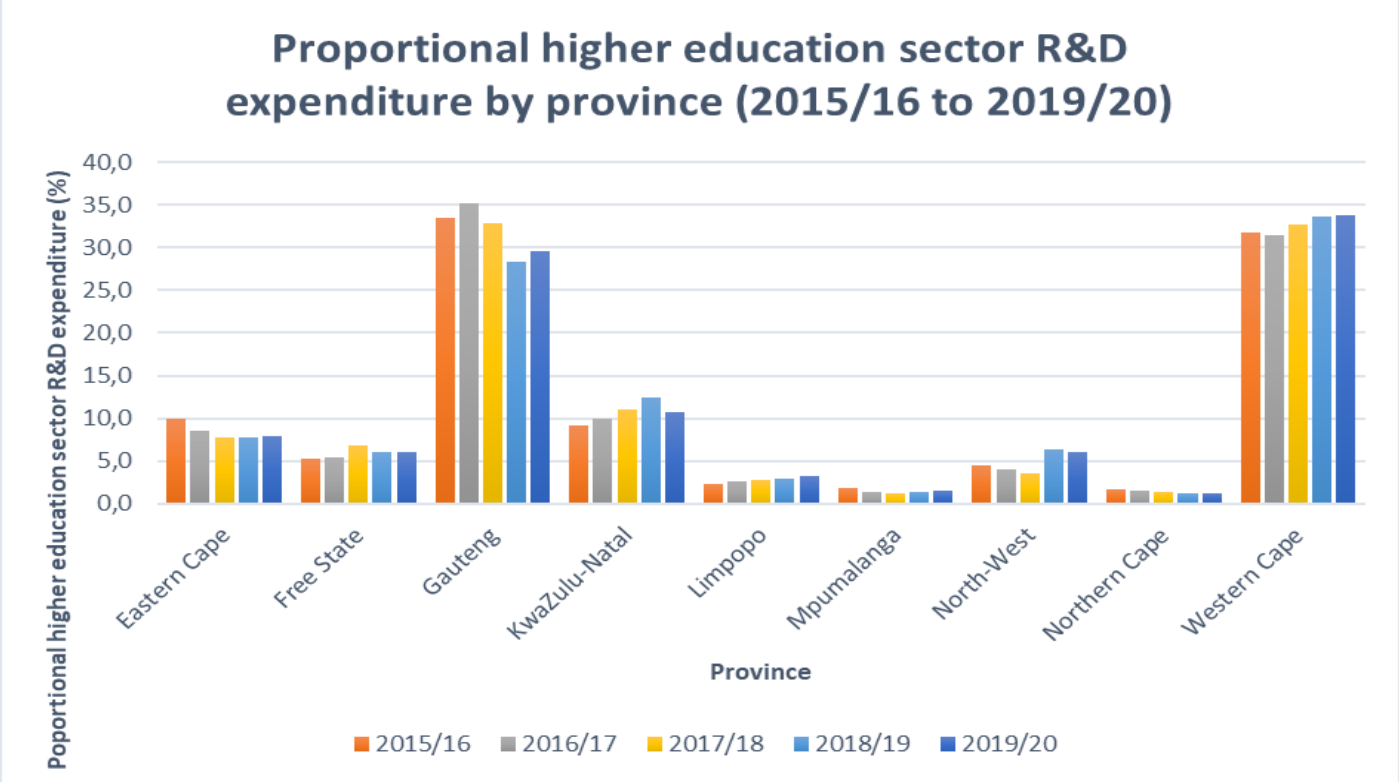


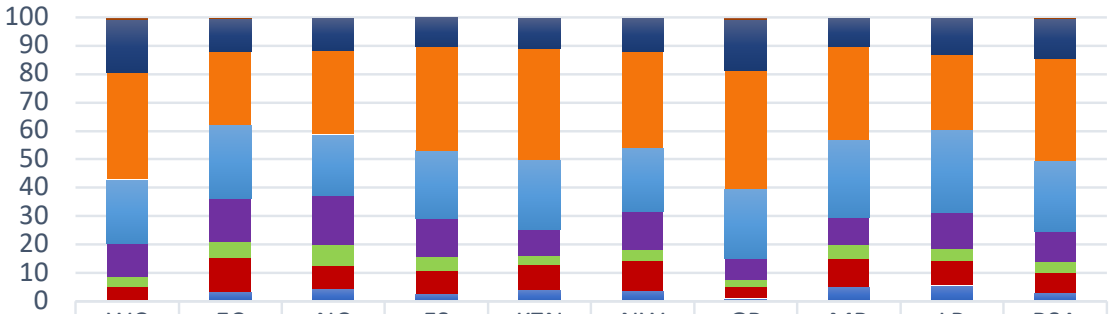

**Figure 8.4: Proportional higher education sector R&D expenditure by province**

*Source: National Surveys of Research and Experimental Development*

### 8.2.3 Human capital

The education level of the population plays a key role in regional innovation and regional economic development. OECD data show that human capital is by far the strongest determinant of innovation output – there is a strong correlation between educational attainment and the level of innovation.

**Figure 8.5** shows the percentage distribution of educational attainment for individuals aged 20 years and older by province. As the data shows, less than 50% of the population of all provinces have a national senior certificate (NSC). Gauteng has the highest level of NSC attainment (41,6%) followed by KwaZulu-Natal (39,3%) and the Western Cape (37,5%).




| | WC | EC | NC | FS | KZN | NW | GP | MP | LP | RSA |
|---|---|---|---|---|---|---|---|---|---|---|
| Other | 0,8 | 0,4 | 0,2 | 0,1 | 0,2 | 0,2 | 0,6 | 0,3 | 0,3 | 0,4 |
| Post-School | 18,7 | 11,6 | 11,5 | 10,5 | 10,7 | 11,8 | 18,1 | 10,2 | 12,9 | 14,1 |
| NSC/Grade 12 | 37,5 | 25,8 | 29,6 | 36,3 | 39,3 | 33,9 | 41,6 | 32,7 | 26,7 | 36,0 |
| Upper Secondary | 22,5 | 26,2 | 21,4 | 23,9 | 24,6 | 22,5 | 24,7 | 27,2 | 29,1 | 24,9 |
| Lower Secondary | 11,8 | 15,1 | 17,5 | 13,6 | 9,0 | 13,4 | 7,3 | 9,7 | 12,6 | 10,6 |
| Completed Primary | 3,5 | 5,7 | 7,1 | 4,8 | 3,6 | 4,1 | 2,5 | 5,1 | 4,1 | 3,8 |
| Some Primary | 4,8 | 11,9 | 8,4 | 8,3 | 8,5 | 10,2 | 3,9 | 9,8 | 8,7 | 7,3 |
| None | 0,4 | 3,4 | 4,3 | 2,6 | 4,1 | 3,9 | 1,2 | 5,1 | 5,7 | 2,9 |

**Figure 8.5: Percentage distribution of educational attainment for individuals aged 20 years and older by province**

*Source General Household Survey, 2020, StatsSA, 2020*

There is low post-school achievement across the provinces. Post-school qualification attainment levels were highest in the Western Cape (18,7%) and Gauteng (18,1%) and lowest in Mpumalanga (10,2%). For South Africa to become a knowledge-driven economy, education levels must be improved in all the provinces.

***Provincial performance in Mathematics and Physical Science***

Mathematics and Physical Science are the foundations for various academic subjects and industrial applications. Science, technology, engineering, and mathematics (STEM) are widely regarded as subjects critical to the national economy and are the pipeline that feeds the post-secondary school system.

As shown in **Table 8.12**, none of the provinces have achieved a pass rate above 80% for Mathematics. Performance has fluctuated and there is no upward trend. In 2021, the Western Cape province had the highest pass rate (73,4%), followed by the Free State (71.5%). Mpumalanga (54%) and the Eastern Cape (46,6%) had the lowest. However, the performance of almost all the provinces improved in 2021 compared to the previous year.

**Table 8.12: Provincial performance in grade 12 Mathematics**

| | 2017 | | 2018 | | 2019 | | 2020 | | 2021 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Total learners who wrote exam | % who got 30% or above | Total learners who wrote exam | % who got 30% or above | Total learners who wrote exam | % who got 30% or above | Total learners who wrote exam | % who got 30% or above | Total learners who wrote exam | % who got 30% or above |
| Eastern Cape | 35 994 | 42,3 | 36 449 | 45,5 | 35 270 | 41,8 | 38 717 | 39,7 | 43 866 | 46,6 |
| Free State | 10 134 | 70,6 | 9 722 | 74,3 | 9 886 | 68,5 | 11 040 | 66,3 | 12 745 | 66,6 |
| Gauteng | 36 937 | 67,7 | 35 279 | 74,7 | 35 412 | 67,8 | 37 670 | 65,4 | 39 842 | 68,2 |
| KwaZulu-Natal | 68 463 | 41,6 | 61 686 | 50,6 | 57 882 | 48,5 | 56 506 | 51,2 | 61 506 | 54,2 |
| Limpopo | 40 723 | 50,1 | 39 216 | 54,9 | 34 148 | 53,1 | 38 447 | 49,7 | 44 874 | 54,2 |
| Mpumalanga | 24 327 | 47,8 | 24 207 | 54,2 | 22 621 | 51,6 | 24 663 | 50,9 | 28 580 | 54,0 |
| North West | 10 232 | 61,2 | 9 083 | 68,9 | 8 783 | 62,2 | 9 232 | 63,4 | 9 815 | 71,5 |
| Northern Cape | 2 796 | 57,4 | 2 798 | 59,0 | 2 613 | 56,6 | 2 708 | 55,3 | 2 689 | 59,2 |
| Western Cape | 15 497 | 73,9 | 15 418 | 76,0 | 15 419 | 70,2 | 14 322 | 71,6 | 15 206 | 73,4 |
| National | 245 103 | 51,9 | 233 858 | 58,0 | 222 034 | 54,6 | 233 315 | 53,8 | 254 143 | 57,6 |

*Source: Department of Basic Education School Subject Reports*

**Table 8.13** shows the performance in Physical Science. In this subject, provinces such as the Free State and Gauteng have occasionally performed above 80%. In 2021, the Western Cape province was the best performer (78,3%) followed by the Free State (75,1%). Mpumalanga (61,5%) and the Eastern Cape (62,3%) are the poorest performers.

In general, the overall performance is much higher in Physical Sciences than in Mathematics. The national average for the former (68%) is much higher than for the latter (57,6%).

**Table 8.13: Provincial performance in grade 12 Physical Sciences**

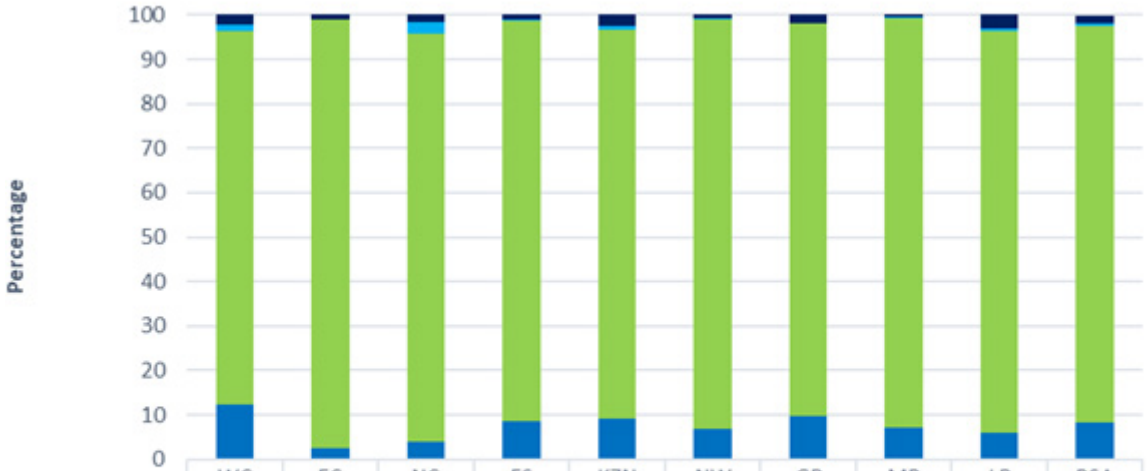
| | 2017 | | 2018 | | 2019 | | 2020 | | 2021 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Total learners who wrote exam | % who got 30% or above | Total learners who wrote exam | % who got 30% or above | Total learners who wrote exam | % who got 30% or above | Total learners who wrote exam | % who got 30% or above | Total learners who wrote exam | % who got 30% or above |
| Eastern Cape | 24 805 | 57,3 | 24 939 | 66,5 | 23 703 | 70,3 | 25 870 | 55,6 | 30 738 | 62,3 |
| Free State | 8 031 | 77,0 | 7 876 | 81,7 | 7 889 | 82,7 | 8 727 | 71,2 | 9 826 | 75,1 |
| Gauteng | 29 178 | 70,4 | 26 763 | 83,5 | 25 765 | 84,0 | 27 096 | 72,6 | 29 425 | 73,5 |
| KwaZulu-Natal | 43 005 | 65,1 | 40 643 | 73,6 | 39 499 | 74,8 | 40 402 | 69,7 | 44 908 | 71,2 |
| Limpopo | 33 584 | 63,2 | 31 717 | 71,8 | 28 911 | 72,0 | 31 290 | 63,0 | 38 659 | 67,2 |
| Mpumalanga | 19 306 | 61,6 | 20 387 | 70,2 | 19 679 | 70,9 | 21 794 | 60,0 | 25 471 | 61,5 |
| North West | 8 451 | 64,3 | 7 348 | 78,6 | 6 939 | 79,0 | 7 482 | 68,5 | 8 054 | 72,5 |
| Northern Cape | 2 344 | 56,8 | 2 259 | 66,9 | 2 111 | 69,2 | 2 186 | 53,4 | 2 086 | 65,2 |
| Western Cape | | 74,0 | 10 387 | 79,5 | 9 982 | 81,8 | 9 463 | 76,2 | 9 801 | 78,3 |
| National | 179 561 | 65,1 | 172 319 | 74,2 | 164 478 | 75,5 | 174 310 | 65,8 | 196 968 | 68,0 |

*Source: Department of Basic Education School Subject Reports*

### 8.2.4 Access to information and communication technology

ICT enables economic growth by broadening the reach of technologies such as high-speed Internet, mobile broadband, and computing. Access to these technologies itself creates growth, and the fact that technologies make it easier for people to interact and make workers more productive creates additional benefits.

**Figure 8.6** summarises statistics collected on access to functional landlines and cellular (mobile) phones within the sampled households during 2020. According to this figure, there is high access to cellphones across all provinces but a low level of access to landlines. The use of cellphones was most common in the Eastern Cape (96,4%) and lowest in Western Cape (84,2%). In the most prosperous provinces, the Western Cape and Gauteng, more households had cellphones and landlines. Western Cape had landline usage of 12,2%, while in Gauteng the usage was 9,8%.

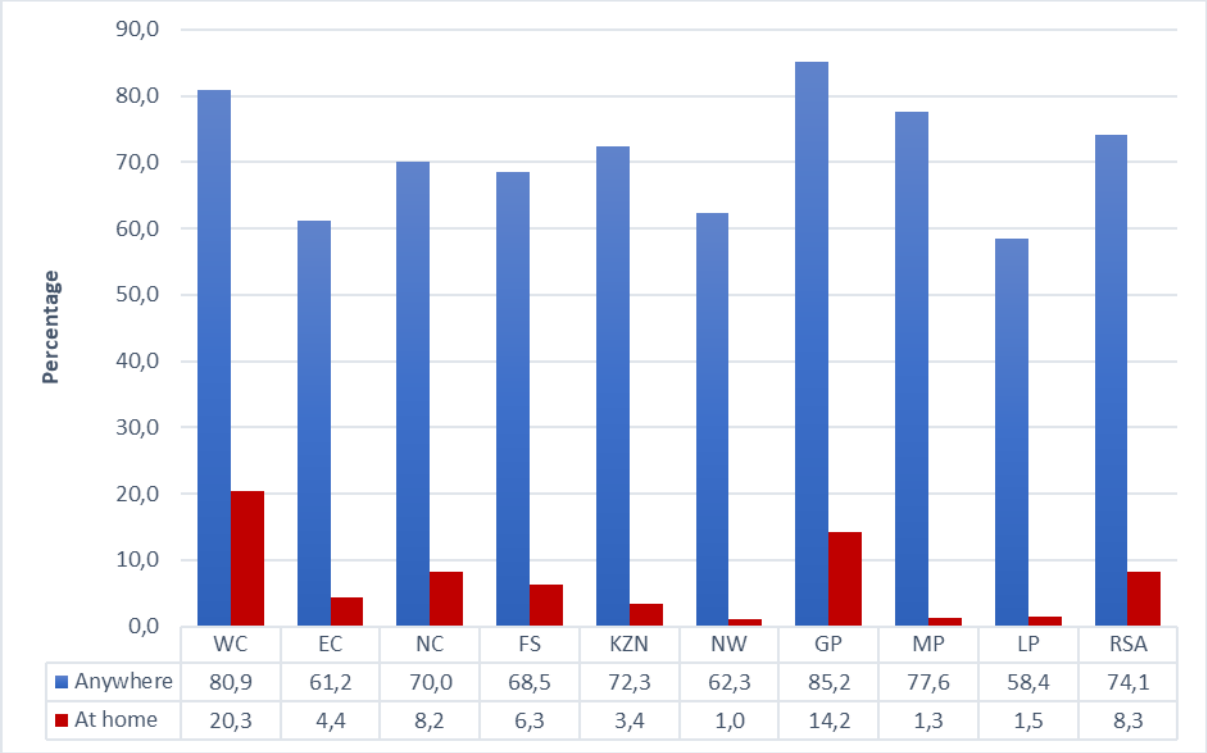



| | WC | EC | NC | FS | KZN | NW | GP | MP | LP | RSA |
|---|---|---|---|---|---|---|---|---|---|---|
| None | 2,2 | 1,1 | 1,7 | 1,0 | 2,4 | 0,9 | 1,8 | 0,5 | 3,2 | 1,8 |
| Only landline | 1,4 | 0,0 | 2,4 | 0,4 | 0,9 | 0,3 | 0,2 | 0,3 | 0,5 | 0,5 |
| Only cell | 84,2 | 96,4 | 92,0 | 90,1 | 87,5 | 92,2 | 88,2 | 92,2 | 90,4 | 89,4 |
| Cell & landline | 12,2 | 2,5 | 3,9 | 8,5 | 9,2 | 6,7 | 9,8 | 7,0 | 5,9 | 8,2 |

**Figure 8.6: Percentage of households that have a functional landline and/or cellphone in their homes by province, 2020**

*Source: General Household Survey, 2020, StatsSA*

**Figure 8.7** compares access to the Internet across all nine provinces. According to the data, access to the Internet using all available means was highest in Gauteng (85,2%), Western Cape (80,9%) and Mpumalanga (77,6%). The provinces with the lowest access were Limpopo (58,4%) and Eastern Cape (61,2%).




| | WC | EC | NC | FS | KZN | NW | GP | MP | LP | RSA |
|---|---|---|---|---|---|---|---|---|---|---|
| Anywhere | 80,9 | 61,2 | 70,0 | 68,5 | 72,3 | 62,3 | 85,2 | 77,6 | 58,4 | 74,1 |
| At home | 20,3 | 4,4 | 8,2 | 6,3 | 3,4 | 1,0 | 14,2 | 1,3 | 1,5 | 8,3 |

**Figure 8.7: Percentage access to Internet per province**

*Source: General Household Survey, 2020*

There are low levels of access to ICT at home across all provinces. The provinces with the highest access to the Internet at home were the Western Cape (20,3%) and Gauteng (14,2%), which are the most prosperous provinces. The disparity in access to the Internet at home is striking and reveals the vast social and economic inequality between the provinces.

### *8.2.5 Government innovation support organisations*

To support innovation, government has invested in provincial innovation support organisations. These organisations were created to provide access to innovation support, especially to SMEs and previously marginalised communities. These include technology stations, incubators, living labs and fabrication labs. They are recognised as important organisations that have helped local industries, particularly SMEs.

The technology stations and incubator programme are the main support instruments. The technology stations are sector-focused and located at universities of technology and universities facilitating technology transfer between these educational institutions and small enterprises. One of the critical contributions of the technology stations is to expose the students at the institutions hosting the stations to small enterprises, thus helping to foster a culture of entrepreneurship. The SEDA incubator programme remains the largest innovation support programme with a broad national footprint. The role of these organisations in the innovation ecosystem at regional level was discussed in detail in NACI's 2019/20 STI Indicators Report.

**Table 8.14** illustrates the diversity of innovation support organisations targeting different audiences. Compared to previous STI Indicators Reports (2020 and 2021), there has been no change in the number of technology stations, incubators, living and fab labs. A recent development that is worth noting is the new support organisations initiated and created by the provinces. This suggests that provinces are beginning to realise the importance of innovation support organisations as key instruments in regional innovation systems. It will be important to evaluate the impact of these organisations.

**Table 8.14: Number and type of innovation support organisations in provinces**

| | Eastern Cape | Free State | Gauteng | KwaZulu-Natal | Limpopo | Mpumalanga | Northern Cape | North West | Western Cape | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| Technology stations | 3 | 2 | 5 | 2 | 1 | 0 | 1 | 0 | 3 | 17 |
| Incubators | 8 | 8 | 34 | 15 | 8 | 11 | 5 | 9 | 9 | 107 |
| Science parks | 1 | 1 | 1 | | 0 | 0 | 0 | | 1 | 4 |
| Fab labs | 2 | 1 | 2 | | 1 | | 1 | 1 | 1 | 9 |
| Living labs | | | | 1 | | | 1 | 1 | 1 | 4 |
| Ekasi labs | | | 10 | | | | | | | 10 |
| Innovation collaboration | | | | 1 | | | | | | 1 |

*Source: The annual reports, websites and internal documents of the various organisations*



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