2022

South African Science, Technology and Innovation Indicators Report

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

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.

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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.

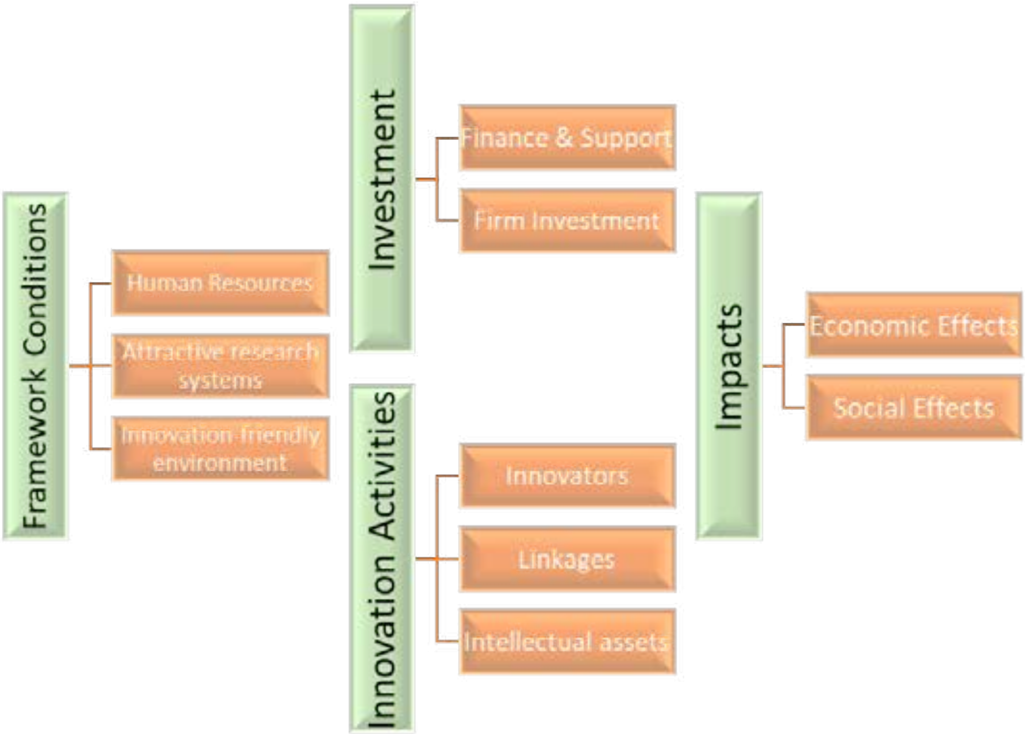


Figure 1.1: South African innovation scorecard framework

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 KwaZulu-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 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.

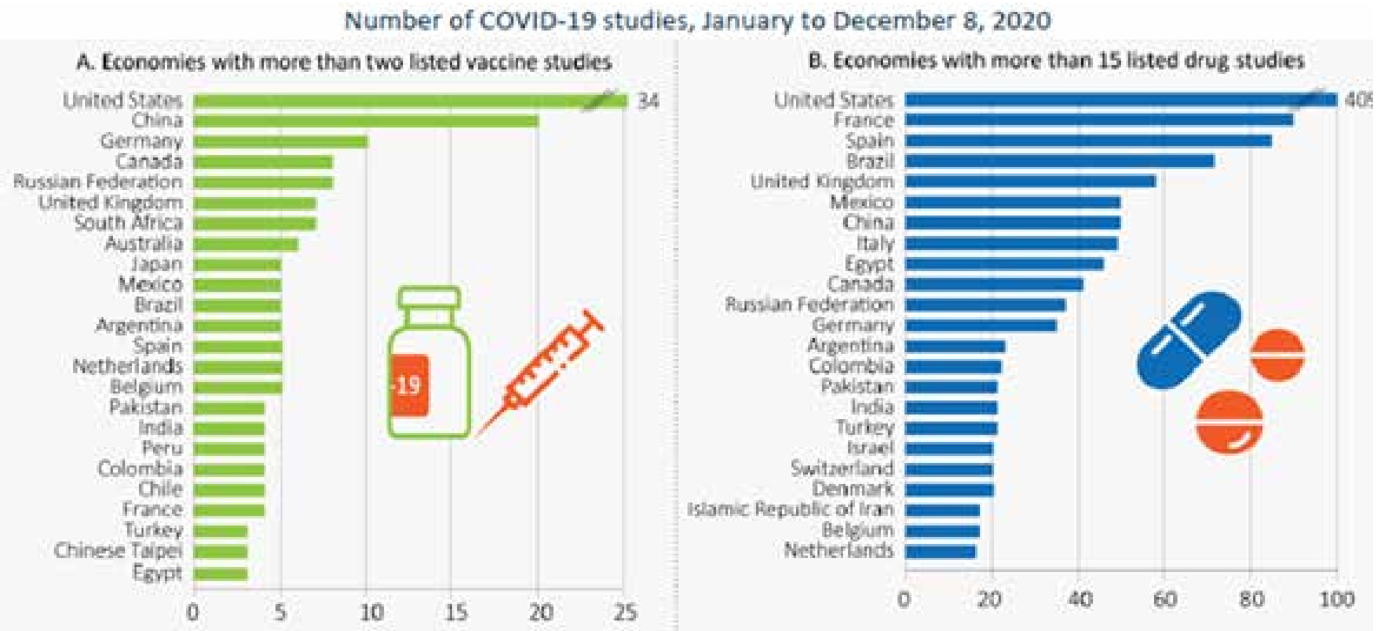


Figure 3.1: Registered Covid-19 vaccine and drug studies by economy

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
CO_2 emissions from fossil fuel combustion and cement production (tCO_2/capita)	7.6	2020	Red (Major challenges remain)	Stagnating
CO_2 emissions embodied in imports (tCO_2/capita)	0.4	2018	Yellow (Challenges remain)	On track
CO_2 emissions embodied in fossil fuel exports (kg/capita)	1 642.8	2020	Yellow (Challenges remain)	Information not available

Source: Sustainable Development Report, 2022

SDG achievement | Challenges remain | Significant challenges remain | Major challenges remain
On track | Moderately increasing | Stagnating | Decreasing | Data not available

The table shows that CO_2 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 CO_2 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).

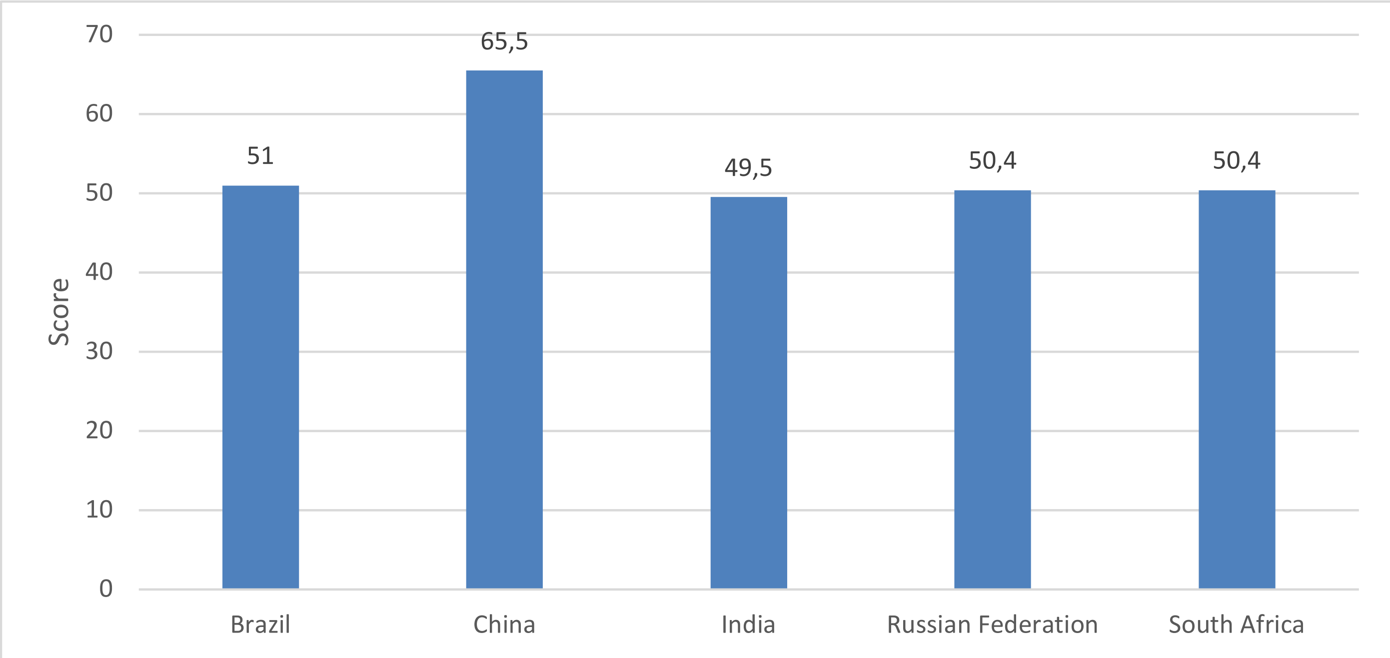


Figure 3.3: BRICS performance in overall economic transformation readiness

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.

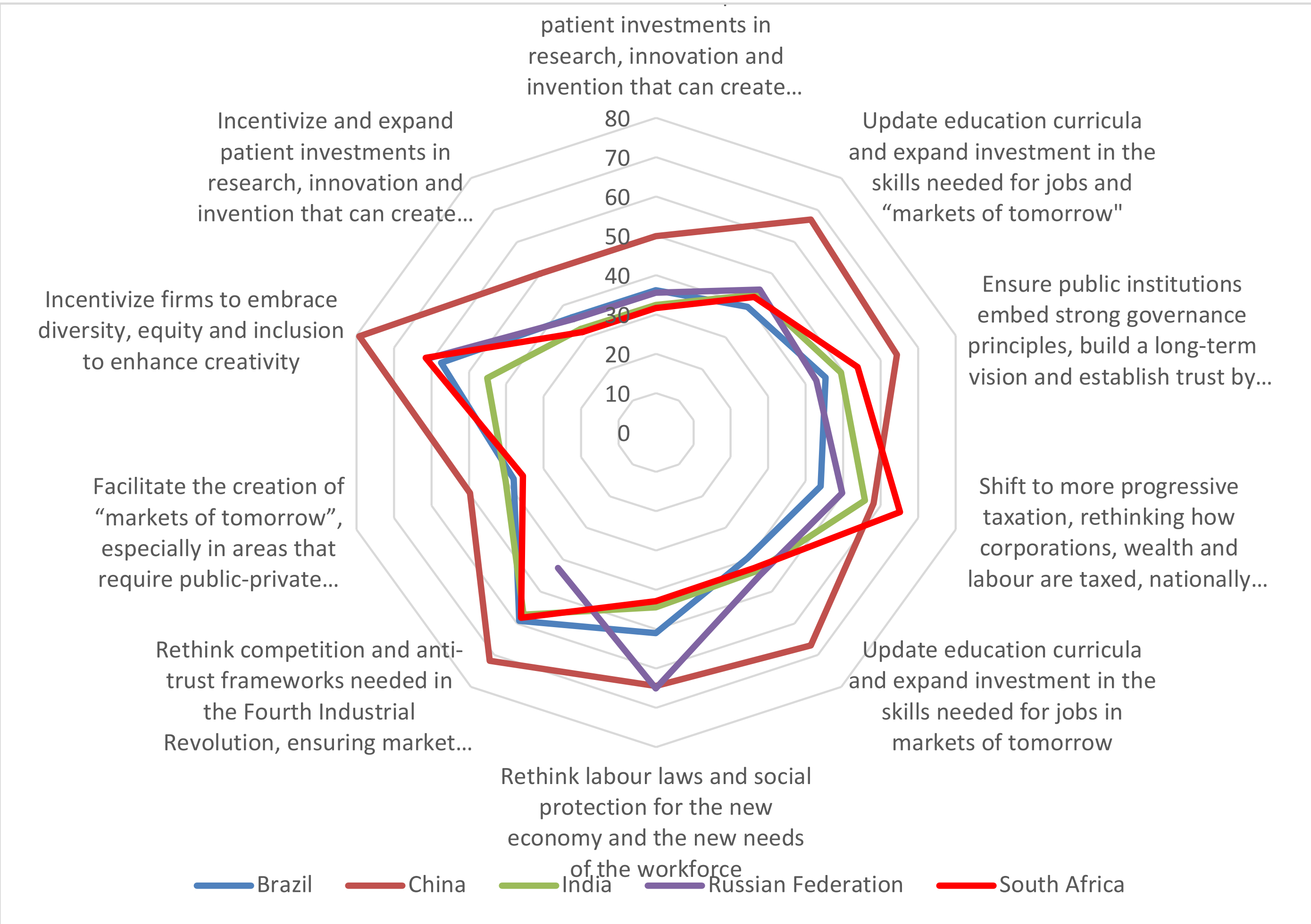


Figure 3.4: BRICS performance in components of economic transformation readiness

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

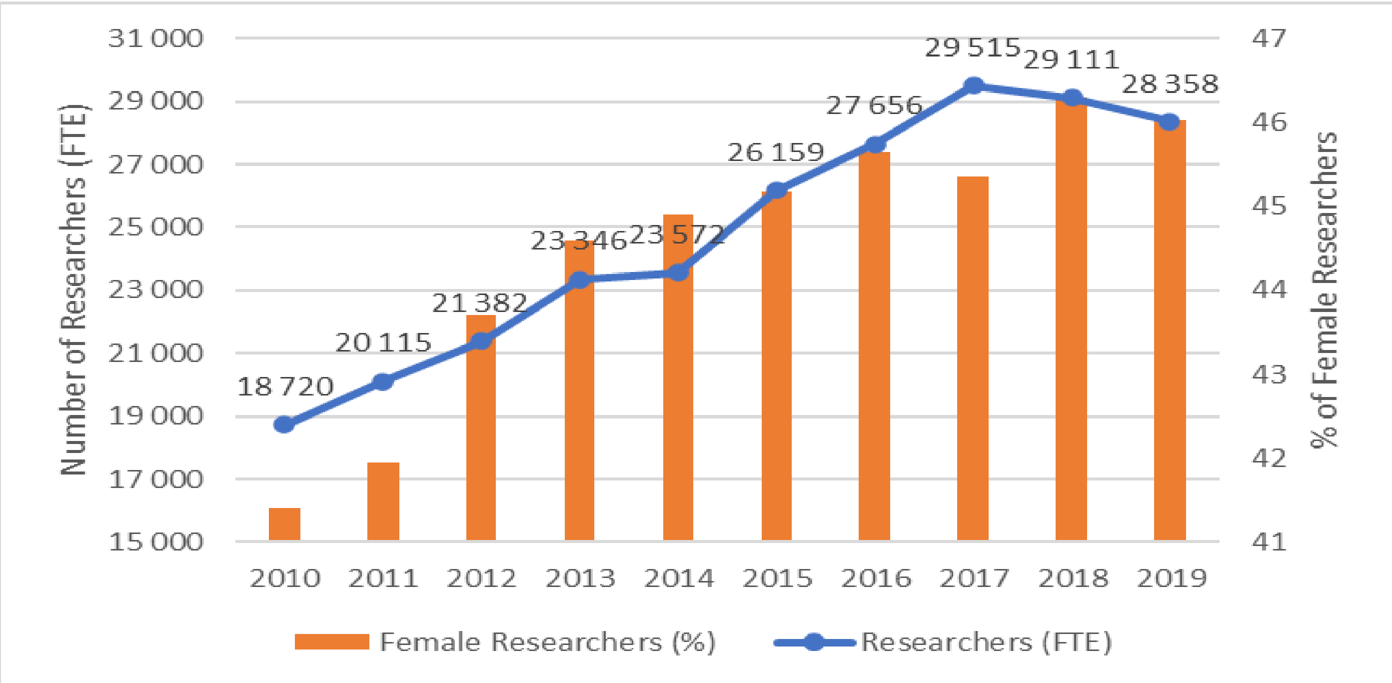


Figure 4.1: Trends in number of researchers (total and by gender)

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%.

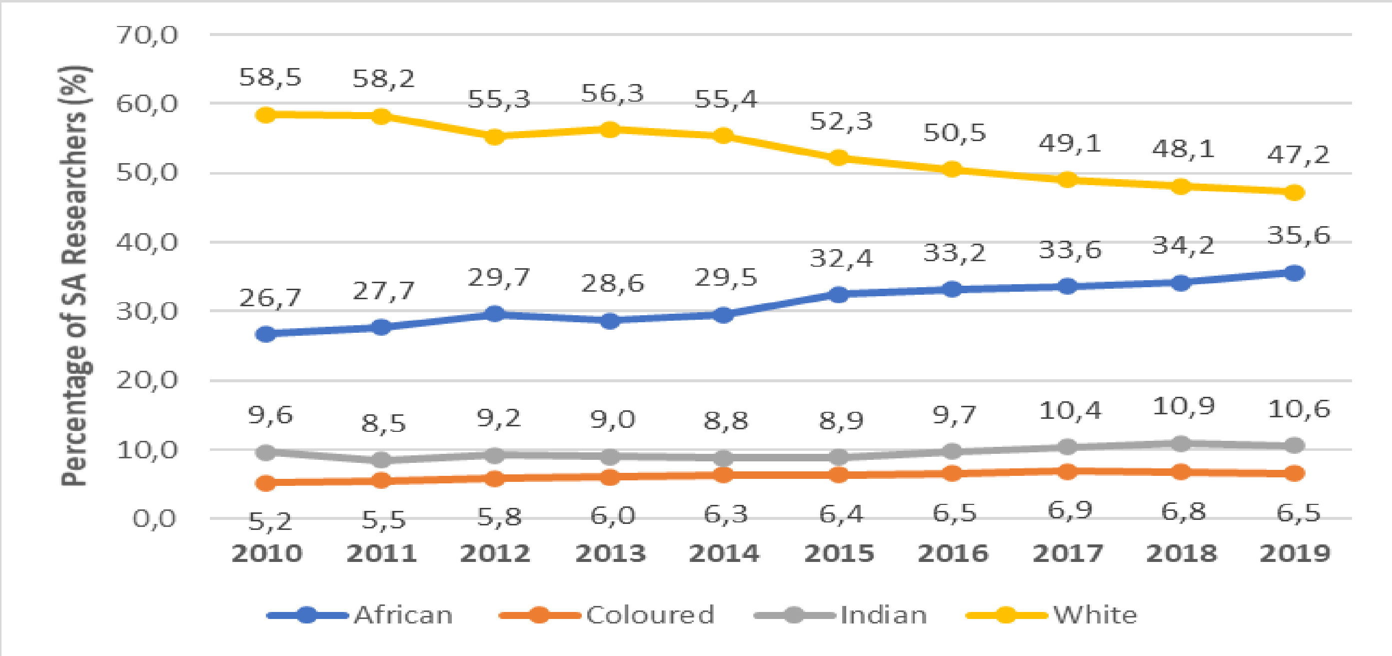


Figure 4.2: Trend in proportion of researchers by race (head count)

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.

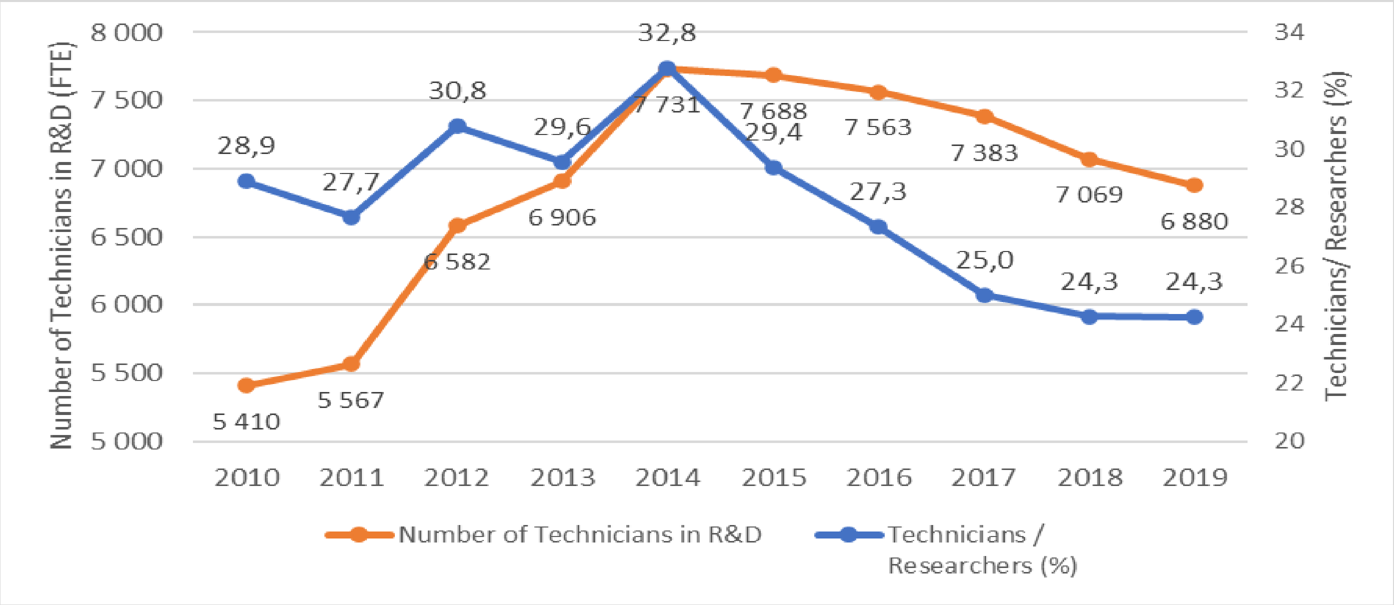


Figure 4.3: Trend in the number of technicians in research and development

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.

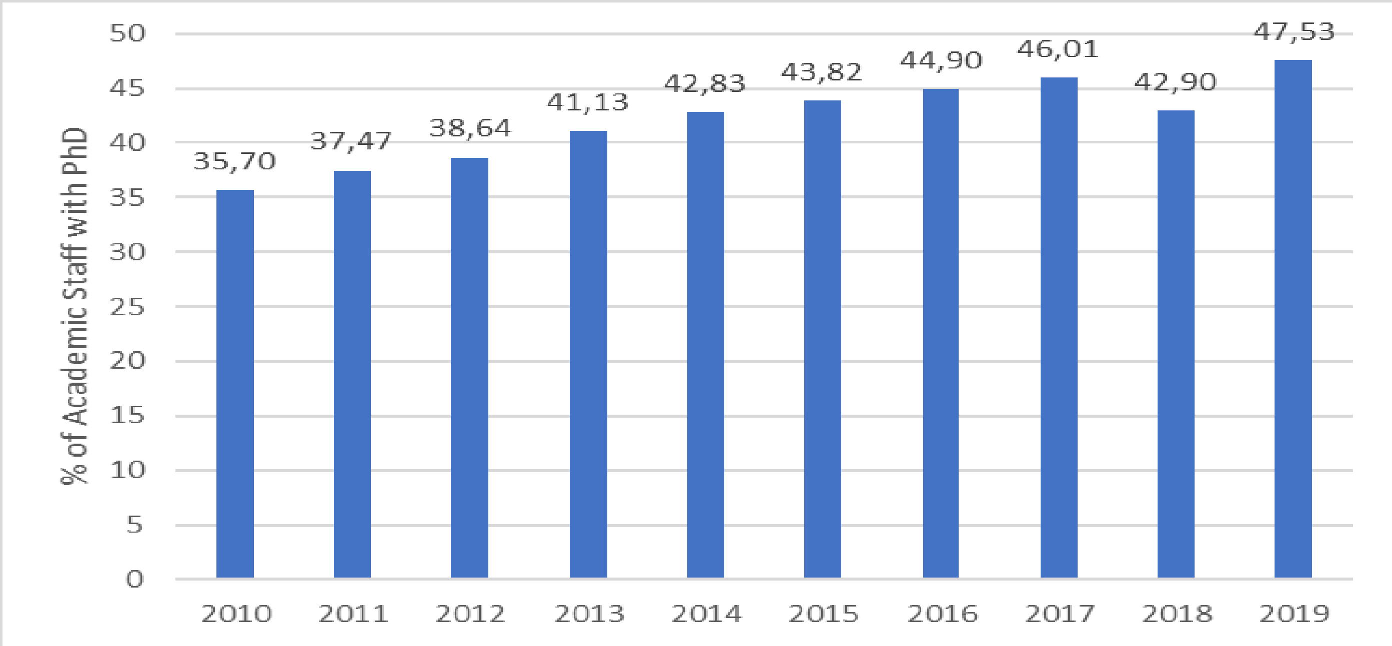


Figure 4.4: Percentage of permanent academic staff with doctoral degrees

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.

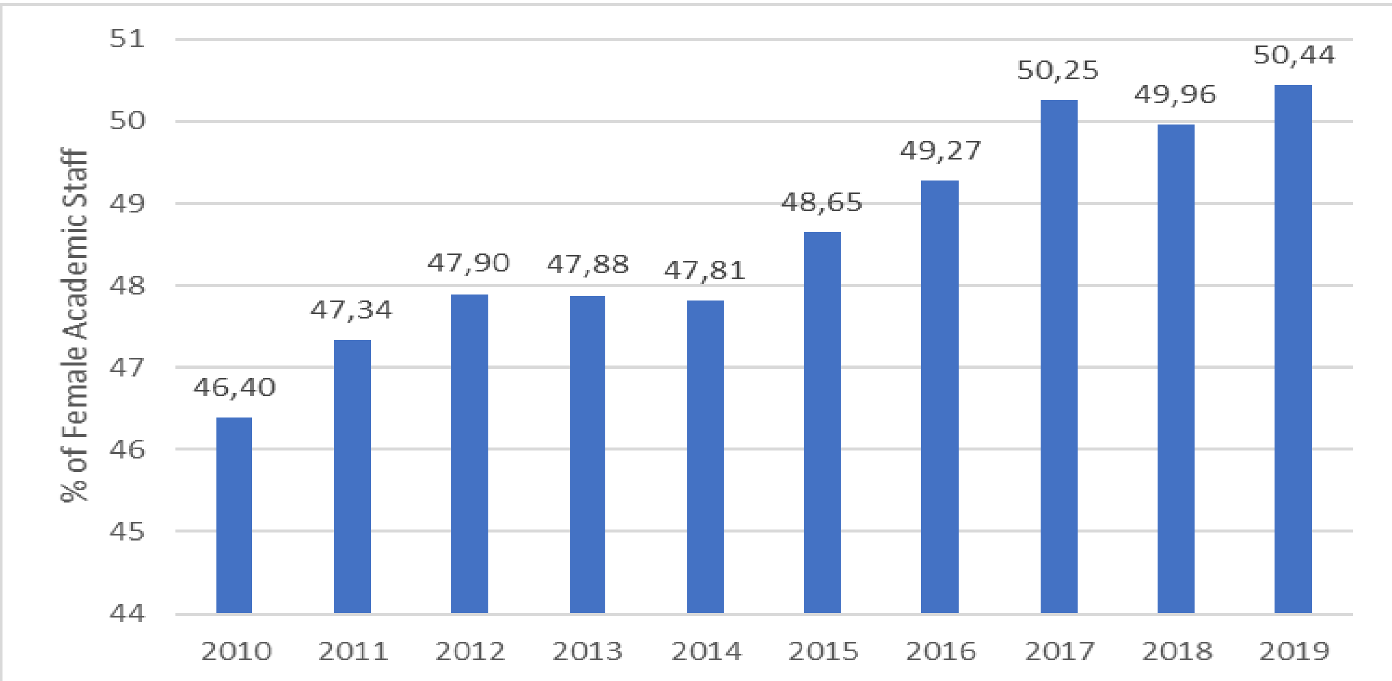


Figure 4.5: Percentage of female academic staff at public universities

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.

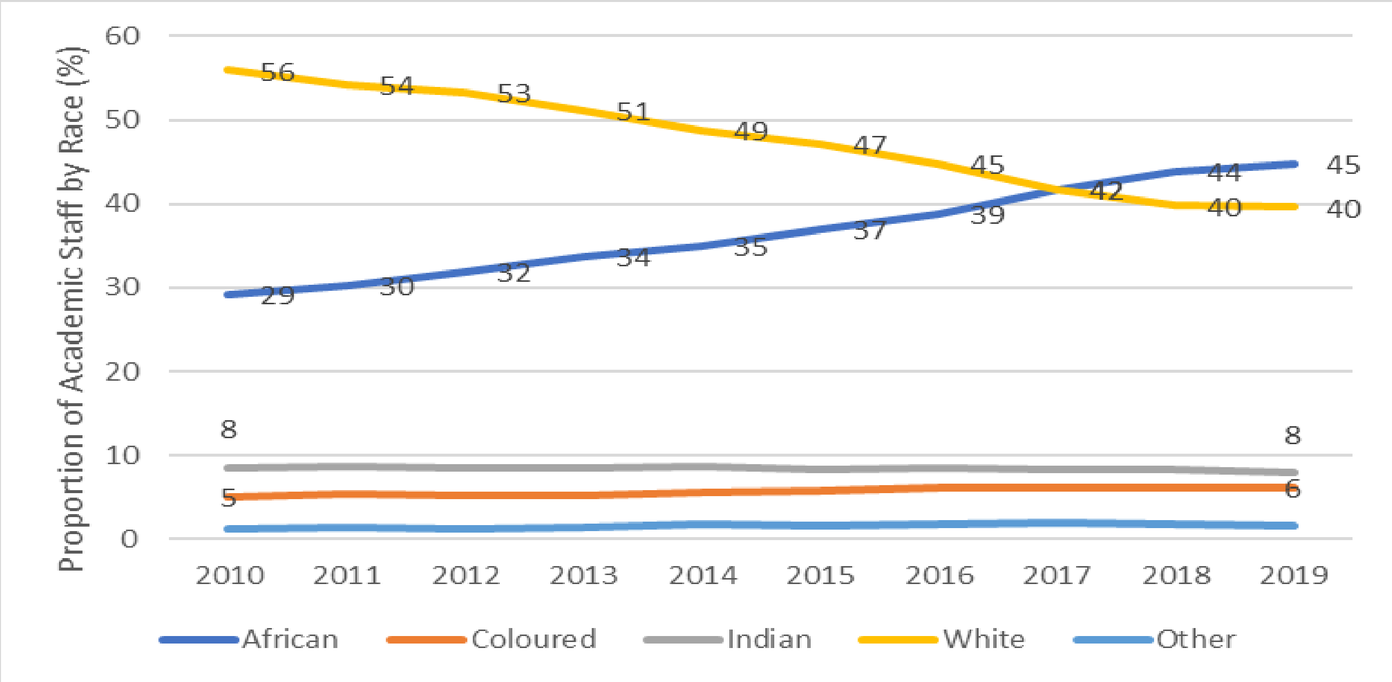


Figure 4.6: Proportion of academic staff at public universities by race

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.

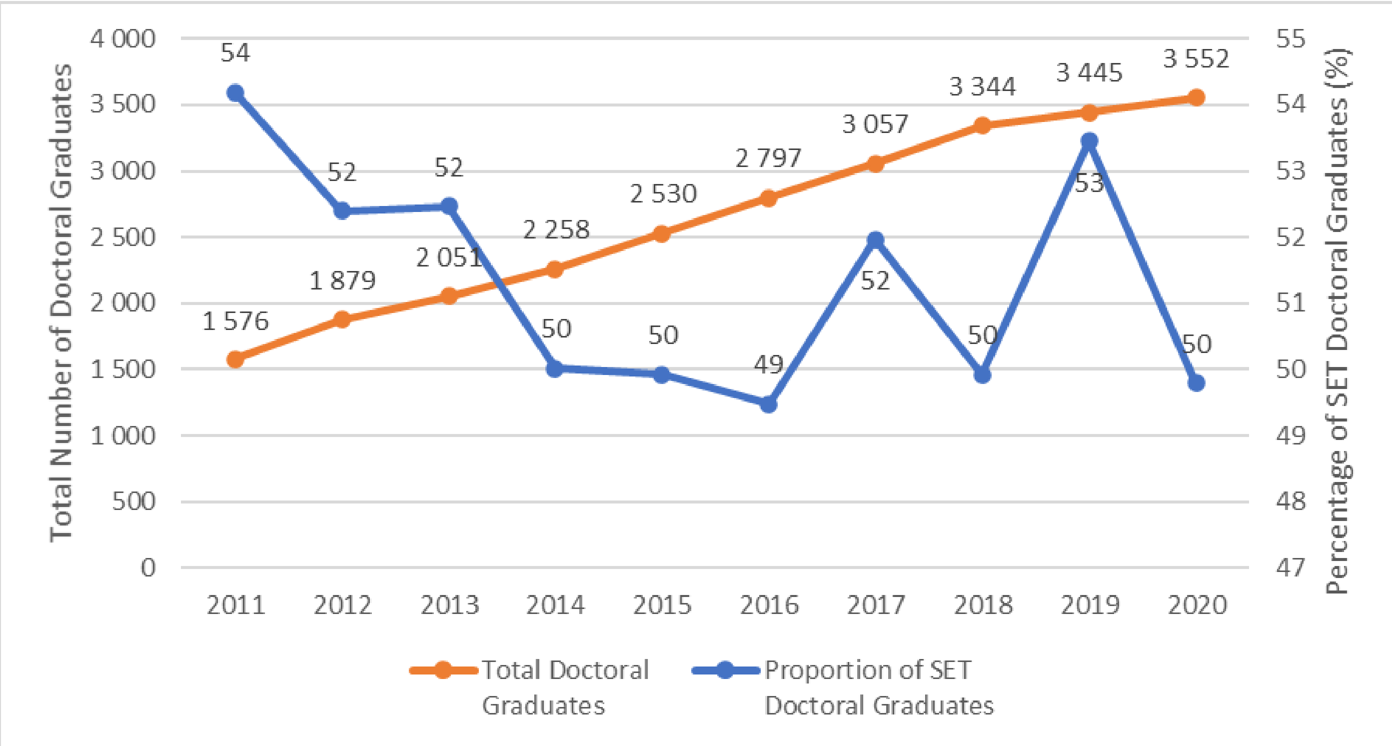


Figure 4.7: Trend Trends in doctoral graduates and SET doctoral graduates

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).

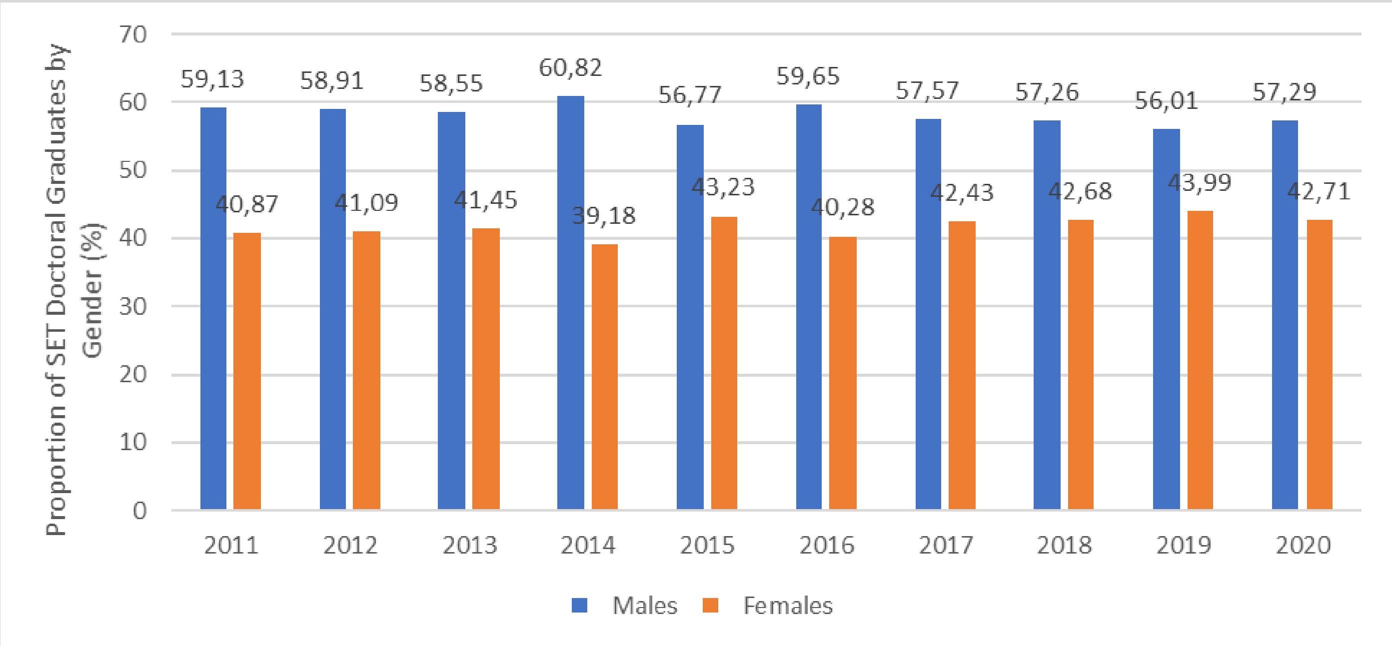


Figure 4.8: Trend of SET Trends in SET doctoral graduates by gender

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).

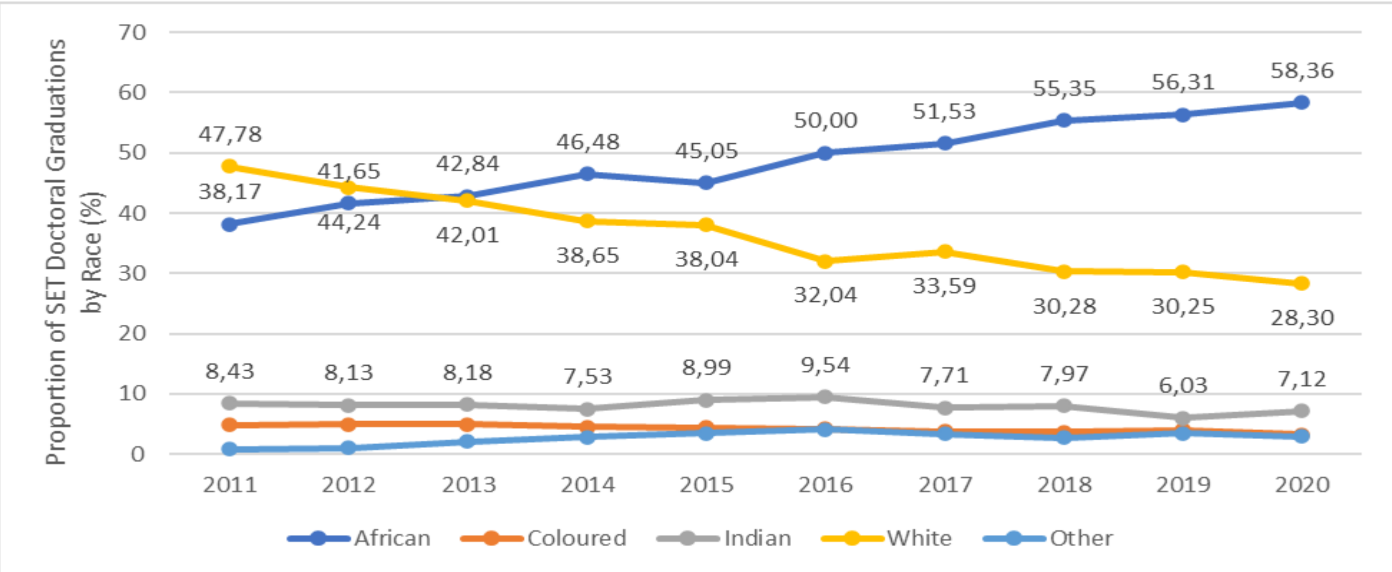


Figure 4.9: Trend of SET Doctoral Graduates by Race

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**).

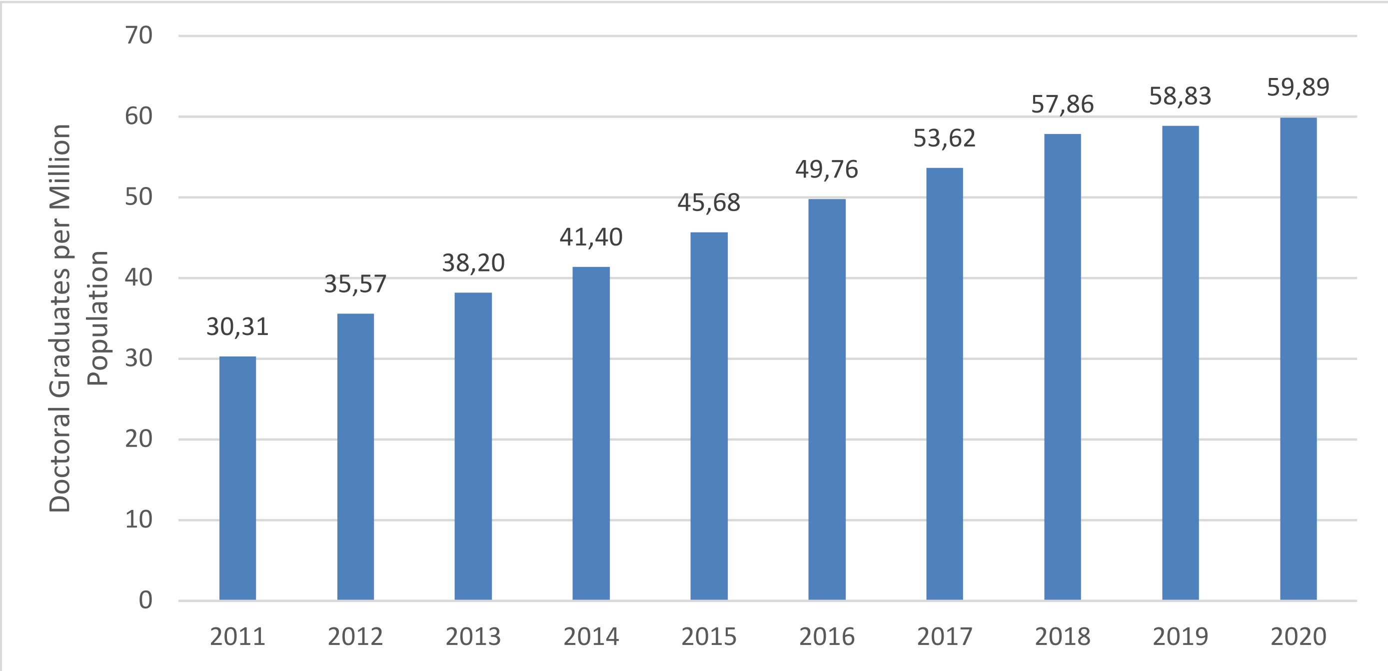


Figure 4.10: Number of doctoral graduates per million population

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%).

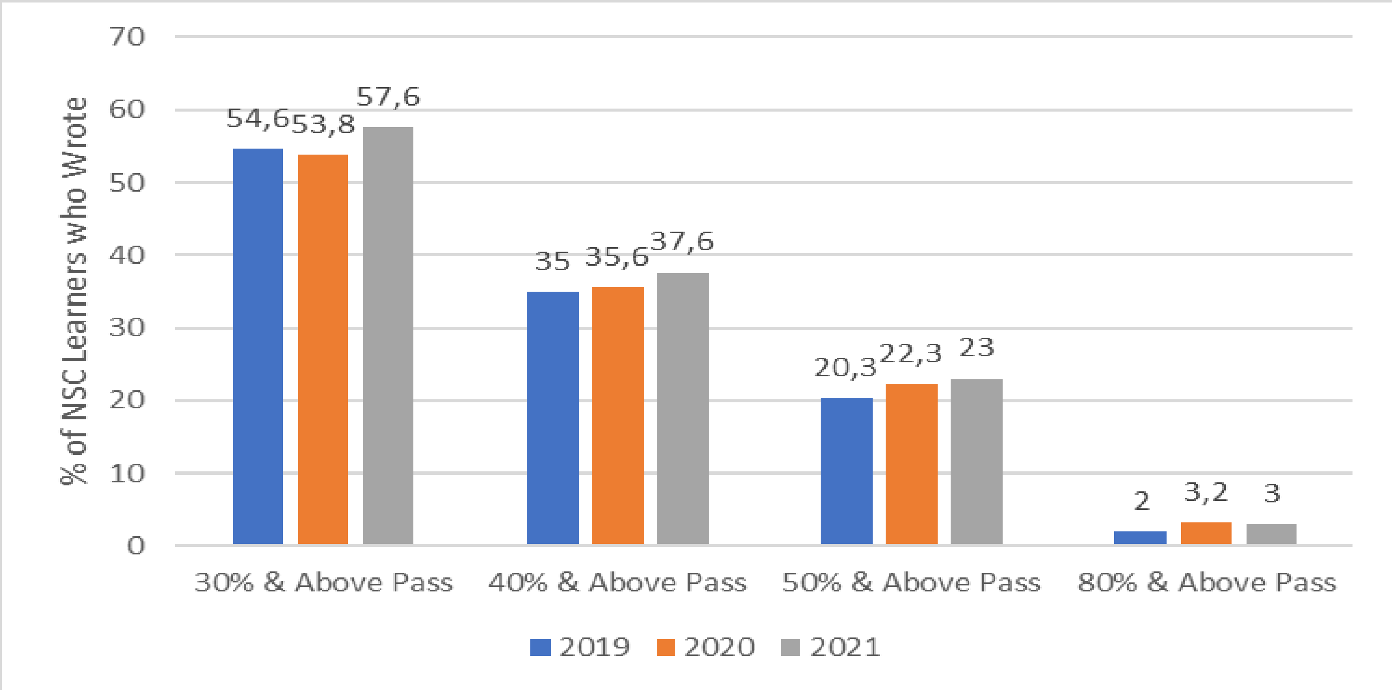


Figure 4.11: Achievement at various levels for NSC Mathematics

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.

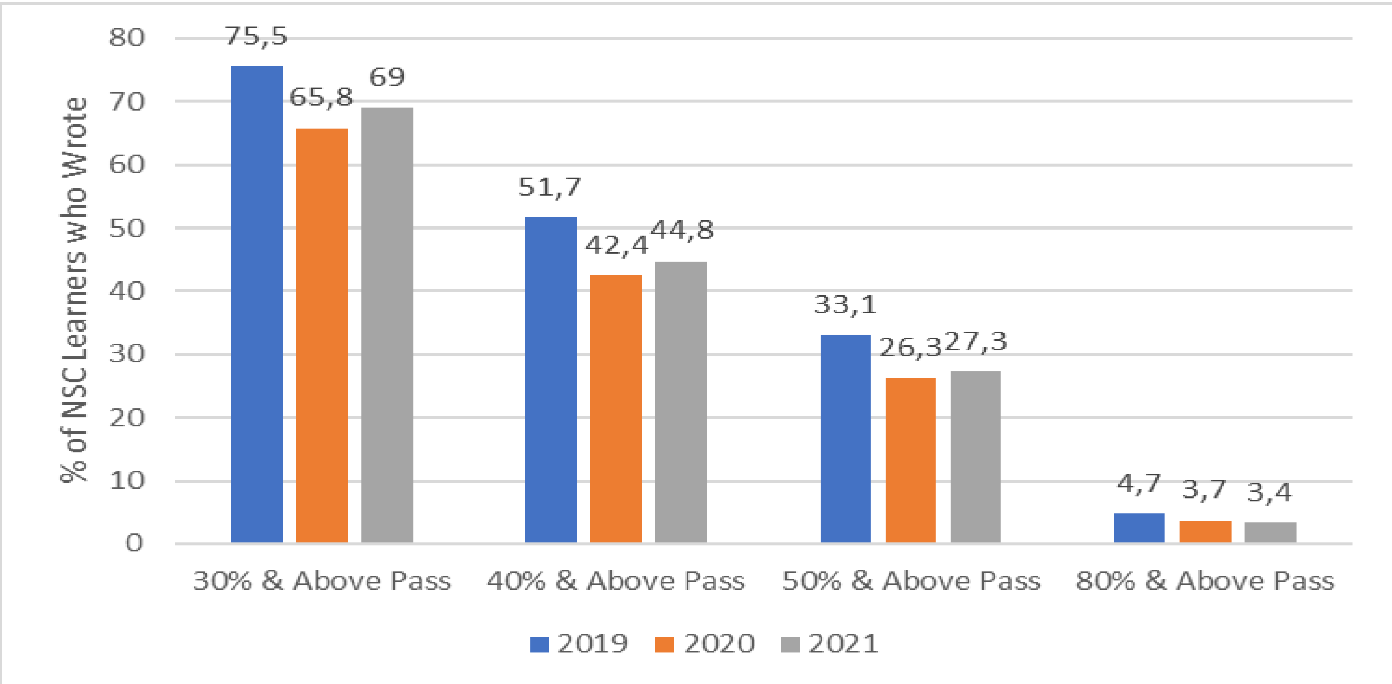


Figure 4.12: Achievement at various levels for NSC Physical Science

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%).

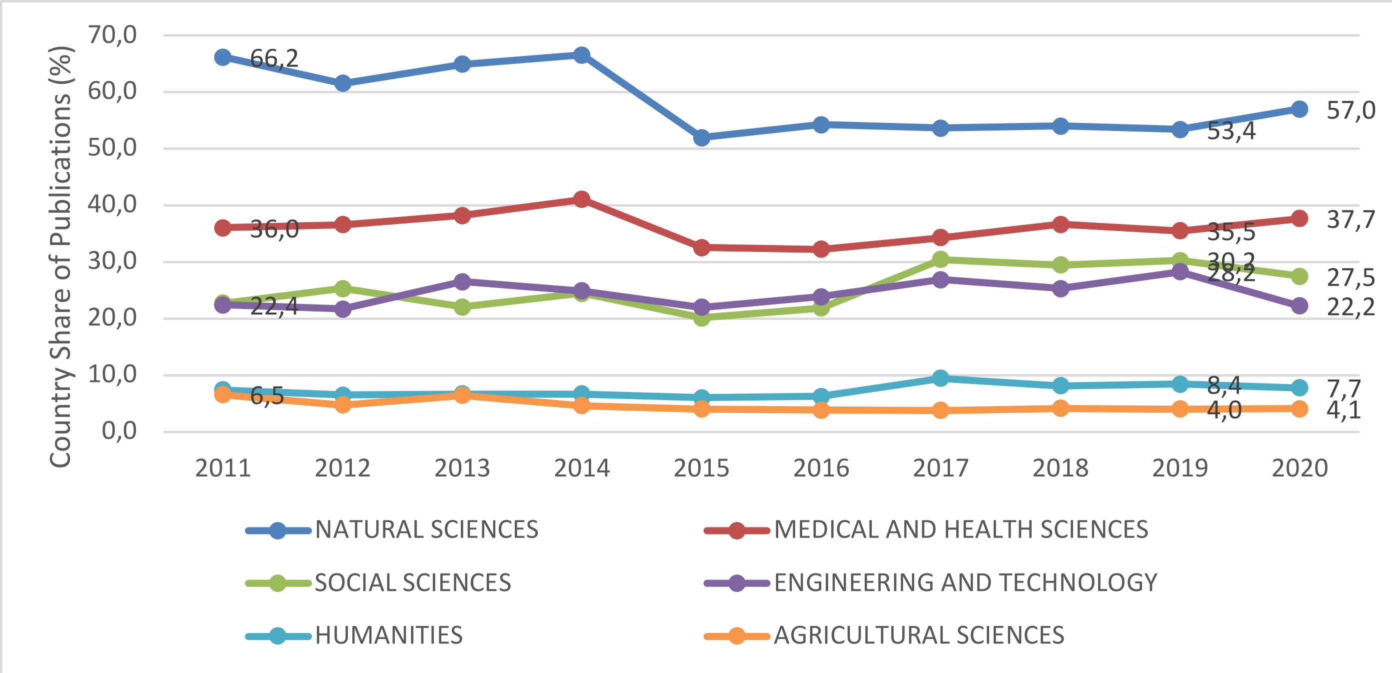


Figure 4.13: Share of publications by scientific field

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.

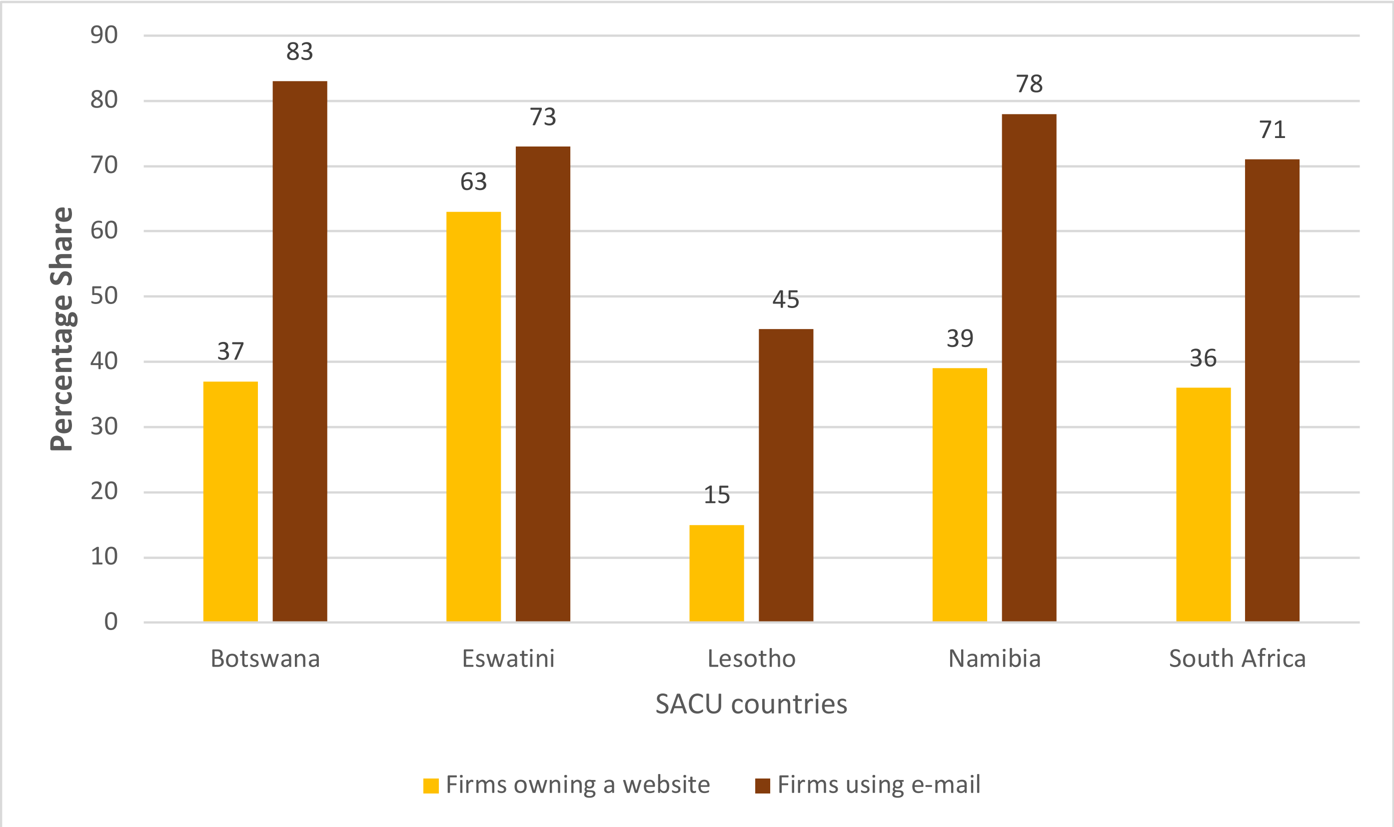
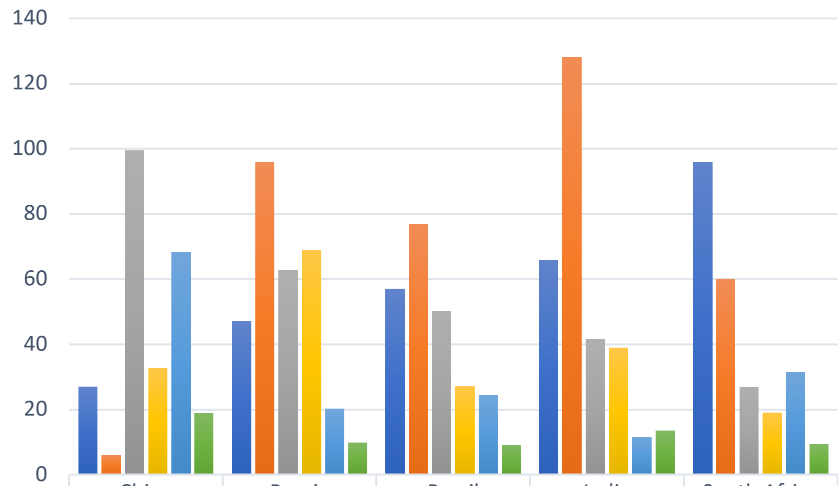


Figure 4.14: Prevalence of digital adoption among manufacturing and service firms in Southern Africa

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%).

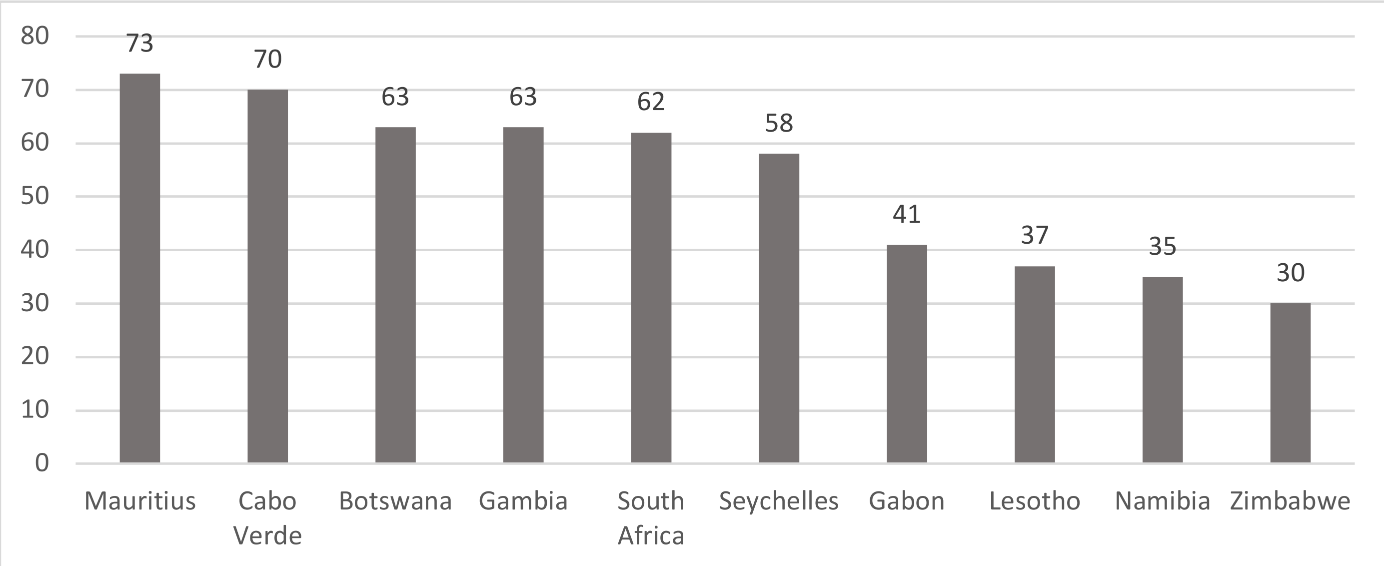


Figure 4.16: Proportion of households with Internet access, Compound Annual Growth Rate 2017-2019

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.

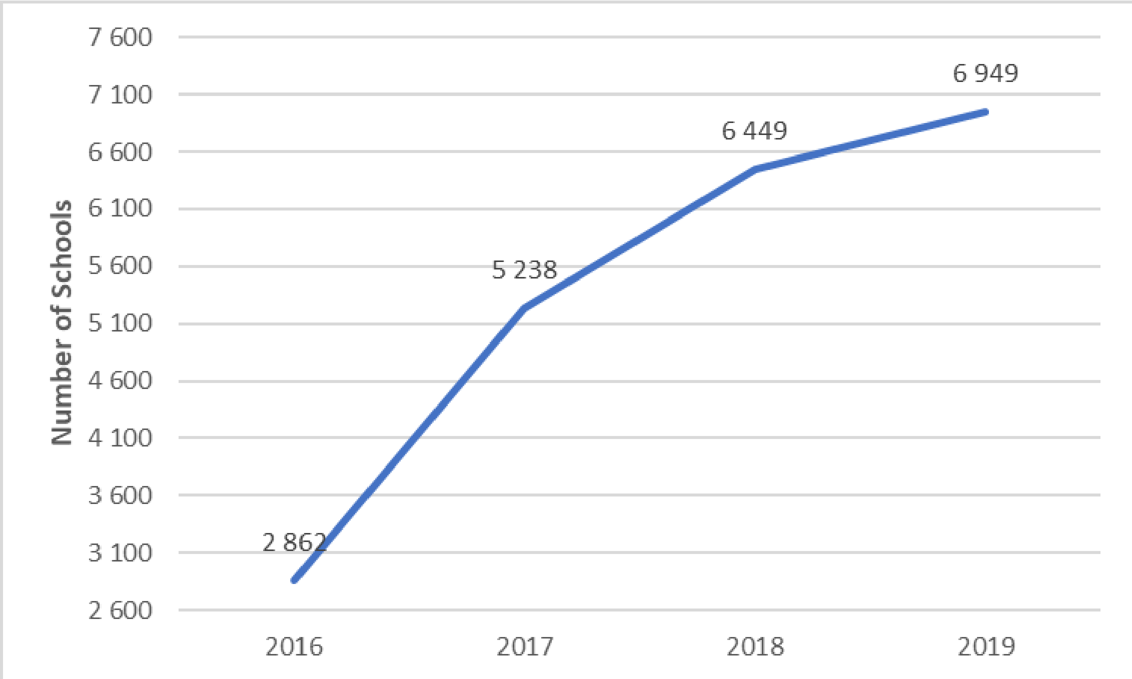


Figure 4.17: Number of schools with Internet access in South Africa

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.

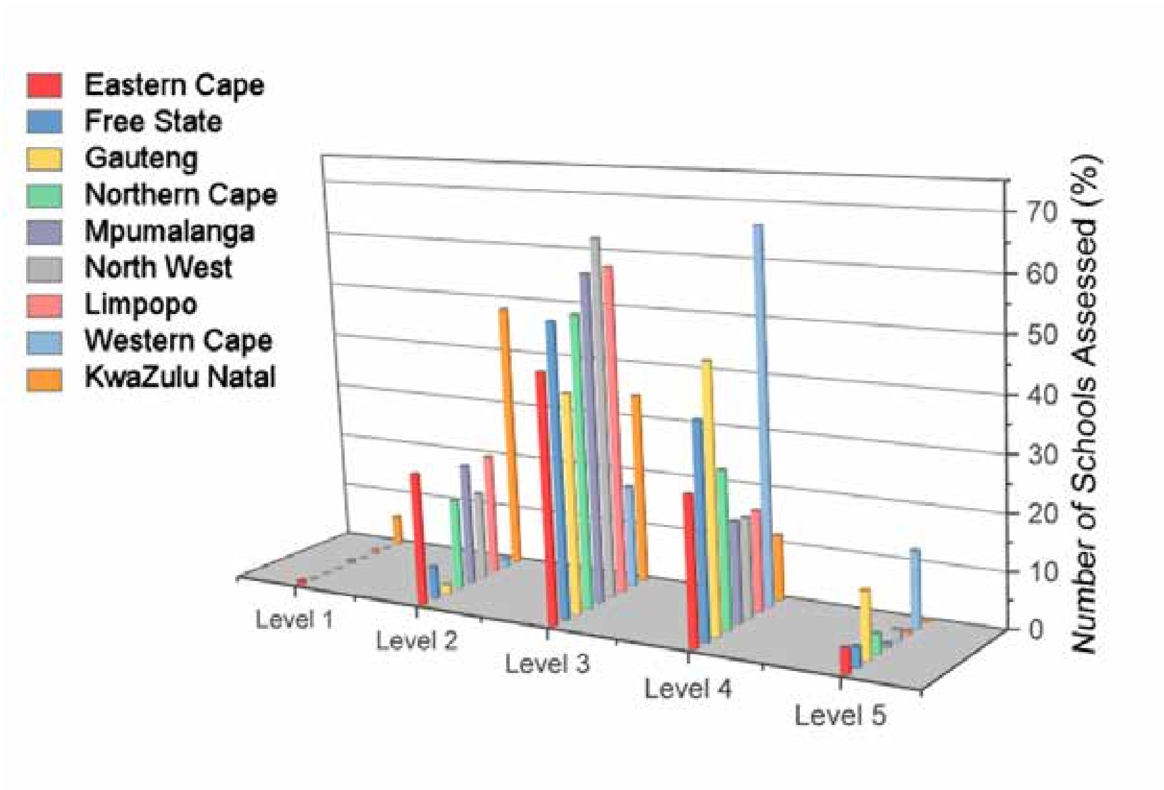


Figure 4.18: Average ICT maturity level of schools in South Africa

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.

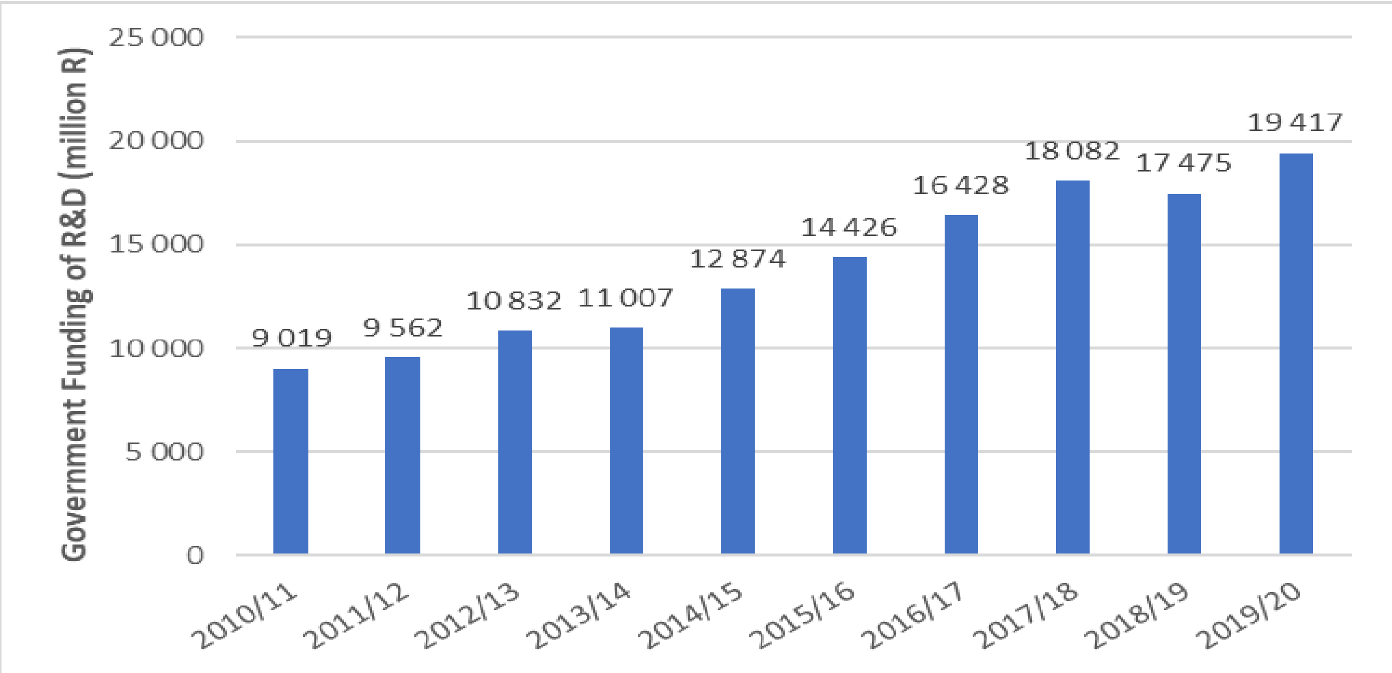


Figure 5.1: Trends in government funding for research and development

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).

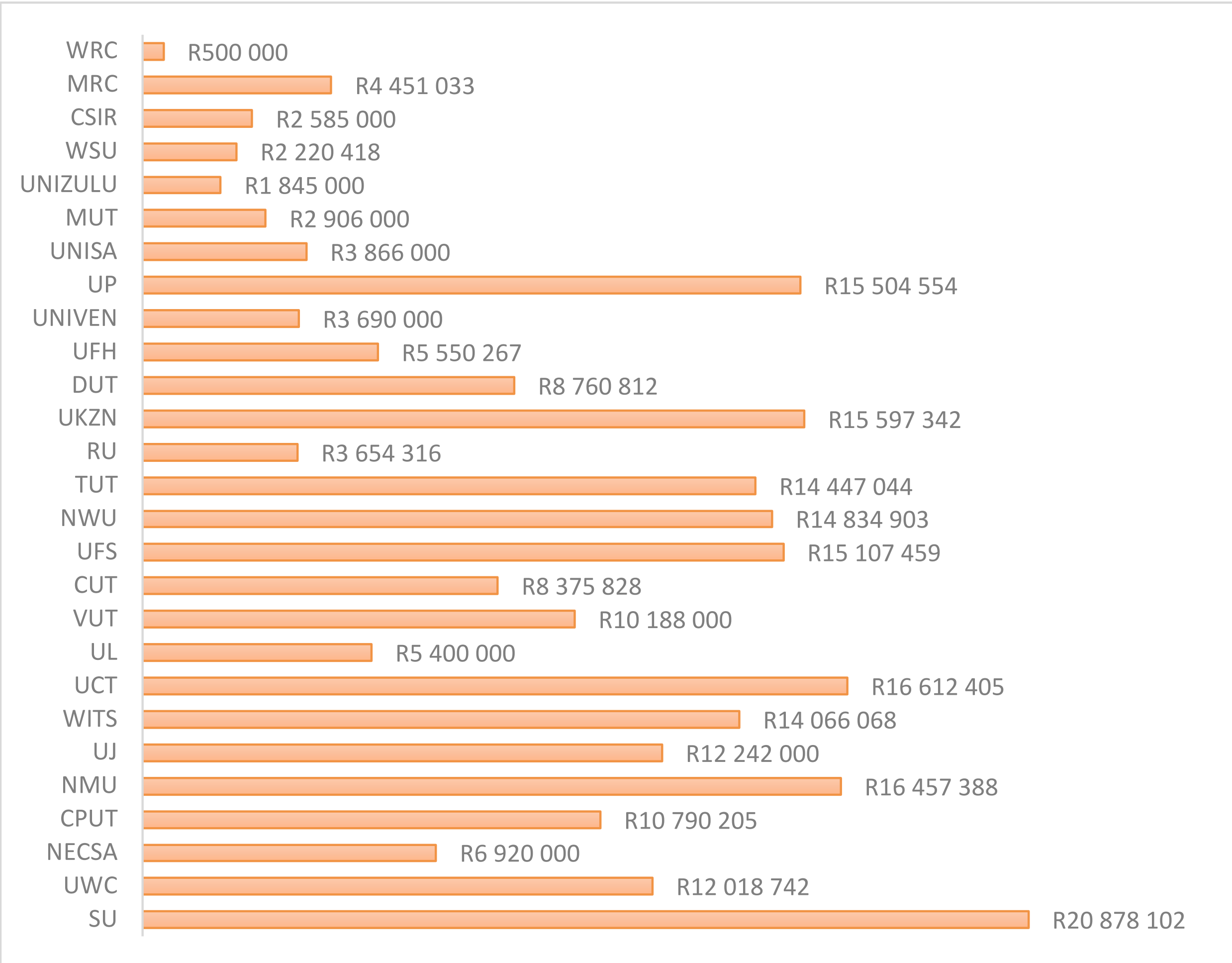


Figure 5.2: Disbursements to higher education institutions and science councils, 2013-2020

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).

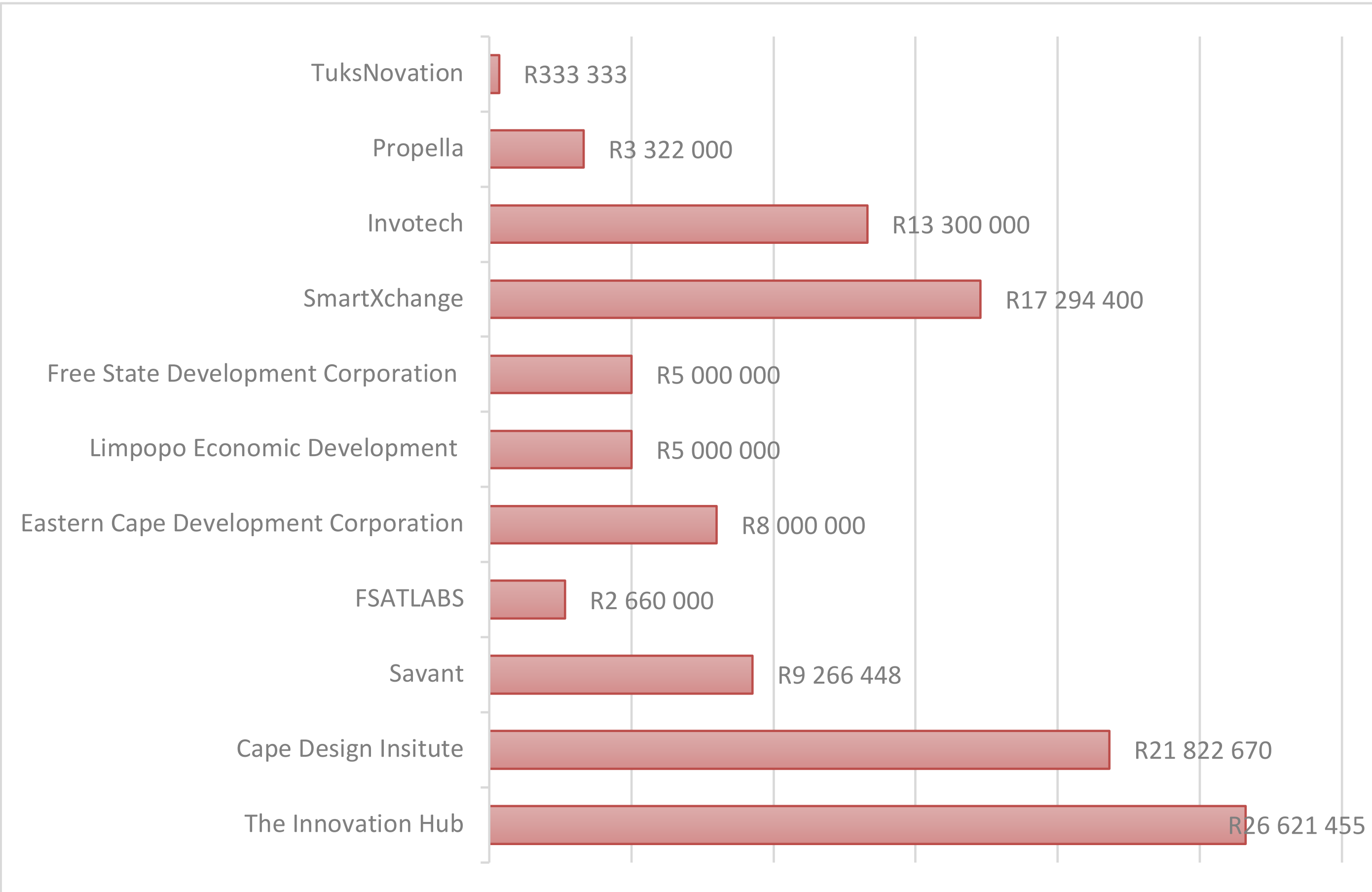


Figure 5.3: Seed fund for SMMEs per implementing partner, 2014-2020

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%).

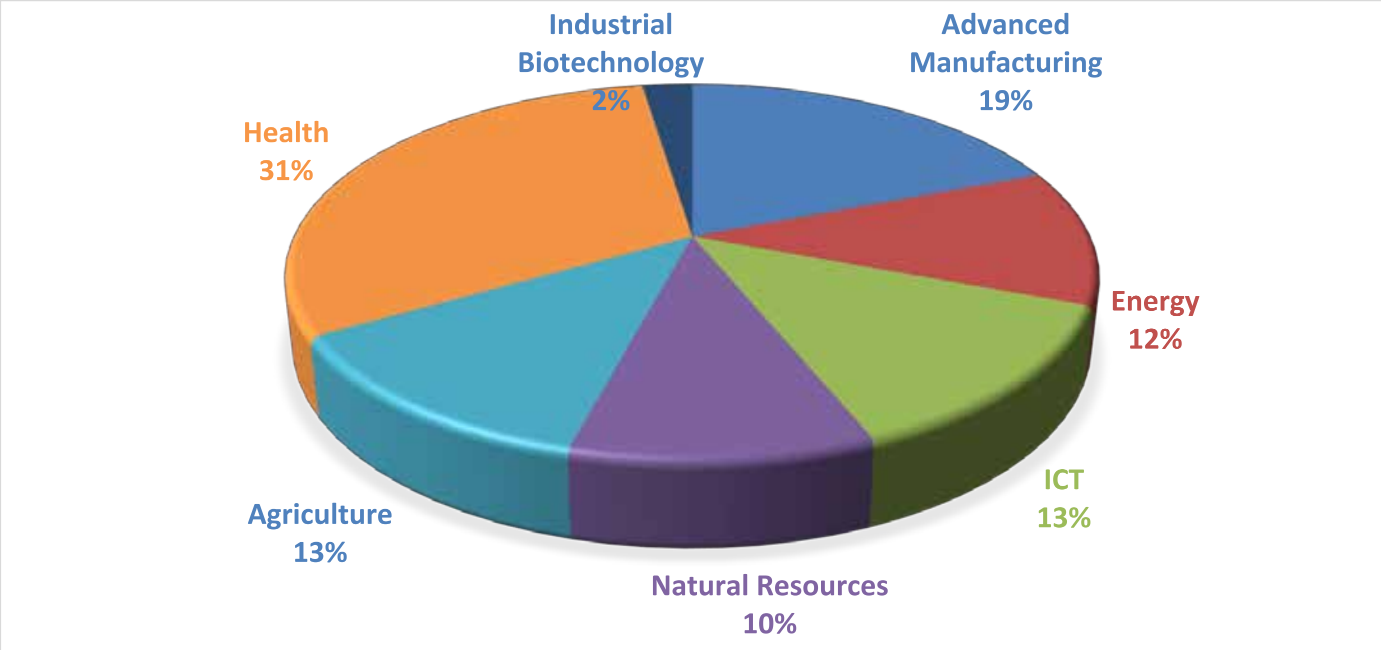


Figure 5.4: Higher Education Seed Fund portfolio per sector, 2013-2020

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%).

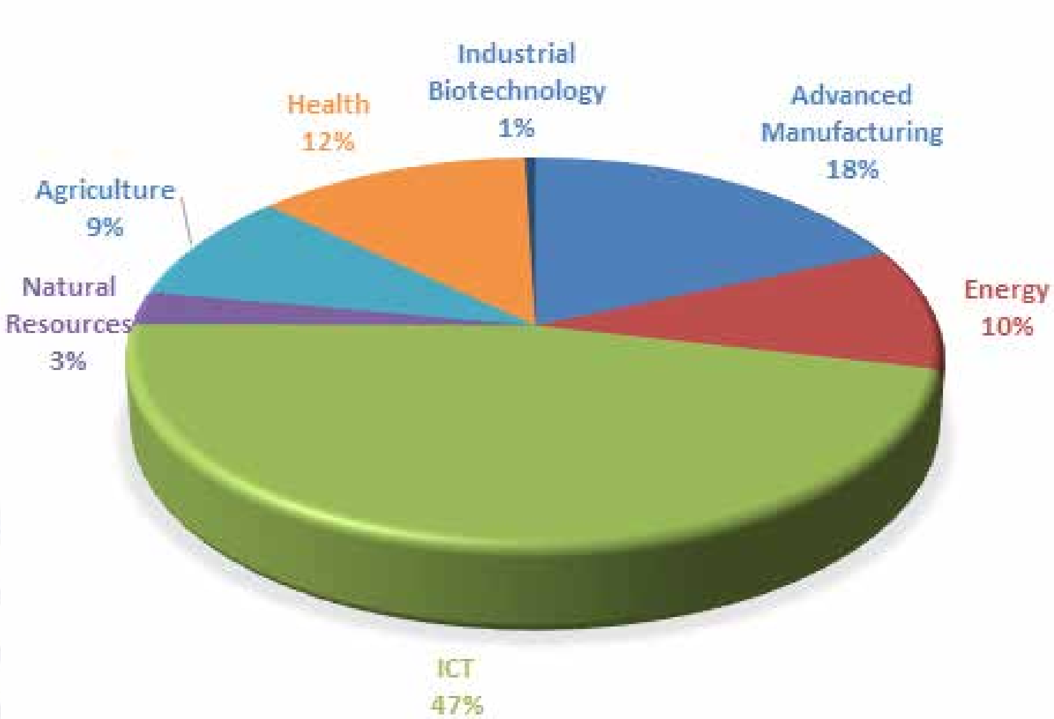


Figure 5.5: SMME Seed Fund portfolio per sector, 2013-2020

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.

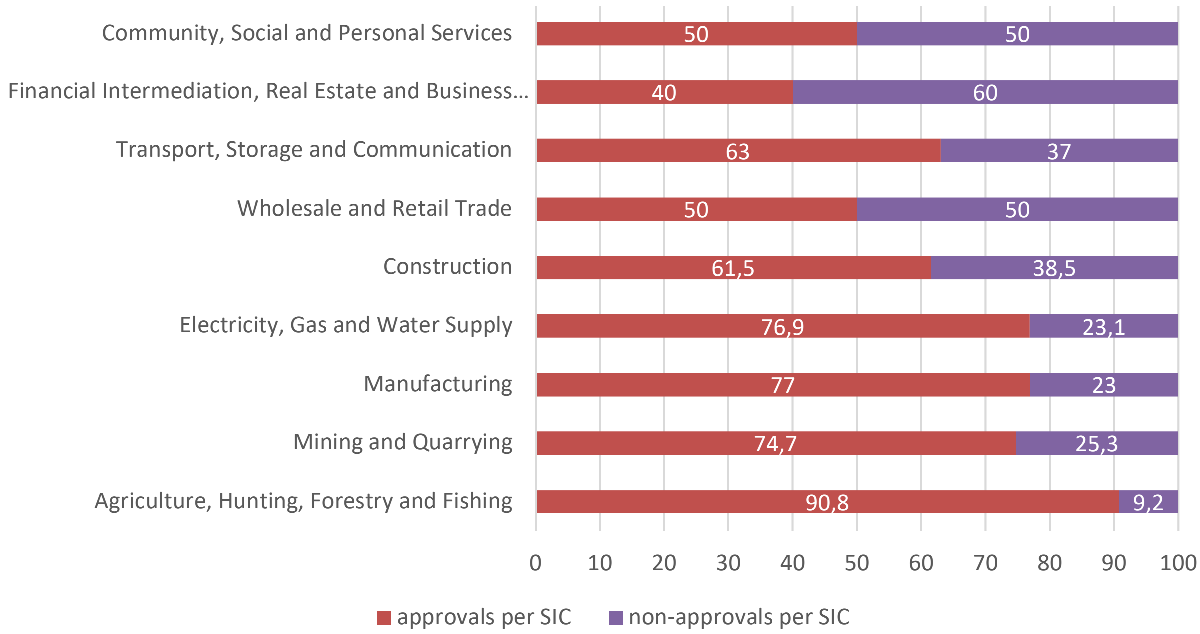


Figure 5.6: Breakdown of approved and non-approved applications for R&D tax incentive per industry sector (Oct. 2012 to Feb. 2021)

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.

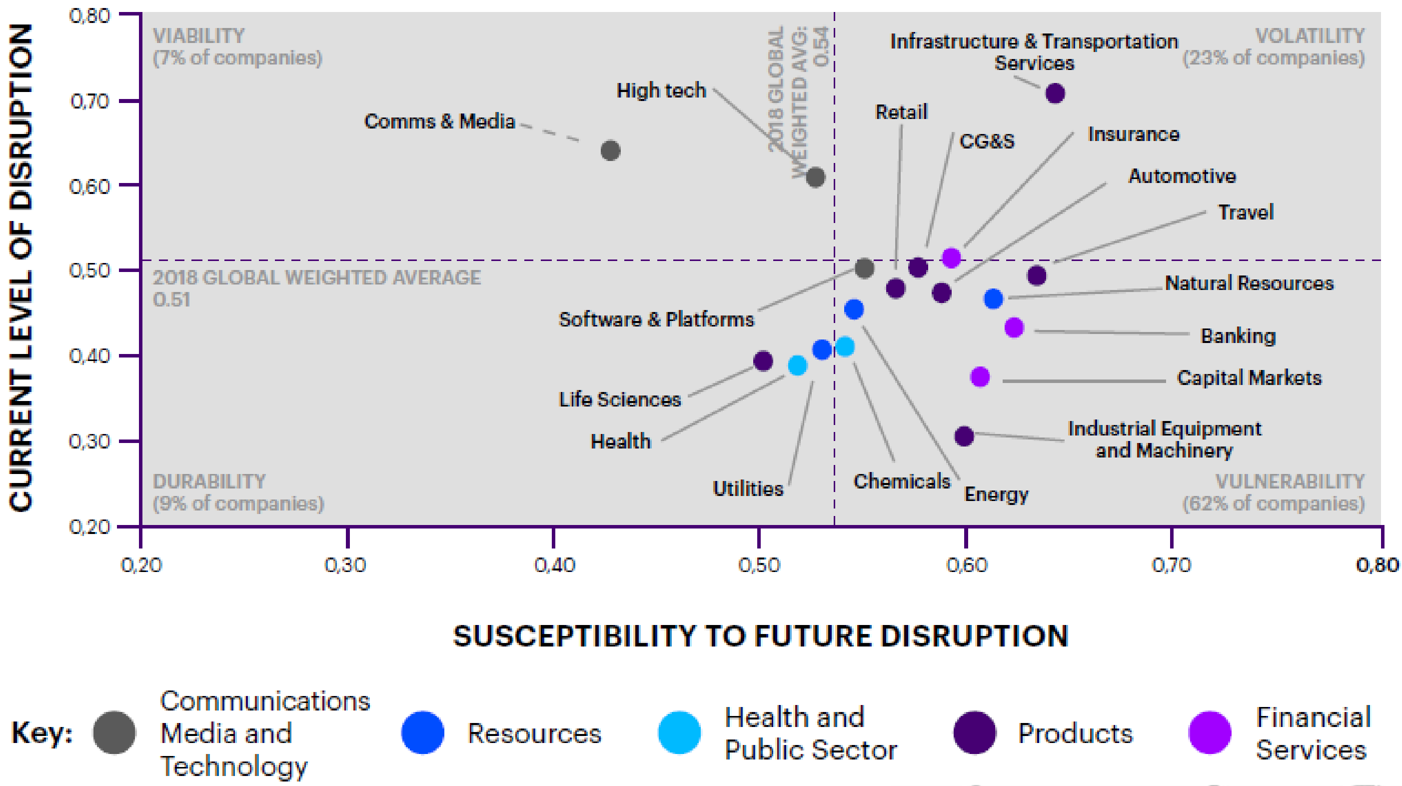


Figure 6.1: South African industry exposure to disruptions, 2018

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**).

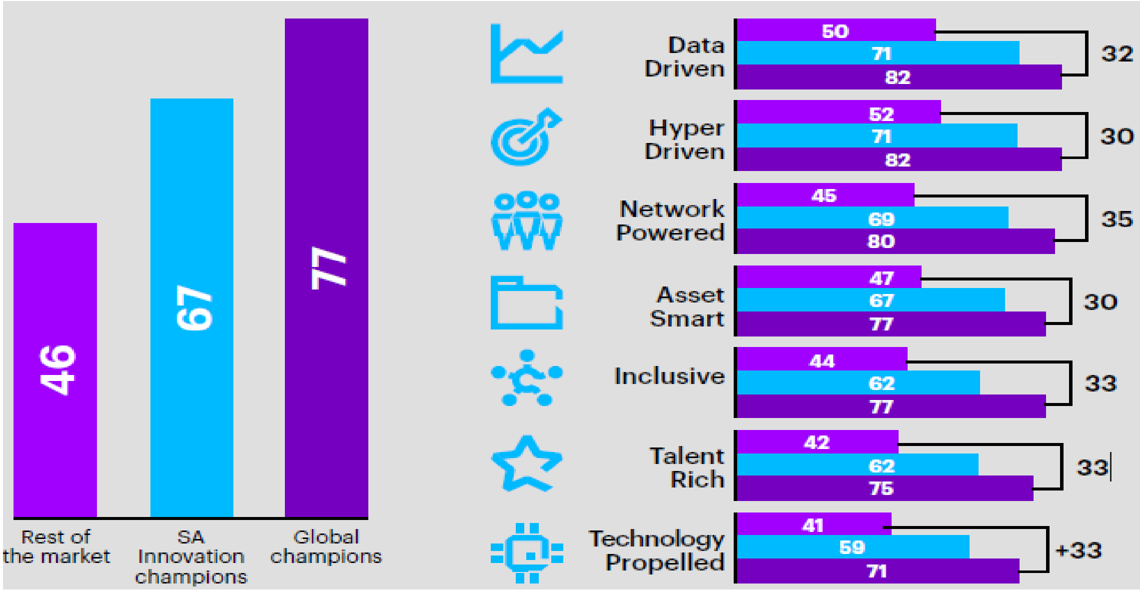


Figure 6.2: Innovation practice scores (out of 100)

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.

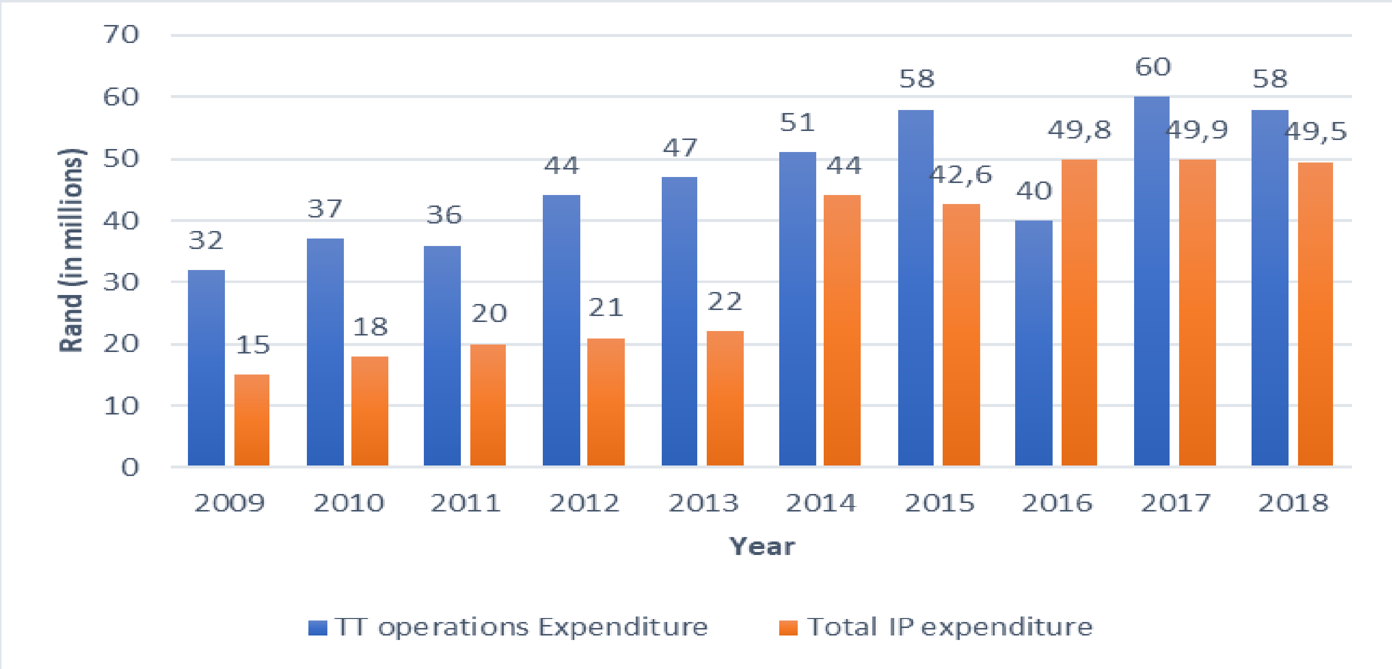


Figure 6.3: Operational and IP expenditure at public research institutions

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.

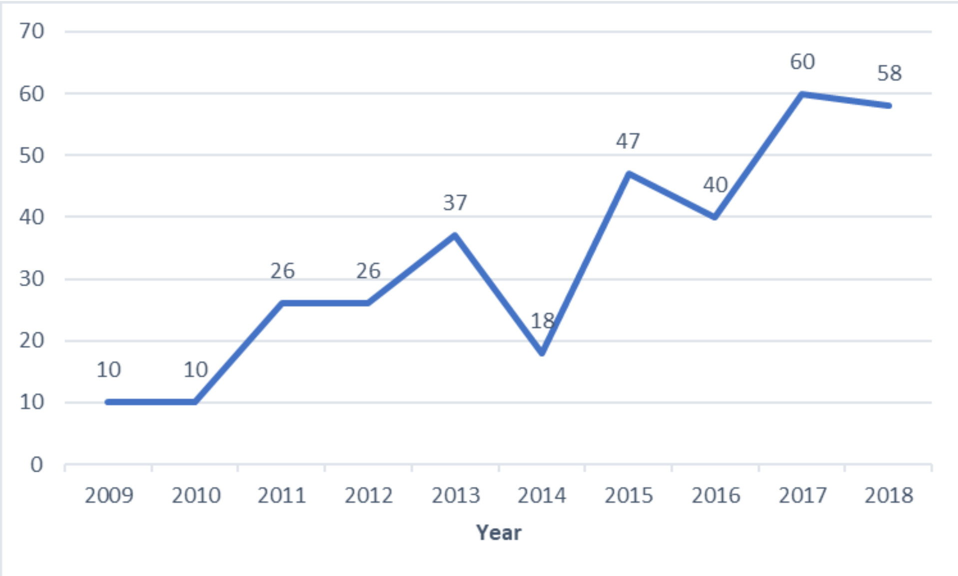


Figure 6.4: Number of IP transactions executed

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.

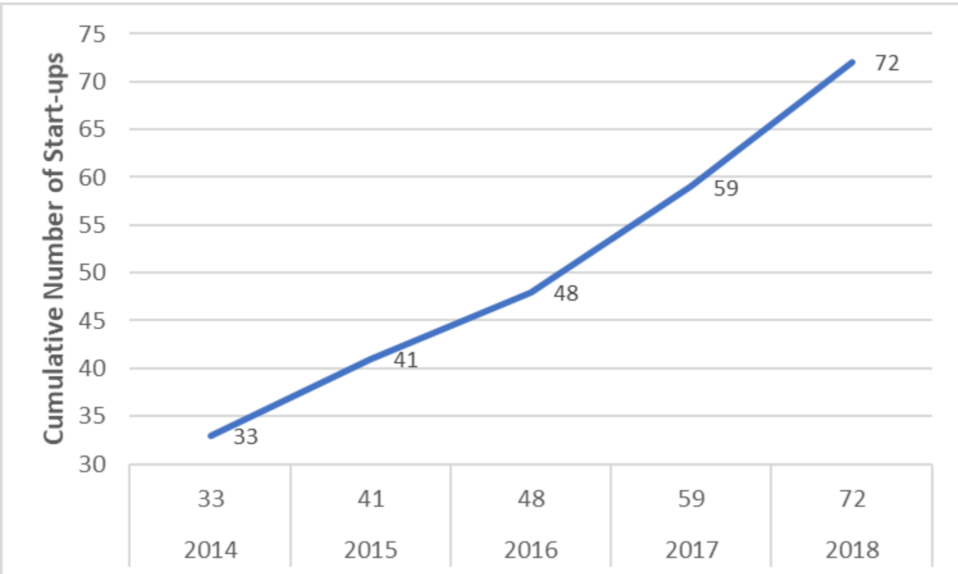


Figure 6.5: Revenues generated from IP transactions

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**.

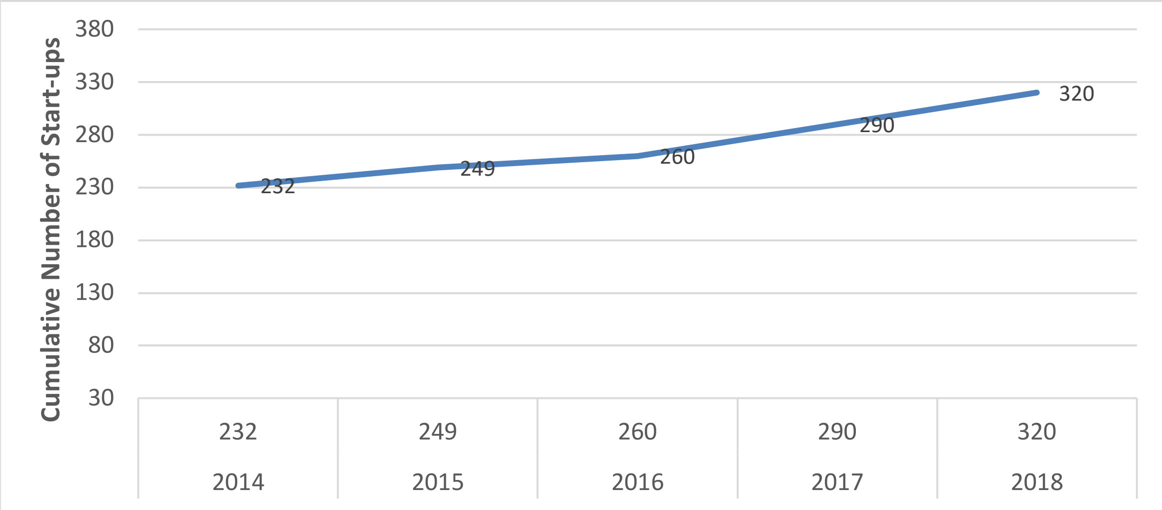


Figure 6.7: Cumulative number of start-ups still in operation

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.

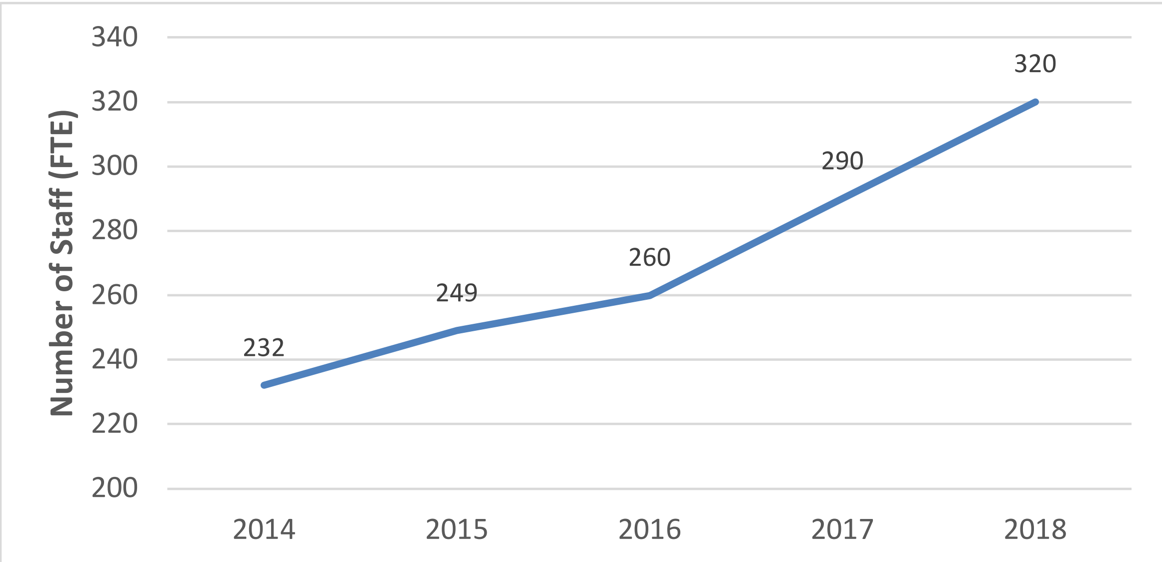


Figure 6.8: Total FTE employment by start-up companies

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.

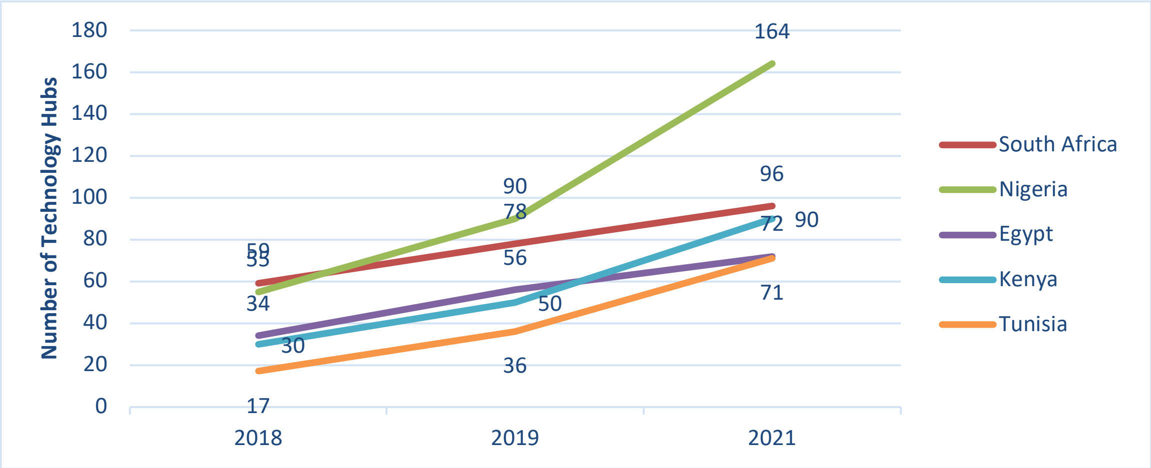


Figure 6.9: Number of technology hubs in SA compared to selected African countries

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

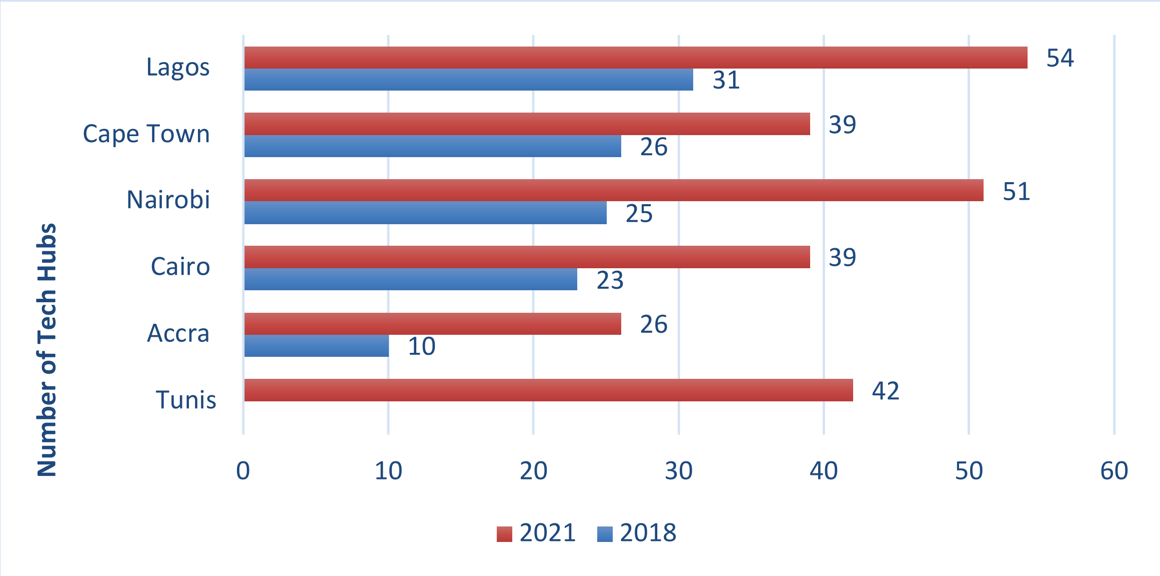


Figure 6.10: Comparison of leading tech hubs in Africa

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.

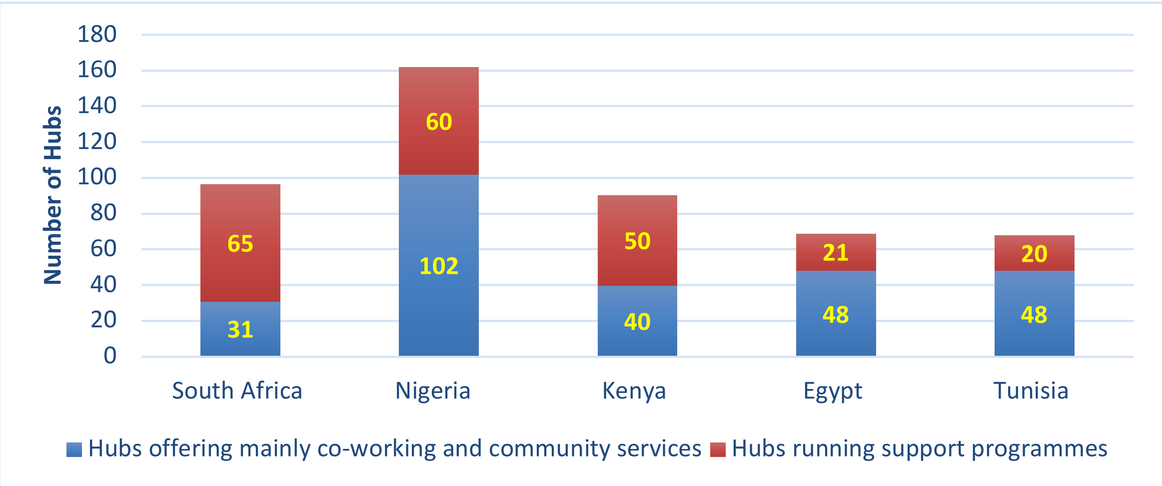


Figure 6.11: Breakdown of leading tech hubs in Africa, including South Africa

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.

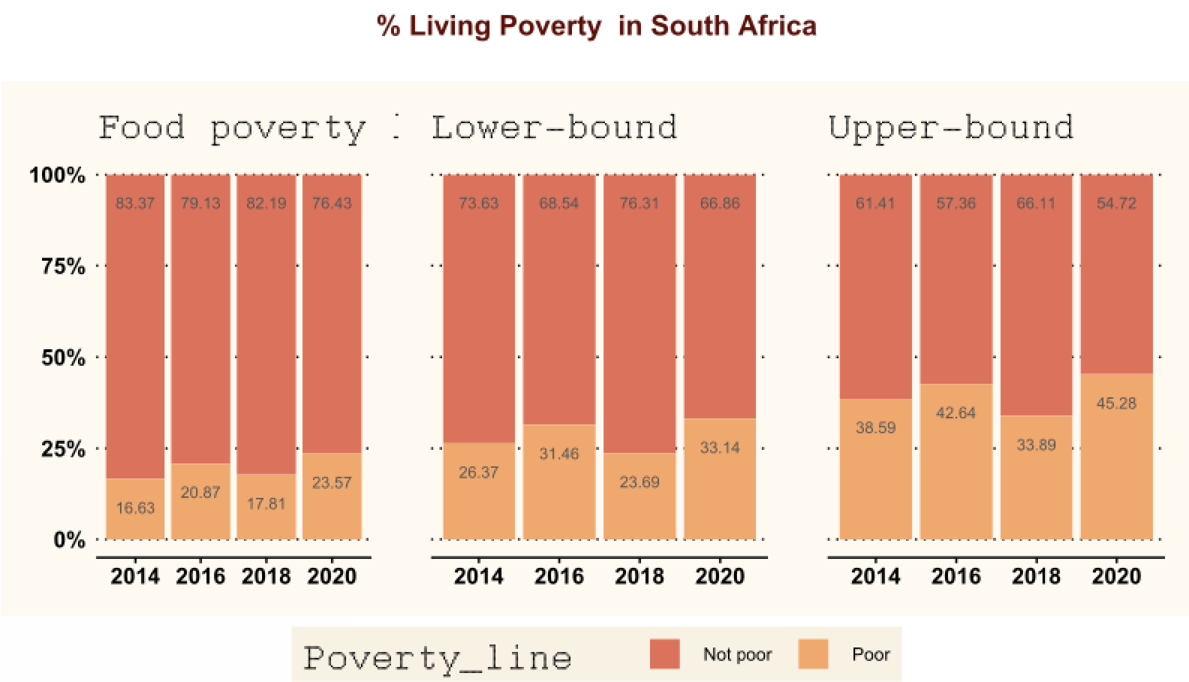


Figure 7.1: Poverty levels in South Africa, 2014-2020

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.

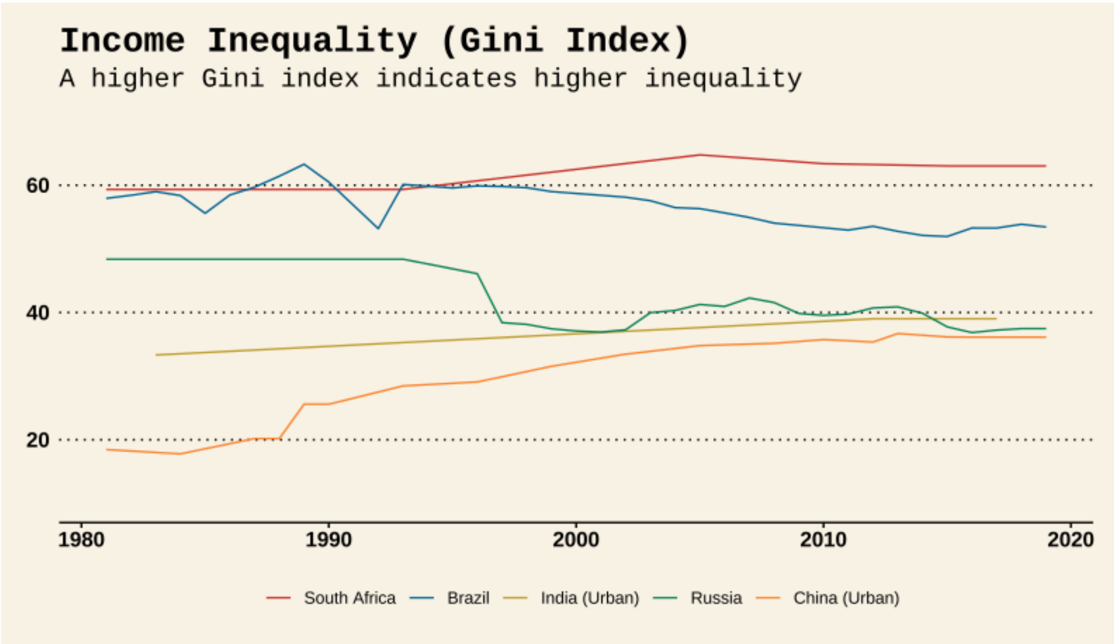


Figure 7.2: Gini index of BRICS countries

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/

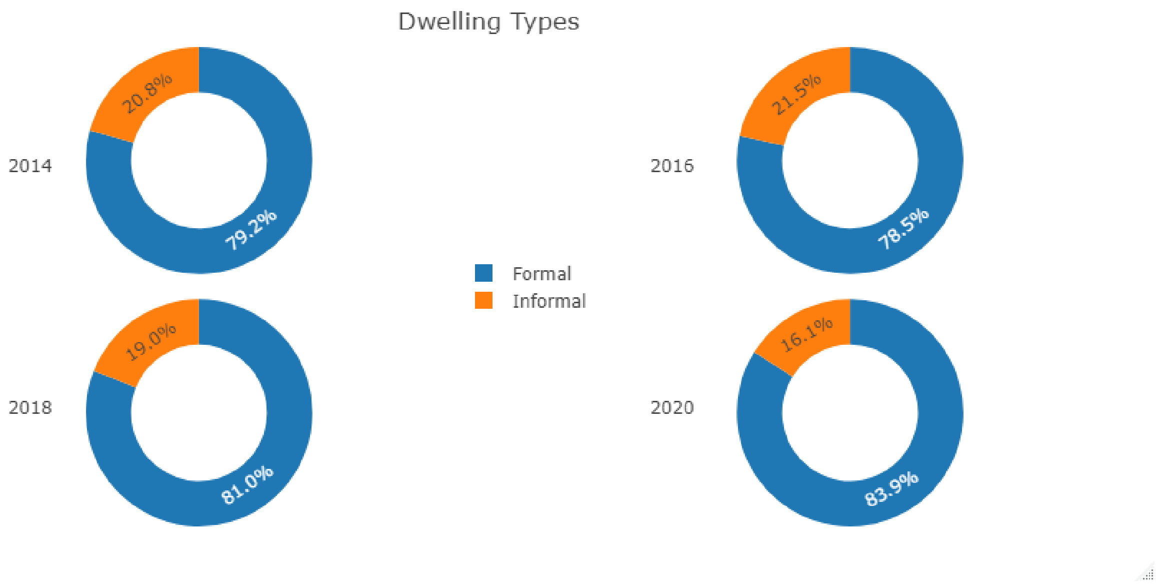


Figure 7.3: Types of dwelling units in South Africa

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.

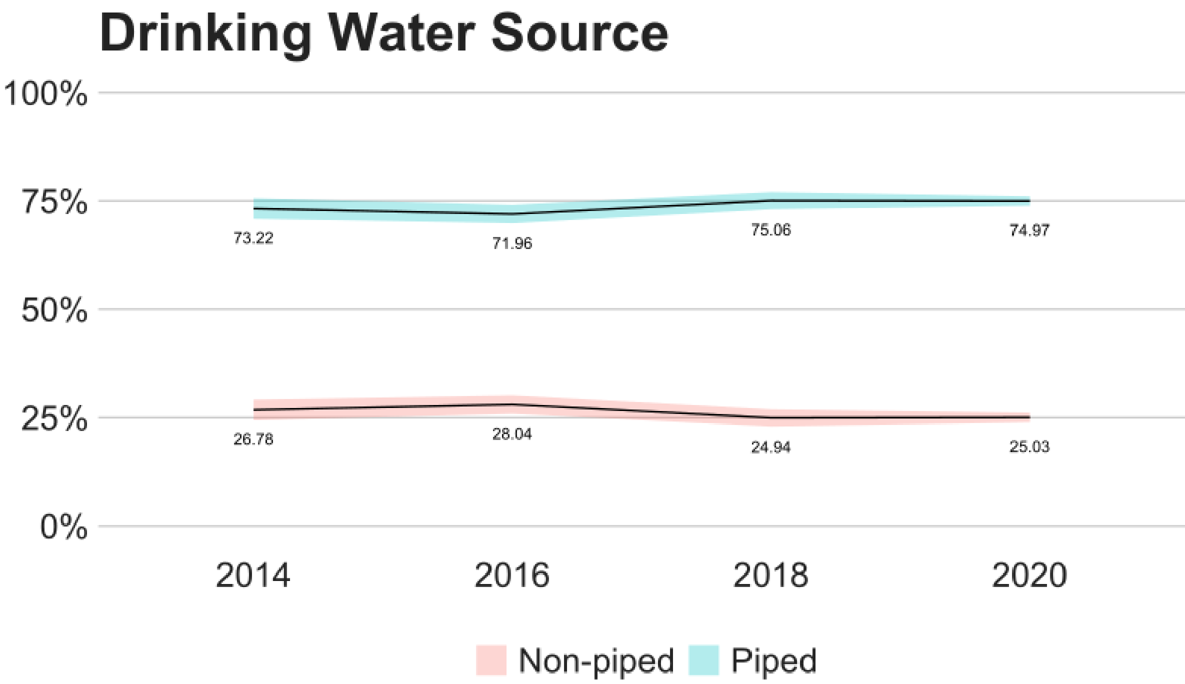


Figure 7.5: Percentage of the South African households with running water

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**.

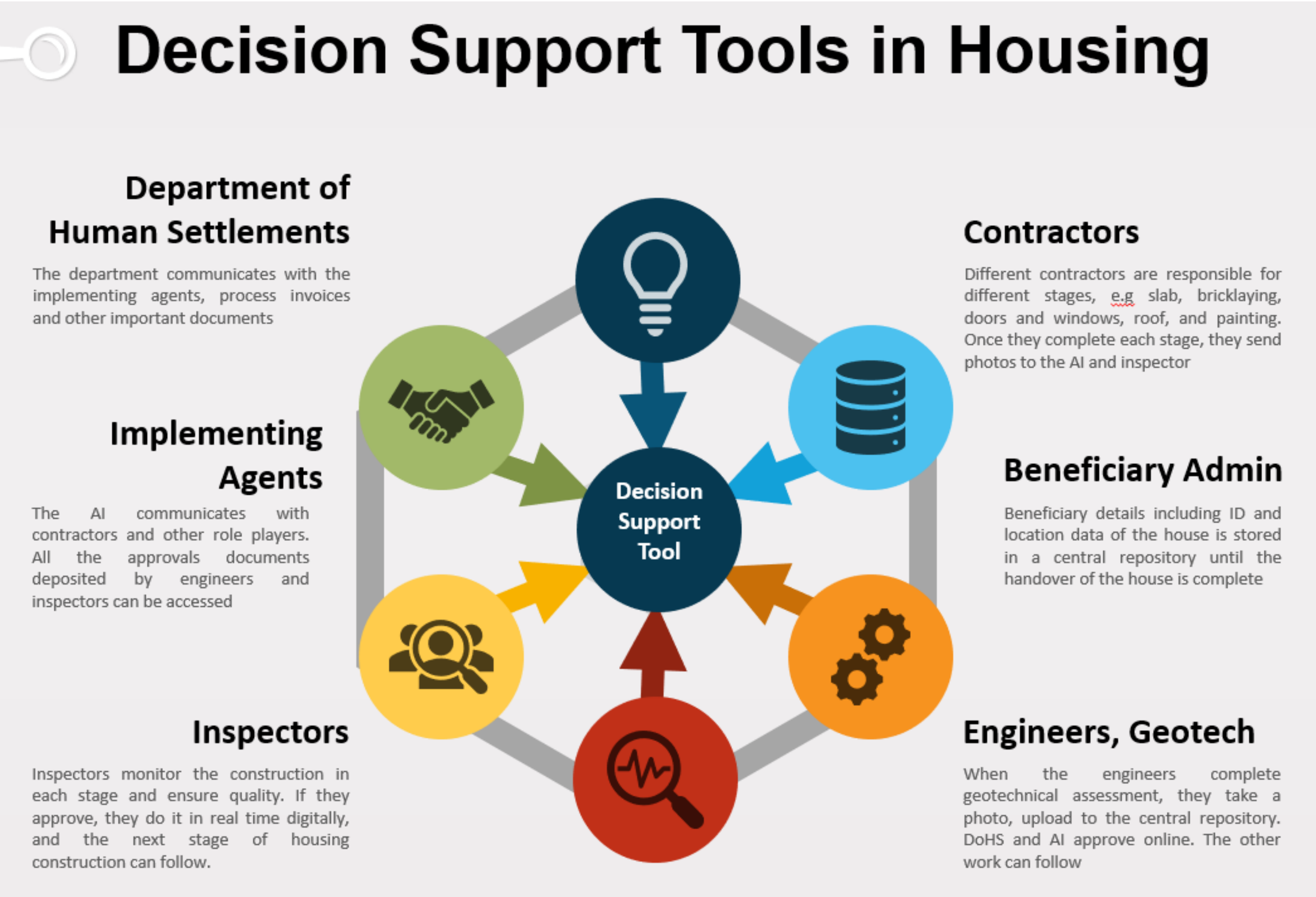


Figure 7.6: The use of decision-support tools in human settlements

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.

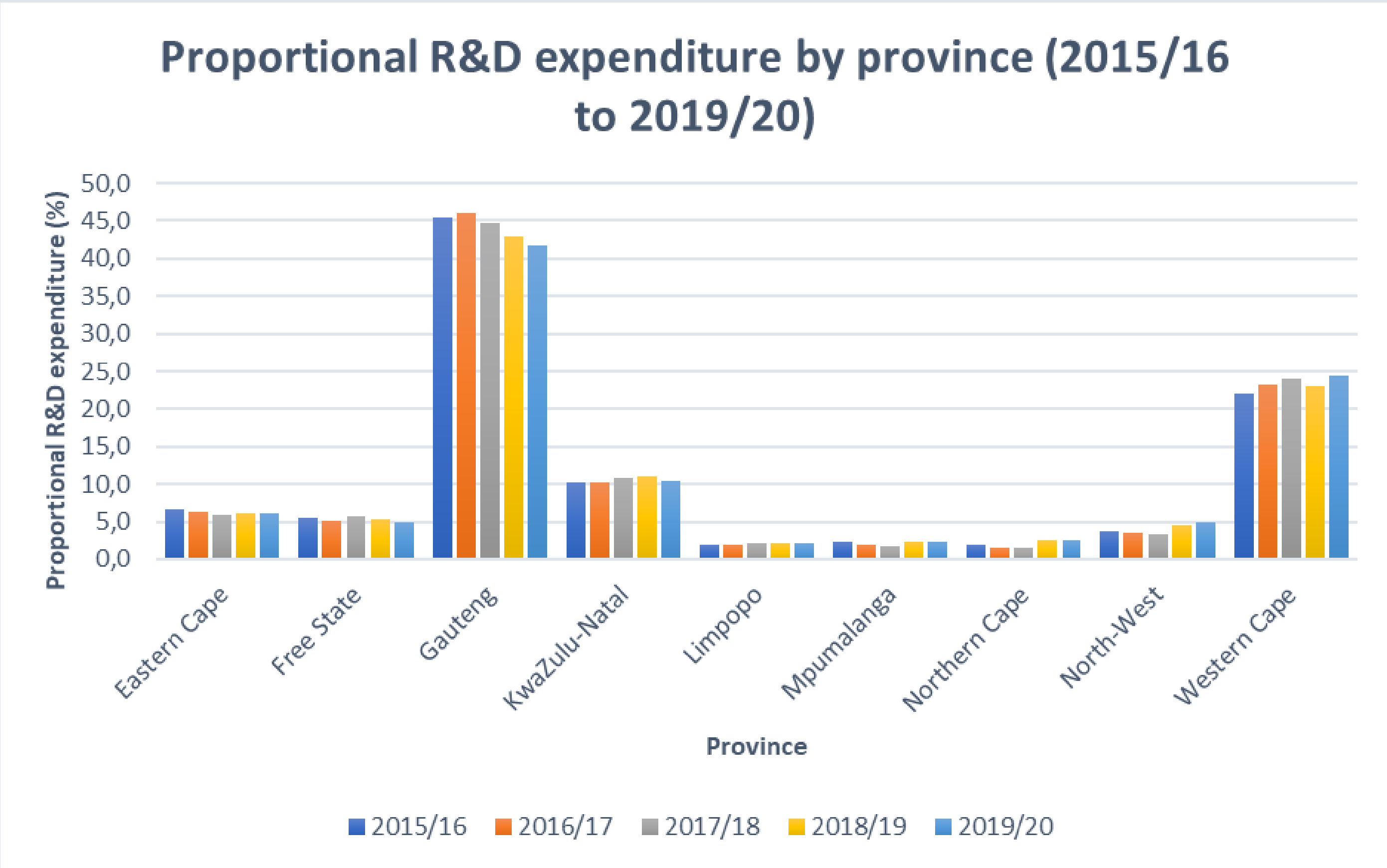


Figure 8.1: Proportion of R&D expenditure by province

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.

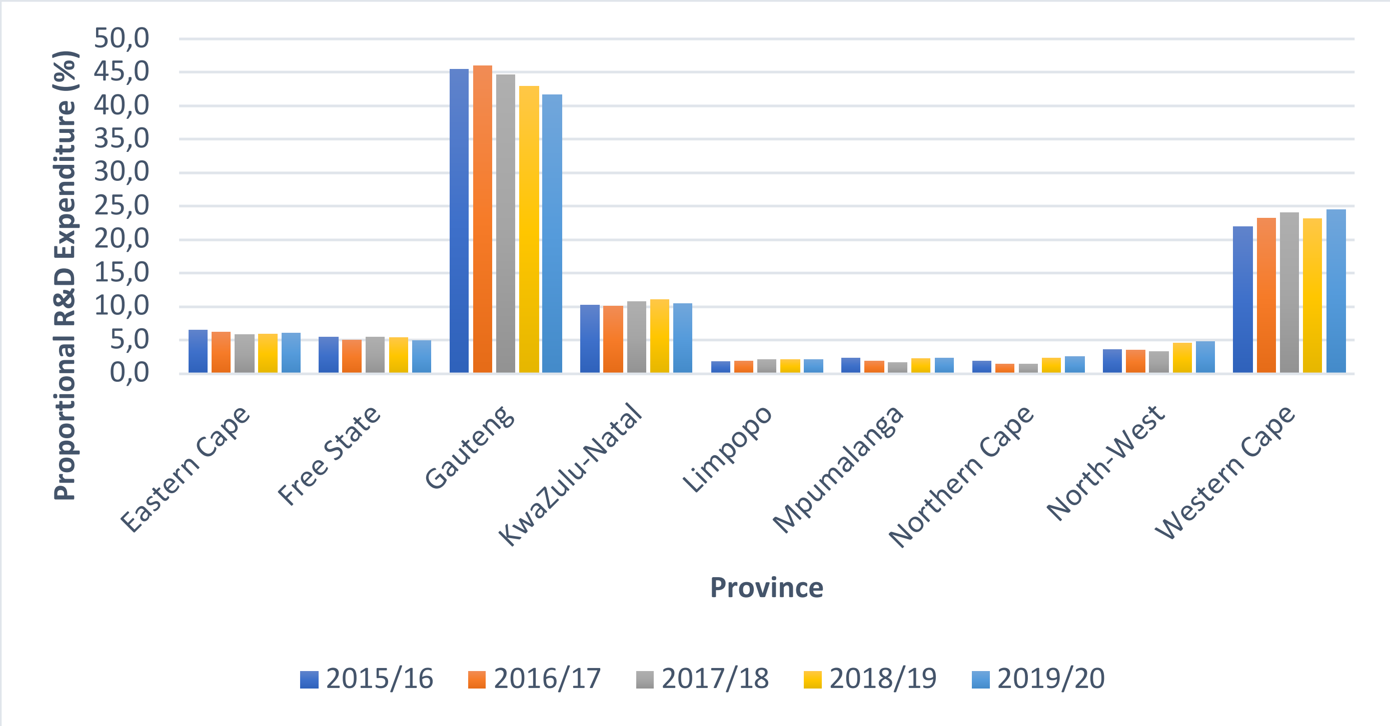


Figure 8.2: Proportional business sector R&D expenditure by province

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.

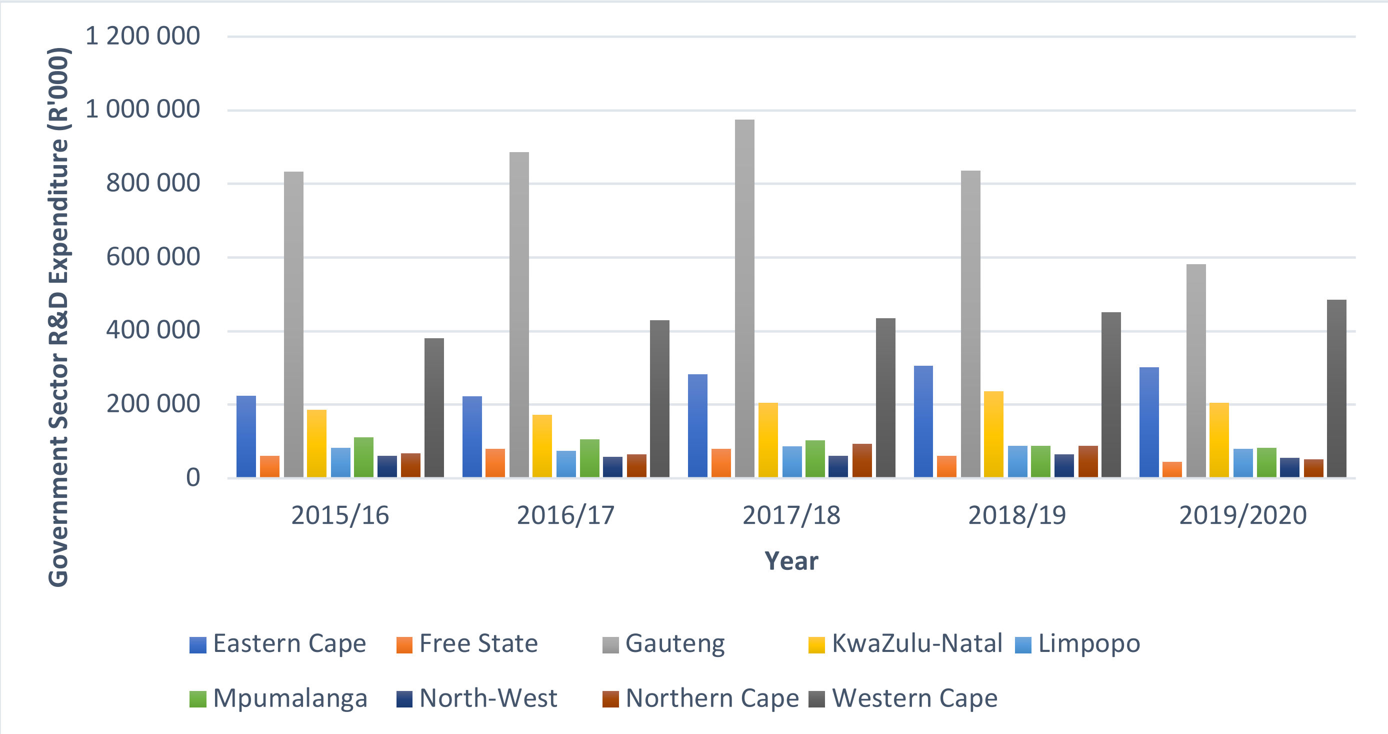


Figure 8.3: Proportional government sector R&D expenditure by province

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.

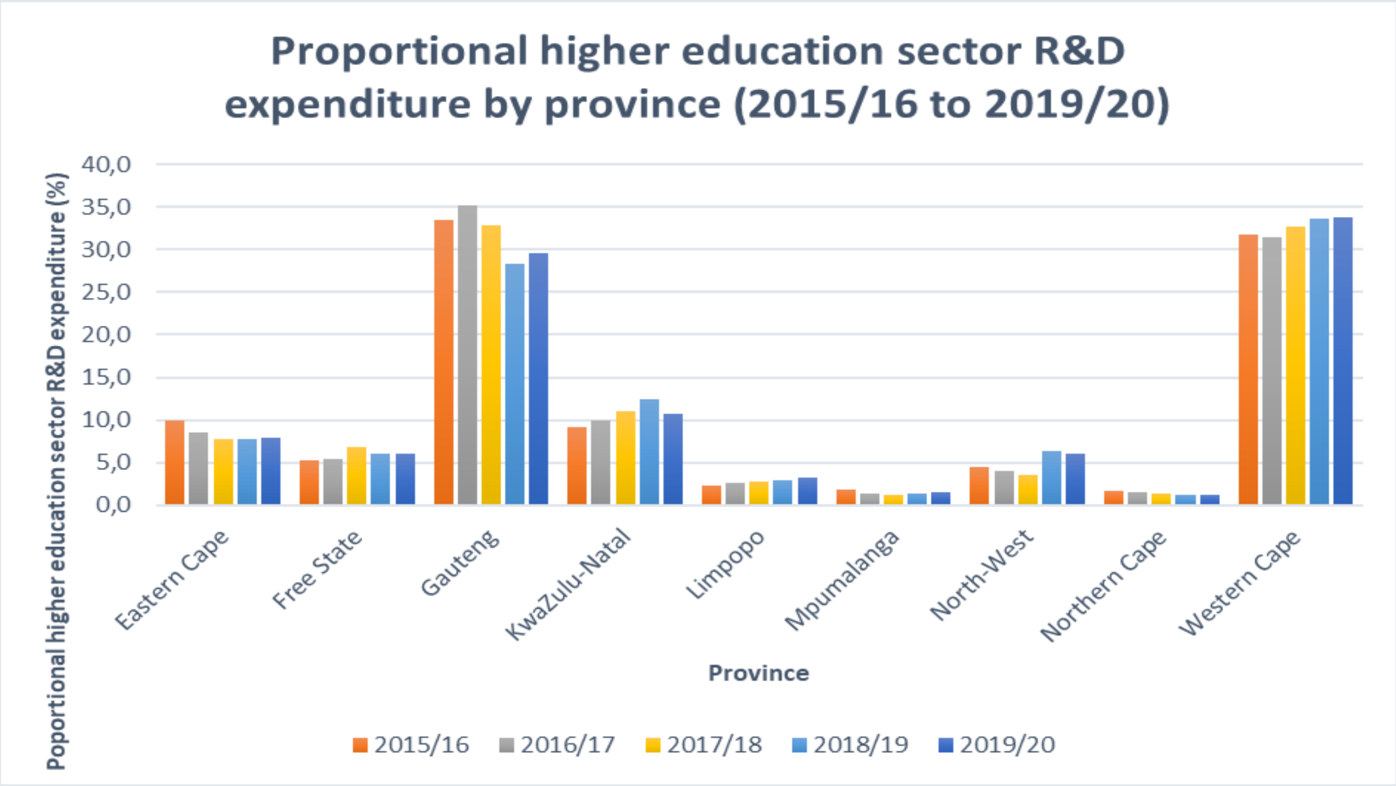


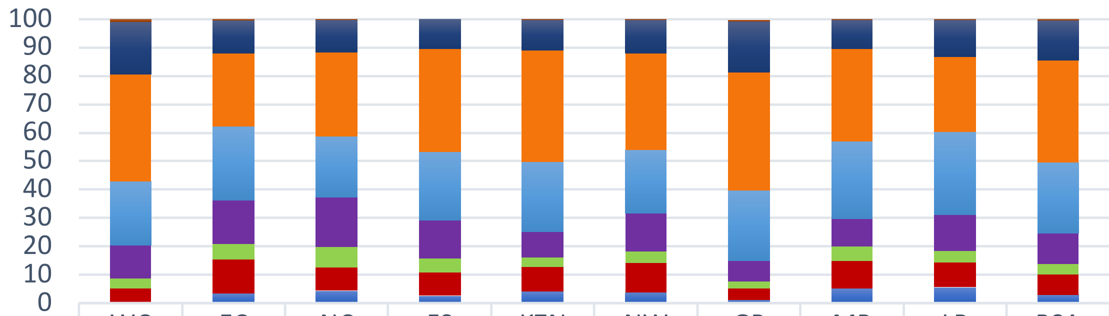
Figure 8.4: Proportional higher education sector R&D expenditure by province

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

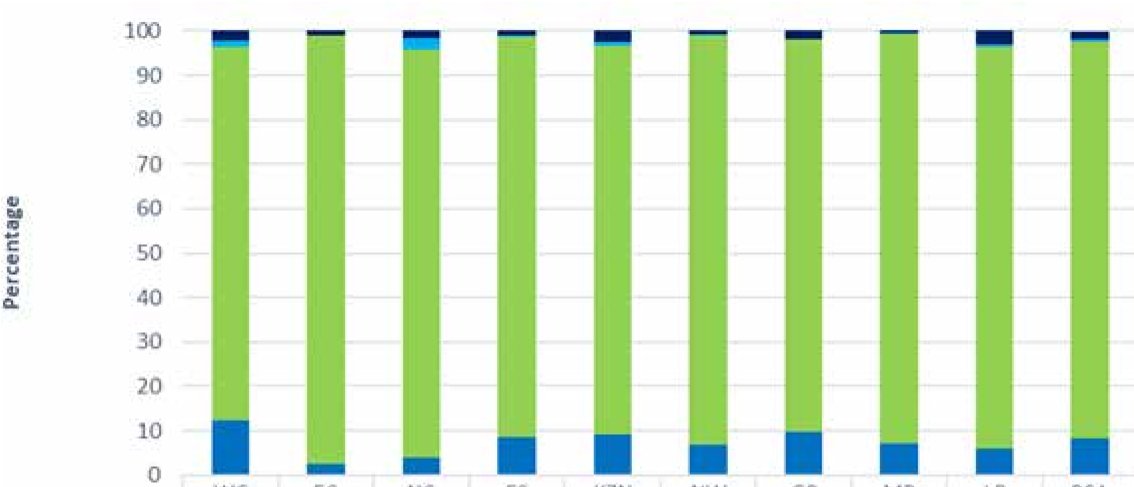
	2017		2018		2019		2020		2021	
	Total learners who wrote exam	% who got 30% or above	Total learners who wrote exam	% who got 30% or above	Total learners who wrote exam	% who got 30% or above	Total learners who wrote exam	% who got 30% or above	Total learners who wrote exam	% who got 30% or above
Eastern 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%).

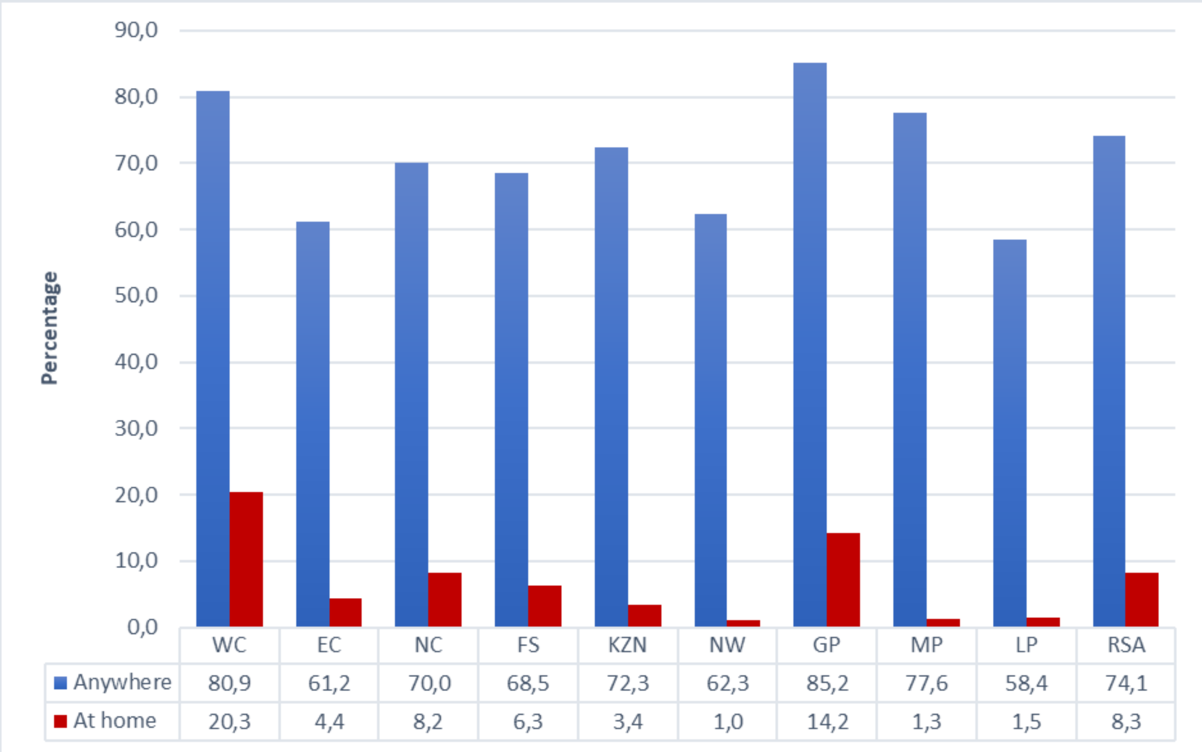


Figure 8.7: Percentage access to Internet per province

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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