SOUTH AFRICAN SCIENCE, TECHNOLOGY AND INNOVATION INDICATORS

2020

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

NACI
NATIONAL ADVISORY COUNCIL ON INNOVATION

2020

SOUTH AFRICAN SCIENCE, TECHNOLOGY AND INNOVATION INDICATORS REPORT

innovation for a better future

The 2020 South African Science, Technology and Innovation Indicators Report was compiled with the latest available data from various organisations and institutions that were mandated to collect the data. In many instances, the data is not necessarily an update of the previous versions of the report as this is not a statistical report.

We welcome comments and suggestions that would enhance the value of the report to our stakeholders by contributing to our continuous efforts to improve the publication. Please email such comments and suggestions to naci@dst.gov.za.

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ACRONYM	DEFINITION
ARC	Agricultural Research Council
BERD	Business Expenditure on Research and Development
BRIC	Brazil, Russia, India, China
CAPRISA	Centre for the AIDS Programme of Research in South Africa
CIPC	Companies and Intellectual Property Commission
CoE	Centre of Excellence
COVID-19	Corona Virus Disease 2019
CSIR	Council for Scientific and Industrial Research
DHET	Department of Higher Education and Training
DSBD	Department of Small Business Development
DSI	Department of Science and Innovation
ECSA	Engineering Council of South Africa
EU	European Union
FabLab	Fabrication Lab
FTE	Full-time Equivalent
GCI	Global Competitiveness Index
GDP	Gross Domestic Product
GERD	Gross Domestic Expenditure on Research and Development
GHS	General Household Survey
GII	Global Innovation Index
H2020	Horizon 2020
HEMIS	Higher Education Management Information System
HERD	Higher Education Expenditure on Research and Development
HSRC	Human Sciences Research Council
ICLEI	Local Governments for Sustainability
ICT	Information and Communications Technology
INSEAD	The Business School of the World
M&E	Monitoring and Evaluation
MTSF	Medium-term Strategic Framework
NACI	National Advisory Council on Innovation
NRF	National Research Foundation
NSI	National System of Innovation
OECD	Organisation for Economic Cooperation and Development
PPP	Purchasing Power Parity
QLFS	Quarterly Labour Force Survey
R&D	Research and Development
SADC	Southern African Development Community
SAIS	South African Innovation Scorecard
SAMRC	South African Medical Research Council
SANBI	South African National Biodiversity Institute
SANSA	South African National Space Agency
SARS-CoV-2	Severe Acute Respiratory Syndrome Coronavirus
SAVCA	Southern African Venture Capital and Private Equity Association
SDG	Sustainable Development Goals
SEDA	Small Enterprise Development Agency
SET	Science, Engineering and Technology
SMEs	Small and Medium-sized Enterprises
SMMEs	Small, Medium and Micro Enterprises
STEM	Science, Technology, Engineering and Mathematics
STI	Science, Technology and Innovation
TIA	Technology Innovation Agency
Unesco	United Nations Educational, Scientific and Cultural Organisation
USPTO	United States Patents and Trademarks Office
VUT	Vaal University of Technology
WIPO	World Intellectual Property Organisation

FOREWORD BY THE **CHAIRPERSON**

It gives me great pleasure to present the South African Science, Technology and Innovation Indicators Report for 2020. This annual report by the National Advisory Council on Innovation (NACI) provides statistics and an assessment of South Africa's Science, Technology and Innovation (STI) performance contextualised globally since 2019.

The report was compiled from the latest available domestic and international STI data. The challenges of generating and maintaining up-to-date local data sets, however, remain problematic. Some of the data sets that have historically been relied upon have now been found to be updated less frequently and have therefore impacted upon this annual report.

The release of this report coincides with a global pandemic caused by an outbreak of a novel virus, the severe acute respiratory syndrome coronavirus (SARS-CoV-2). The Corona Virus Disease (COVID-19) pandemic has caused many deaths and exposed the inadequacies of many countries' national systems of innovation especially at the intersection with the health sector. Without a vaccine, the COVID-19 pandemic has tended to exacerbate economic, social and political inequities. In South Africa, this has meant that the structural challenges of inequality, unemployment, poverty and ecological degradation require even more urgent attention. There is global consensus that progress towards the achievement of the Sustainable Development Goals (SDGs) of the United Nations has already been impeded. Difficulties in transforming energy systems and fulfilling carbon-reduction targets established at the 21st United Nations Framework Convention on Climate Change (Paris Agreement) also imperil keeping a global temperature rise this century well below 2 °C above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 °C. Developing countries and emerging economies are expected to become even more exposed to greater risks in agriculture, food security, premature deindustrialisation, health and social care systems. In all these challenges, the need for robust and resilient scientific and technological capacities and capabilities has become critical. In an uneven yet combined world system, domestic systems of innovation are crucial to transform science and technology into socially useful products and practices.

The 2020 STI Indicators Report reflects progress on some indicators, while pointing to areas of concern. Although South Africa's research system, particularly public institutions such as universities and science councils, has shown a steady increase in scientific publications over many years, more recent performance indicates a decline. South Africa's publications per million population declined from 371 in 2017 to 360 in 2018. The world's scientific publications per million population also declined from 471 in 2017 to 464 in 2018. In contrast, the upper middle-income countries increased their scientific publications per million population from 317 to 327 during the same period.

Improvements continue to be evident at the school level. The Senior Certificate pass rate in physical sciences improved from 58.6% in 2015 to 75.5% in 2019. The mathematics pass rate improved from 49.1% in 2015 to 58% in 2018, before declining to 54.6% in 2019.

Most of the doctoral degrees produced in South Africa are in the field of natural and agricultural sciences, with 1 051 doctorates produced in 2018. Only 7% of the doctoral degrees produced are in the field of engineering. The number of researchers within the business and higher education sectors increased by 14.7 and 15.7%, respectively, between 2016/17 and 2017/18. Unemployment is lower among those with higher levels of education. Among those with master's and doctoral degrees, unemployment increased from 2.4% in 2018 to 2.8% in 2019.

Financing of the National System of Innovation (NSI) continues to be a challenge. In 2017/18, South Africa's gross domestic expenditure on R&D (GERD), as a percentage of gross domestic product (GDP) was 0.83%, which remains below the 1.5% target. Business expenditure on R&D (BERD), as a percentage of GERD, also declined from 58.6% in 2008/09 to 41.0% in 2017/18 and as a percentage of GDP from 0.52% in 2008/09 to 0.34% in 2017/18. There may be some anecdotal evidence pointing to different reasons for this decline. However, it is important that a deeper and systematic analysis should be considered to understand the problem better.

In contrast to the business sector, GERD increased from R4.1 billion in 2008/09 to R13 billion in 2017/18; an increase of 85% in 2010 rand value. Increased funding at universities contributed to an increase in the number of postgraduate students (which is a national long-term objective) and the number of publications from universities. The number of master's degrees (by research) increased from 6 460 in 2013 to 8 610 in 2018. The number of doctoral graduates increased from 2 051 in 2013 to 3 307 in 2018.

The report suggests that, if the underlying forces during the past period remain intact, the number of doctoral graduates will reach the target of 5 000 by 2030. Partnerships between science councils and universities have contributed to the significant enrolment and graduation of both master's and doctoral degree candidates. Furthermore, it is identified that holders of doctoral degrees have a very low unemployment rate (2 to 3%).

Knowledge management and applications of innovations for economic activity are intrinsically essential for an impactful NSI. A brief analysis of data in the United States Patents and Trademarks Office (USPTO) indicated that South African inventors receive a relatively small number of US patents when compared to other countries. However, South Africa is ranked 16th out of 55 countries in terms of plant variety patents (equivalent to Plant Breeders' Rights), while it is ranked 30th in terms of utility patents. The latter is significant as South Africa's commercial agriculture is highly competitive with significant exports of fruits and grains; thus contributing to GDP and jobs.

Recent results from both the Global Innovation Index (GII) and the Global Competitiveness Index (GCI) indicate that South Africa has been losing its relative position to other countries that are utilising their capacities, capabilities and competencies in science and technology better. It is therefore essential to deepen our analysis based on high-quality data about the real performance of the NSI, and to clearly ascertain its inefficacies and contradictions. It is only upon such critical reflections that a better-performing NSI is possible, and deemed necessary to the development of the people of South Africa.

We sincerely hope that NSI role-players and stakeholders will find this report useful and a resource to appreciate the emerging STI trends, challenges and opportunities that are available both locally and internationally. We also encourage those interested to conduct deeper analysis of trends, some of which are indicated in the report.

On behalf of the NACI Council, I would like to acknowledge inputs and reviews by Dr Lehohla, Prof Kahn, Prof Kaplan, Prof Maharajh, Prof Mugabe and Prof Pouris, among others, and thank all contributors, including the employees of NACI, who made the development of this report possible.

Dr Shadrack Moephuli
NACI Interim Chairperson

1. EXECUTIVE SUMMARY

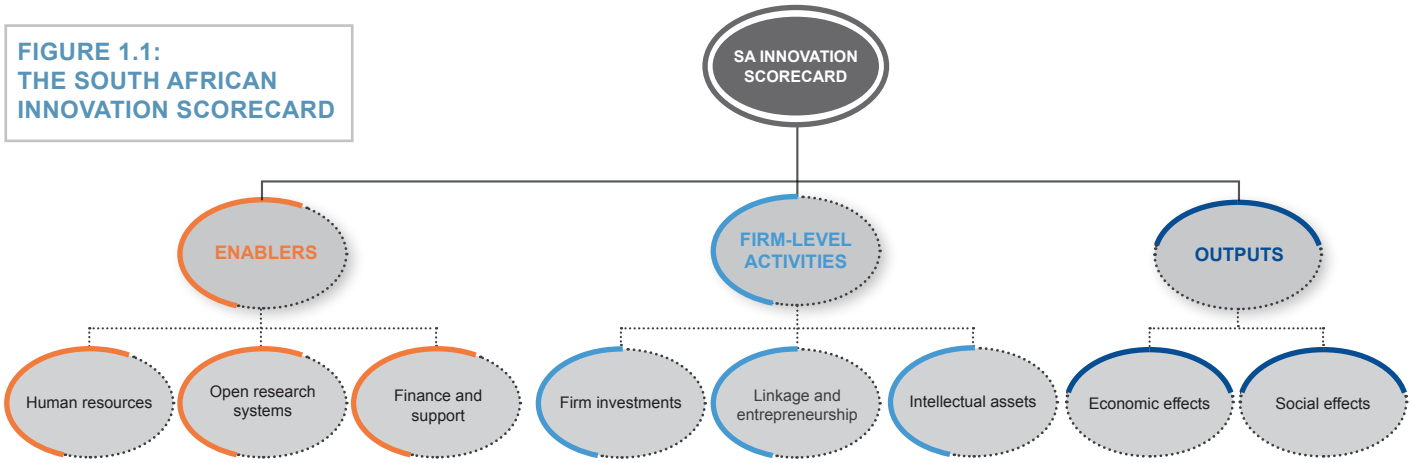
1.1 BACKGROUND

In order to continuously monitor the state of STI in South Africa, NACI produces the annual South African Science, Technology and Innovation Indicators Report. The 2020 STI Indicators Report provides information on the state of STI in South Africa over time and within a global context. It collates select STI data and information from different sources so that it may become an integrated resource for NSI actors. It strives to be a factual source of South African and international data. The STI Indicators Report contains a lot of quantitative evidence, which may require further analysis (including qualitative) in order to understand some issues or questions better. As much as it is tempting, the STI Indicators Report does not offer direct policy options nor does it make policy recommendations.

1.2 FRAMEWORK FOR THE 2020 SOUTH AFRICAN STI INDICATORS REPORT

The 2017 South African Innovation Scorecard (SAIS) (as shown in Figure 1.1) informed the STI Indicators Report. The SAIS categorises STI activities into three broad categories or pillars: **enablers**, **firm-level activities** and **outputs**.

FIGURE 1.1: THE SOUTH AFRICAN INNOVATION SCORECARD



1. The enablers pillar comprises the following components: STI human resources, an open research system, and STI finance and support. In order to broaden the analysis of human resources across various STI activities, data on registered engineers, a key human resource, has been incorporated into the report for the first time. NACI intends to deepen its analysis of this area in future, in partnership with the Engineering Council of South Africa (ECSA).

   In order to support South Africa as the innovation champion of the Southern African Development Community (SADC) region, the analysis of knowledge generation, as part of the research system, is done at SADC level. The National Research Foundation (NRF) and Horizon 2020 (H2020) research funding are analysed as part of the STI funding and support instruments.

2. The firm-level activities pillar comprises the following components: firm investments, linkages and entrepreneurship, and intellectual assets. In this report, the results of the Business Innovation Survey are used to show the key characteristics, factors and drivers of business innovation activities.

3. Lastly, the innovation outputs pillar reveals the state of high-technology and commercial service exports from South Africa, and discusses the country's technology balance of payments in comparison to other countries.

The STI Indicators Report benefited from the analysis of local and global STI trends, as well as local systems of innovation.

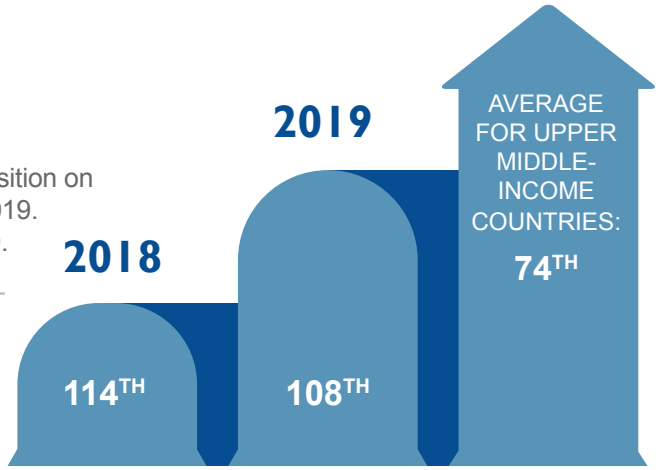
1.3 KEY HIGHLIGHTS

The main findings of the 2020 South African Science, Technology and Innovation Indicators Report are framed according to the following broad categories: **STI human resources**, **STI funding**, **scientific outputs**, **firm-level innovation** and **technology exports**.

1.3.1 STI HUMAN RESOURCES

HUMAN RESOURCES RANKING

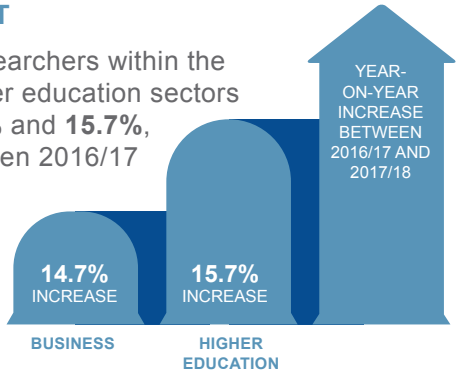
The country's human resources ranking improved from **114th** position on the Global Competitiveness Index in 2018 to **108th** position in 2019. The average of upper middle-income countries was **74th** in 2019.



Global Competitiveness Index 2019

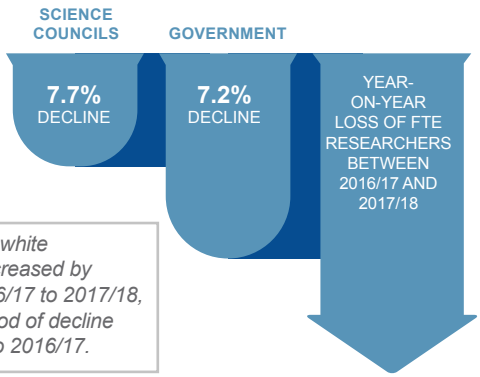
STI EMPLOYMENT

The number of researchers within the business and higher education sectors increased at **14.7%** and **15.7%**, respectively, between 2016/17 and 2017/18.



The number of full-time equivalent (FTE) researchers per 1 000 in total employment is **1.8** in 2018, which is similar to what it has been for at least the past 10 years.

*The number of white researchers increased by **4.3%** from 2016/17 to 2017/18, following a period of decline from 2015/16 to 2016/17.*



Between 2016/17 and 2017/18, the science councils lost **149** FTE researchers and government lost **70** FTE researchers, which equates to a loss of **7.7%** and **7.2%**, respectively.

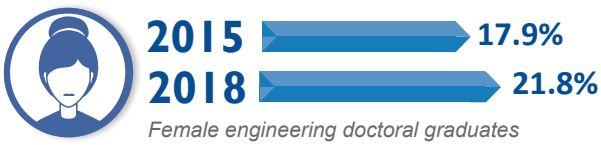
DOCTORAL RESEARCH

Most of the doctoral degrees produced in South Africa are in the field of natural and agricultural sciences, with **1 051** doctorates produced during 2018. Doctoral degrees in social sciences and humanities follow with **913** and **759** doctoral degrees, respectively. Engineering fared the lowest, with **229** doctorates during 2018.

Only 7% of the doctoral degrees produced are in the field of engineering.

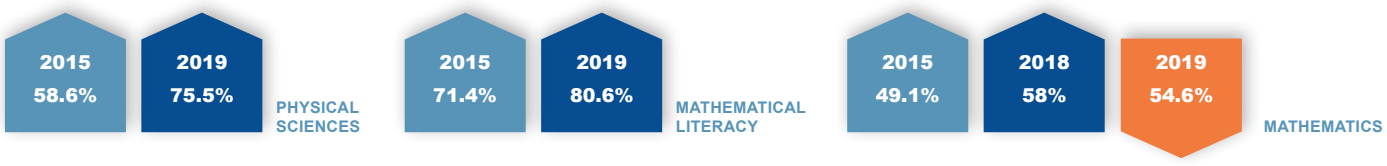
Engineering, as a career, is still male-dominated, although between 2015 and 2018, there was a visible shift across all qualification types in the proportion of female engineering graduates. The imbalance is more at the doctoral level as the share of female graduates was **21.8%** in 2018, which increased from **17.9%** in 2015.

1 051 NATURAL AND AGRICULTURAL SCIENCES
913 SOCIAL SCIENCES
759 HUMANITIES
229 ENGINEERING



Female engineering doctoral graduates

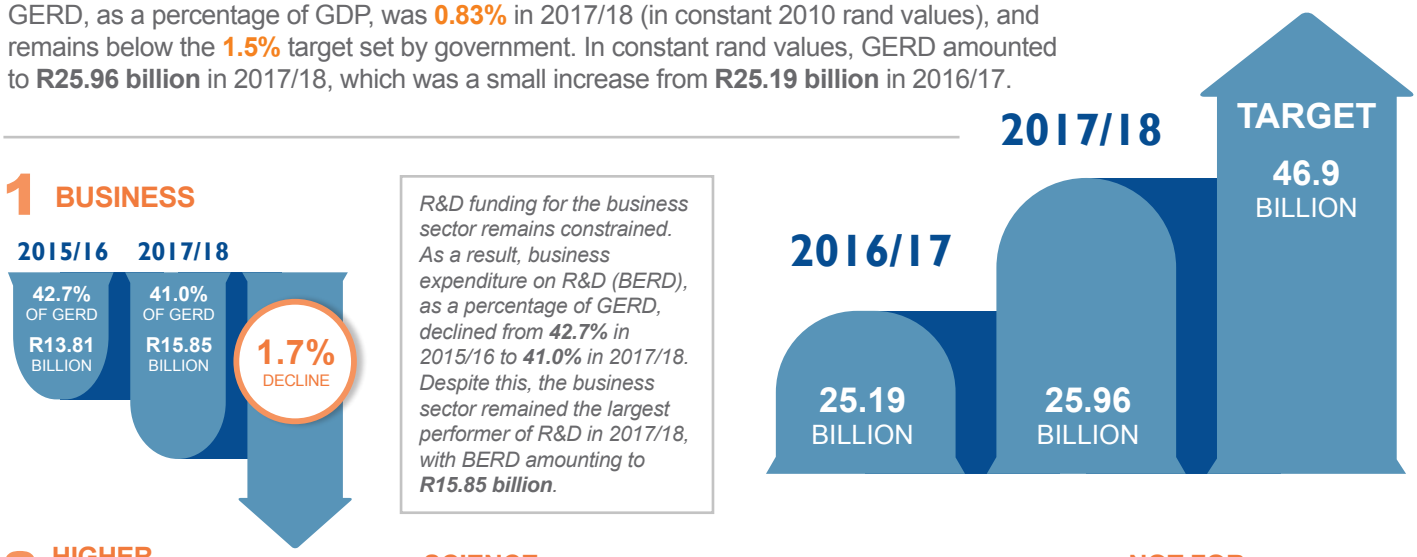
NATIONAL SENIOR CERTIFICATE PASS RATE IN SELECTED STI SUBJECTS



1.3.2 STI FUNDING

GROSS DOMESTIC EXPENDITURE ON R&D (GERD) AS A PERCENTAGE OF GDP

GERD, as a percentage of GDP, was **0.83%** in 2017/18 (in constant 2010 rand values), and remains below the **1.5%** target set by government. In constant rand values, GERD amounted to **R25.96 billion** in 2017/18, which was a small increase from **R25.19 billion** in 2016/17.

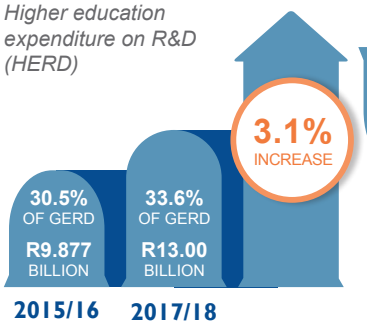


1 BUSINESS

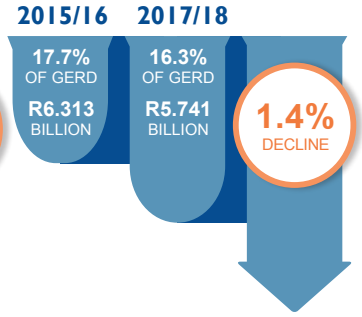
*R&D funding for the business sector remains constrained. As a result, business expenditure on R&D (BERD), as a percentage of GERD, declined from **42.7%** in 2015/16 to **41.0%** in 2017/18. Despite this, the business sector remained the largest performer of R&D in 2017/18, with BERD amounting to **R15.85 billion**.*

2 HIGHER EDUCATION

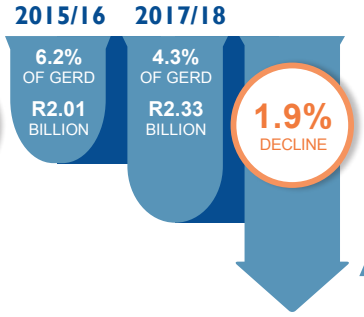
Higher education expenditure on R&D (HERD)



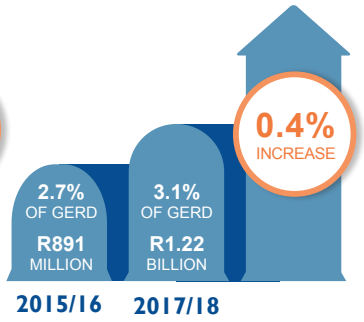
3 SCIENCE COUNCILS



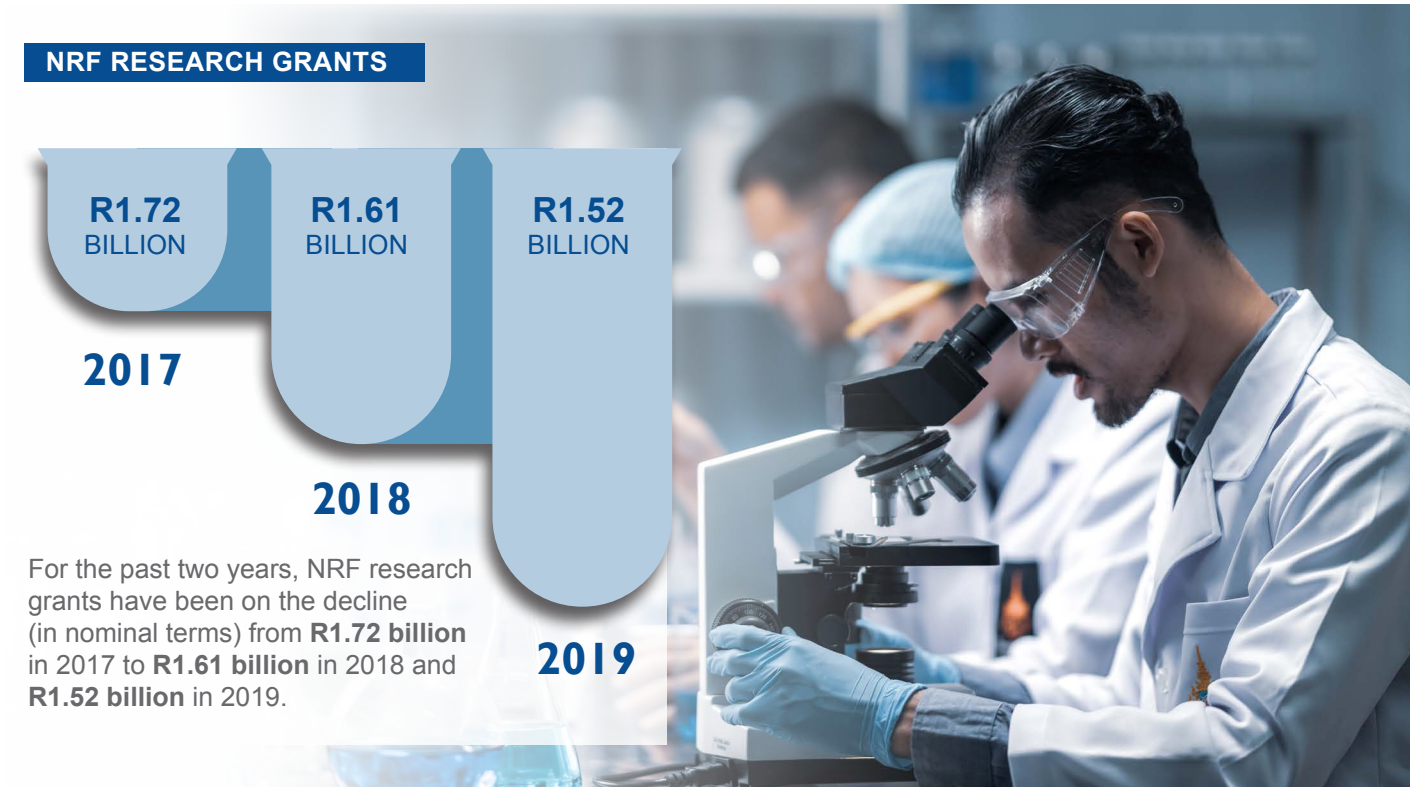
4 GOVERNMENT



5 NOT-FOR-PROFITS



NRF RESEARCH GRANTS

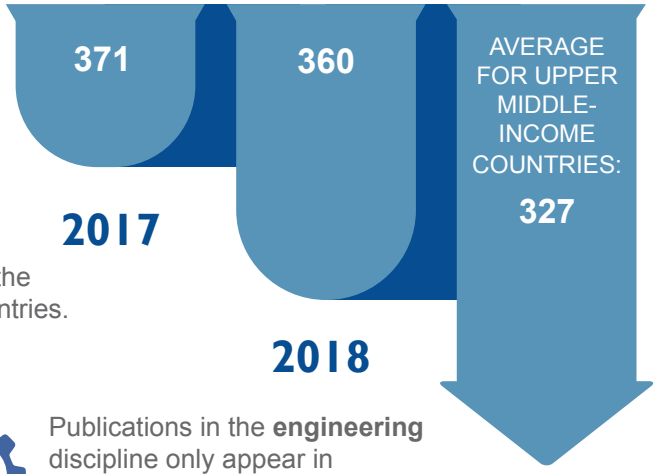


For the past two years, NRF research grants have been on the decline (in nominal terms) from **R1.72 billion** in 2017 to **R1.61 billion** in 2018 and **R1.52 billion** in 2019.

1.3.3 SCIENTIFIC OUTPUTS

PUBLICATIONS

The number of scientific publications per million population was **360** in 2018 and **371** in 2017. The average of upper middle-income countries was **327** in 2018.



77.4%
South Africa

South Africa accounts for **77.4%** of the publications arising from SADC countries.

The publications on **infectious diseases** appear among the top three most prolific scientific disciplines in 15 of the 16 SADC countries.

Publications in the **engineering** discipline only appear in publications from Botswana, South Africa and Mauritius.

CO-AUTHORS

South African scientific publications are co-authored with scientists from various SADC countries. Between 2013 and 2017, the major co-authors for South Africa were Zimbabwe **(1 113)**, Namibia **(578)**, Botswana **(560)** and Malawi **(555)**.

HIGHLY CITED PAPERS

2 022

GLOBALLY RECOGNISED

32ND

South Africa is ranked **32nd** in the world in terms of most highly cited papers, with **2 022** papers recognised as such between 1 January 2010 and 29 February 2020.

1.3.4 TECHNOLOGY OUTPUTS

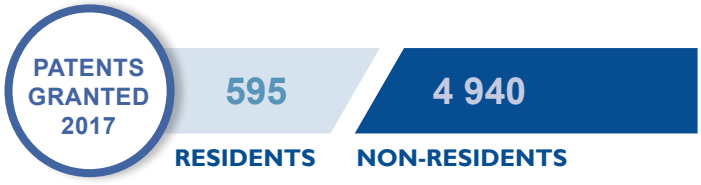
PATENTS

The majority of patent applications filed with the Companies and Intellectual Property Commission (CIPC) are in the following areas:

5 609	4 469	2 892	2 635
PHARMACEUTICALS	ORGANIC FINE CHEMICALS	BASIC MATERIALS CHEMISTRY	BIOTECHNOLOGY

Note: Out of 44 204 foreign patents (2008 to 2015)

The majority of patents were granted to non-residents of South Africa.



South Africans are granted a limited number of patents in the USPTO – the largest technology market in the world.

During 2017, South African inventors received **182** utility patent and **10** plant patent grants. South Africa is ranked **30th** in the world in terms of utility patents and **16th** in terms of plant patents.

10
Granted plant patents

182
Granted utility patents

16TH
South Africa ranked globally for plant patents

30TH
South Africa ranked globally for utility patents

1.3.5 FIRM-LEVEL INNOVATION

Innovation-active industrial and service sector enterprises

2014 **69.9%** 2016

During the period 2014–2016, **69.9%** of the enterprises from the industrial and service sectors were innovation-active.

Service sectors are more likely to get the information that they require to innovate from education and research institutions than is the case with industrial sectors.

Between 2014 and 2016, **11.9%** of service-sector enterprises derive the information that they require to innovate from public research institutions; **11.1%** from government. By contrast, only **1.2%** of industrial-sector enterprises derive the information that they require from public research institutions and **1.5%** from government.

Information for innovation for service sector enterprises

2014 **11.1%** GOVERNMENT | **11.9%** PUBLIC RESEARCH INSTITUTES 2016

Information for innovation for industrial-sector enterprises

2014 **1.5%** GOVERNMENT | **1.2%** PUBLIC RESEARCH INSTITUTES 2016

1.3.6 TECHNOLOGY EXPORTS

South Africa's exports are focused in primary products and medium-technology manufacture.

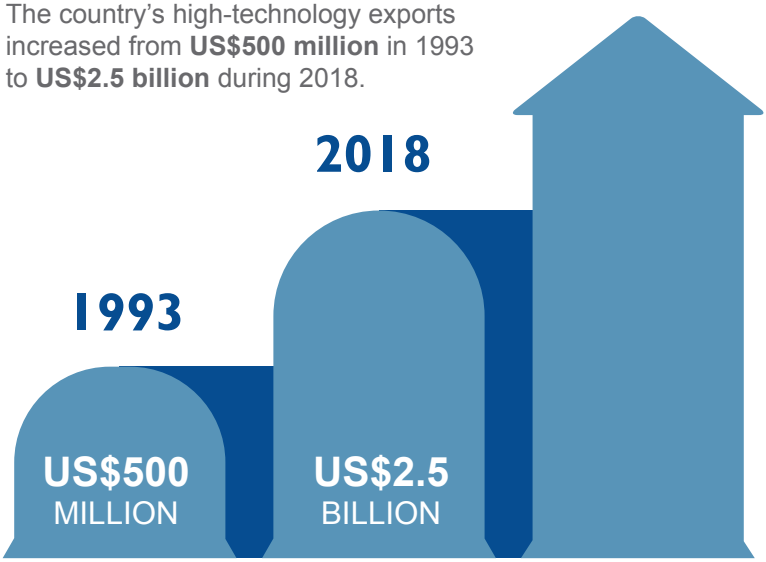
26.6% *Primary products*

28.2% *Medium-technology manufacture*

South Africa has a low share of high-technology exports as a percentage of manufactured exports.

5.2% *South Africa* « **30%+** *Korea and China*

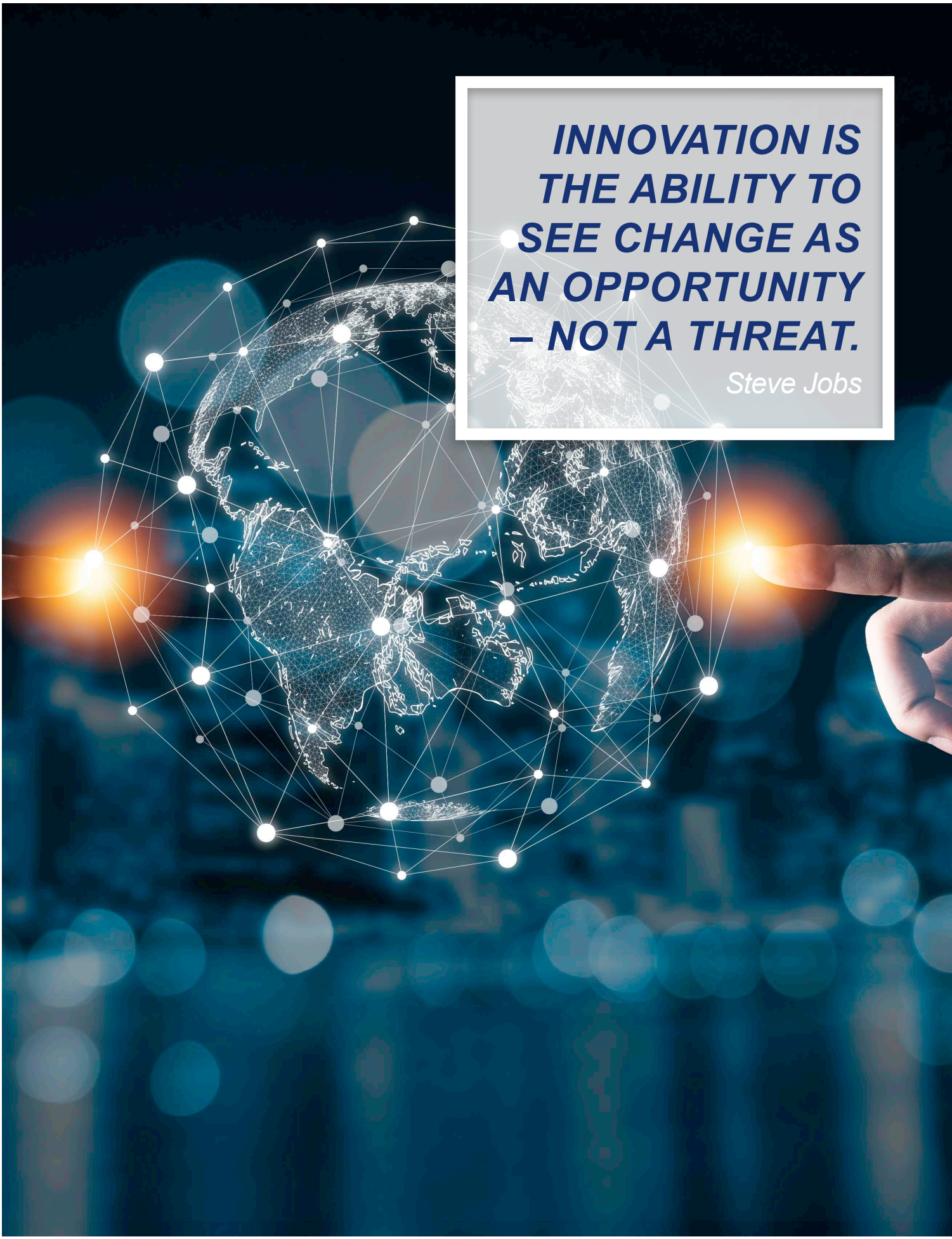
The country's high-technology exports increased from **US$500 million** in 1993 to **US$2.5 billion** during 2018.



COMMERCIAL SERVICE EXPORTS VS IMPORTS

US$120 MILLION
Receipts
RANKED **30TH**
Exporter of commercial services

US$1.8 BILLION
Payments
RANKED **33RD**
Importer of commercial services


INNOVATION IS THE ABILITY TO SEE CHANGE AS AN OPPORTUNITY – NOT A THREAT.
Steve Jobs

2. CURRENT TRENDS

2.1 Global standing of South Africa's science, technology and innovation

2.1.1 R&D expenditure

Global spending on research and development (R&D) reached a record high of almost **US$2.2 trillion*** in 2017. Ten countries accounted for 80% of the total. This R&D expenditure constitutes about **1.7%** of world GDP.

TABLE 2.1: GLOBAL TRENDS IN GERD AS A PERCENTAGE OF GDP

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
World	1,60	1.65	1.62	1.64	1.65	1.67	1.68	1.69	1.69	1.72
Low-income	0.24	0.26	0.28	0.29	0.31	0.33	0.32	0.33	0.33	0.29
Lower middle-income	0.49	0.49	0.49	0.49	0.47	0.46	0.43	0.42	0.42	0.43
Upper middle-income	0.98	1.13	1.15	1.19	1.27	1.32	1.37	1.42	1.46	1.48
High-income	2.26	2.31	2.27	2.31	2.30	2.33	2.36	2.35	2.33	2.42
South Africa	**0.89**	**0.84**	**0.74**	**0.73**	**0.73**	**0.72**	**0.77**	**0.80**	**0.82**	**0.83**

Source: United Nations Educational, Scientific and Cultural Organisation (Unesco) Institute for Statistics

**Current PPP*

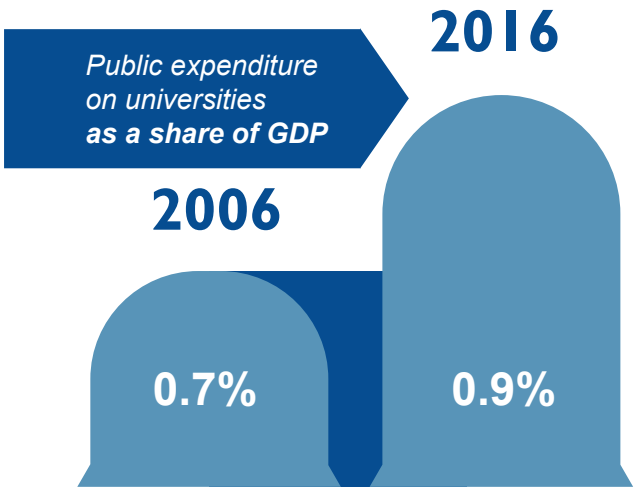
A significant change has been the increasing importance of China. In 2017, China's R&D expenditure was **USD$496 billion** (current purchasing power parity (PPP)) as opposed to **USD$543 billion** for the USA. However, China's R&D intensity, measured as GERD/GDP, is still below that of the USA at **2.13%** in 2017, as opposed to **2.8%**.

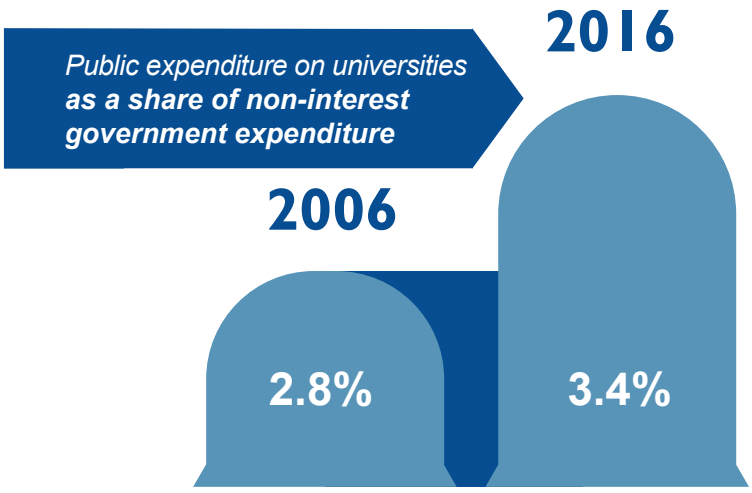
In 2017 (the most recent year for international data), South African GERD, as a percentage of GDP, was **0.82%**. This is approximately half the global average and considerably lower than upper middle-income countries (1.46%). While the upper middle-income category saw a steady increase in GERD as a share of GDP, South Africa experienced a decline between 2008 and 2013. However, South Africa's GERD, as a percentage of GDP, increased from 0.77% in 2014 to 0.83% in 2017.

2.1.2 Human resources development

South Africa allocates a larger share of its GDP to the public funding of primary, secondary and post-school education and training than many comparative countries. However, while the literacy rate has risen and a much larger number of youth are gaining access to secondary education, very few attain tertiary education.

As a share of GDP, public expenditure on universities increased from **0.7%** in 2006 to **0.9%** in 2016, and, as a share of non-interest government expenditure, increased from **2.8%** to **3.4%**. The share of the total budget allocation of the Department of Higher Education and Training (DHET) going to universities remained largely unchanged (at 60%) over the 10-year period.





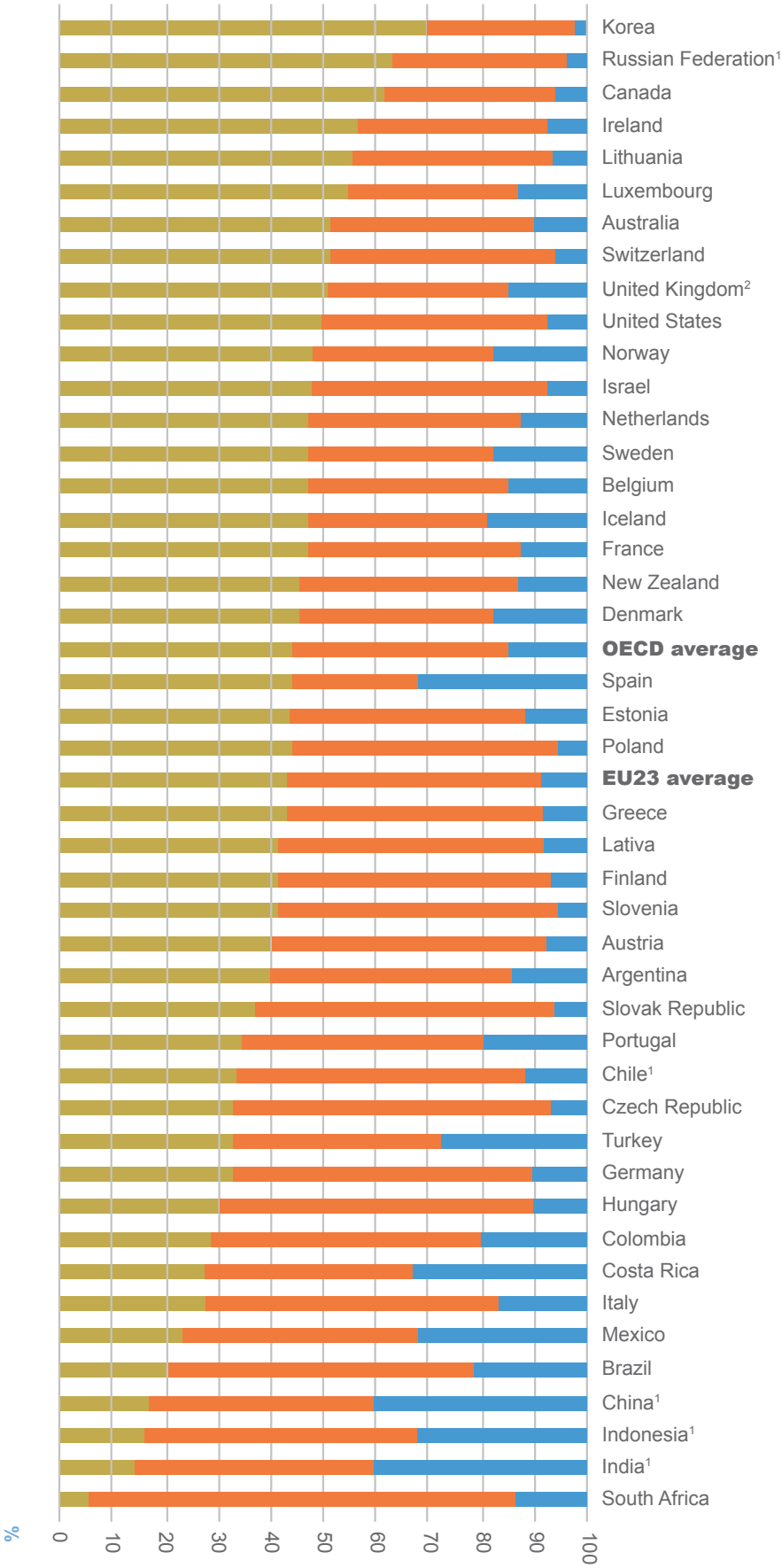


Figure 2.1 shows the educational attainment of the 24- to 35-year-old cohort in South Africa and a number of other countries. Korea has the most 24- to 35-year-olds enrolled in tertiary education with approximately 70% of the relevant population attaining tertiary education. South Africa has the least 24- to 35-year-olds enroled in tertiary education.

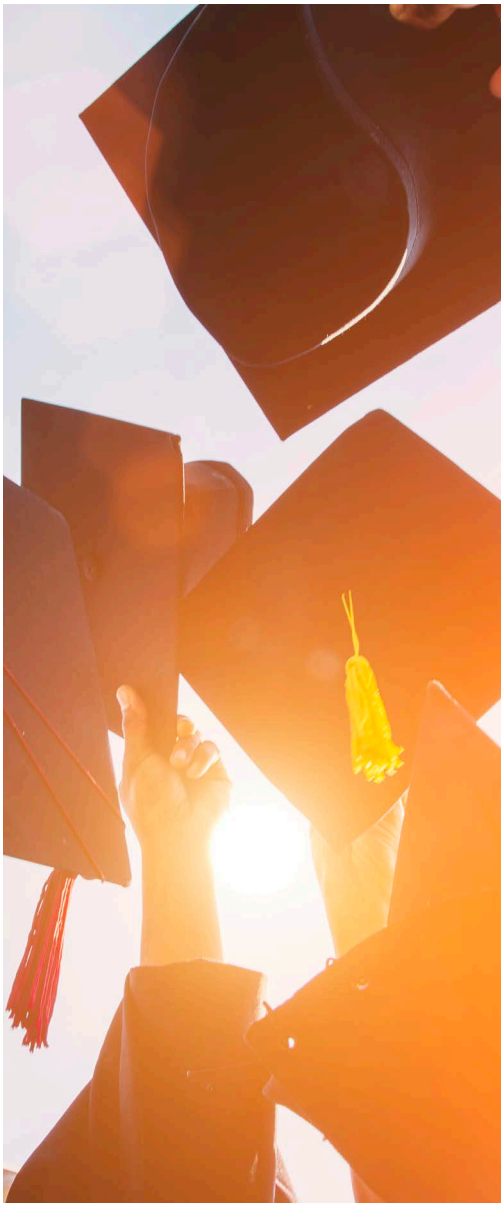


FIGURE 2.1: EDUCATIONAL ATTAINMENT OF THE 24- TO 35-YEAR-OLD COHORT, 2018

Source: OECD "Education at a glance 2019"

1. *Year of reference differs from 2018.*
2. *Data for upper secondary attainment includes completion of a sufficient volume and standard of programmes that would be classified individually as completion of intermediate upper secondary programmes (13% of adults aged 25–64 are in this group).*

2.1.3 Scientific publications

The world's scientific publications per million population declined from **471 per million population** in 2017 to **464 per million population** in 2018. This global slow-down in knowledge generation was driven mainly by a decline in the high-income countries.

South Africa also experienced a decline in publications from **371 per million population** in 2017 to **360 per million population** in 2018. In contrast, upper middle-income countries increased their scientific publications from **317 per million population** in 2017 to **327 per million population** in 2018.

TABLE 2.2: GLOBAL TRENDS IN SCIENTIFIC PUBLICATIONS PER MILLION OF THE POPULATION

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
World	348	356	372	390	408	428	442	463	471	464
Low-income	9	10	11	11	13	13	16	16	20	19
Lower middle-income	34	36	39	43	48	55	59	66	71	73
Upper middle-income	170	176	200	221	237	257	277	301	317	327
High-income	1 617	1 657	1 710	1 778	1 846	1 925	1 970	2 043	2 055	2 004
South Africa	**213**	**219**	**248**	**278**	**285**	**309**	**326**	**358**	**371**	**360**

Source: Computed from Clarivate Analytics's InCites

South Africa's number of publications and world share has increased in recent years.

TABLE 2.3: SOUTH AFRICAN PUBLICATIONS AND WORLD RATIO 2009–2018 (WHOLE COUNTS)

Year	South Africa	Total	Ratio
2009	10 774	2 142 893	0.005028
2010	11 200	2 178 009	0.005142
2011	12 876	2 278 505	0.005651
2012	14 690	2 381 706	0.006168
2013	15 293	2 479 361	0.006168
2014	16 845	2 583 721	0.006520
2015	21 520	2 936 312	0.007329
2016	23 753	3 069 922	0.007737
2017	25 265	3 152 794	0.008014
2018	25 371	3 123 378	0.008123

Given the challenges related to the current global pandemic, a preliminary assessment was conducted of COVID-19-related research in 2020. The results of the assessment are summarised below.

South Africa is keeping up with international research on COVID-19

The Corona Virus Disease 2019 (COVID-19) global pandemic has generated an abundance of research. Within only a few months, more than a thousand studies on this topic have already appeared in the scientific literature, ranging from clinical subjects to issues related to the biosafety of laboratories, mental health and domestic safety. The Web of Science was utilised to assess whether the South African research system has been able to react to the global pandemic by producing relevant research. The objective was to estimate the Activity Index for research related to COVID-19 in the five-year period ending June 2020.

The Activity Index characterises the relative research effort a country devotes to a given subject field. Its definition is the country's share in the world's publication output in the given field divided by the country's share in the world's publication output in all science fields. An Activity Index of 1 indicates that the country's research effort in the given field corresponds precisely to the world average. An Activity Index > 1 reflects higher than average effort and an Activity Index < 1 reflects an effort lower than the world average.

The assessment identified that South Africa has produced **44** publications in comparison to **5 410** publications globally. The estimated Activity Index is **1.01**, indicating that the country is producing the expected number of publications by its research size and the average effort allocated to the field internationally. Most South African publications were in the field of public environmental occupational health (18%) and infectious diseases (11.3%).

2.1.4 Citations

Table 2.4 shows the ranking of countries according to the number of highly cited papers they produced during the most recent 10-year period. Citations can be used as a proxy for quality. The citation threshold for highly cited papers is the minimum number of citations obtained by ranking papers in a research field in descending order by citation count and then selecting the top 1% of articles.

During the last decade, South Africa contributed **2 022** highly cited articles and was ranked **32nd** in the world.

TABLE 2.4: COUNTRY RANKING BY HIGHLY CITED PAPERS (MOST RECENT TEN YEARS)

Number	Country/region	Web of Science documents	Citations	Citations per paper	Highly cited papers
1.	USA	4 043 382	74 284 319	18.37	72 890
2.	People's Republic of China	2 828 904	32 346 967	11.43	34 332
3.	England	1 023 026	19 518 520	19.08	22 855
4.	Federal Republic of Germany	1 086 152	19 126 569	17.61	18 844
5.	Canada	682 827	11 985 467	17.55	13 080
6	Australia	607 758	10 327 733	16.99	12 480
7.	France	743 632	12 757 198	17.16	12 422
8.	Italy	671 230	10 867 136	16.19	10 399
9.	The Netherlands	403 497	8 600 642	21.32	10 247
10.	Spain	583 239	9 136 519	15.67	8 961
11.	Switzerland	301 461	6 750 978	22.39	8 283
12.	Japan	815 466	10 464 742	12.83	7 389
13.	Sweden	271 988	5 124 171	18.84	5 751
14.	Belgium	221 413	4 290 774	19.38	5 191
15.	South Korea	562 404	6 677 341	11.87	5 067
16.	Denmark	180 152	3 687 396	20.47	4 534
17.	India	624 774	6 180 737	9.89	4 342
18.	Scotland	155 212	3 333 282	21.48	4 200
19.	Singapore	130 103	2 736 858	21.04	3 548
20.	Austria	155 945	2 846 805	18.26	3 547
21.	Brazil	445 024	4 201 616	9.44	3 239
22.	Hong Kong	138 555	2 381 325	17.19	3 066
23.	Norway	134 322	2 361 438	17.58	2 906
24.	Saudi Arabia	121 163	1 649 645	13.62	2 785
25.	Finland	130 510	2 336 152	17.9	2 538
26.	Israel	142 622	2 405 583	16.87	2 537
27.	Iran	310 862	2 811 004	9.04	2 512
28.	Poland	267 673	2 676 195	10	2 466
29.	Taiwan	270 398	3 205 181	11.85	2 202
30.	Russia	341 773	2 529 867	7.4	2 143
31.	Portugal	141 243	2 081 435	14.74	2 142
32.	South Africa	125 549	1 625 905	12.95	2 022

Source: InCites, Essential Science Indicators

Table 2.5 shows the number of highly cited papers with South African authorship for the period 1 January 2010 to 29 February 2020.

TABLE 2.5: SOUTH AFRICAN HIGHLY CITED PAPERS PER RESEARCH FIELD (MOST RECENT TEN YEARS)

Number	Research field	Web of Science documents	Citations	Citations per paper	Highly cited papers
1.	Clinical medicine	14 898	336 246	22.57	540
2.	Social science, general	179 96	113 631	6.31	191
3.	Physics	6 491	107 350	16.54	181
4.	Plant and animal science	13 397	127 363	9.51	164
5.	Environment/ecology	9 115	131 511	14.43	163
6.	Space science	3 538	106 207	30.02	119
7.	Engineering	6 641	60 765	9.15	98
8.	Geosciences	6 166	79 031	12.82	77
9.	Chemistry	10 087	120 279	11.92	71
10.	Immunology	5 686	104 987	18.46	62
11.	Psychiatry/psychology	4 146	37 567	9.06	57
12.	Biology and biochemistry	3 756	56 856	15.14	52
13.	Mathematics	3 306	14 117	4.27	48
14.	Microbiology	2 602	39 788	15.29	39
15.	Agricultural sciences	4 158	33 946	8.16	33
16.	Molecular biology and genetics	1 694	40 671	24.01	30
17.	Pharmacology and toxicology	2 839	30 598	10.78	29
18.	Neuroscience and behaviour	1 500	25 798	17.20	27
19.	Economics and business	2 824	12 134	4.30	16
20.	Materials science	3 407	34 632	10.16	13
21.	Computer science	1 049	9 225	8.79	11
22.	Multidisciplinary	253	3 203	12.66	1
	All fields	**125 549**	**1 625 905**	**12.95**	**2 022**

Source: InCites, Essential Science Indicators

2.1.5 Patents

World patents per million population globally increased continuously over the decade 2009–2018. This increase was greatest in the upper middle-income countries, with China being the outstanding contributor to this increase. In contrast, in South Africa, there has been a tendency for patent applications per million population to decline.

TABLE 2.6: GLOBAL TRENDS IN PATENT APPLICATIONS PER MILLION OF THE POPULATION

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
High-income	1 167	1 204	1 213	1 258	1 278	1 282	1 293	1 293	1 290	1 286
Low-income	17	16	16	17	3	3	3	3	3	3
Lower middle-income	21	24	25	26	25	25	26	26	26	28
Upper middle-income	180	211	266	317	383	419	485	569	579	634
World	275	296	315	341	367	379	399	430	432	449
South Africa	**39**	**39**	**34**	**32**	**41**	**42**	**38**	**36**	**38**	**32**

Source: Computed from the World Intellectual Property Organisation (WIPO)'s IP Statistics Data Centre

Figure 2.2 shows South Africa's share of the total number of patents granted during the period 2006–2018. South Africa's share of total global patents at the USPTO, while fluctuating, has shown a tendency to decline in the last four years.

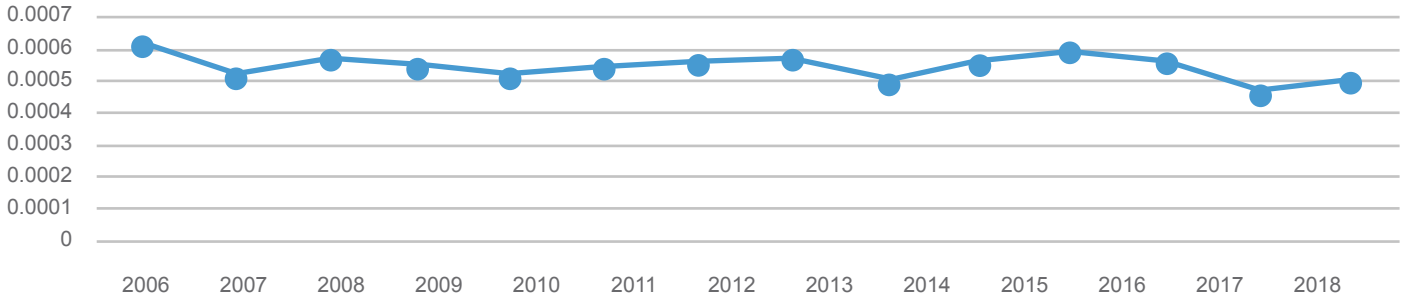


FIGURE 2.2: RATIO OF SOUTH AFRICAN PATENTS TO THE TOTAL PATENTS AT USPTO

2.2 The Global Innovation Index

The Johnson Cornell University, INSEAD (The Business School of the World) and the WIPO launched the Global Innovation Index in 2007. The objective was to develop metrics and approaches that capture the richness of innovation better than single indicators do.

South Africa`s ranking is lower on all three dimensions of the GII. In the GII 2019, South Africa experienced a drop in its ranking from **58th** in 2018 to **63rd**. The equivalent ranking on GII sub-indices shows the main challenge to be infrastructure (where it is ranked **83rd**) and creative outputs (where it is ranked **91st**).

TABLE 2.7: GLOBAL INNOVATION INDEX EQUIVALENT RANKING BY INCOME GROUP

	OVERALL GII		INNOVATION INPUTS		INNOVATION OUTPUTS	
	Ranking out of 127 and 129 countries in 2018 and 2019 respectively					
	2018	**2019**	**2018**	**2019**	**2018**	**2019**
High-income	30	30	26	26	30	29
Low-income	117	122	110	117	115	118
Lower middle-income	88	88	96	94	79	76
Upper middle-income	66	67	66	70	67	65
World	51	53	51	56	53	56
South Africa	**58**	**63**	**48**	**51**	**65**	**68**

Source: Global Innovation Index data

TABLE 2.8: EQUIVALENT RANKING OF THE GII PILLARS BY INCOME GROUP

	INNOVATION INPUTS												INNOVATION OUTPUTS	
	INSTITUTIONS		HUMAN RESOURCES AND RESEARCH		INFRA-STRUCTURE		MARKET SOPHISTI-CATION		BUSINESS SOPHISTI-CATION		KNOWLEDGE AND TECHNOLOGY OUTPUTS		CREATIVE OUTPUTS	
	2018	**2019**	**2018**	**2019**	**2018**	**2019**	**2018**	**2019**	**2018**	**2019**	**2018**	**2019**	**2018**	**2019**
High-income	29	27	30	29	29	28	27	31	29	27	26	26	30	31
Low-income	102	108	106	111	111	117	112	114	103	100	108	115	112	117
Lower middle-income	96	101	92	90	94	98	79	81	92	95	71	73	87	86
Upper middle-income	70	70	69	69	70	72	67	66	64	67	66	69	71	69
World	57	59	56	60	64	69	58	63	48	48	51	50	55	59
South Africa	**53**	**55**	**64**	**65**	**84**	**83**	**23**	**19**	**47**	**55**	**55**	**57**	**76**	**91**

Source: Global Innovation Index data

South Africa's most significant deterioration on the GII's pillars is for creative outputs, in which it dropped from **76th** in 2018 to **91st** in 2019. In terms of creative outputs, the country ranks very low on creative goods and services (**95th** in 2019) and intangible assets (**89th** in 2019). Creative goods and services incorporate exports, the production of national feature films, the entertainment and media market, as well as printing, publications and other media outputs. Intangible assets include indicators such as trademarks, industrial designs, information and computer technologies (ICTs) and business model creation, as well as ICTs and organisational model creation.

The GII provides an important indicator of the efficiency of the NSI, i.e. the extent to which inputs (resources) devoted to innovation result in innovation outputs. The GII measures innovation inputs and outputs for 126 countries. The overall score is the simple average of the two.

The efficiency ratio measures the degree to which innovation inputs are transformed into innovation outputs. The discrepancy between the input and output scores for South Africa results in a very low score in terms of the efficiency ratio. South Africa's score on the efficiency ratio was **0.55** in 2019, which ranks it at **83rd**. Of the 57 countries that have a higher overall GII score than South Africa, only the United Arab Emirates has a lower efficiency ratio.

South Africa performs comparatively far better in terms of inputs than outputs, which strongly suggests that, compared with other countries, South Africa's NSI is not converting inputs into outputs as effectively as other countries. South Africa is operating less efficiently than other countries. Moreover, the data indicates that the efficiency of the NSI has been declining over time. Accordingly, there is considerable scope for South Africa's NSI to employ its existing resources more effectively.

2.3 Global Competitiveness Index

The Global Competitiveness Index is produced by the World Economic Forum. Competitiveness is defined as the set of institutions, policies and factors that determine a country's level of productivity.

The GCI ranks countries according to their international competitiveness. South Africa's overall ranking on the GCI improved from **67th** in 2018 to **60th** in 2019. This improvement in ranking results from improvements in the enabling environment and human resources categories. However, South Africa still performs poorly in human resources, which covers health and skills. In terms of innovation, South Africa declined between 2018 and 2019.

TABLE 2.9: GLOBAL COMPETITIVENESS INDEX EQUIVALENT RANKING BY INCOME GROUP

	OVERALL GCI		ENABLING ENVIRONMENT		HUMAN RESOURCES		MARKETS		INNOVATION	
	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
High-income	29	30	32	31	31	28	33	35	31	30
Low-income	122	128	124	129	120	127	125	128	118	122
Lower middle-income	101	110	98	104	103	107	93	99	101	108
Upper middle-income	74	76	77	77	78	74	64	67	72	73
World	69	74	69	71	87	86	61	65	55	63
South Africa	**67**	**60**	**66**	**61**	**114**	**108**	**31**	**32**	**46**	**50**

Source: Computed from the 2018 Global Competitiveness Index reports

Note: Ranking out of 140 and 141 countries in 2018 and 2019, respectively

South Africa has improved overall, but this has been driven by improvement in only one category: human resources; a category in which South Africa's score is very low. The improvement in the enabling environment score results from a significant increase in the ranking on institutions from **69th** in 2018 to **55th** in 2019. The improvement in human resources is driven by the improved ranking on health.

TABLE 2.10: EQUIVALENT RANKING OF GCI PILLARS BY INCOME GROUP

		HIGH-INCOME		LOW-INCOME		LOWER MIDDLE-INCOME		UPPER MIDDLE-INCOME		WORLD		SOUTH AFRICA	
		2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
Enabling environment	Institutions	27	26	112	116	98	108	76	77	60	67	69	55
	Infrastructure	28	26	121	126	95	108	79	78	78	79	64	69
	ICT adoption	32	30	122	130	100	104	72	70	76	72	85	89
	Macroeconomic stability	43	43	119	122	88	112	64	64	63	64	57	59
Human resources	Health	37	36	115	124	103	107	87	77	88	87	125	118
	Skills	32	27	118	130	97	108	82	72	78	78	84	90
Markets	Product market	27	28	114	116	98	104	89	86	67	67	74	69
	Labour market	32	31	103	113	93	100	78	81	69	69	55	63
	Financial system	31	32	118	120	87	105	62	69	61	62	18	19
	Market size	54	51	112	115	69	76	61	62	65	65	35	35
Innovation ecosystem	Business dynamism	33	32	123	125	90	107	73	75	66	71	56	60
	Innovation capability	30	29	113	113	81	101	67	71	51	54	46	46

Source: Derived from the 2018 Global Competitiveness Index

2.4 Conclusion on current trends

At a system level, the indicators suggest that there are areas of strength and areas of weakness.

A key area of strength is in the broad area of science. Research output measured in terms of publications has been increasing steadily. South Africa has increased its global share of publications and citations. However, recent data suggests that this increase is slowing down.

In terms of technology, by contrast, several indicators suggest that the system is not working as well as it could. South Africa's share of patents at the USPTO has declined significantly, and the country's share has also declined significantly against the global total. South Africa has also not performed well in terms of composite indices.

In addition, in terms of innovation, several indicators suggest that the system is not very efficient. Despite the best efforts of policy makers, new policies and additional resources, technology and innovation outputs have stagnated or risen only very slowly. There is accordingly an urgent need to ensure that policies and resources are rendered more effectively in respect of technology and innovation. There is considerable scope for efficiency gains within the existing resource constraints.

3. STI ENABLERS

The STI enablers covered in this section are **funding**, **human resources** and **knowledge generation**. In respect of funding, the analysis of South Africa's participation in the Horizon 2020 Programme is provided to understand the cooperation in terms of STI between South Africa and countries in the European Union (EU). The focus in STI human reesources is on the pipeline of researchers and engineers. The analysis of knowledge generation focuses on the areas of research in which the country, as well as other SADC countries, has competitive advantage.

3.1 STI funding and support mechanisms

This subsection analyses the performance of both the local and international STI funding and funding agencies, which support and enable the NSI. As the H2020 Programme is nearing its end, it is an opportune time to assess its contribution to the funding of South African researchers.

3.1.1 The performance of STI funding agencies

NACI's mandate includes monitoring the performance of local funding and support mechanisms across the STI spectrum. This covers research, technology and innovation. However, information on grants management and support for innovation is still lacking. The NRF is applauded for taking the lead in making its Register of Grants publicly available online and in real-time.

The NRF's Register of Grants

The NRF distributes a large portion of its funding budget to researchers, via research grants, infrastructure grants, travel grants, and scholarships and fellowships[1]. Grants include funding initiatives that are awarded by the organisation, as well as those that are administered by the NRF on behalf of the Department of Science and Innovation (DSI) and other entities.

In the context of a constrained fiscal environment, the NRF's funding of research and other grants declined from **R1.7 billion** in 2017 to **R1.5 billion** in 2019. These grants exclude all bursaries, scholarships and fellowships.

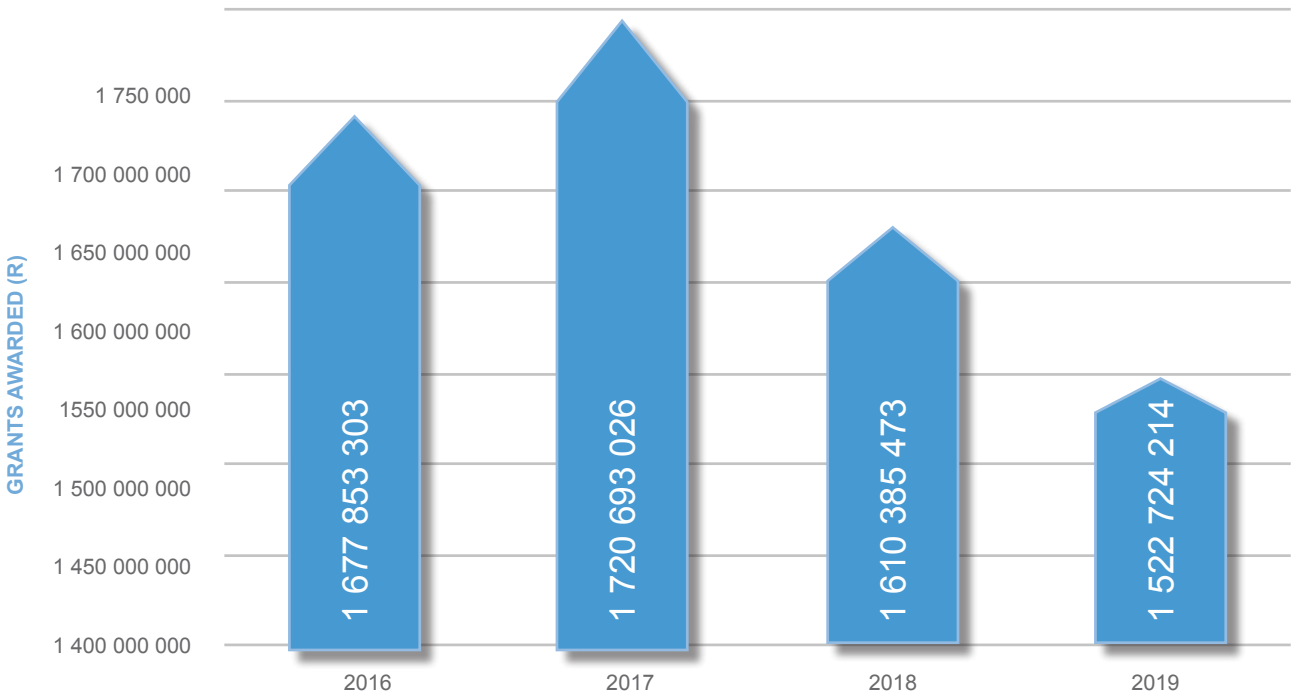


FIGURE 3.1: ANNUAL NRF GRANTS

Source: National Research Foundation Information Portal

1 https://www.nrf.ac.za/information-portal/register-of-grants

As Figure 3.2 shows, most of the grants on the NRF's Register of Grants are geared towards institutional grants (45.63%), such as the Research Chairs and Centres of Excellence (CoEs), followed by general research grants (35.57%). The research grants include support for rated and unrated researchers, the Black Academics Advancement Programme, the Blue Skies funding instrument, the Thuthuka Programme, international bilateral and multilateral grants, and others.

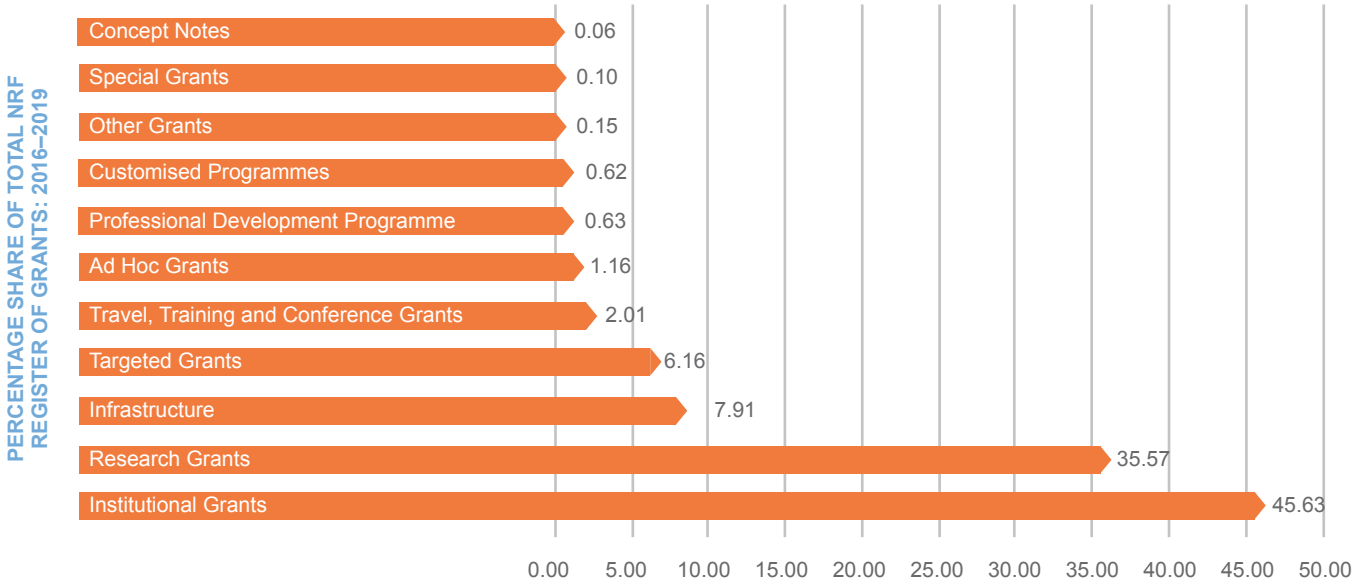


FIGURE 3.2: DISTRIBUTION OF NRF GRANTS BY TYPE

Source: Computed from the NRF Information Portal

Figure 3.3 shows that biological sciences is the leading category of NRF grants (**20.24%**). In combination, the medical, health and biological sciences constitute about a third of all grants. The South African Medical Research Council is also funding research in these fields.

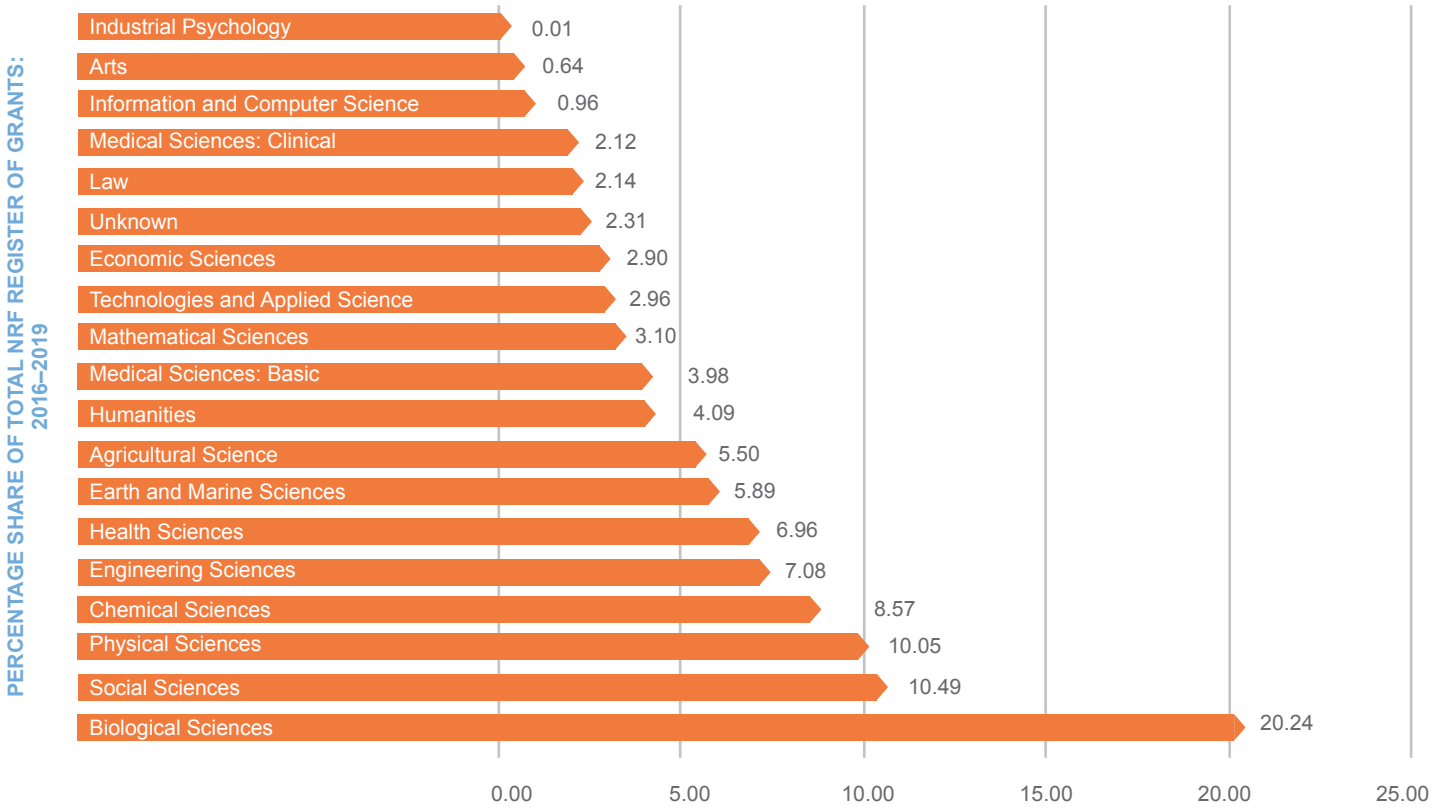


FIGURE 3.3: DISTRIBUTION OF NRF GRANTS BY RESEARCH FIELDS

Source: Computed from the NRF's Information Portal

During the period 2016–2019, the University of Cape Town's share of NRF grants was 16.02%, followed by Stellenbosch University (14.65%), the University of the Witwatersrand (14.65%), the University of Pretoria (8.69%) and the University of KwaZulu-Natal (6.52%). This distribution of R&D funding correlates well with similar patterns that are seen on other indicators, such as the proportion of scientific publications by public South African universities.

The NRF also supports science councils and public research institutes such as the Council for Scientific and Industrial Research (CSIR) (1.58%), the Agricultural Research Council (ARC) (1.42%), the South African National Space Agency (SANSA) (0.29%), the South African National Biodiversity Institute (SANBI) (0.26%), the South African Medical Research Council (SAMRC) (0.22%) and the Human Sciences Research Council (HSRC) (0.15%).

A significant amount of research grants during the period under review went to the Centre for the AIDS Programme of Research in South Africa (CAPRISA) (R45.78 million). This organisation conducts research in four main scientific programmes: HIV pathogenesis and vaccines, HIV and TB treatment, microbicides, and prevention and epidemiology. A fifth area of research on the prevention of mother-to-child transmission is mainly conducted in partnership with other centres[2]. CAPRISA has also been on the forefront of advice regarding COVID-19.

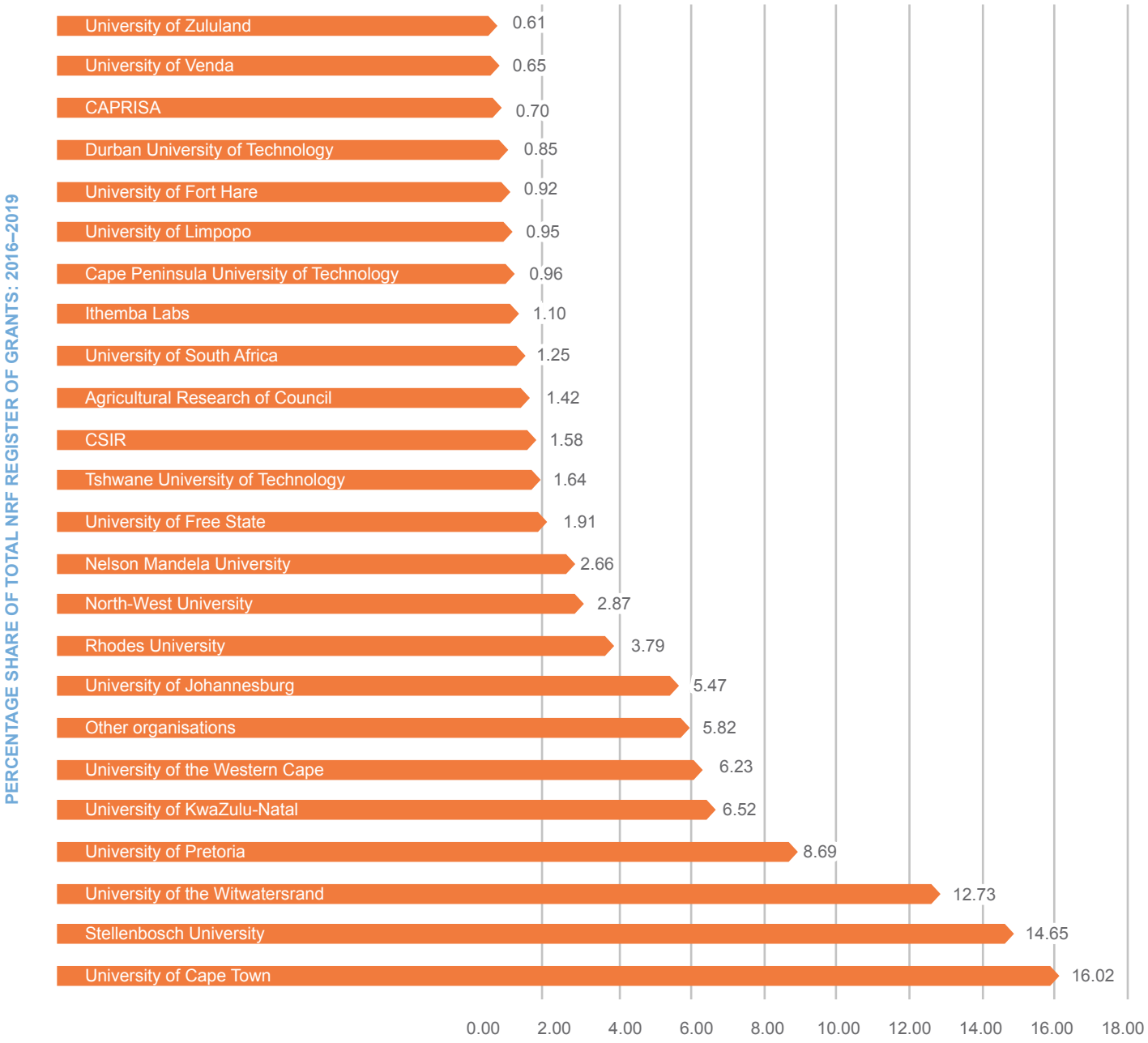


FIGURE 3.4: DISTRIBUTION OF NRF GRANTS BY RESEARCH ORGANISATIONS

Source: Computed from the NRF's Information Portal

2 https://www.caprisa.org/

3.1.2 South Africa's participation in the H2020 Programme

Since the inception of the H2020 Programme in 2014, South African STI organisations acquired more than **€33.273 million** in funding from the EU (Table 3.1). This represents a share of **0.068%** of the Programme's funding received by **216** organisations.

TABLE 3.1: H2020 PROGRAMME PARTICIPATION STATISTICS

	South Africa	Overall H2020 participants
Net EU contribution (Euro)	33.27 million	48.75 billion
Applications	983	748 656
Eligible proposals	729	220 472
Success rate (%)	20.71	11.94
Participation	216	128 314
Signed grants	152	26 683
Percentage share of higher education sector's participation	40.5	39.0
Percentage share of business enterprise sector's participation	10.6	28.7
Percentage share of research organisations' participation	22.4	25.5
Percentage share of public organisations' participation	18.3	3.2
Percentage share of other organisations' participation	8.2	3.7

Source: European Commission's Horizon Dashboard

South Africa's success rate of **20.71%** is significantly higher than the average success rate of **11.94%** for the H2020 Programme as a whole.

Overall, the higher education sector is responsible for the largest proportion of South Africa's participation in H2020 (**40.5%**), followed by the research organisations (**22.4%**) and other public organisations such as the NRF and DSI (**18.3%**). This share of business enterprises (**10.6%**) is very low vis-à-vis the rest of H2020's participating countries (**28.7%**).

The value of the support received from the EU 2020 programme is detailed in Figure 3.5.

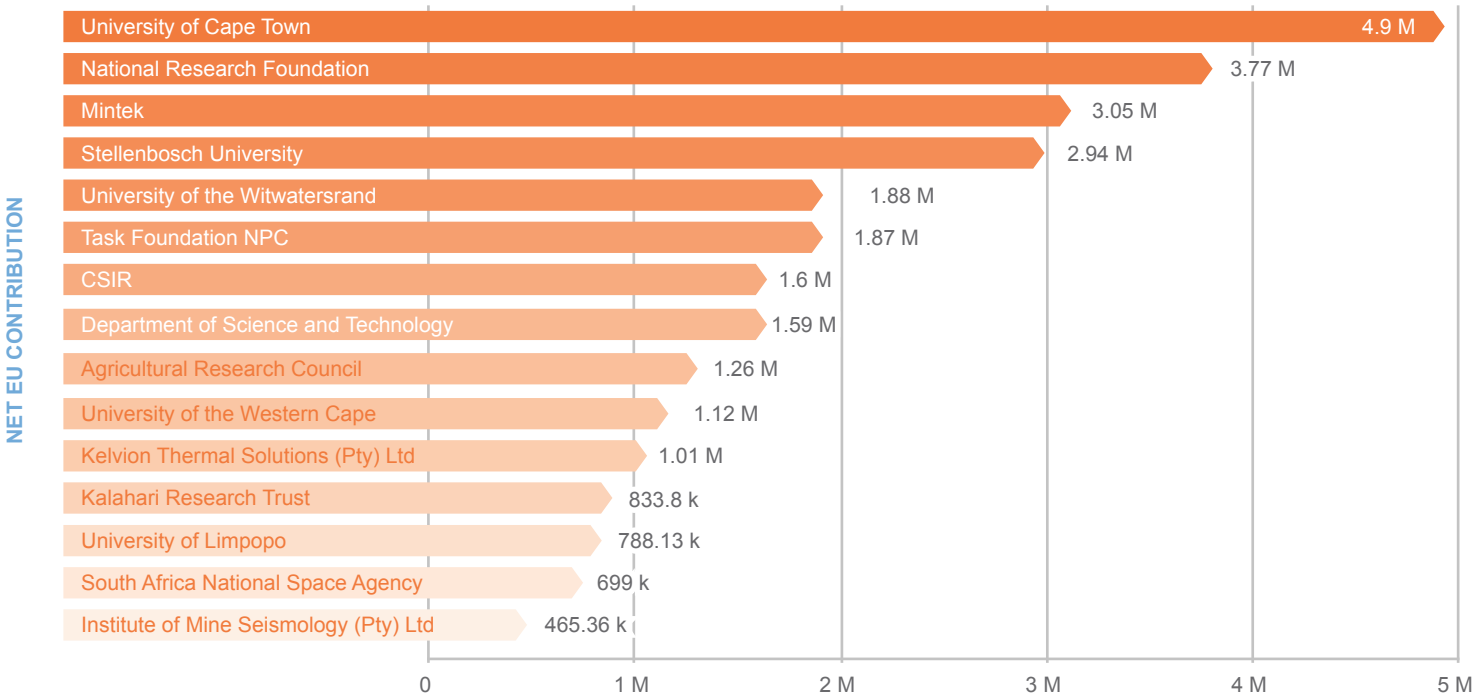


FIGURE 3.5: TOP SOUTH AFRICAN PARTICIPATING ORGANISATIONS IN H2020

Source: European Commission's Horizon Dashboard

About two thirds of the business enterprises involved are small and medium-sized enterprises (SMEs) with a total of **€2.37 million** net contribution received, which represents **0.029%** of the overall SMEs' participation in H2020 (see Table 3.2).

Source: European Commission's Horizon Dashboard

TABLE 3.2: SOUTH AFRICAN SMEs' PARTICIPATION IN H2020

	SOUTH AFRICA	OVERALL H2020 PARTICIPANTS
Net EU contribution (€)	2.37 million	8.22 billion
Applications	42	186 873
Participation	11	26 250

Figure 3.6 shows the level of support to top South African SMMEs in H2020.

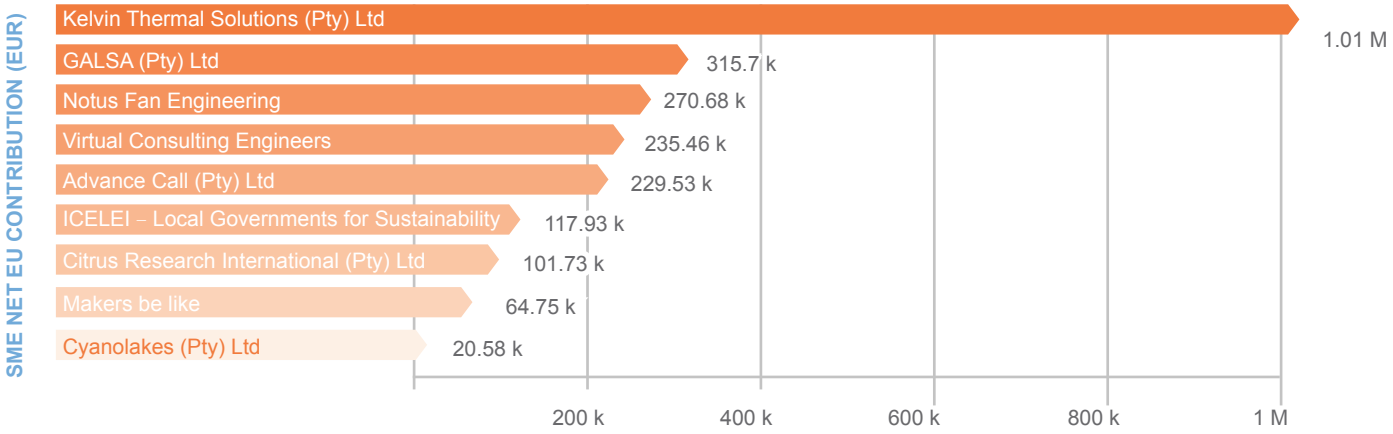


FIGURE 3.6: SOUTH AFRICAN SMME RECIPIENTS OF SUPPORT FROM H2020

Source: European Commission's Horizon Dashboard

3.2 Science, technology and innovation human resources

Human resources across the STI value chain is a critical input for knowledge creation and exploitation. This includes researchers, engineers, technicians, technologists, artisans, medical doctors, actuaries and data analysts. This section analyses the state of STI human resources development and transformation in terms of researchers, engineers, master's and doctoral graduates and Grade 12 STI-related gateway subjects.

3.2.1 Human resources in research and technology

Employment of researchers

There has been a noticeable increase in the number of FTE researchers. During the period 2008/09–2014/15, the annual number of researchers grew by an average of **3.4%**. Impressively, this annual increase averaged **7.8%** during the period 2015/16–2017/18.

The number of researchers per million population and researchers per thousand of total employment also increased at a fast pace. It is encouraging that this increase is more rapid among female researchers.

TABLE 3.3: TREND IN THE NUMBER OF RESEARCHERS

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Number of FTE researchers	19 384	19 793	18 720	20 115	21 382	23 346	23 572	26 159	27 656	29 515
FTE researchers per million inhabitants	385	392	365	387	405	435	432	472	492	518
FTE researchers per thousand employed	1.4	1.5	1.4	1.5	1.5	1.6	1.5	1.7	1.7	1.8

Source: HSRC and DSI's National Survey of Research and Experimental Development

The social composition of researchers is changing. In terms of racial groupings, the number of African researchers increased from **6 595** in 2008 to **10 815** in 2017. Overall, this indicates that the increased number of non-white science, engineering and technology (SET) doctoral graduates is starting to have a positive impact on the research workforce in South Africa.

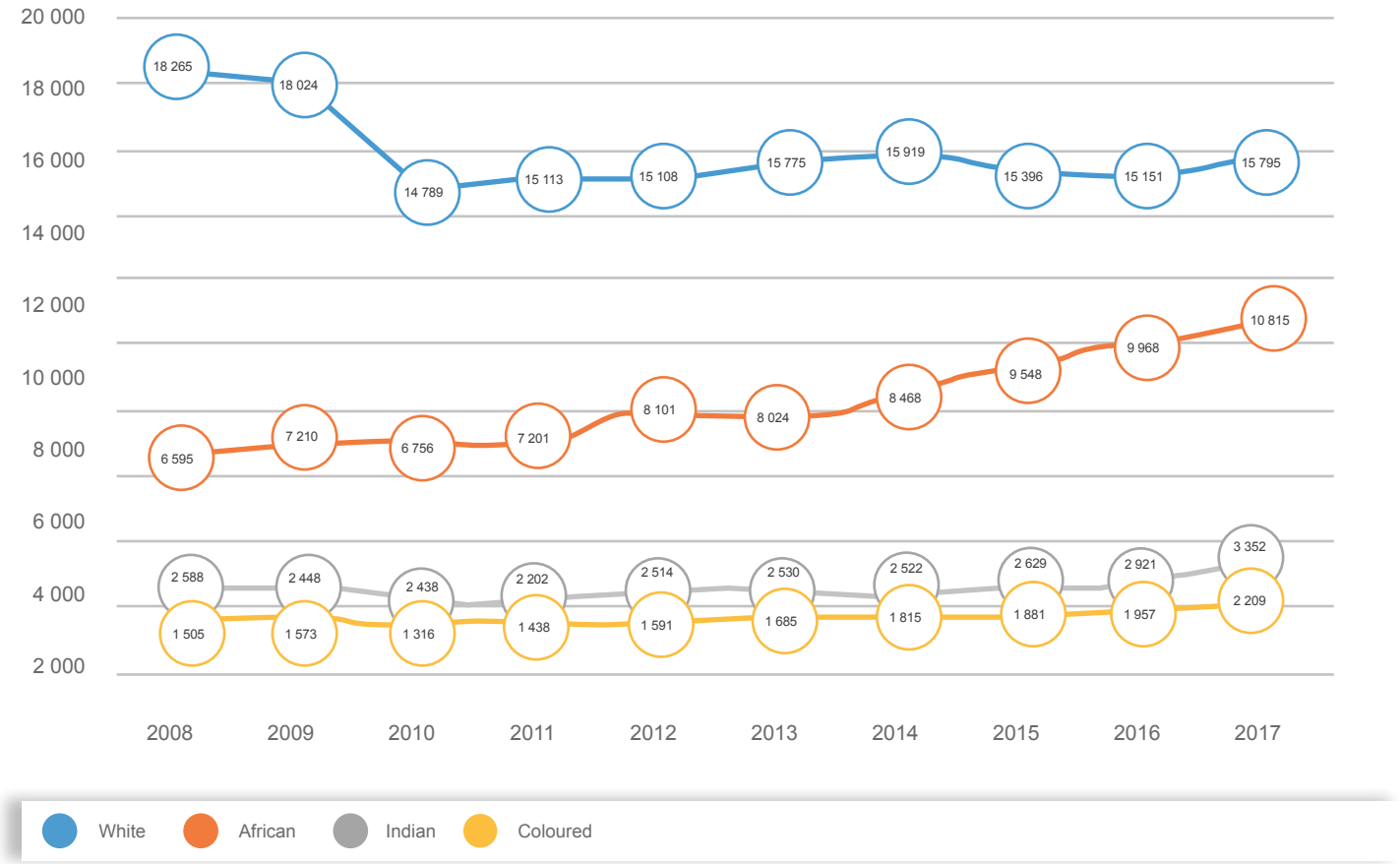


FIGURE 3.7: TREND IN THE DISTRIBUTION OF SOUTH AFRICAN RESEARCHERS BY RACE

Source: HSRC and DSI's National Survey of Research and Experimental Development

Table 3.4 shows the trend in percentage of female researchers. Over the past ten years, the percentage of female researchers has been steadily increasing. In 2017, 45.3% of the total number of researchers was women.

TABLE 3.4: PERCENTAGE OF FEMALE RESEARCHERS

	Percentage female	Researchers (head count)
2008	38.8%	28 952
2009	39.8%	29 255
2010	41.4%	25 300
2011	41.9%	25 954
2012	43.7%	27 314
2013	44.6%	28 014
2014	44.9%	28 723
2015	45.1%	29 455
2016	45.6%	33 035
2017	45.3%	36 233

Source: HSRC and DSI's National Survey of Research and Experimental Development

The highest number of researchers are in the business and higher education sectors, both of which had relatively large increases in the number of researchers. However, the science councils and government research institutions experienced a decrease in the number of researchers.

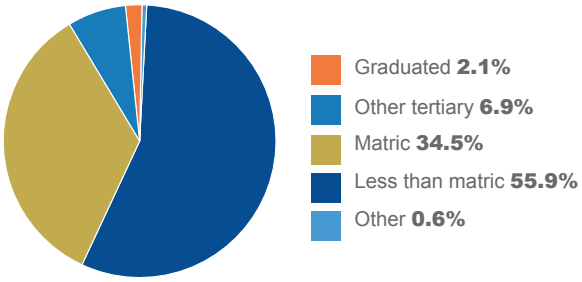
The decrease in researchers at the science councils is one issue that requires deeper analysis. Science councils serve as an important intermediary between basic research produced at universities and knowledge application in both the public and private sectors.

TABLE 3.5: EMPLOYMENT OF SOUTH AFRICAN FTE RESEARCHERS BY SECTOR

	Business	Higher education	Science councils	Government	NPOs
2008	6 172	3 644	2 247	805	208
2009	6 060	3 762	2 252	680	188
2010	4 804	3 614	1 777	874	196
2011	4 452	4 355	1 635	1 010	191
2012	4 556	4 701	1 697	1 091	295
2013	4 530	5 001	1 781	924	338
2014	4 636	5 098	1 765	970	396
2015	4 627	4 702	1 827	954	385
2016	4 777	5 220	1 941	969	341
2017	5 482	6 041	1 792	899	346

Source: HSRC and DSI's National Survey of Research and Experimental Development

Unemployment of graduates



A recent Quarterly Labour Force Survey (QLFS) of Statistics South Africa identified that the overall unemployment rate had increased to **27.6%** from **27.1%** during the last quarter of 2018. Figure 3.8 shows the proportion of unemployed by education level. The majority of unemployed (**55.9%**) has a qualification lower than matric. Only **2.1%** of the unemployed are graduates.

FIGURE 3.8: PROPORTION OF UNEMPLOYED BY EDUCATION LEVEL

Source: Statistics South Africa's Quarterly Labour Force Survey 1 (2019)

TABLE 3.6: UNEMPLOYMENT RATE BY LEVEL OF EDUCATION (15–64 YEARS)

	April to June 2018	July to September 2018	October to December 2018	January to March 2019	April to June 2019
	PERCENTAGE				
No schooling	18.0	21.1	17.2	19.6	20.8
Grade R/0	25.3	21.8	30.3	24.7	29.6
Grade 1	15.4	22.6	34.2	36.3	30.7
Grade 2	28.6	22.9	26.2	28.6	24.8
Grade 3	19.8	24.3	23.1	25.2	21.7
Grade 4	23.9	18.5	25.2	23.3	26.0
Grade 5	25.0	26.6	25.9	32.5	29.1
Grade 6	26.4	26.8	29.9	24.5	27.6
Grade 7	27.6	27.0	25.7	26.7	30.2
Grade 8	29.0	27.0	28.3	28.3	32.3
Grade 9	31.4	32.7	33.2	33.1	35.7
Grade 10	33.6	34.2	33.2	33.6	37.1
Grade 11	37.3	36.9	37.0	37.8	38.1
Grade 12 (No exemption)	28.4	29.8	28.4	28.9	29.8
Grade 12 (Exemption/Bachelor's pass)	25.4	21.2	19.8	22.4	21.9
NTC1/N1/NC (V) Level 2	24.7	36.3	11.7	30.8	47.1
NTC2/N2/NC (V) Level 3	28.9	32.0	38.1	36.8	28.6

	April to June 2018	July to September 2018	October to December 2018	January to March 2019	April to June 2019
	PERCENTAGE				
NTC3/N3/NC (V) Level 4	36.7	29.5	29.8	35.4	32.8
N4/NTC 4	24.2	23.6	27.1	32.8	24.6
N5/NTC 5	27.3	30.8	30.0	28.0	37.9
N6/NTC 6	24.6	25.1	26.9	26.7	34.2
Certificate with less than Grade 12/Std 10	30.7	20.7	30.7	26.0	35.4
Diploma with less than Grade 12/Std 10	14.6	17.1	25.1	25.7	28.7
Certificate with Grade 12/Std 10	24.3	23.6	21.9	21.1	23.7
Diploma with Grade 12/Std 10	12.7	13.0	11.6	12.9	13.8
Higher Diploma	10.0	10.7	10.3	13.9	10.0
Post Higher Diploma (Master's, Doctoral, Diploma)	4.1	8.1	1.2	7.8	12.7
Bachelor's Degree	8.6	7.6	7.9	9.0	10.8
Bachelor's Degree and Postgraduate Diploma	5.7	8.0	7.5	11.8	7.8
Honours Degree	4.8	3.5	5.2	6.1	8.1
Higher Degree (Master's/PhD)	2.4	3.1	3.6	2.6	2.8
Other	13.6	13.1	16.9	14.0	15.1
Do not know	18.4	16.8	19.1	16.1	10.9
Total	**27.2**	**27.5**	**27.1**	**27.6**	**29.0**

Source: Statistics South Africa

It is apparent that unemployment is lower among those with higher levels of education. Nevertheless, unemployment among those with higher education is increasing.

3.2.2 Engineering, master's and doctoral graduates

In order to increase the innovation potential of South Africa, there should be a sufficient supply of technicians, engineers and scientists with capabilities that are aligned to the needs of industry and society. This subsection shows trends in the public higher education graduation of engineering, master's and doctoral students.

Engineering graduates

A trend in the attainment of different engineering qualifications, including undergraduate and postgraduate qualifications, is shown in Table 3.7. There is a discontinuity in 2015 with regard to the attainment of Bachelor of Engineering degrees of four years or more. This is as a result of BTech graduations being reported separately by the DHET. Therefore, overall, there is a steady increase in the attainment of various engineering degrees, although there is a decline in the attainment of honours degrees or National Higher Diploma qualifications.

The number of master's degrees is higher than the number of honours degree or National Higher Diploma qualifications as – at some universities – the engineering honours degree is treated as a coursework component of the master's degree.

TABLE 3.7: ENGINEERING GRADUATES BY QUALIFICATION TYPE 2010–2018

	2010	2011	2012	2013	2014	2015	2016	2017	2018
BTech	-	-	-	-	-	3 407	3 339	3 703	4 424
Four-year degree	4 183	4 458	4 923	5 522	5 680	2 934	2 980	3 054	3 143
Honours or National Higher Diploma	540	554	546	632	665	707	619	649	614
Master's degree	665	868	888	940	1 085	1 200	1 130	1 159	1 318
Doctorate degree	107	120	134	133	154	201	231	240	229

Source: DHET's Higher Education Management Information System (HEMIS) Database

Some of the specialised engineering disciplines, such as systems engineering and operations research, have higher numbers of graduates at honours degree/National Higher Diploma and master's levels. Although the supply of civil engineers has generally been on the decline from 2015 to 2018, there was a huge increase in the number of civil engineering graduates at BTech level.

Table 3.8 shows the number of graduate engineers in various disciplines in 2018. A large pool of graduates is from mechanical and mechatronic engineering, followed by electrical, electronics and communications engineering. These fields are more generic as they can be applied in various sectors across the economy. However, there is a relatively low proportion of mechanical and mechatronic engineers that eventually proceed to postgraduate level.

TABLE 3.8: ENGINEERING GRADUATES PER FIELD

	BTech		Four-year degree		Honours/ National Higher Diploma		Master's degree		Doctoral degree	
	2015	2018	2015	2018	2015	2018	2015	2018	2015	2018
Mechanical and Mechatronic Engineering	480	647	802	884	65	81	180	213	29	49
Electrical, Electronics and Communications Engineering	804	993	520	542	43	43	248	289	53	63
Chemical Engineering	380	392	427	485	55	83	151	165	38	40
Civil Engineering	681	973	560	479	109	72	215	156	24	33
Industrial Engineering	490	867	221	255	55	69	88	73	5	10
Mining and Mineral Engineering	98	137	149	161	18	8	38	64	7	3
Metallurgical Engineering	170	144	54	73	70	25	37	54	7	13
Computer Engineering	36	35	38	52	10	3	18	11	3	2
Surveying Engineering	51	44	24	44	12	11	5	1	0	0
Environmental/Environmental Health Engineering	1	1	18	24	0	0	0	0	0	0
Agricultural/Biological Engineering and Bio-Engineering	25	0	12	18	1	2	2	6	0	4
Engineering Science	6	3	10	12	4	23	0	0	1	1
Aerospace, Aeronautical and Astronautical Engineering	0	0	16	11	0	0	0	0	0	0
Engineering Mechanics	44	54	0	6	0	3	0	0	0	0
Geological/Geophysical Engineering	0	0	7	6	23	20	2	4	2	1
Manufacturing Engineering	40	43	1	3	5	4	1	0	0	0
Operations Research	2	0	0	2	21	15	7	24	3	0
Engineering Physics	0	0	0	1	0	0	0	0	0	0
Architectural Engineering	0	0	0	0	0	0	0	0	0	0
Biomedical/Medical Engineering	0	0	0	0	0	0	8	11	4	4
Ceramic Sciences and Engineering	0	0	0	0	0	0	0	0	0	0
Materials Engineering	36	32	4	0	12	15	0	0	0	0
Naval Architecture and Marine Engineering	0	0	0	0	1	1	0	0	0	0
Nuclear Engineering	0	0	0	0	2	15	9	10	0	2
Ocean Engineering	0	0	0	0	0	0	2	0	0	0
Petroleum Engineering	0	0	0	0	0	0	0	0	0	0
Systems Engineering	47	43	0	0	200	121	149	110	1	2
Textile Sciences and Engineering	0	0	0	0	0	0	2	2	1	1
Materials Science	0	0	0	0	0	0	0	0	0	0
Polymer/Plastics Engineering	17	16	0	0	0	0	1	3	2	0
Construction Engineering	0	1	0	0	0	0	9	16	1	0
Forest Engineering	0	0	0	0	0	0	0	0	0	0
Engineering, Other	0	0	71	85	2	2	28	106	20	2
Total	**3 407**	**4 424**	**2 934**	**3 143**	**707**	**614**	**1 200**	**1 318**	**201**	**229**

Source: DHET's HEMIS Database

As shown in Figure 3.9, engineering is still male-dominated, although from 2015 to 2018, there was a visible shift in the proportion of female engineering graduates for all qualification types. The greater imbalance is at doctoral level as the ratio of female graduates was only **21.8%** in 2018, increasing from **17.9%** in 2015. However, there is a small but evident increase in females in each category.

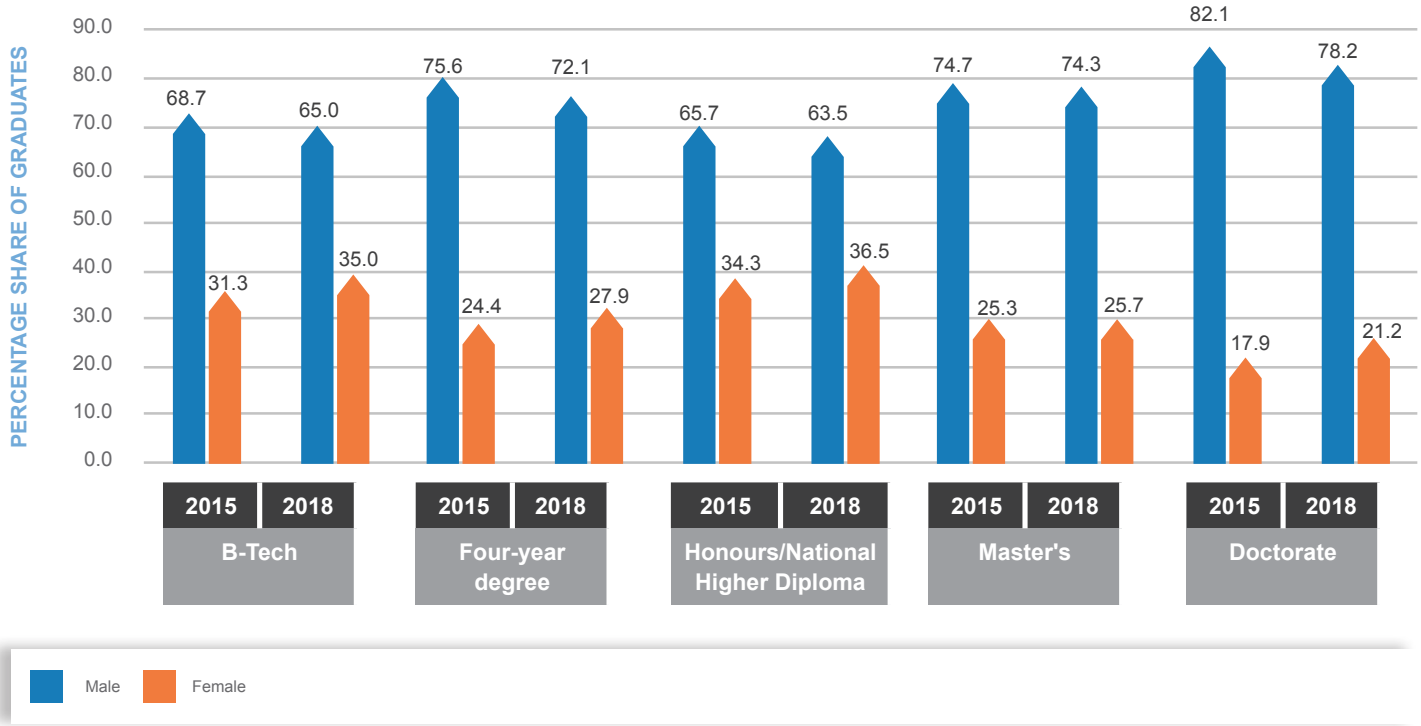


FIGURE 3.9: DISTRIBUTION OF ENGINEERING GRADUATES BY GENDER AND LEVEL

Source: DHET's HEMIS Database

In terms of race, there was a rise in the share of African graduates, with a significant increase in each category between 2015 and 2018. The proportion of African engineering graduates was higher at honours degree/National Higher Diploma, master's and doctoral levels (Table 3.9).

The proportion of Coloured and Indian engineering graduates remained approximately constant in all qualification levels between 2015 and 2018. During the same period, the proportion of white engineering graduates declined across all the levels.

TABLE 3.9: PERCENTAGE DISTRIBUTION OF ENGINEERING GRADUATES BY RACE

	BTech		Four-year degree		Honours/ National Higher Diploma		Master's degree		Doctoral degree	
	2015	2018	2015	2018	2015	2018	2015	2018	2015	2018
	PERCENTAGE									
African	77	82	30	36	46	56	36	49	37	53
Coloured	5	5	4	5	2	4	4	4	2	2
Indian	6	5	11	13	6	5	9	8	8	7
White	11	8	53	44	45	35	46	36	48	35
Other	0	0	2	2	1	1	5	3	4	3

Source: DHET's HEMIS Database

Master's and doctoral graduates

Figure 3.10 shows the number of master's and doctoral graduates produced by South African public universities during the period 2013–2018. The number of master's degrees (by research) increased from **6 460** in 2013 to **8 610** in 2018. The number of master's by coursework reached **5 277** in 2018. The number of doctoral graduates increased from **2 051** in 2013 to **3 307** in 2018. If this trend continues during the next 10 years, South Africa will be producing **5 000** doctoral graduates annually by 2030. However, it should be emphasised that **1 485** of the doctoral graduates (in 2018) are foreigners and it is not clear what percentage will remain in the country.

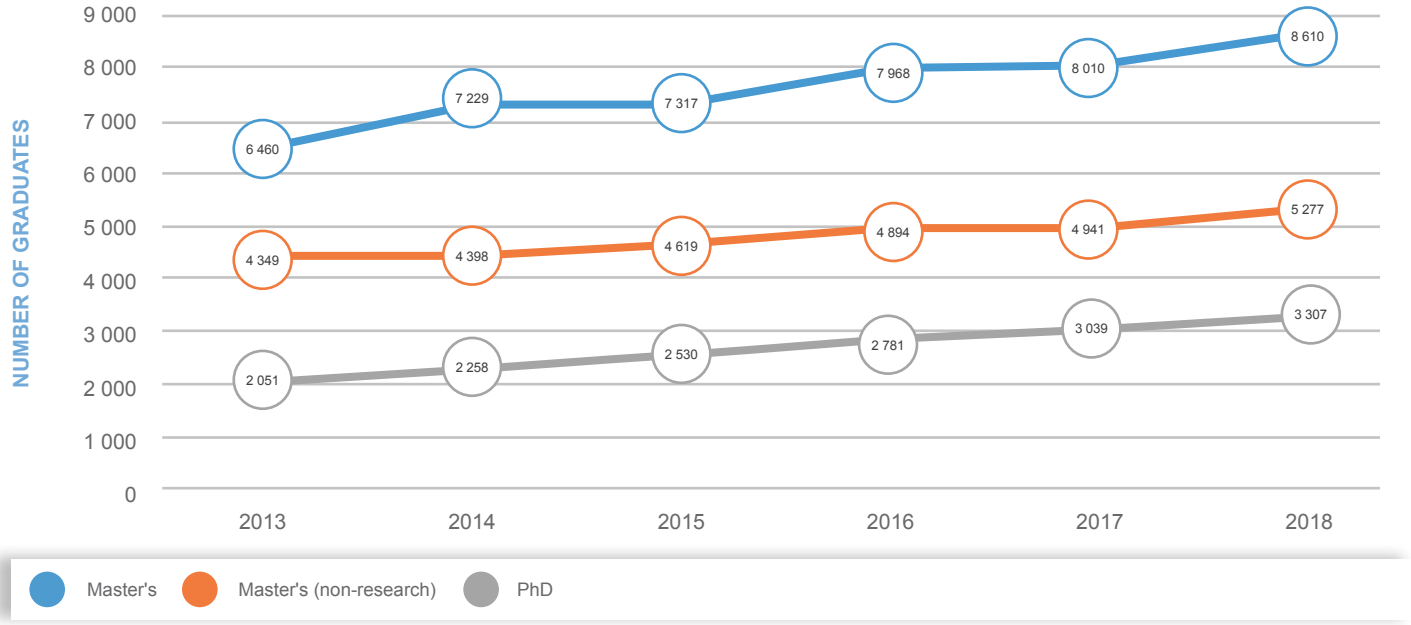


FIGURE 3.10: DOCTORAL AND MASTER'S GRADUATES 2013–2018

Source: DHET's HEMIS Database

The contributions that doctoral graduates make to the economy and the demand for their skills varies from discipline to discipline. Employment status after graduation with a doctoral degree also varies according to doctoral field. In a recent investigation[3], the highest share of unemployed (9%) was observed in the group of respondents with a doctorate in humanities. Unemployment in other doctoral fields varied between 2 and 4%. Figure 3.11 shows the number of doctoral graduates produced in South Africa according to broad scientific fields.

Natural and agricultural sciences are at the top of the list with this discipline producing **1 051** doctorates in 2018. Social sciences and humanities follow with **913** and **759** doctoral graduates, respectively. Engineering is at the bottom of the list, producing **229** doctoral graduates in 2018 (7% of graduates).

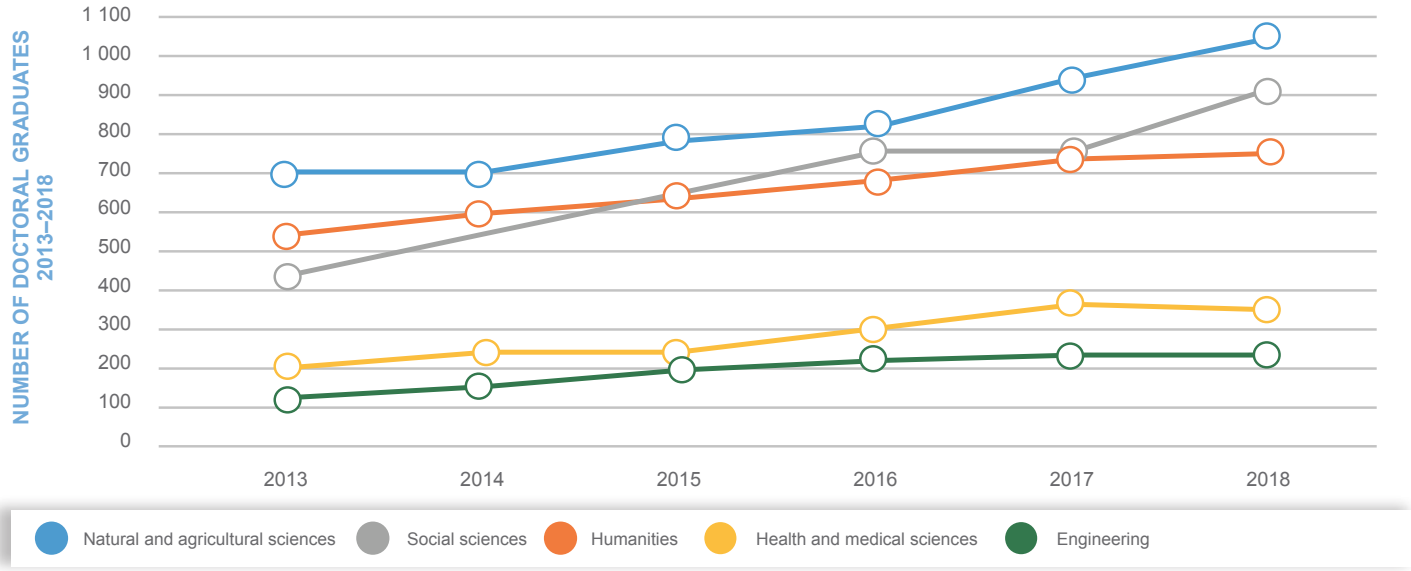


FIGURE 3.11: NUMBER OF DOCTORAL GRADUATES ACCORDING TO BROAD SCIENTIFIC AREAS

Source: DHET's HEMIS Database

3 European Science Foundation (2017) "Career tracking survey of doctorate holders", Strasbourg, France.

It should be mentioned that the various scientific areas remained approximately constant over the period, with the exception of social sciences, which surpassed humanities during 2015. It should also be noted that social sciences and humanities produce approximately **50%** of all the doctoral graduates in the country.

It should be emphasised that **1 026** of the doctoral graduates during 2018 were from abroad, of which **200** were in the field of physical sciences, **141** in education, **136** in social sciences and **132** in life sciences. Figure 3.12 shows the number of doctoral graduates in the various subdisciplines constituting the major group of natural and agricultural sciences.

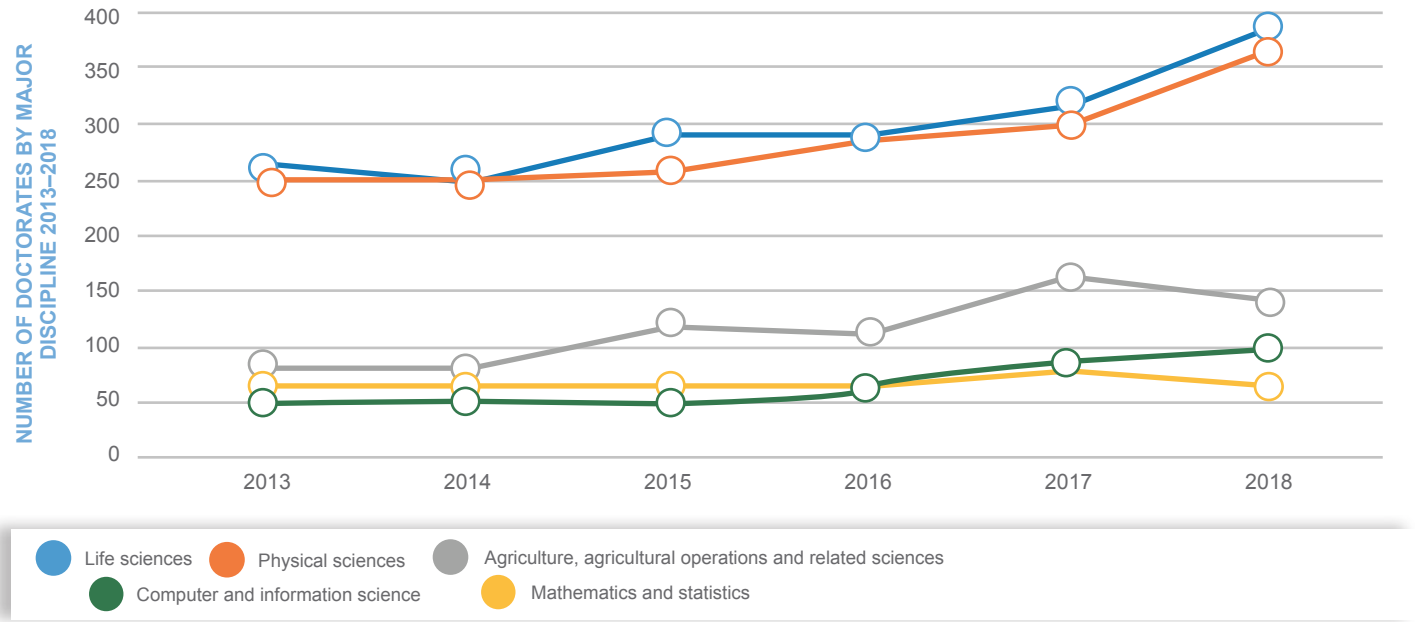


FIGURE 3.12: NUMBER OF DOCTORAL GRADUATES IN SUBDISCIPLINES IN THE NATURAL AND AGRICULTURAL SCIENCES

Source: DHET's HEMIS Database

Life sciences surpassed physical sciences at the top of the list in 2017. Computer and information sciences, and mathematical statistics are at the bottom of the list, with **90** and **68** doctorates, respectively, during 2018. Figure 3.13 shows the number of doctoral degrees in the various subdisciplines constituting the major group of social sciences.

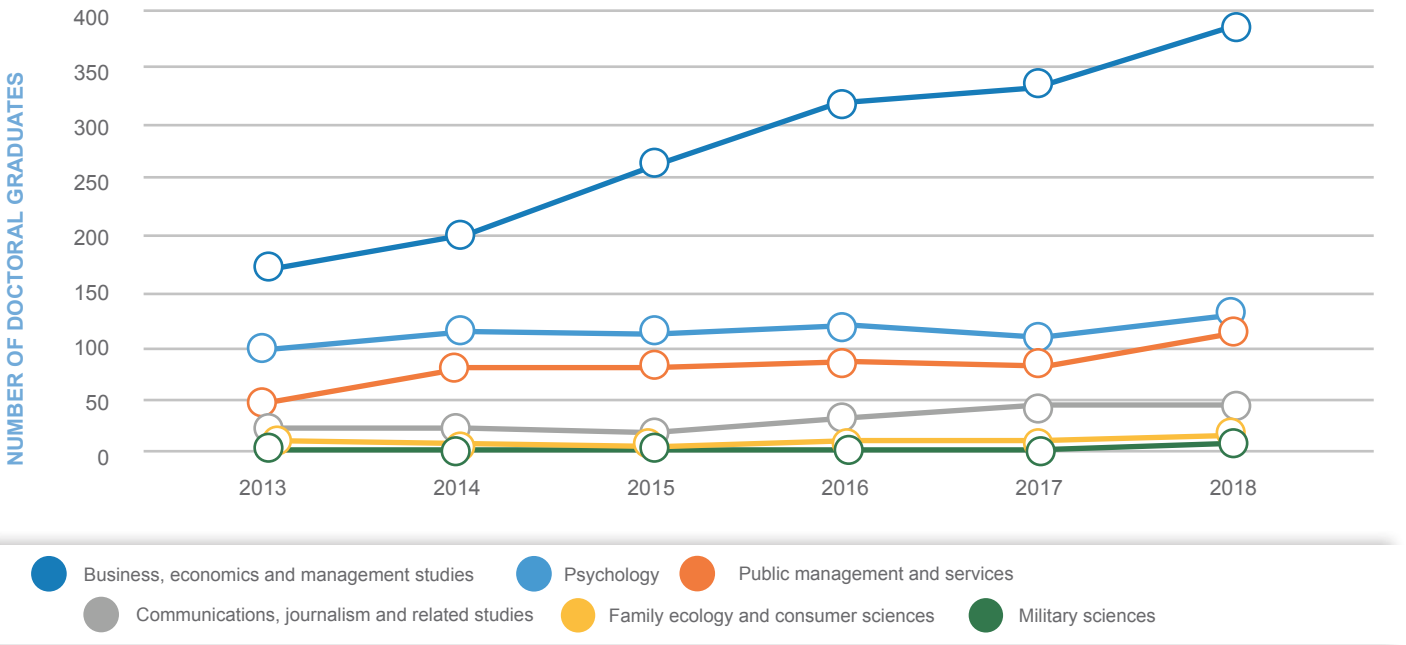


FIGURE 3.13: NUMBER OF DOCTORAL GRADUATES IN SUBDISCIPLINES IN THE SOCIAL SCIENCES

Source: DHET's HEMIS Database

The number of doctorates in business management, economics and management sciences increased from **159** in 2013 to **387** in 2018. This is an increase of more than 100% over a five-year period. The number of psychology doctorates remained constant during the period, producing approximately 100 doctorates annually.

Figure 3.14 shows the number of doctorates in the various disciplines within the humanities. The number of graduates in education is more than twice as large as that of any other discipline. Architecture and built environment, and visual and performing arts, are the lowest with **25** and **38** graduates per annum, respectively.

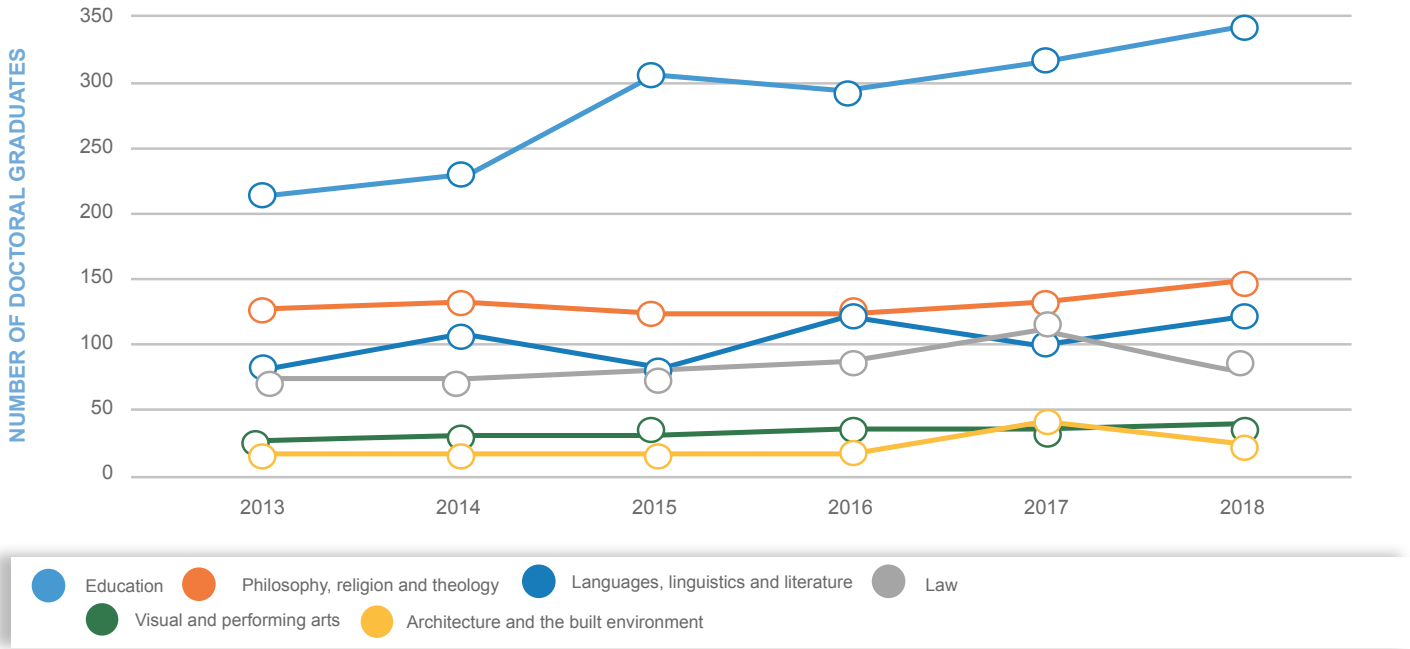


FIGURE 3.14: NUMBER OF DOCTORAL GRADUATES IN SUBDISCIPLINES IN THE HUMANITIES

Source: DHET's HEMIS Database

Figure 3.15 shows the number of master's graduates (by research) produced by the public South African universities during the period 2013–2018. Social sciences master's degrees have been at the majority between 2013 and 2017, with a decline in 2018. Humanities and engineering showed a decline from 2016 to 2017 and a recovery in 2018.

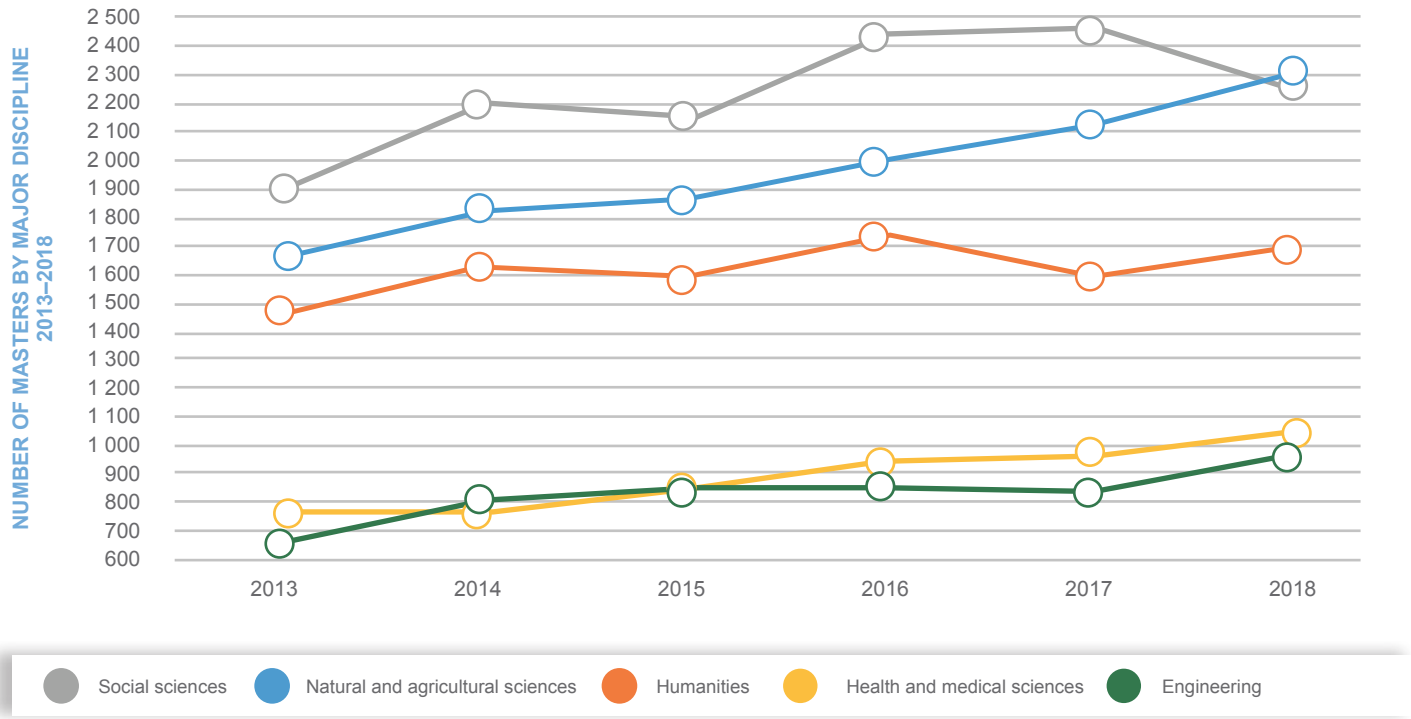


FIGURE 3.15: NUMBER OF RESEARCH MASTER'S DEGREES ACCORDING TO BROAD SCIENTIFIC AREAS

Source: DHET's HEMIS Database

Figure 3.16 shows the total number of master's graduates (coursework and research) produced in the country annually according to broad scientific areas. Social sciences was consistently at top of the list during the period. The number of master's degrees produced increased from **4 000** in 2013 to **5 000** in 2017. In 2018, there was a drop in the number of master's graduates to **4 529**.

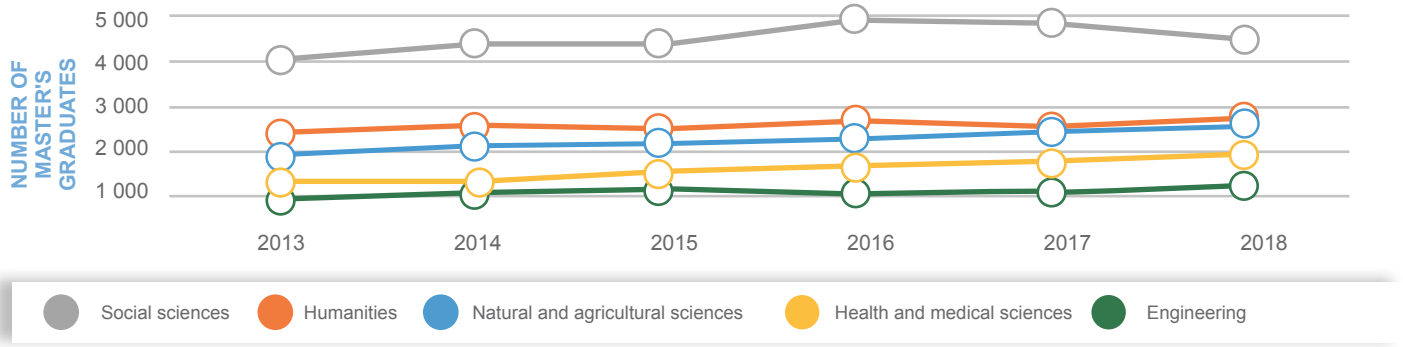


FIGURE 3.16: MASTER'S GRADUATES ACCORDING TO BROAD SCIENTIFIC AREAS

Source: DHET's HEMIS Database

Humanities has the second largest number of master's graduates, with natural and agricultural sciences producing almost the same number of master's degrees during 2017 and 2018. Engineering is at the bottom of the list, producing approximately **1 300** master's degrees annually.

Table 3.10 shows the number of master's degree students who graduated during 2015 and the number of doctoral students who graduated during 2017, as well as the ratios. The ratios are only indicative as the number of doctorates are affected by different factors and not only by the number of master's degree students who graduated two years earlier.

TABLE 3.10: RATIO OF DOCTORAL TO MASTER'S DEGREE GRADUATES

Discipline	Master's (2015)	Doctorates (2017)	Ratio %
Social sciences	4 384	762	17
Humanities	2 560	731	29
Natural and agricultural sciences	2 207	942	43
Engineering	1 200	240	20
Health and medical Sciences	1 584	366	23

Source: DHET's HEMIS Database

In the natural and agricultural sciences, the ratio of doctoral graduates in 2017 compared to master's graduates in 2015 is **43%**. However, in engineering, the ratio of doctoral graduates in 2017 compared to master's graduates in 2015 is **20%**. To the extent that the production of master's degree graduates is the primary source of doctoral candidates, engineering will require a greater number of master's degree graduates than other disciplines to produce the same number of doctorates.

Figure 3.17 shows the number of master's degrees produced by the public universities in South Africa in the social sciences during the period 2013–2018. Business, economics and management sciences produced by far the most master's degree graduates (just below **1 400** in 2018). Other social sciences subfields follow with **535** master's degrees graduates. The recent drop in certain disciplines is the subject of further research.

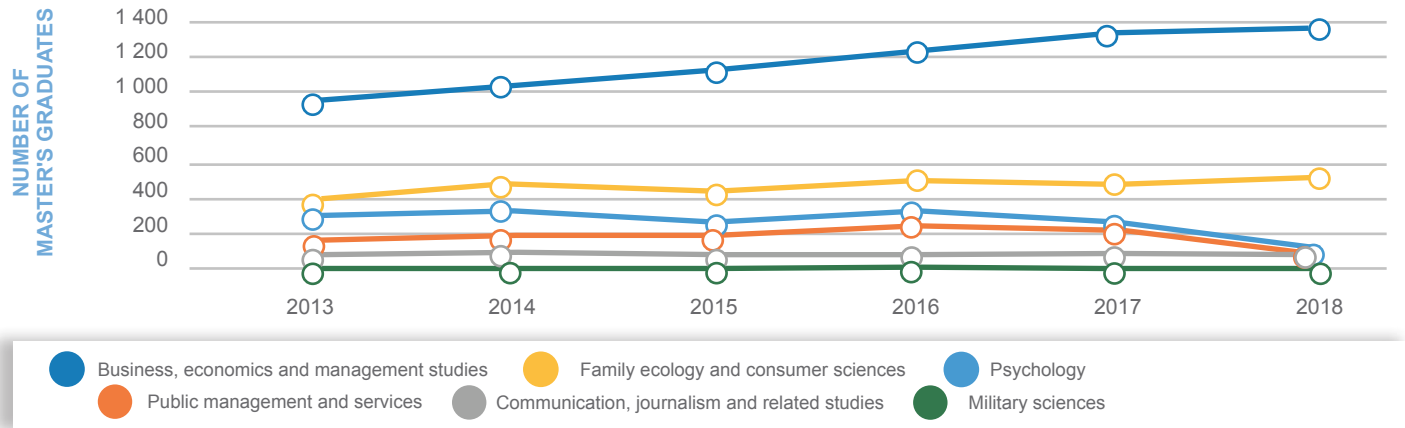


FIGURE 3.17: NUMBER OF MASTER'S GRADUATES IN SUBDISCIPLINES IN THE SOCIAL SCIENCES

Source: DHET's HEMIS Database

Figure 3.18 shows the number of master's degrees produced by the South African public universities in the humanities.

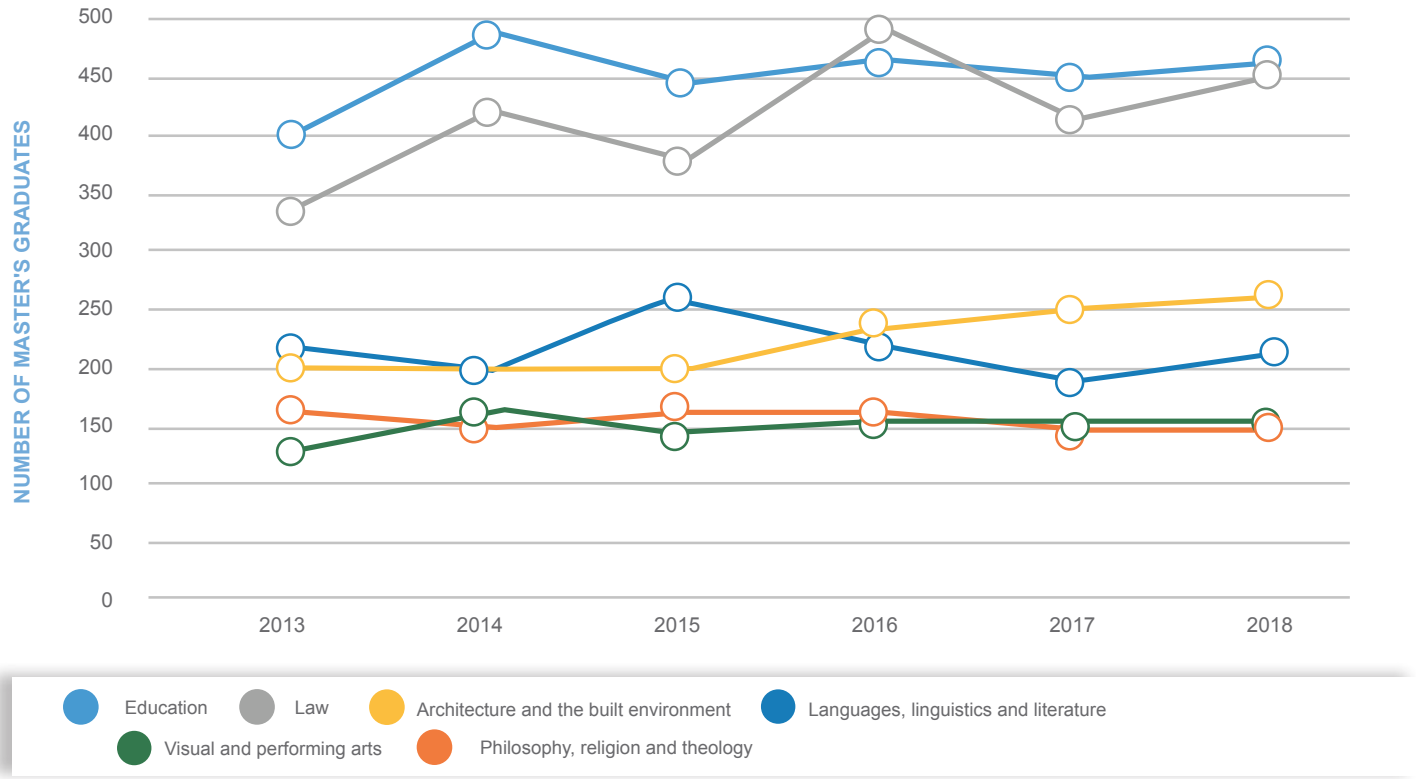


FIGURE 3.18: NUMBER OF MASTER'S DEGREE GRADUATES IN SUBDISCIPLINES IN THE HUMANITIES

Source: DHET's HEMIS Database

Figure 3.19 shows the number of master's degree graduates produced by the South African public universities in the natural and agricultural sciences.

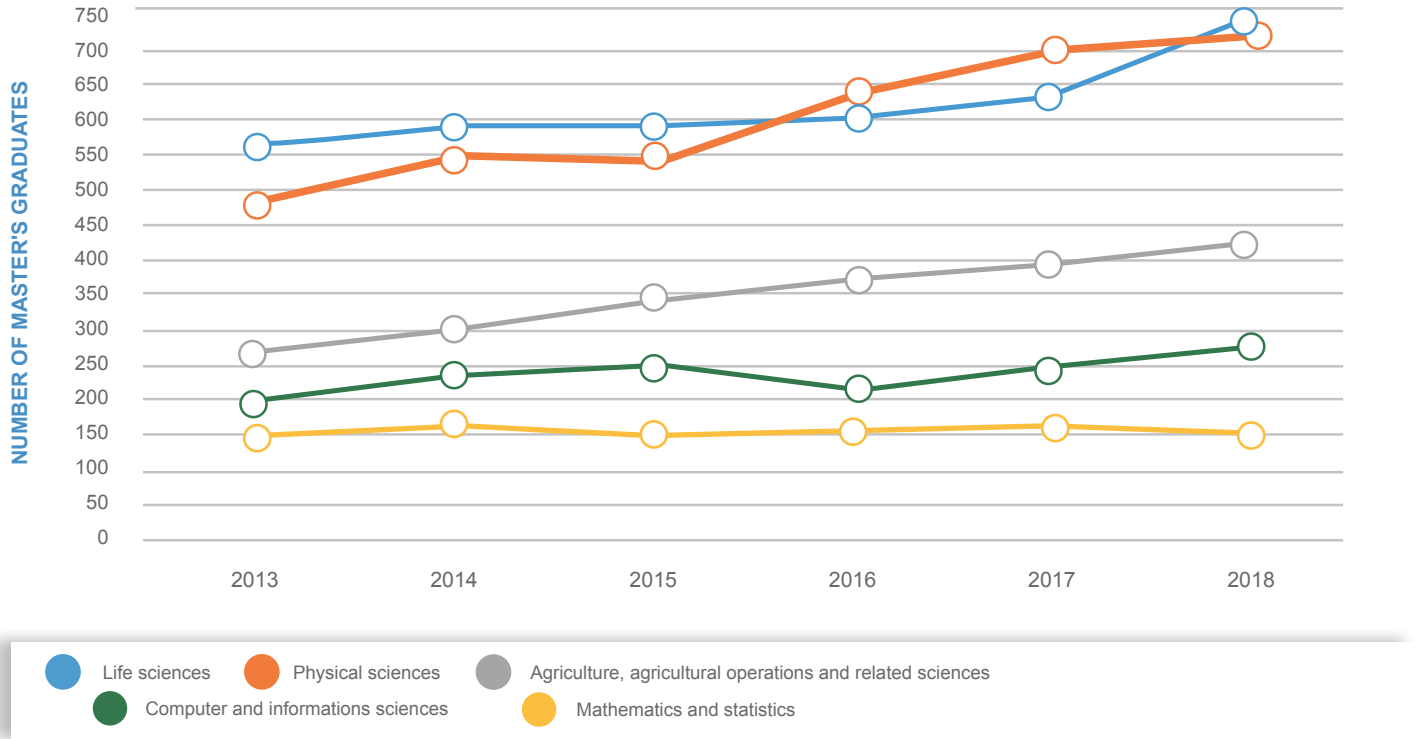


FIGURE 3.19: NUMBER OF MASTER'S GRADUATES IN SUBDISCIPLINES IN THE NATURAL AND AGRICULTURAL SCIENCES

Source: DHET's HEMIS Database

3.2.3 Grade 12 performance on STEM-related subjects

Table 3.11 shows the last five years' performance of Grade 12 science, technology, engineering and mathematics (STEM)-related school subjects. Successful achievement in these subjects is likely to open doors for careers in STI areas.

In terms of pass rates, from 2015 to 2019, there has been a significant improvement in subjects such as physical sciences (from **58.6%** to **75.5%**) and mathematical literacy (from **71.4%** to **80.6%**). The mathematics pass rate improved from **49.1%** in 2015 to **58%** in 2018, before declining to **54.6%** in 2019. It should be emphasised that the pass rate is **30%**.

TABLE 3.11: NATIONAL SENIOR CERTIFICATE PERFORMANCE IN SCIENCE, TECHNOLOGY, ENGINEERING AND MATHEMATICS (STEM)-RELATED SUBJECTS

		Agricultural Sciences	Geography	Life Sciences	Mathematical Literacy	Mathematics	Physical Sciences
2015	**Total**	**104 251**	**303 985**	**348 076**	**388 845**	**263 903**	**193 189**
	Achieved at 30% and above	80 125	234 209	245 164	277 594	129 481	113 121
	Percentage achieved at 30% and above	76.9	77	70.4	71.4	49.1	58.6
2016	Total who wrote	106 386	302 600	347 662	361 865	265 810	192 618
	Achieved at 30% and above	80 184	231 588	245 070	257 881	135 958	119 427
	Percentage achieved at 30% and above	75.4	76.5	70.5	71.3	51.1	62
2017	Total who wrote	98 522	276 771	318 474	313 030	245 103	179 561
	Achieved at 30% and above	69 360	212 954	236 809	231 230	127 197	116 862
	Percentage achieved at 30% and above	70.4	76.9	74.4	73.9	51.9	65.1
2018	Total who wrote	95 291	269 621	310 041	294 204	233 858	172 319
	Achieved at 30% and above	66 608	200 116	236 584	213 225	135 638	127 919
	Percentage achieved at 30% and above	69.9	74.2	76.3	72.5	58	74.2
2019	Total who wrote	92 680	271 807	301 037	298 607	222 034	164 478
	Achieved at 30% and above	69 132	218 821	217 729	240 816	121 179	124 237
	Percentage achieved at 30% and above	74.6	80.5	72.3	80.6	54.6	75.5

Source: Department of Basic Education

3.2.4 Knowledge generation within SADC countries

This subsection identifies the state of scientific knowledge generation in the 16 SADC countries. SADC was established in 1992 under Article 2 of the SADC Treaty. SADC's vision is one of a common future, within a regional community that will ensure economic wellbeing, improvement of the standards of living and quality of life, freedom and social justice, and peace and security for the peoples of the region. The most recent country to become a member of SADC is the Union of Comoros, which was admitted to SADC at the 37th SADC Summit of the Heads of State and Government in August 2017. It became a full member at the 38th Summit of the Heads of State and Government in Windhoek, Namibia, in August 2018.

Table 3.12 shows the number of publications produced by each country during the two-year period 2016–2017. South Africa, with **48 955** publications, is at the top of the list with **77%** of publications produced in the region.

TABLE 3.12: NUMBER OF PUBLICATIONS PER SADC COUNTRY (2016–2017)

Country	Number of publications	SADC's percentage share of publications produced
South Africa	48 955	77.4
Tanzania	3 204	5.1
Malawi	1 662	2.6
Zimbabwe	1 637	2.6
Zambia	1 388	2.2
Congo	1 303	2.1
Botswana	1 210	1.9
Mozambique	979	1.5
Madagascar	731	1.2
Namibia	698	1.1
Mauritius	664	1.1
Angola	275	0.4
Eswatini	222	0.4
Lesotho	132	0.2
Seychelles	119	0.2
Comoros	31	0.0
Total	**63 210**	**100**

Source: Clarivate Analytics's InCites

Table 3.13 shows the scientific disciplines emphasised in the SADC countries as they are manifested in the number of publications produced with at least one author from that particular country. Infectious diseases appears among the top three scientific disciplines in 15 of the 16 countries. Mauritius is the only country for which infectious diseases does not appear among the top three emphasised disciplines.

TABLE 3.13: NUMBER OF PUBLICATIONS BY LEADING DISCIPLINES IN SADC COUNTRIES (2013–2017)

SADC country	Number of publications
Angola	
Infectious diseases	144
Public environmental occupational health	127
Environmental sciences ecology	122
Botswana	
Infectious diseases	214
Environmental sciences ecology	190
Engineering	175
Comoros	
Zoology	18
Environmental sciences ecology	15
Infectious diseases	14
Congo	
Public environmental occupational health	1 063
Infectious diseases	917
Environmental sciences ecology	783
Eswatini	
Infectious diseases	162
Environmental sciences ecology	127
Immunology	116
Lesotho	
Infectious diseases	162
Environmental sciences ecology	127
Immunology	116
Madagascar	
Environmental sciences ecology	735
Zoology	642
Infectious diseases	426
Malawi	
Infectious diseases	1 429
Public environmental occupational health	1 226
Health care sciences services	1 155

SADC country	Number of publications
Mauritius	
Engineering	304
Environmental sciences ecology	273
Computer science	251
Mozambique	
Infectious diseases	745
Public environmental occupational health	629
Environmental sciences ecology	528
Namibia	
Environmental sciences ecology	510
Zoology	291
Infectious diseases	287
Seychelles	
Infectious diseases	162
Environmental sciences ecology	127
Health care sciences services	94
South Africa	
Environmental sciences ecology	18 875
Infectious diseases	13 525
Engineering	13 512
Tanzania	
Infectious diseases	2 371
Public environmental occupational health	2 283
Environmental sciences ecology	2 002
Zambia	
Infectious diseases	1 234
Public environmental occupational health	1 025
Immunology	845
Zimbabwe	
Environmental sciences ecology	1 185
Infectious diseases	1 042
Immunology	762

Source: Clarivate Analytics's InCites

It is noted that engineering only appears in Botswana, South Africa and Mauritius. Mauritius appears to have a different pattern of priorities to the other SADC countries as computer sciences appears among the country's top scientific disciplines.

Table 3.14 shows the activity indices with high values in the various SADC countries. Indices above 1 indicate that the country over-emphasises the particular discipline. For example, Angola is producing 33 times the number of articles in parasitology as that expected from the size of its scientific system and the production of parasitology articles in the world. Scientifically, small countries are expected to have a certain number of large activity indices as they specialise in particular disciplines. Such specialisation may be the result of foreign funders who support research in the particular country[4].

TABLE 3.14: TOP ACTIVITY INDICES OF SADC COUNTRIES (2013–2017)

SADC country	Activity Index
Angola	
Parasitology	33.5
Public environmental occupational health	9.1
Paediatrics	8.5
Botswana	
Engineering	12.5
Environmental sciences ecology	6.7
Education and educational research	5.3
Comoros	
Public environmental occupational health	219.1
Biochemistry and molecular biology	68.1
Meteorology and atmospheric sciences	62.5
Congo	
Tropical medicine	156.4
Parasitology	31.5
Public environmental occupational health	17.8
Eswatini	
Behavioural sciences	122.7
Infectious diseases	14.3
Public environmental occupational health	10.4
Lesotho	
Behavioural sciences	200.2
Psychology	27.3
Infectious diseases	23.3
Madagascar	
Tropical medicine	104.8
Parasitology	33.5
Agriculture	24.8
Malawi	
Tropical medicine	98.9
Nutrition dietetics	53.1
Paediatrics	17.2

SADC country	Activity Index
Mauritius	
Plant sciences	26.2
Business economics	13.3
Education and educational research	10.0
Mozambique	
Tropical medicine	118.7
Parasitology	34.1
Agriculture	17.2
Namibia	
Engineering	14.9
Biodiversity conservation	12.0
Zoology	9.3
Seychelles	
Behavioural sciences	189.5
Reproductive biology	146.3
Nutrition dietetics	52.5
South Africa	
Business economics	7.96
Education and educational research	7.28
Infectious diseases	4.98
Tanzania	
Tropical medicine	125.5
Parasitology	35.0
Agriculture	23.1
Zambia	
Tropical medicine	118.3
Virology	85.0
Parasitology	30.0
Zimbabwe	
Agriculture	28.6
Business economics	12.0
Infectious diseases	11.9

Source: Clarivate Analytics's InCites

4 CAAST-Net Plus, 2017 (CAAST-Net Plus is a network of 26 partner organisations from all over Europe and sub-Saharan Africa working together to support bi-regional cooperation in research and innovation)

Table 3.15 shows the number of co-authored articles between the various SADC countries and South Africa. Zimbabwe has the largest number of co-authored publications (**1 113**) with South Africa. It follows Tanzania with **711** co-publications and Namibia with **578** co-publications.

TABLE 3.15: CO-AUTHORSHIP OF PUBLICATIONS BETWEEN SADC COUNTRIES AND SOUTH AFRICA (2013–2017)

Country	Number of co-authored publications with South Africa
Zimbabwe	1 113
Tanzania	711
Namibia	578
Botswana	560
Malawi	555
Zambia	537
Mozambique	295
Congo	211
Eswatini	148
Mauritius	132
Madagascar	93
Lesotho	81
Seychelles	45
Angola	41
Comoros	1

Source: Clarivate Analytics's InCites

TABLE 3.16: DISCIPLINES IN WHICH SOUTH AFRICA COLLABORATES WITH SADC COUNTRIES (2013–2017)

Country	Top discipline	Number of publications	Second discipline	Number of publications
Angola	Environmental sciences ecology	8	General internal medicines	6
Botswana	Engineering	59	Infectious diseases	58
Comoros	Meteorology atmospheric sciences	1	Physical sciences other topics	1
Congo	General internal medicine	24	Infectious diseases	22
Eswatini	Zoology	23	Infectious diseases	15
Lesotho	Infectious diseases	25	Health care science services	21
Madagascar	Zoology	14	Infectious diseases	12
Malawi	Infectious diseases	138	Immunology	95
Mauritius	Chemistry	40	Biochemistry molecular biology	13
Mozambique	Public environmental occupational health	38	Infectious diseases	37
Namibia	Engineering	59	Environmental sciences ecology	58
Seychelles	Environmental sciences ecology	20	Zoology	20
Tanzania	Infectious diseases	104	Public environmental occupational health	85
Zambia	Infectious diseases	147	Immunology	101
Zimbabwe	Infectious diseases	182	Immunology	127

Source: Clarivate Analytics's InCites

Engineering is the top collaborating discipline between South Africa and Botswana and Namibia. Infectious diseases appears among the top two collaborating disciplines in **10** of the 15 countries.

Table 3.17 shows the main organisations collaborating with South African researchers.

TABLE 3.17: MAIN ORGANISATIONS COLLABORATING WITH SOUTH AFRICAN RESEARCHERS (2013–2017)

Country	Top collaborating organisation	Number of publications	Second organisation	Number of publications
Angola	Universidade Do Porto	10	University of London	10
Botswana	Harvard University	55	University of London	47
Comoros	Addis Ababa University	1	National Civil Aviation and Meteorological Agency	1
Congo	Universite de Kinshasa	58	World Health Organisation	45
Eswatini	Ministry of Health	14	Harvard University	10
Lesotho	Johns Hopkins University	8	Ministry of Health	7
Madagascar	Université d'Antananarivo	24	Le Reseau International Des Instituts Pasteur	22
Malawi	London School of Hygiene Tropical Medicine	94	Johns Hopkins University	65
Mauritius	King Saud University	14	University of London	11
Mozambique	Eduardo Mondlane University	140	University of London	55
Namibia	Centre National de la Recherche Scientifique	52	Helmholtz Association	51
Seychelles	Ministry of Health	22	University of Lausanne	21
Tanzania	University of London	161	London School of Hygiene Tropical Medicine	114
Zambia	University of London	135	London School of Hygiene Tropical Medicine	101
Zimbabwe	University of London	102	Johns Hopkins University	74

Source: Clarivate Analytics's InCites

It is interesting to note that, for certain countries, non-SADC organisations are at the top of the list. For example, the second organisation appearing in the list of collaborating organisations with Angola is the University of London. It can be argued that these foreign organisations are leading the relevant local research organisations in collaboration.

Table 3.18 shows the main organisations funding published articles. The dominance of non-SADC funders indicates that the region does not have an established research funder. The main funders appear to be health-related organisations.

TABLE 3.18: MAIN FUNDERS SUPPORTING COLLABORATIVE RESEARCH WITH SOUTH AFRICA (2013–2017)

Country	Top funders	Number of publications	Second funders	Number of publications
Angola	Calouste Gulbenkian Foundation	11	Fundação para a Ciência e a Tecnologia	10
Botswana	University of Botswana	40	US National Institutes of Health	39
Comoros	European Union	3	US National Institutes of Health	3
Congo	World Health Organisation	109	Medical Research Council, UK	34
Eswatini	US Agency for International Development	30	US Department of Health	23
Lesotho	US Agency for International Development	16	US Department of Health	10
Madagascar	National Science Foundation	65	Volkswagen Foundation	44
Malawi	US Department of Health	481	US National Institutes of Health	452
Mauritius	University of Mauritius	48	Mauritius Research Council	26
Mozambique	Bill and Melinda Gates Foundation	47	Fogarty International Center	34
Namibia	University of Namibia	60	National Research Foundation	56
Seychelles	US Department of Health	41	US National Institutes of Health	40
Tanzania	Wellcome Trust	225	Medical Research Council, UK	212
Zambia	Bill and Melinda Gates Foundation	93	Medical Research Council, UK	70
Zimbabwe	Wellcome Trust	142	Medical Research Council, UK	70

Source: Clarivate Analytics's InCites

Table 3.19 shows the co-publications between the particular SADC countries and the Brazil, Russia, India, China (BRIC) group. South Africa is at the top of the list with **8 493** co-authored publications. Tanzania and Malawi follow with **439** and **243** co-publications, respectively. The majority of the SADC countries collaborate more with South Africa than with countries in the BRIC group.

TABLE 3.19: CO-PUBLICATIONS BETWEEN SADC COUNTRIES AND THE BRIC GROUP (2013–2017)

SADC country	Co-publications
South Africa	8 493
Tanzania	439
Malawi	243
Zimbabwe	204
Zambia	212
Congo	227
Botswana	146
Mozambique	313
Madagascar	130
Namibia	110
Mauritius	191
Angola	87
Eswatini	24
Seychelles	19
Lesotho	13
Comoros	8

Source: Clarivate Analytics's InCites

The countries that collaborate more with countries in the BRIC group than with South Africa are Angola, Comoros, Congo, Madagascar, Mauritius and Mozambique. With the exception of Mauritius, all these countries are non-English-speaking countries, which implies that language might be a barrier to communicating with the South African researchers.

Table 3.20 shows the citations and H-indices of the SADC countries. South Africa has the highest H-index and Namibia has the highest average number of citations per document.

TABLE 3.20: SADC CITATIONS AND H-INDICES (2018)

Country	Documents	Citations per document	H-index
South Africa	25 888	3.21	468
Tanzania	1 736	3.54	175
Zimbabwe	1 043	2.3	140
Malawi	816	3.07	147
Botswana	779	3.17	109
Zambia	642	4.61	131
Mozambique	508	5	108
Namibia	491	5.91	101
Madagascar	364	4.21	98
Mauritius	346	3.39	81
Democratic Republic Congo	180	3.36	66
Swaziland	155	2.35	62
Angola	118	2.11	49
Seychelles	54	3.02	65
Lesotho	52	2.06	40
Comoros	20	1.6	18

Source: Scimago Journal and Country Ranking

4. FIRM ACTIVITIES ON SCIENCE, TECHNOLOGY AND INNOVATION

This section focuses on the business sector and provides data on South Africa's R&D by sector. In order for the country's economy to grow and to improve the standard of living, it is vital that knowledge be converted into new products and production processes. Innovation within businesses is vital in achieving these objectives.

4.1 Investments

4.1.1 Business-sector R&D expenditure

Business expenditure on R&D, as a percentage of GERD, has been declining since 2008 (see Table 4.1). The BERD, as a share of GDP, has also shown a tendency to decline. However, real expenditures on R&D on the part of the business sector has increased, albeit at a slow rate, since 2010.

TABLE 4.1: BERD EXPENDITURE

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
BERD (R' million)	12 332	11 139	10 059	10 464	10 571	11 783	13 291	13 815	14 781	15 859
BERD as a percentage of GERD	58.6	53.2	49.7	47.1	44.3	45.9	45.3	42.7	41.4	41.0
BERD as a percentage of GDP	0.52	0.44	0.37	0.35	0.32	0.33	0.35	0.34	0.34	0.34

Source: HSRC and DSI's National Survey of Research and Experimental Development

Table 4.2 shows the R&D expenditure by performer for the period 2008/09 to 2017/18. The GERD increased from **R21 billion** in 2008/09 to **R38.7 billion** in 2017/18. At the end of the period, the major research performer was business with an expenditure of **R15.8 billion**, followed by the higher education sector spending **R13 billion**. While the business sector has remained the largest performer of R&D, its share of GERD has declined from 58.6% in 2008/9 to 41% in 2017/18.

TABLE 4.2: SOUTH AFRICAN R&D EXPENDITURE BY SECTOR (R'000) (2008/09–2017/18)

Year	GERD	Government	Science councils	Higher education	Business	Not for profit
2008/09	21 041 046	1 139 676	3 137 343	4 191 366	12 332 012	240 649
2009/10	20 954 677	1 067 302	3 458 074	5 101 224	11 139 237	188 840
2010/11	20 253 805	1 011 340	3 596 023	5 424 602	10 059 010	162 830
2011/12	22 209 192	1 235 669	3 729 680	6 609 216	10 464 022	170 605
2012/13	23 871 219	1 437 509	4 025 998	7 333 153	10 570 726	503 833
2013/14	25 660 573	1 697 151	4 304 556	7 292 853	11 782 848	583 165
2014/15	29 344 977	1 893 010	5 004 669	8 377 575	13 290 951	778 772
2015/16	32 336 679	2 013 021	5 740 897	9 876 623	13 814 995	891 142
2016/17	35 692 973	2 098 646	6 136 183	11 659 258	14 781 270	1 017 616
2017/18	38 724 590	2 325 875	6 313 344	13 009 876	15 859 185	1 216 310

Source: HSRC and DSI's National Survey of Research and Experimental Development

Table 4.3 shows South African R&D expenditure by sector in constant rand values for the period 2008/09 to 2017/18. The GERD increased from **R24 billion** in 2008/09 to **R25.9 billion** in 2017/18. The highest growth was exhibited by the higher education sector, while expenditure in the business sector shrank from **R14 billion** to **R10.6 billion** in constant rand values.

TABLE 4.3: SOUTH AFRICAN R&D EXPENDITURE BY SECTOR (CONSTANT 2010 RAND VALUES) (R'000)

Year	GERD	Government	Science councils	Higher education	Business	Not for profit
2008/09	24 056 681	1 303 016	3 586 992	4 792 079	14 099 455	275 139
2009/10	22 285 515	1 135 087	3 677 697	5 425 204	11 846 693	200 833
2010/11	20 253 802	1 011 340	3 596 022	5 424 601	10 059 009	162 830
2011/12	20 847 389	1 159 901	3 500 987	6 203 958	9 822 399	160 144
2012/13	21 283 167	1 281 658	3 589 510	6 538 113	9 424 677	449 209
2013/14	21 551 944	1 425 413	3 615 334	6 125 162	9 896 243	489 792
2014/15	23 351 132	1 506 354	3 982 443	6 666 417	10 576 214	619 704
2015/16	24 478 150	1 523 812	4 345 732	7 476 385	10 457 645	674 575
2016/17	25 304 686	1 487 844	4 350 273	8 265 881	10 479 245	721 444
2017/18	25 962 839	1 559 379	4 232 771	8 722 451	10 632 765	815 473

Source: HSRC and DSI's National Survey of Research and Experimental Development

Table 4.4 shows the R&D expenditure in the business sector by major sector.

TABLE 4.4: BERD EXPENDITURE BY MAJOR SECTOR (2008–2017)

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
	PERCENTAGE									
Primary sectors	**6.5**	**6.4**	**12.1**	**14.9**	**17.4**	**17.3**	**13.5**	**12.3**	**10.4**	**9.4**
Agriculture, forestry and fishing	1.8	1.9	1.6	2.0	2.7	3.1	3.5	3.5	3.2	2.5
Mining and quarrying	4.7	4.5	10.5	12.9	14.7	14.2	10.1	8.8	7.2	6.9
Secondary sectors	**57.6**	**47.4**	**41.1**	**38.7**	**36.6**	**35.3**	**38.0**	**35.4**	**31.5**	**32.3**
Manufacturing	38.8	38.8	35.7	33.9	32.9	32.2	33.9	32.2	27.8	28.2
Electricity, gas and water	18.7	8.6	5.3	4.7	3.6	3.0	4.1	3.2	3.7	4.0
Construction	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0
Tertiary sectors	**35.9**	**46.2**	**46.9**	**46.3**	**46.0**	**47.4**	**48.4**	**52.3**	**58.1**	**58.3**
Wholesale and retail trade, hotels and restaurants	2.7	3.9	6.2	5.2	1.7	0.9	0.6	0.3	0.4	0.5
Transport, storage and communication	3.4	3.7	3.5	4.6	4.4	3.8	4.8	6.5	10.4	6.2
Finance, real estate and business services	27.4	33.9	33.1	34.8	37.0	40.1	40.3	42.8	44.3	48.8
Community, social and personal services	2.4	4.7	4.1	1.6	2.8	2.6	2.7	2.7	2.9	2.8

Source: HSRC and DSI's National Survey of Research and Experimental Development

The proportional R&D expenditure within the primary sectors showed a period of increase until 2011/12 before experiencing a declining trend. The secondary sectors' share has seen a constant decline, albeit with a slight increase in 2016–2017. By contrast, the share of the tertiary sectors in overall R&D expenditure has seen a continuous increase. Within the secondary sectors, the manufacturing sector's proportion of R&D expenditure declined from **38.8%** in 2009/10 to **28.2%** in 2017/18. The tertiary sectors that have experienced the most significant growth in R&D expenditure are the finance, real estate and business services sector. This sector now accounts for just below **60%** of all R&D in the business sector.

The distribution of R&D within the manufacturing industry (high-, medium- and low-technology) is shown in Table 4.5. R&D expenditure is concentrated in the medium-technology sectors, especially the petroleum products, chemicals, rubber and plastic sector. Among the medium-technology sectors, only the electrical machinery and apparatus, and the metals, metal products, machinery and equipment sector, are increasing.

TABLE 4.5: PERCENTAGE SHARE OF R&D EXPENDITURE IN THE MANUFACTURING SECTOR

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
High technology	**10.7**	**13.7**	**16.4**	**18.0**	**18.9**	**19.6**	**15.7**	**12.8**	**15.3**	**14.0**
Radio, television, instruments, watches and clocks	10.7	13.7	16.4	18.0	18.9	19.6	15.7	12.8	15.3	14.0
Medium technology	**80.8**	**78.2**	**72.8**	**69.5**	**67.7**	**66.4**	**71.2**	**73.7**	**73.8**	**72.7**
Petroleum products, chemicals, rubber and plastic	47.4	40.7	33.3	38.9	32.8	33.1	40.8	40.5	41.3	37.8
Other non-metal mineral products	2.8	2.8	2.4	2.0	1.4	1.4	1.1	0.6	0.9	0.6
Metals, metal products, machinery and equipment	6.6	7.6	6.7	11.1	16.8	16.4	13.5	14.9	12.6	13.0
Electrical machinery and apparatus	3.5	3.4	5.8	8.7	9.0	6.7	6.7	8.6	11.1	14.2
Transport equipment	20.6	23.7	24.6	8.7	7.7	8.8	9.1	9.1	7.8	7.1
Low technology	**8.5**	**8.1**	**10.8**	**12.5**	**13.4**	**14.1**	**13.1**	**13.5**	**10.9**	**13.1**
Food, beverages and tobacco	4.5	3.8	6.2	8.0	9.2	9.0	8.1	8.5	8.0	10.0
Textiles, clothing and leather goods	0.3	0.4	0.1	0.0	0.1	0.8	0.8	0.2	0.2	0.5
Wood, paper, publishing and printing	2.5	2.6	3.0	2.3	1.5	1.6	1.6	2.2	2.1	2.0
Furniture and other manufacturing (including the informal sector)	1.3	1.4	1.6	2.3	2.7	2.6	2.6	2.7	0.6	0.6

Source: Computed from the HSRC and DSI's National Survey of Research and Experimental Development

4.1.2 Business-sector R&D funding

Funding of business-sector R&D

Financial resources for R&D in the business sector derived from outside the business sector have declined significantly. Government funding of business-sector R&D declined from **R2.6 billion** in 2008/09 (**20.8%** of business-sector R&D funding) to **R371.2 million** in 2017/18 (**2.3%** of business-sector R&D funding). Business's share of its own funds for R&D increased significantly from **65.9%** in 2008/09 to **93.8%** in 2017/18.

Foreign sources have also significantly reduced their funding of the business sector's R&D. In 2017/18, the share of business-sector R&D contributed by foreign sources was **3.0%**, down from **11.3%** in 2008/09. During the period under review, businesses received **R3 billion** less than they had received during 2008.

TABLE 4.6: SOURCES OF FUNDING FOR R&D IN THE BUSINESS SECTOR (2008–2017)

	2008		2015		2016		2017	
	R' 000	%	R' 000	%	R' 000	%	R' 000	%
Own funds	**8 130 033**	**65.9**	**11 122 965**	**80.5**	**12 451 802**	**84.2**	**14 868 724**	**93.8**
Government	**2 567 140**	**20.8**	**522 631**	**3.8**	**453 958**	**3.1**	**371 165**	**2.3**
Grants	1 979 423	16.1	134 005	1.0	231 273	1.6	202 371	1.3
Contracts	587 717	4.8	388 627	2.8	222 685	1.5	168 794	1.1
Local business	**209 346**	**1.7**	**261 745**	**1.9**	**134 307**	**0.9**	**94 473**	**0.6**
Other South African sources	**29 460**	**1.7**	**374 888**	**2.7**	**402 542**	**2.7**	**50 060**	**0.3**
Higher education	2 120	0.0	1.0	0.0	230	0.0	0	0.0
Not-for-profit	19 160	0.2	372 776	2.7	400 233	2.7	50 060	0.3
Individual donations	8 180	0.1	2 111	0.0	2 079	0.0	0	0.0
Foreign sources	**1 396 033**	**11.3**	**1 532 766**	**11.1**	**1 338 662**	**9.1**	**474 762**	**3.0**
Total	**12 332 012**	**100**	**13 814 995**	**100**	**14 781 270**	**100**	**15 859 185**	**100**

Source: Computed from HSRC and DSI's National Survey of Research and Experimental Development

4.2 Venture capital investments

Venture capital is a form of private equity and financing provided to new businesses and start-ups with long-term growth potential. This capital is provided by investment banks, individual investors or firms specifically dedicated to venture capital investments.

After declining from 2008 to 2012, the number of venture capital investments increased rapidly, reaching **181** venture capital deals in 2018. The Section 12J venture capital companies invested in **155** qualifying companies, very few of which were in technology-based businesses. A Section 12J investment provides the investor a unique opportunity to invest in a tax-deductible investment vehicle.

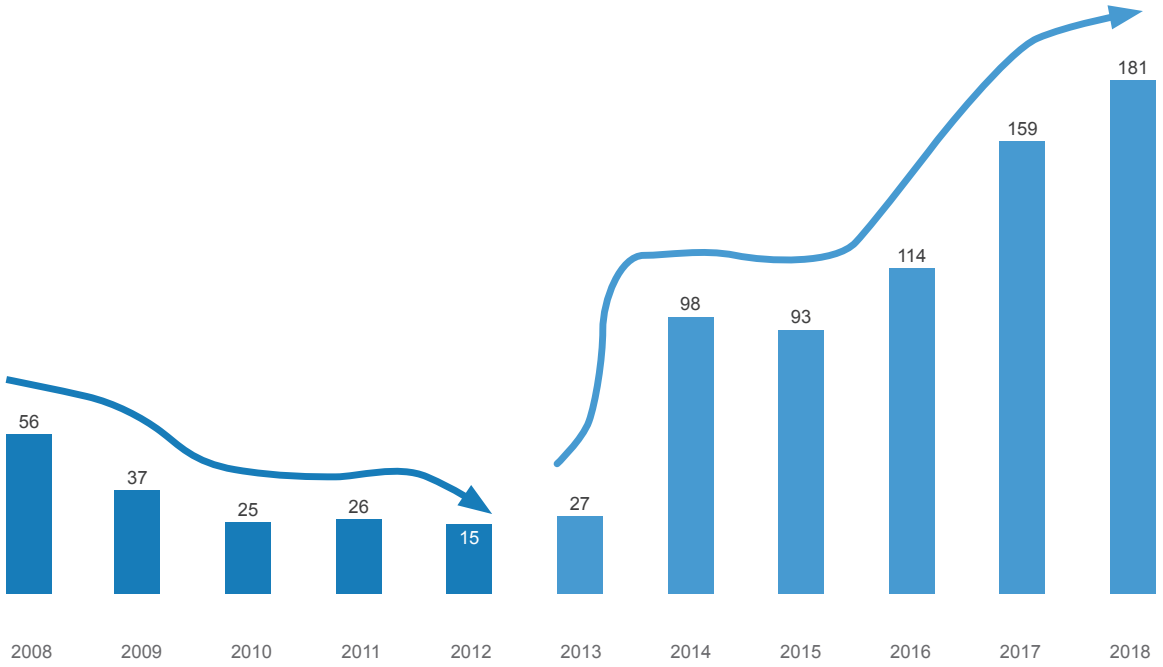


FIGURE 4.1: NUMBER OF VENTURE CAPITAL INVESTMENTS RECORDED BETWEEN 2008 AND 2018

Source: Southern African Venture Capital and Private Equity Association (SAVCA)'s Venture Capital Industry Survey

Figure 4.2 shows the sources of venture capital funds. Independent funds contributed **37.2%** of the funds invested in 2017. Government captive funds contributed **33.7%** of the total venture capital funds invested in 2018, which represents a slight increase from **31.9%** in 2017.

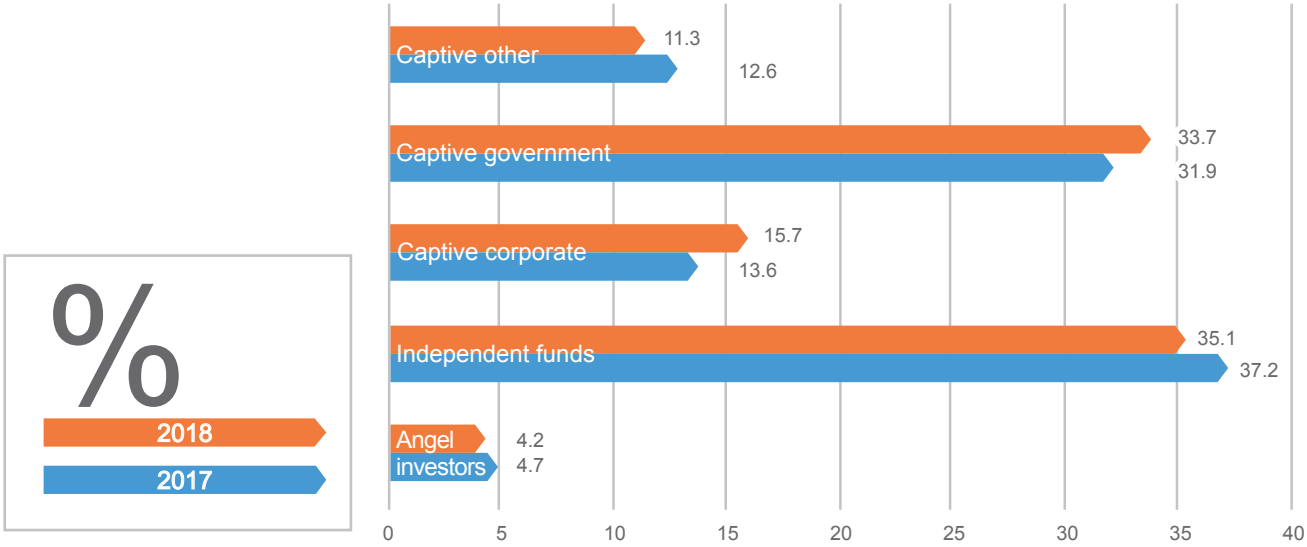


FIGURE 4.2: SOURCES OF VENTURE CAPITAL FUNDS INVESTED (AS A PERCENTAGE)

Source: The Southern African Venture Capital and Private Equity Association (SAVCA)'s Venture Capital Industry Survey

Figure 4.3 shows the distribution of venture capital funds according to stage of investment. Start-ups are the largest category for venture capital investments (**41.1%** in 2018), followed by growth-stage companies (**29.4%**) and later-stage funding (**19.4%**).

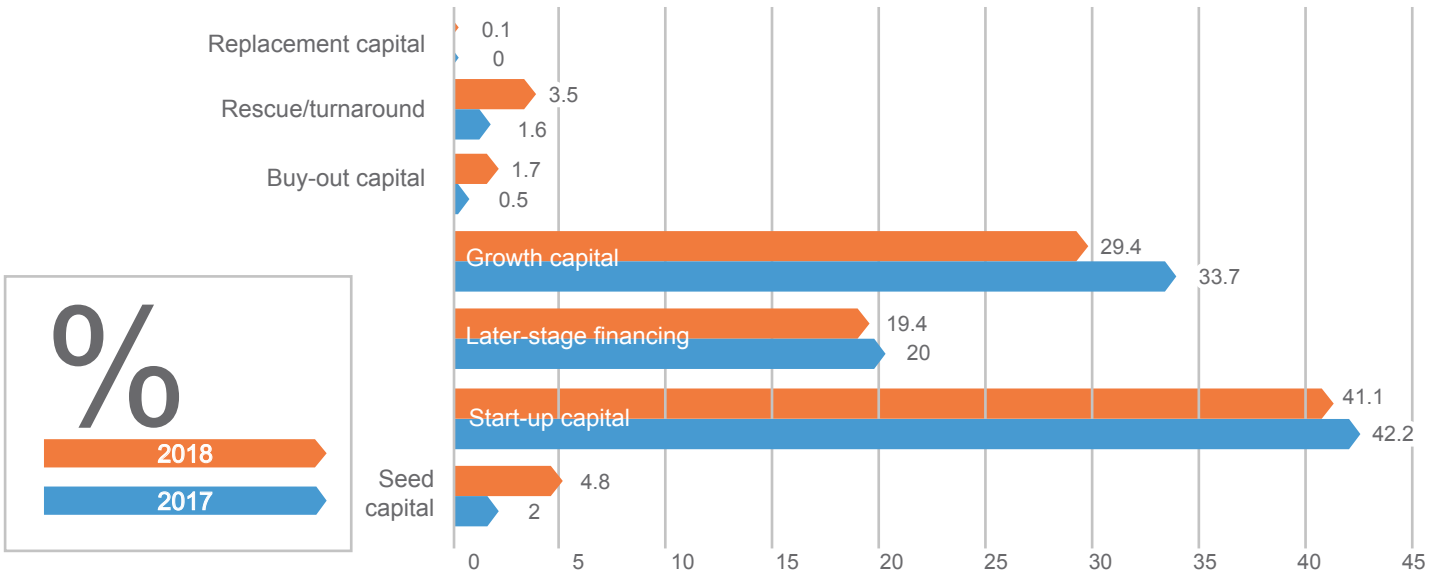


FIGURE 4.3: DISTRIBUTION OF DEALS INVESTED BY STAGE AND VALUE OF DEAL

Source: SAVCA's Venture Capital Industry Survey

Figure 4.4 shows the venture capital investment by sector. The sectors that have attracted most funding are manufacturing, food and beverage, medical devices and equipment, and energy.

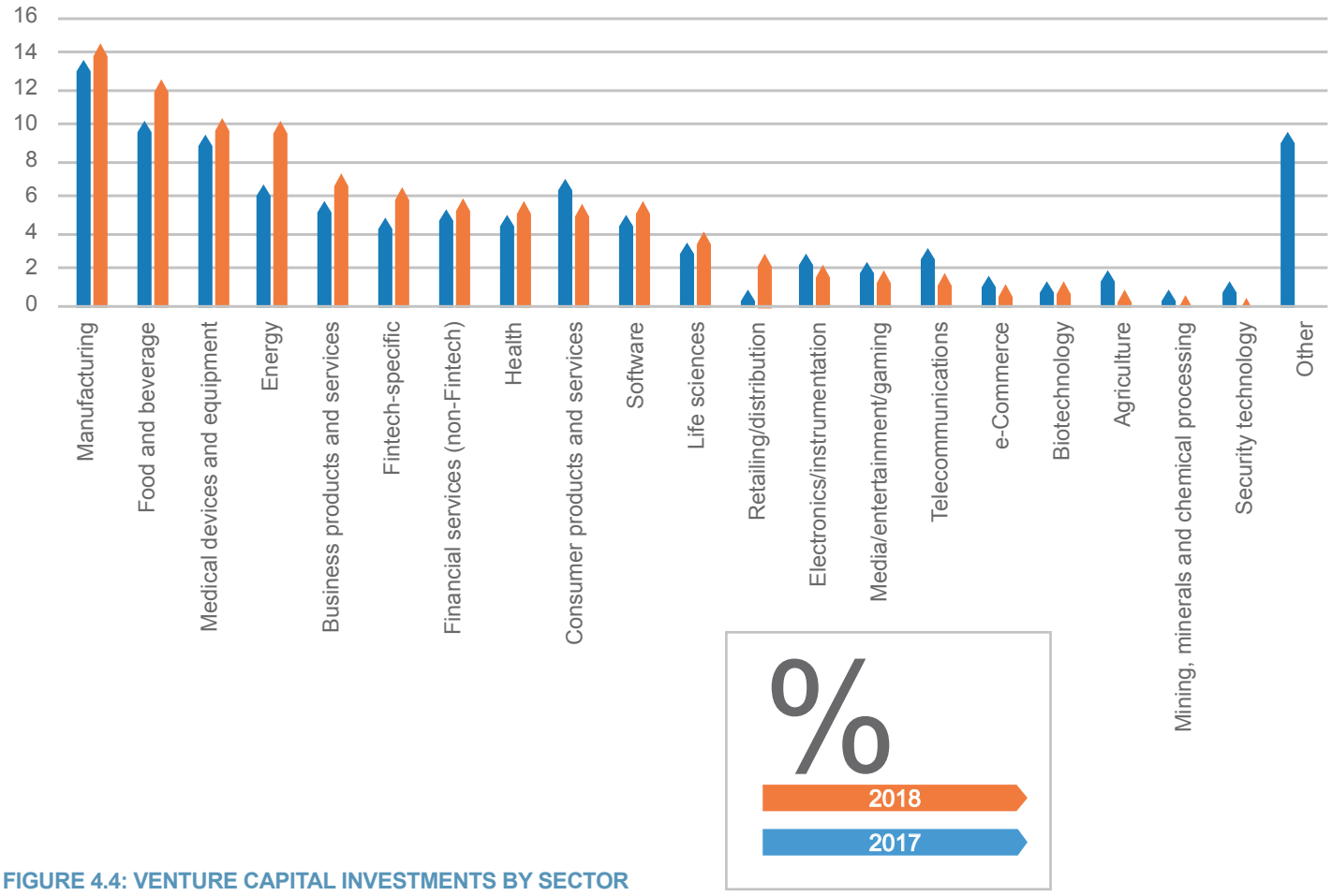


FIGURE 4.4: VENTURE CAPITAL INVESTMENTS BY SECTOR

Source: SAVCA's Venture Capital Industry Survey

4.3 Business innovation characteristics

Innovation is recognised as a key driver for long-term economic growth, competitiveness and a better quality of life. With innovation, one can expect to see job creation and increased incomes resulting from the production of new products, processes and services, and the establishment of new industries. The data for this section is derived from the South African Business Innovation Survey 2014–2016 (the most recent survey available).

Prevalence and different types of firm-level innovations

Of the enterprises in South Africa, **70.7%** are innovation-active in the industrial sector and **69.4%** are innovation-active in the service sector. In total, **69.9%** of all the enterprises surveyed are innovation-active (Figure 4.5). These rates of innovation need to be interpreted with caution. For many South African firms, innovation activity is confined to imitation. Much of the remaining innovation is incremental. Radical and breakthrough innovations at firm-level are very scarce.

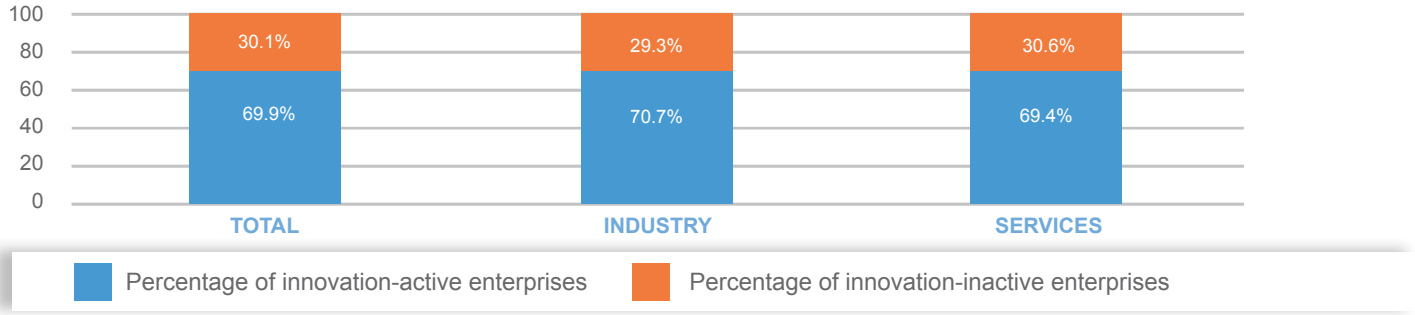
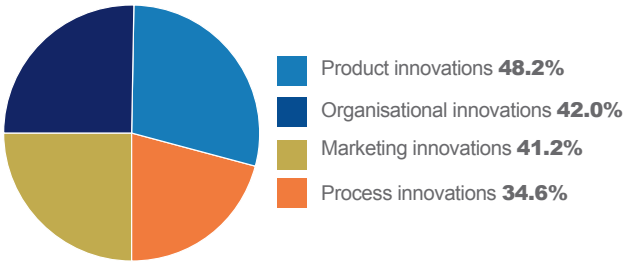


FIGURE 4.5: PREVALENCE OF INNOVATION WITHIN SOUTH AFRICAN ENTERPRISES

Source: HSRC's 2014–2016 South African Business Innovation Survey



Product innovation (incorporating goods or services) is the most dominant form of innovation within firms, accounting for almost half of all innovation (Figure 4.6). Marketing innovations entail activities such as new media or techniques for goods or service promotion (**42.9%** of all innovation-active enterprises), changes to the design or packaging of goods or services (**31.9%**), change of sales or distribution methods (**27.0%**), methods for goods or services placement (**22.1%**) and methods of pricing goods and services (**20.8%**).

FIGURE 4.6: DIFFERENT TYPES OF INNOVATIONS BY SOUTH AFRICAN ENTERPRISES

Source: HSRC's 2014–2016 South African Business Innovation Survey

Sources of information for innovation

The most important source of information for innovation on the part of firms is derived from the firm's internal sources, followed by clients or customers and suppliers of equipment, materials, components or software. Education and research institutions are far more significant to the service sector than to other sectors.

TABLE 4.7: SOURCES OF INFORMATION FOR INNOVATION-ACTIVE ENTERPRISES

SOURCES OF INFORMATION	2008	2009	2010
	PERCENTAGE OF INNOVATION-ACTIVE ENTERPRISES		
Internal sources			
Sources within your enterprise or enterprise group	45.6	48.6	43.7
External – market resources			
Clients or customers	37.8	49.8	30.3
Suppliers of equipment, materials, components or software	30.8	25.7	34.1
Competitors or other enterprises in your sector	17.4	23.3	13.8
Consultants, commercial laboratories or private R&D institutes	11.5	9.0	13.1
External – education and research			
Private research institutes	7.8	1.2	11.9
Government and public research institutions	7.4	1.5	11.1
Universities and other higher education institutions	2.8	1.7	3.5
External – other sources			
Conferences, trade fairs and exhibitions	22.2	22.9	21.8
Professional and industry associations	16.5	15.1	17.4
Scientific journals and trade/technical publications	7.2	6.8	7.4

Source: HSRC's 2014–2016 South African Business Innovation Survey

Innovation outcomes

For firms that undertake product innovation, by far the largest share of their turnover is derived from unchanged or marginally modified products. Only **1.8%** of their turnover is derived from innovations that are new to the world.

TABLE 4.8: BREAKDOWN OF TURNOVER BY PRODUCT'S LEVEL OF NOVELTY

LEVEL OF NOVELTY	Total (%)
All product innovators	
Innovations new to the world	1.8
Innovations new to the market	10.8
Innovations new to the firm	7.0
Unchanged or marginally modified	80.5

Source: HSRC's 2014–2016 South African Business Innovation Survey

Figure 4.7 shows the geographic distribution of goods and services sold by innovative firms vis-à-vis non-innovative enterprises. Compared to non-innovative firms, innovation-active enterprises tend to export a larger share of their output. With regard to domestic sales, innovative firms sell a larger share of their output on the national market as opposed to regional markets.

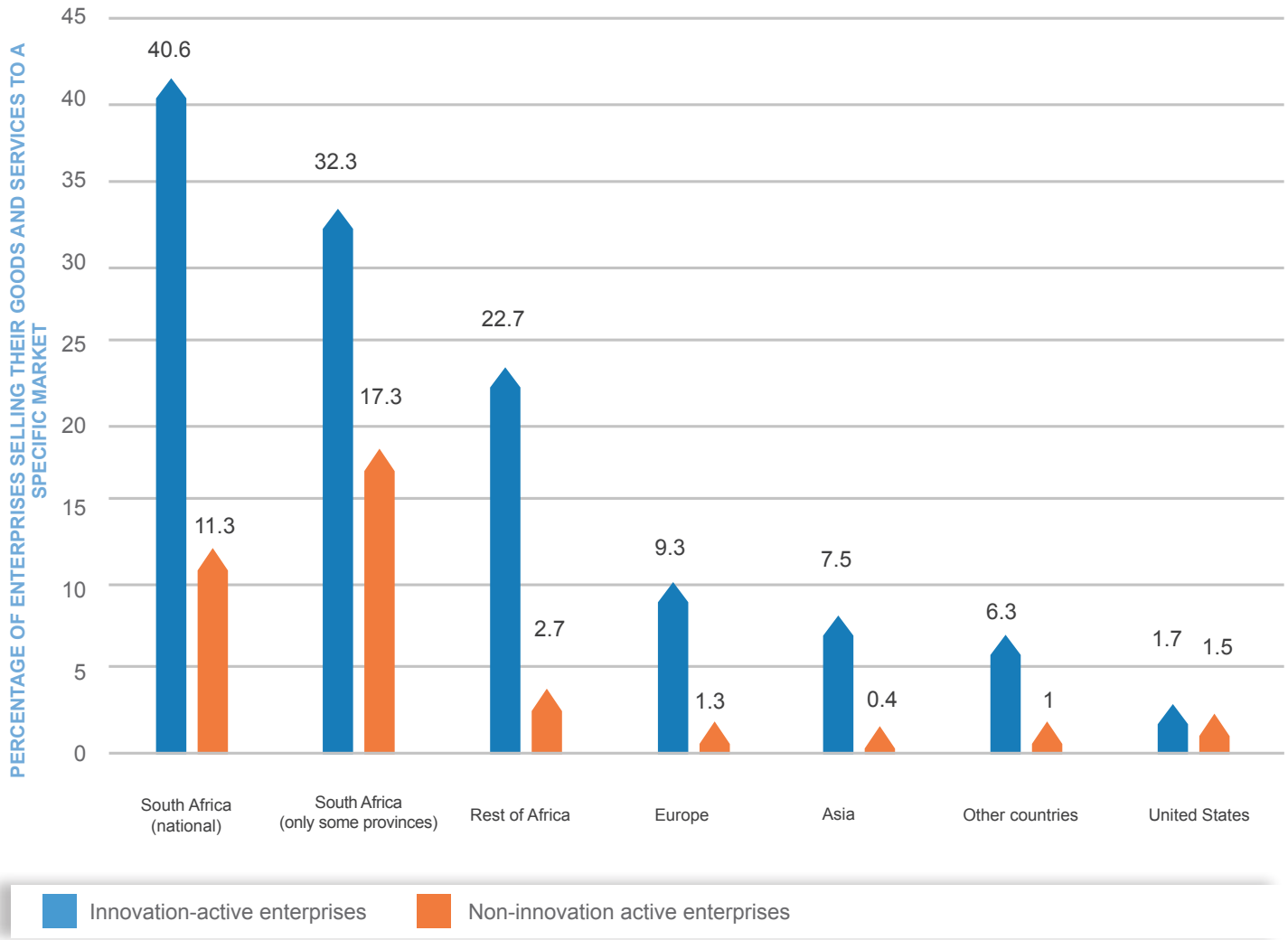


FIGURE 4.7: GEOGRAPHIC DISTRIBUTION OF GOODS AND SERVICES SOLD BY INNOVATIVE AND NON-INNOVATIVE ENTERPRISES

Source: HSRC's 2014–2016 South African Business Innovation Survey

It is apparent that innovation-active enterprises tend to export a larger share of their output in comparison to non-innovative firms. With regard to domestic sales, innovative firms sell a larger share of their output on the national market as opposed to regional markets.

5. INTELLECTUAL PROPERTY RIGHTS REGIME

5.1 Patents

Patents are among the most often used indicators of inventive activity. They are used internationally as indicators for corporate and national activity. Patents fulfil two roles. They provide inventors with legal protection for novel products and processes, and simultaneously ensure that the knowledge of these products and processes becomes available to society.

This section focuses on patents registered in the South African CIPC and patents granted to South African inventors by the USPTO.

The CIPC is a non-examining authority that registers patents. This means that patents may be of dubious quality and value, and they may attract international companies that may try to stifle innovation by local firms in particular technological domains. Data on domestic registrations is not very useful in determining local technological capacities.

Between 2008 and 2018, the number of patent applications to the CIPC averaged 7 250 per annum. However, there has recently been a decline in patents from 2017 to 2018. Patents are at a similar level to where they were a decade ago.

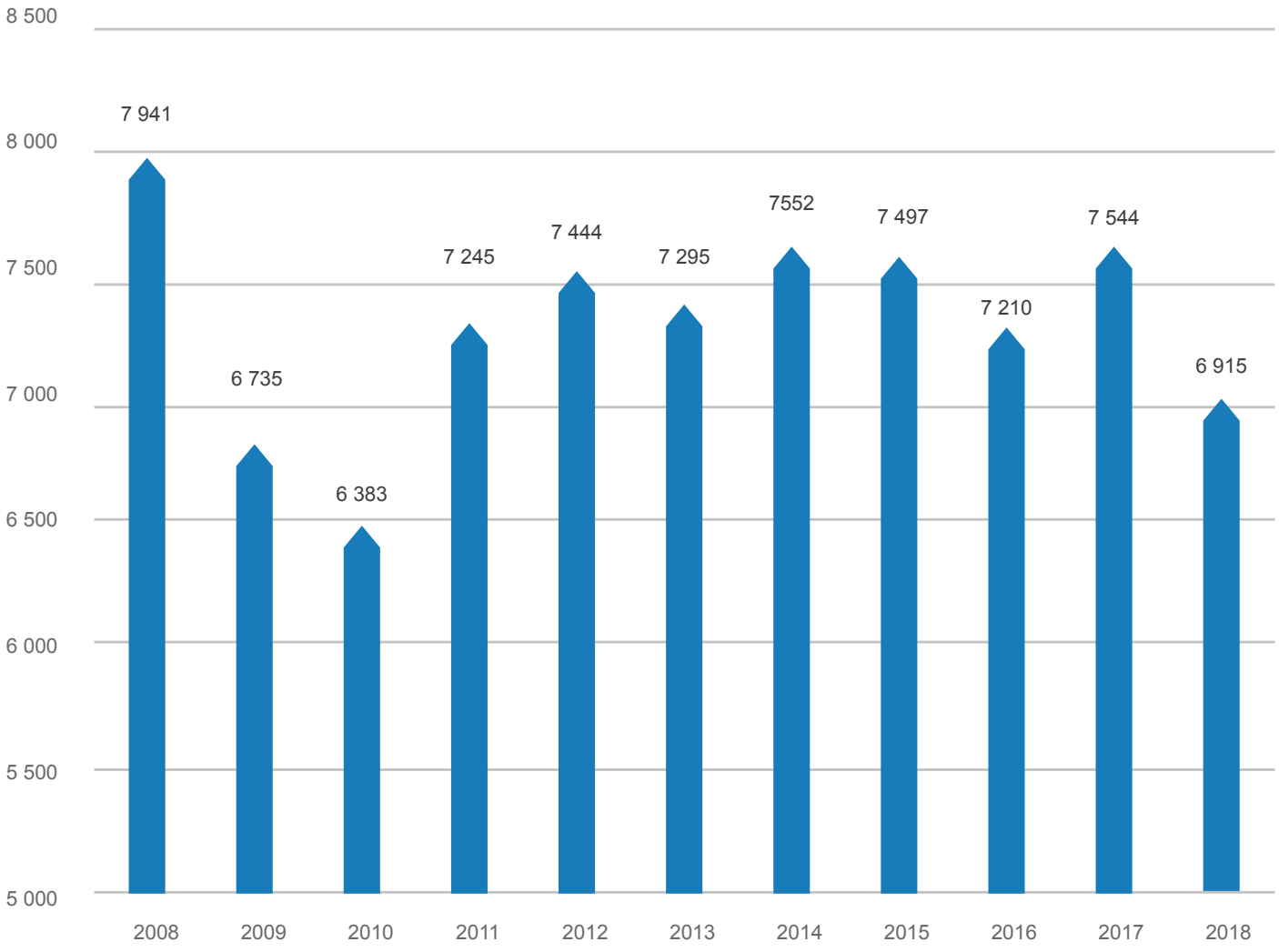


FIGURE 5.1: TOTAL NUMBER OF PATENT APPLICATIONS AT CIPC

Source: WIPO's IP Statistics Data Centre

Note: Includes both local and international applications and excludes provisional applications.

Table 5.1 shows the share of patent grants received by residents in the country by technology field. In the high-technology domains like pharmaceuticals and biotechnology, South Africa received a very small percentage of the patents by CIPC.

TABLE 5.1: PERCENTAGE SHARE OF RESIDENT PATENT GRANTS BY TECHNOLOGY FIELD AT CIPC

	2008	2009	2010	2011	2012	2013	2014
Civil engineering	39.0	38.1	34.2	31.9	34.9	29.6	29.5
Mechanical elements	26.0	24.8	27.8	18.5	31.2	18.6	28.7
Basic communication processes	9.1	18.8	50.0	0.0	18.2	0.0	25.0
Transport	30.7	23.5	23.1	23.9	22.3	23.1	23.7
Control	25.7	26.4	26.6	23.8	21.5	29.8	19.0
Other special machines	19.1	12.5	20.6	12.3	13.4	14.6	19.0
Furniture, games	14.9	22.2	32.2	28.6	40.0	21.4	18.0
IT methods for management	18.0	34.8	37.2	31.0	20.0	32.0	17.6
Semiconductors	8.3	3.3	14.3	30.0	2.9	5.4	17.2
Electrical machinery, apparatus, energy	17.5	22.1	29.4	20.7	14.3	11.3	15.6
Other consumer goods	23.8	28.8	35.0	30.6	29.1	18.2	15.3
Telecommunications	14.3	19.0	9.2	12.9	9.3	14.6	14.5
Thermal processes and apparatus	21.1	21.4	31.3	16.4	16.0	18.1	14.2
Handling	20.2	20.8	21.8	17.9	18.6	16.0	12.0
Audio-visual technology	25.6	23.8	25.0	18.2	19.3	15.6	11.1
Measurement	11.6	14.7	9.8	14.6	9.9	12.0	9.9
Machine tools	10.9	17.2	17.0	10.5	17.3	7.9	9.7
Optics	12.8	3.2	10.0	0.0	7.1	6.3	9.4
Environmental technology	15.7	22.9	21.7	12.2	7.4	17.8	9.3
Computer technology	16.3	15.6	17.2	10.4	20.4	17.0	8.6
Chemical engineering	13.0	14.5	11.1	4.3	9.8	7.4	8.0
Medical technology	8.6	5.6	6.4	9.6	10.7	4.8	7.1
Engines, pumps, turbines	11.9	12.3	14.8	17.2	8.0	8.8	6.3
Materials, metallurgy	10.9	7.4	8.3	7.8	7.7	5.5	5.0
Digital communication	4.4	7.0	6.3	5.1	4.4	5.4	4.2
Textile and paper machines	8.3	5.3	8.9	6.9	5.4	6.6	4.0
Food chemistry	7.4	4.3	3.6	5.3	7.0	6.1	3.1
Basic materials chemistry	8.1	4.6	5.0	4.8	3.9	3.8	2.5
Pharmaceuticals	1.3	1.3	1.2	2.0	2.6	1.7	1.4
Surface technology, coating	6.5	8.5	7.3	0.0	6.1	5.8	1.4
Macromolecular chemistry, polymers	2.7	2.2	7.8	0.0	1.5	4.7	1.3
Biotechnology	1.4	3.8	4.4	3.3	4.0	2.3	0.9
Organic fine chemistry	0.5	1.0	0.6	1.3	1.8	3.5	0.6
Micro-structural and nanotechnology	0.0	50.0	0.0	N/A	0.0	0.0	0.0
Unknown	16.7	15.8	15.8	11.9	14.9	21.8	22.9
Analysis of biological materials	12.5	0.0	0.0	N/A	N/A	N/A	N/A

Source: WIPO's IP Statistics Data Centre

While most countries have domestic patent offices, elements like domestic regulations, examination and costs vary considerably between countries. Thus, the number of patents at the USPTO are widely utilised for country comparative purposes. Although most countries in the world have their own patent authorities, the use of the USPTO provides a number of advantages. Firstly, in the majority of patent offices, patents are not examined for originality, usefulness and novelty. Consequently, counting and comparing patents awarded by different patent offices in different countries may be misleading because of differences in the criteria used and the ease of awarding patents, as well as bias towards local patents. The obvious solution in avoiding the abovementioned shortcomings is to use a common denominator such as an external patent system with an objective approach in its approach to awarding patents (i.e. the USPTO).

The USPTO examines claims according to a number of criteria: subject matter, utility, novelty, non-obviousness and definiteness. Moreover, the USA represents the most important single market for technological sales. Hence, it is a key drawcard for technology-based products. Owners of important commercial inventions will make sure that they are protected in the US market. Finally, the costs involved and the complexity of filing foreign patents in the USA tend to screen out trivial patents.

The USPTO grants a number of different types of patents. The most important patents are the utility patents or patents for invention. These patents constitute more than 90% of the USPTO's patents. Another type is plant patents. A plant patent is an intellectual property right that protects a new and unique plant's key characteristic from being copied, sold or used by others.

Table 5.2 shows the total number of grants awarded during the relevant years, the number of foreign (non-USA) grants, the number of local grants and the number of patents granted to South African inventors. A patent is allocated to South Africa when the first-mentioned inventor declares a South African domicile.

It is apparent that the total number of patents granted is almost equally divided between local and foreign owners.

TABLE 5.2: USPTO – PATENTS 2006–2019

Year	Total	Foreign	South African
2006	173 772	83 949	109
2007	157 282	77 755	82
2008	157 772	80 270	91
2009	167 349	84 967	93
2010	219 614	111 823	116
2011	224 505	115 884	123
2012	253 155	132 129	142
2013	277 835	144 243	161
2014	300 677	156 056	152
2015	298 408	157 439	166
2016	303 049	159 324	181
2017	318 828	167 876	182
2018	307 760	163 348	145
2019	354 430	187 315	182

Source: USPTO databases

The number of South African patents at the USPTO doubled between 2008 (91) and 2019 (182). Although there has been a general tendency for the number of patents granted to South Africans to increase over the last decade, there was a significant decline in 2018. The decline during 2018 is an issue that requires further investigation.

In 2019, South Africa was ranked **30th** in the world according to the number of patents granted at the USPTO. The country outside the USA that was granted the largest number of patents was Japan with **53 542** patents during 2019, followed by South Korea (**21 684** patents), the People's Republic of Korea (**19 209** patents) and Germany (**18 293** patents). India received **5 378** patents, Russia **622** patents and Brazil **425** patents.

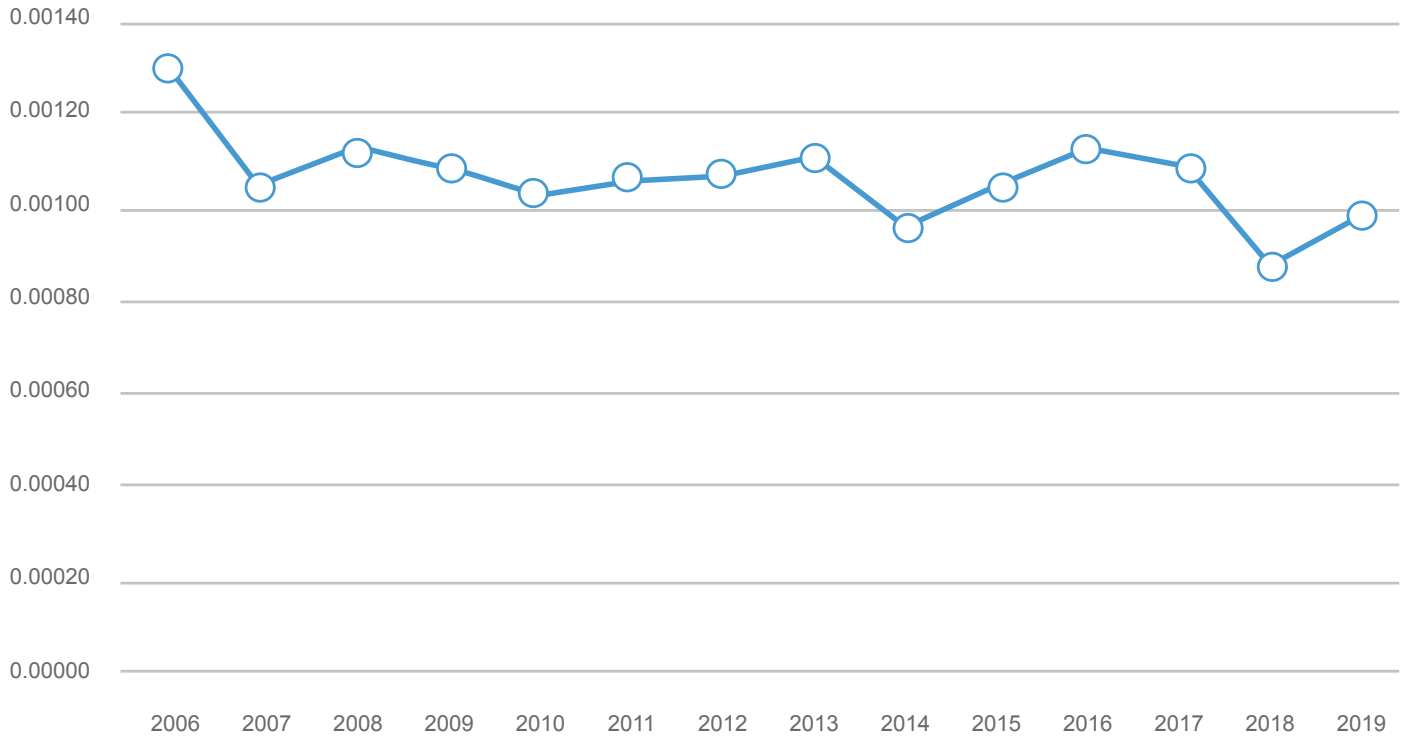


FIGURE 5.2: SHARE OF SOUTH AFRICAN TO FOREIGN USPTO PATENTS (2006–2019)

Source: USPTO databases

While there have been fluctuations, South African patents as a share of foreign patents at the USPTO has tended to decline.

Table 5.3 provides the plant patent statistics from USPTO. The USPTO grants a small number of plant patents compared to utility patents. Foreign recipients of plant patents by the USPTO are more than local recipients. South Africa was awarded 10 plant patents in 2019.

TABLE 5.3: USPTO PLANT PATENT STATISTICS

	Total, US and foreign origin	Subtotal US origin	Subtotal foreign origin	South Africa
Pre-2006	7 115	3 240	3 875	22
2006	1 149	430	719	5
2007	1 047	364	683	3
2008	1 240	433	807	1
2009	1 009	389	620	6
2010	981	297	684	2
2011	823	308	515	2
2012	860	315	545	1
2013	847	354	493	0
2014	1072	401	671	2
2015	1074	400	674	4
2016	1235	474	761	13
2017	1311	516	795	6
2018	1208	493	715	4
2019	1275	525	750	10
All years	**22 246**	**8 939**	**13 307**	**81**

Source: USPTO databases

Table 5.4 shows the top countries as ranked by the number of plant patents granted by the USPTO. South Africa, with **81** patents during the period, is ranked 16th. In terms of utility patents, South Africa is ranked **30th**. India is ranked **17th**, just after South Africa, the People's Republic of China is ranked **19th** and South Korea is ranked **20th**.

TABLE 5.4: COUNTRY RANKING ACCORDING TO TOTAL PLANT PATENTS

	Country	Number of plant patents
1.	The Netherlands	4 171
2.	Germany	2 553
3.	Japan	1 161
4.	Denmark	961
5.	United Kingdom	870
6.	Australia	749
7.	France	602
8.	Israel	447
9.	Belgium	347
10.	New Zealand	316
11.	Canada	178
12.	Costa Rica	133
13.	Italy	128
14.	Thailand	109
15.	Spain	85
16.	South Africa	81
17.	India	58
18.	Czech Republic	38
19.	People's Republic of China	30
20.	South Korea	27

Source: USPTO databases

5.2 Innovation outputs

This section elaborates on issues of exports according to technological intensity and commercial service exports, and the technology balance of payments.

5.2.1 Merchandise exports by technology intensity

Figure 5.3 shows South African merchandise exports for the period 2008-2018 in US dollars.

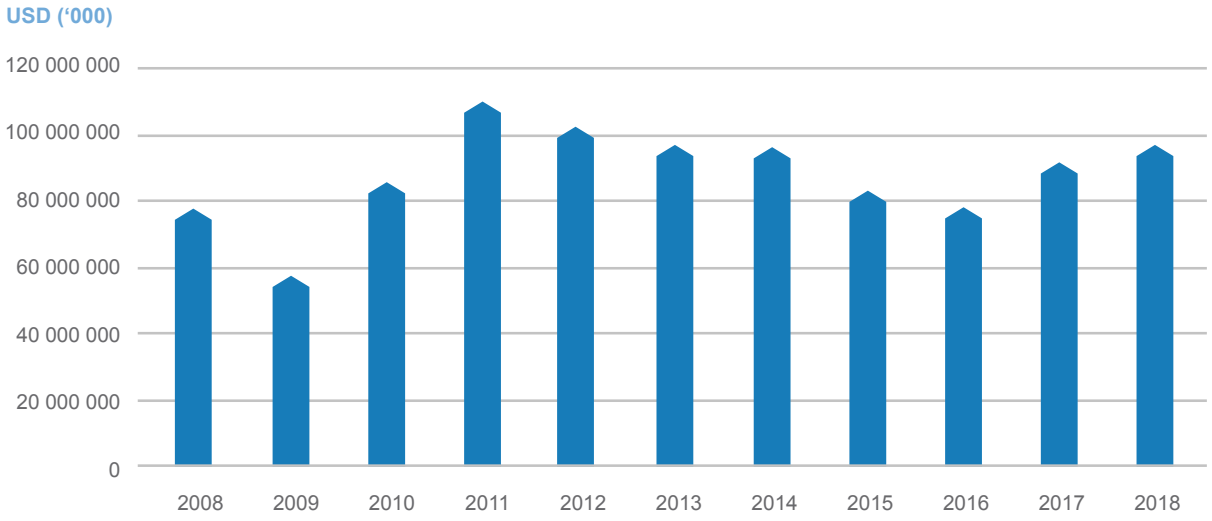


FIGURE 5.3: TOTAL SOUTH AFRICAN MERCHANDISE EXPORTS (2008–2018)

Source: United Nations Conference on Trade and Development

Table 5.5 shows the distribution of merchandise exports by technology intensity. South Africa's exports are focused on primary products, resource-based manufacture and medium-technology manufacture. The largest contributor to the export of medium-term technology exports is the automotive industry, whose share has increased slowly over the last decade. The export share of high-technology manufacture showed some increase in the period 2014–2016. However, there has been a notable decline since then and the share of high-technology manufacture exports was lower in 2018 than it was in 2008.

TABLE 5.5: DISTRIBUTION OF MERCHANDISE EXPORTS BY TECHNOLOGY INTENSITY

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
	PERCENTAGE										
Primary products	30.1	31.6	28.0	25.9	23.6	24.8	22.8	24.6	25.0	26.6	26.6
Resource-based manufacturer	26.3	28.3	29.3	28.7	29.1	30.7	29.6	26.9	26.4	28.0	28.1
Agro-based	5.3	7.1	7.1	6.0	6.2	6.5	6.7	6.9	7.1	6.8	6.6
Other	21.0	21.1	22.2	22.7	22.9	24.2	22.9	20.0	19.4	21.2	21.5
Low-technology manufacture	7.3	7.7	8.8	6.8	7.2	6.8	7.1	6.9	7.1	6.8	6.8
Textile, garment and footwear	0.7	0.8	1.3	1.2	1.3	1.4	1.5	1.5	1.5	1.4	1.4
Other products	6.5	6.9	7.4	5.6	5.9	5.4	5.6	5.4	5.6	5.3	5.5
Medium-technology manufacture	32.1	28.1	29.2	25.0	26.6	26.3	28.2	30.0	30.5	27.8	28.2
Automotive	9.8	9.1	9.0	7.6	8.5	8.2	9.1	11.1	11.9	10.8	11.3
Process	12.9	10.8	11.4	9.3	9.6	9.8	10.8	10.5	10.4	10.0	9.7
Engineering	9.4	8.2	8.8	8.1	8.5	8.3	8.3	8.4	8.2	7.0	7.2
High-technology manufacture	3.4	3.6	3.4	3.0	3.4	3.3	3.8	4.1	4.0	3.2	2.9
Electronic and electrical	1.9	2.2	2.0	1.8	2.0	2.0	2.3	2.3	2.2	1.8	1.7
Other	1.5	1.4	1.4	1.2	1.3	1.3	1.5	1.8	1.9	1.4	1.2
Unclassified products	0.8	0.8	1.3	10.6	10.0	8.2	8.5	7.5	6.9	7.7	7.5

Source: United Nations Conference on Trade and Development

High-technology exports refer to products with high R&D intensity, such as in aerospace, computers, pharmaceuticals, scientific instruments and electrical machinery. Their importance lies in their high-technology intensity and high values in comparison to the value of the primary products.

Table 5.6 shows the values of South African high-technology exports for the period 2007–2018. The value of exports increased from **US$1.9 billion** in 2007 to **US$2.2 billion** in 2018.

TABLE 5.6: VALUE OF SOUTH AFRICA'S HIGH-TECHNOLOGY EXPORTS (US$)

Date	Value	Percentage change
2018	2 239 945 787	9.80
2017	2 040 001 338	-9.26
2016	2 248 150 985	-15.78
2015	2 669 358 887	-5.64
2014	2 829 000 147	7.44
2013	2 633 031 431	-7.56
2012	2 848 376 245	5.65
2011	2 696 075 884	12.52
2010	2 396 111 473	60.62
2009	1 491 786 653	-28.58
2008	2 088 731 883	8.04
2007	1 933 241 745	

Source: World Data Atlas (https://knoema.com/atlas/South-Africa)

Figure 5.4 shows the country's high-technology exports since 1992. The exports increased from **US$500 million** to **US$ 2.5 billion** by the end of the period.

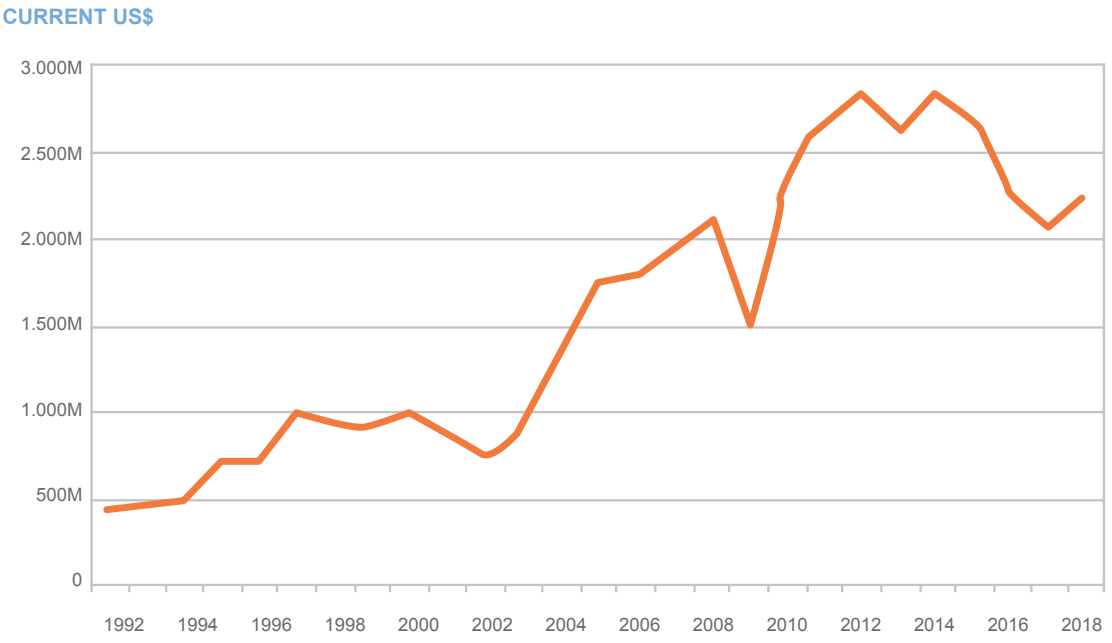


FIGURE 5.4: SOUTH AFRICA'S HIGH-TECHNOLOGY EXPORTS (1992–2018)

Source: World Data Atlas (https://knoema.com/atlas/South-Africa)

Table 5.7 shows that, during 2018, high-technology exports constituted only **5.3%** of South Africa's total merchandise exports. Hong Kong had **64.6%** of its exports in high-technology products.

TABLE 5.7: HIGH-TECHNOLOGY EXPORTS AS A SHARE OF MANUFACTURED EXPORTS – SOUTH AFRICA AND COUNTRIES WITH HIGH-TECHNOLOGY SHARES

		2018	2017	2016	2015	2014	2013	2012	2011	2010	2005	2000	1990
76	South Africa	5.3	5.2	6.2	7.0	6.6	6.5	6.6	6.1	6.0	6.7	7.0	–
1	Hong Kong SAR, China	64.6	61.6	13.5	12.3	11.1	13.9	18.5	20.8	36.8	15.6	23.4	–
2	Philippines	61.1	60.2	55.1	53.1	49.0	49.2	48.9	46.4	55.3	70.8	72.6	–
3	Malaysia	52.8	50.5	48.9	48.2	49.1	48.4	47.5	47.2	49.3	54.6	59.6	38.2
4	Singapore	51.7	53.1	52.4	52.4	50.8	50.4	48.4	47.7	52.3	34.7	62.8	39.9
5	Palau	51.7	26.8	60.5	41.2	20.2	–	19.3	–	–	–	–	–
6	Sao Tome and Principe	46.0	34.7	68.2	47.0	1.4	14.5	14.5	2.0	14.0	7.7	–	–
7	Vietnam	40.2	41.4	37.8	–	31.7	33.2	26.9	18.6	13.0	5.4	11.1	–
8	Lao PDR	37.1	37.4	33.6	35.2	24.9	9.8	8.7	8.2	6.8	–	–	–
9	Republic of Korea	36.3	32.5	30.5	31.2	30.0	29.8	28.2	28.1	32.0	32.5	35.1	18.0
10	Malta	32.2	29.9	22.0	30.5	34.8	38.8	46.1	47.5	47.2	52.0	71.7	44.9
11	China	31.4	30.9	30.2	30.4	29.7	31.6	30.9	30.5	32.1	30.8	19.0	–
12	Andorra	28.5	23.3	24.3	22.6	20.7	23.6	20.7	18.5	23.6	26.4	10.9	–
13	France	25.9	26.1	28.1	28.4	27.6	27.3	26.9	25.3	26.6	20.3	24.6	16.7
14	Ireland	24.7	29.0	32.7	2.2	24.8	24.8	25.5	24.8	22.8	34.7	47.8	41.1
15	Iceland	23.5	26.4	23.4	20.1	17.1	15.7	15.4	21.1	21.2	34.0	12.9	10.0
16	Thailand	23.3	24.7	24.1	23.8	22.5	22.0	22.6	22.6	26.2	26.7	33.4	20.9
17	Angola	23.1	17.0	13.6	13.8	–	–	–	–	–	–	–	–
18	Israel	22.8	21.4	21.8	22.9	19.4	19.0	19.9	18.5	19.5	14.0	19.4	10.7
19	Netherlands	22.7	22.5	23.8	24.1	25.8	26.0	25.5	25.1	27.8	30.9	35.8	16.5

Source: World Data Atlas (https://knoema.com/atlas/South-Africa)

Table 5.8 shows the values of imports and exports in commercial services and the rankings of the different countries. South Africa is ranked 30th as an exporter to commercial services and **33rd** as an importer of commercial services.

TABLE 5.8: RANKING OF COUNTRIES ACCORDING TO THE EXPORT AND IMPORT OF COMMERCIAL SERVICES

Rank	Exporters	Value	Share	Annual percentage change
1	Extra-EU (28) exports	1 089	25.1	7
2	United States of America	808	18.7	4
3	China	265	6.1	17
4	India	204	4.7	11
5	Japan	187	4.3	3
6	Singapore	184	4.2	7
7	Switzerland	123	2.8	2
8	Hong Kong, China	114	2.6	9
9	Republic of Korea	95	2.2	10
10	Canada	92	2.1	6
11	Thailand	84	1.9	11
12	United Arab Emirates	71	1.6	2
13	Australia	68	1.6	7
14	Russian Federation	64	1.5	12
15	Chinese Taipei	50	1.2	12
16	Israel	50	1.2	12
17	Turkey	48	1.1	11
18	Macao, China	44	1.0	12
19	Norway	43	1.0	5
20	Malaysia	40	0.9	7
21	Philippines	37	0.9	8
22	Brazil	33	0.8	-1
23	Mexico	28	0.7	5
24	Indonesia	27	0.6	10
25	Egypt	23	0.5	23
26	Morocco	18	0.4	8
27	Qatar	18	0.4	1
28	Kingdom of Saudi Arabia	17	0.4	0
29	New Zealand	17	0.4	5
30	South Africa	16	0.4	1
31	Ukraine	15	0.4	12
32	Lebanese Republic	15	0.4	1
33	Vietnam	15	0.3	15
34	Argentina	14	0.3	-4
35	Panama	14	0.3	3
36	Kingdom of Bahrain	12	0.3	5
37	Cuba	11	0.2	-6
38	Iran (1)	10	0.2	...
39	Chile	10	0.2	0
40	Colombia	9	0.2	12
	Total of above	**4082**	**94.2**	**-**
	World (excl. intra-EU (28))	**4333**	**100.0**	**7**

Rank	Importers	Value	Share	Annual percentage change
1	Extra-EU (28) imports	865	20.6	7
2	United States of America	536	12.8	3
3	China	521	12.4	12
4	Japan	198	4.7	4
5	Singapore	187	4.4	3
6	India	175	4.2	14
7	Republic of Korea	123	2.9	2
8	Canada	112	2.7	5
9	Switzerland	103	2.5	0
10	Russian Federation	93	2.2	7
11	Hong Kong, China	81	1.9	5
12	United Arab Emirates	71	1.7	1
13	Australia	71	1.7	6
14	Brazil	66	1.6	-1
15	Chinese Taipei	56	1.3	6
16	Kingdom of Saudi Arabia	55	1.3	2
17	Thailand	55	1.3	19
18	Norway	52	1.2	4
19	Malaysia	44	1.1	5
20	Mexico	37	0.9	1
21	Indonesia	35	0.8	7
22	State of Kuwait	34	0.8	23
23	Qatar	31	0.7	3
24	Nigeria	31	0.7	70
25	Israel	30	0.7	7
26	Philippines	26	0.6	2
27	Argentina	24	0.6	-4
28	Turkey	22	0.5	-3
29	Iran (1)	19	0.4	...
30	Vietnam	18	0.4	8
31	Egypt	18	0.4	11
32	Iraq	18	0.4	10
33	South Africa	16	0.4	2
34	Lebanese Republic	14	0.3	4
35	Chile	14	0.3	5
36	Ukraine	14	0.3	12
37	New Zealand	14	0.3	6
38	Colombia	13	0.3	7
39	Oman (1)	12	0.3	...
40	Kazakhstan	12	0.3	18
	Total of above	**3915**	**93.3**	**-**
	World (excl. intra-EU (28))	**4198**	**100.0**	**7**

Source: World Trade Statistical Review 2019

5.3 Technology balance of payments

TABLE 5.9: TECHNOLOGY BALANCE OF PAYMENTS (CURRENT US$) – SELECTED COUNTRIES (2018)

Country	Current US$ billion
South Africa	1.7
Australia	3.6
Brazil	5.1
Canada	11.8
China	35.7
India	7.9
Republic of Korea	9.8
Malaysia	2.0
Russia	6.2

Source: World Bank data

The technology balance of payments registers commercial transactions related to international technology and know-how transfers. It consists of money paid or received for the use of patents, licences, know-how, trademarks, patterns, designs, technical services (including technical assistance) and for industrial R&D carried out abroad.

Technology balance of payments reflects a country's ability to sell its technology. Receipts from the sale of technology are an indication of a country's capacity to produce technology that is in demand globally and hence is a good indication of a country's technological development.

Table 5.9 shows the technology balance of payments in South Africa and a number of other countries. South Africa's technology balance of payment of US$1.7 billion is the smallest.

Table 5.10 shows the technology balance of payments in South Africa for the period 2000–2018. The technology receipts increased from around **US$20 million** at the beginning of the period to **US$120 million** at the end of the period. Payments, however, increased even more rapidly from **US$250 million** to approximately **US$2 billion** by the end of the period. Since 2012, the payments have stabilised to around **US$2 billion** annually (**R28 billion** at a 2017 exchange rate). Considering that BERD was around **R15 billion**, the ratio of BERD to the technology balance of payments is **53%**. In other words, South African businesses spend an equal amount of money abroad as they do locally.

TABLE 5.10: TECHNOLOGY BALANCE OF PAYMENTS IN SOUTH AFRICA (2000–2018)

Year	Payments	Receipts	Payments minus receipts (technology balance of payments)
2000	245 895 910	49 094 178	196 801 732
2001	329 528 506	21 490 396	308 038 110
2002	446 513 324	19 454 588	427 058 736
2003	616 743 679	26 550 160	590 193 519
2004	891 018 800	37 391 888	853 626 912
2005	1 071 000 000	45 302 063	1 025 697 937
2006	1 282 000 000	55 106 998	1 226 893 002
2007	1 596 000 000	75 106 030	1 520 893 970
2008	1 676 000 000	78 842 738	1 597 157 262
2009	1 658 000 000	75 704 499	1 582 295 501
2010	1 941 000 000	113 985 144	1 827 014 856
2011	2 118 000 000	134 505 552	1 983 494 448
2012	2 017 000 000	124 888 029	1 892 111 971
2013	1 937 000 000	119 974 977	1 817 025 023
2014	1 732 000 000	116 468 991	1 615 531 009
2015	1 708 000 000	103 118 206	1 604 881 794
2016	1 984 000 000	109 422 730	1 874 577 270
2017	2 124 000 000	119 040 051	2 004 959 949
2018	1 817 000 000	120 715 706	1 696 284 294

Source: World Bank data

6. PROVINCIAL INDICATORS

Regional innovation is an important driver of overall regional economic development. The White Paper on Science, Technology and Innovation has re-iterated the importance of innovation at regional level. One of its policy intents is to increase the spatial footprint of innovation in South Africa by developing "local innovation systems"[5].

In order to stimulate innovation, several provinces have developed regional innovation strategies. These include Gauteng, Limpopo, the Eastern Cape and the Western Cape. At provincial level, regional innovation forums have been established to create linkages and networking.

This section examines the state of South Africa's provincial systems of innovation.

6.1 Indicators for regional innovation systems

This subsection presents the findings on provincial R&D expenditure, human resources, access to the internet and non-R&D investment among the nine provinces.

6.1.1 Provincial R&D performance

Successful innovation, increased productivity and the resulting prosperity are the outputs of the dynamic interplay of a variety of regional factors. One of the key inputs is investment in R&D. Access to capital is vital to supporting entrepreneurship and innovation. In this subsection, the level of investment in R&D by the various innovation actors in South Africa's nine provinces is summarised.

The data in Table 6.1 compares R&D expenditure in the nine provinces according to the sources of funding. The data in this table also displays the information in terms of the various sources of funds. The data shows that Gauteng has the highest proportion of South Africa's total R&D expenditure (**44.7%**), followed by the Western Cape (**24.1%**) and KwaZulu-Natal.

This is expected, as these provinces are South Africa's main economic hubs. They are home to the largest companies in the country, most of which invest in R&D. They are also home to the top universities and science councils in the country and can attract R&D funding from both government sources and the private sector. The provinces with the lowest share of R&D expenditure are the Northern Cape (**1.5%**), Mpumalanga (**1.6%**) and Limpopo (**2.2%**). The key finding is that the data in Table 6.1 reveals a great disparity in R&D expenditure among the various provinces. Gauteng and the Western Cape dominate innovation activities and attract the overwhelming share of funding from all sources.

TABLE 6.1: PROVINCIAL R&D EXPENDITURE TRENDS (2017/18)

	Eastern Cape	Free State	Gauteng	KwaZulu-Natal	Limpopo	Mpumalanga	Northern Cape	North West	Western Cape
Total R&D expenditure (R million)	2 300	2 149	17 319	4 172	854	715	576	1 306	9 328
Provincial GDP	331 093	217 849	1 507 082	692 222	311 686	323 722	90 883	279 733	596 043
Provincial expenditure as a percentage of GERD	0.7	0.99	1.15	0.61	0.28	0.22	0.64	0.47	1.57
BERD (R million)	707	1 105	8 285	1 679	223	304	565	60	2 927
Proportional business sector R&D expenditure by province	4.5	7.0	52.2	10.6	1.4	1.9	3.6	0.4	18.5
Proportional higher education sector R&D expenditure by province (%)	7.8	6.9	32.8	11.0	2.8	1.2	3.5	1.4	32.7
Proportional science councils sector R&D expenditure by province (%)	4.4	0.9	53.1	8.6	1.7	1.9	1.5	3.8	24.1
Proportional government sector R&D expenditure by province (%)	12.1	3.5	41.9	8.9	3.7	4.5	2.6	4.1	18.7
Proportional not-for-profit sector R&D expenditure by province (%)	1.2	0.7	36.2	26.1	6.5	2.7	11.0	0.4	15.2

Source: HSRC and DSI's National Survey of Research and Experimental Development

5 Department of Science and Innovation, 2019

6.1.2 Human resources

Adult literacy

Literacy rates can be used as a key social indicator of development. A simple definition of literacy is the ability to read and write in at least one language. The simplicity of this measure is, however, complicated by the need to know what is read and written, for what purpose, and how well it is done. Because it is so difficult to measure literacy, Statistics South Africa's General Household Survey (GHS) has historically measured adult literacy rates based on an individual's functional literacy (whether they have completed at least Grade 7 or not). Since a specific educational achievement is not necessarily a good reflection of an individual's literacy ability, a question that directly measures literacy was introduced in 2009. This question requires respondents to indicate whether they have "no difficulty", "some difficulty", "a lot of difficulty" or "are unable" to read newspapers, magazines and books in at least one language; or to write a letter in at least one language.

The adult literacy rates for persons aged 20 years and older, by province, from 2013 to 2017, is shown in Table 6.2. Overall, the literacy rate is high. The Western Cape had the highest level in 2017 and the gaps in literacy level among the provinces is low.

TABLE 6.2: ADULT LITERACY RATES FOR PERSONS AGED 20 YEARS AND OLDER BY PROVINCE

	Eastern Cape	Free State	Gauteng	KwaZulu-Natal	Limpopo	Mpumalanga	Northern Cape	North West	Western Cape
2013	90.2	92.9	97.9	88.0	91.4	88.1	88.3	88.0	97.8
2015	90.3	94.6	97.8	89.4	92.8	90.5	88.5	89.5	97.8
2017	91.1	94.2	97.8	89.9	94.0	91.6	89.5	89.6	98.1

Source: Statistics South Africa's 2017 General Household Survey

Post-secondary educational attainment

Table 6.3 shows post-secondary educational attainment among individuals aged between 25 and 64 years by province in 2016. Gauteng has the highest percentage of individuals with post-secondary education (**16.3%**) compared to the other provinces. The Northern Cape has the lowest percentage of individuals with post-secondary qualifications (**7.8%**).

TABLE 6.3: POST-SECONDARY EDUCATION ATTAINMENT AMONG INDIVIDUALS AGED 25 TO 64 BY PROVINCE (2016)

Eastern Cape	Free State	Gauteng	KwaZulu-Natal	Limpopo	Mpumalanga	Northern Cape	North West	Western Cape
9.5	10.2	16.3	10.7	10.7	9.5	8.2	7.8	13.0

Source: Statistics South Africa's 2016 Education Series Volume III: Educational Enrolment and Achievement

Matric performance in maths and physical science

Mathematics and physical science are priority subjects in terms of the Sector Plan for Basic Education in government's Medium-term Strategic Framework (MTSF) and the National Development Plan. Both subjects are an important foundation for STI-related careers as they enable logical reasoning.

Table 6.4 shows the provincial performance of matric candidates in mathematics in 2018. It shows data for learners who achieved 30% and above and also for those who achieved 40% and above. If one focuses on the data that shows the percentage of candidates who achieved 40% and above, the Western Cape had the highest percentage of learners that were the highest performers (**55.7%**), followed by Gauteng (**52.5%**) and the Free State (**49.3%**). The performance of all the other provinces was below 50%, with the Eastern Cape recording the lowest performance (**25.9%**).

TABLE 6.4: MATRIC PERFORMANCE IN MATHEMATICS BY PROVINCE AND LEVEL OF ACHIEVEMENT (2018)

Province	Total who wrote	Total who achieved 30% and above	Percentage that achieved 30% and above	Total that achieved 40% and above	Percentage that achieved 40% and above
Eastern Cape	36 449	16 576	45.5	9 438	25.9
Free State	9 722	7 226	74.3	4 794	49.3
Gauteng	35 279	26 366	74.7	18 510	52.5
KwaZulu-Natal	61 686	31 191	50.6	19 327	31.3
Limpopo	39 216	21 538	54.9	13 032	33.3
Mpumalanga	24 207	13 112	54.2	8 029	33.2
North West	9 083	6 259	68.9	3941	43.4
Northern Cape	2 798	1 652	59.0	1 057	37.8
Western Cape	15 418	11 718	76.0	8 746	56.7
National	**233 858**	**135 638**	**58.0**		

Source: Department of Basic Education's National Senior Certificate Examination Report 2018

Table 6.5 shows the performance of learners in physical science by province and level of achievement. In physical sciences, learners in Gauteng achieved the highest performance in the 40% and above category (**60.2%**), followed by the Western Cape (**60.2%**), the Free State (**55.6%**) and North West (**50.2%**). The weakest performer was the Eastern Cape (**39.4%**). The rest of the provinces fell below 50% in this category.

TABLE 6.5: MATRIC PERFORMANCE IN PHYSICAL SCIENCE BY PROVINCE (2018)

Province	Total who wrote	Total who achieved 30% and above	Percentage that achieved 30% and above	Total that achieved 40% and above	Percentage that achieved 40% and above
Eastern Cape	24 939	16 582	66.5	9 816	39.4
Free State	7876	6 433	81.7	4 378	55.6
Gauteng	26 763	22 335	83.5	16 308	60.9
KwaZulu-Natal	40 643	29 919	73.6	19 730	48.5
Limpopo	31 717	22 785	71.8	13 914	43.9
Mpumalanga	20 387	14 321	70.2	8 982	44.1
North West	7 348	5775	78.6	3 688	50.2
Northern Cape	2259	1512	66.9	930	41.2
Western Cape	10 857	8 039	79.5	6 256	60.2
National	**172 319**	**127 919**	**74.2**	**84 002**	**48.7**

Source: Department of Basic Education's National Senior Certificate Examination Report 2018

6.1.3 Access to the internet

Connectivity through access to the internet underpins the growth of the information society and serves as the basis for transition to its economic counterpart, the knowledge-based economy.

According to Statistics South Africa's data from the GHS of 2016, household internet usage nationally was reported at **59.3%**. This essentially means that, for **59.3%** of households, at least one member in that household had access to the internet either at home, at the workplace, at their place of study, or at an internet café. Gauteng had the highest percentage at **72.2%**, followed by the Western Cape at 68.5%.

TABLE 6.6: ACCESS TO THE INTERNET AT PROVINCIAL LEVEL

	Eastern Cape	Gauteng	Free State	KwaZulu-Natal	Limpopo	Mpumalanga	Northern Cape	North West	Western Cape
Anywhere	49.2	72.2	56.1	51.2	42.4	58.1	54.9	53.7	68.5
At home	3.9	14.8	5.3	5.3	1.6	5.9	5.5	3.5	23.6

Source: Statistics South Africa's 2016 General Household Survey

The percentage of households with access to the internet at home, or for which at least one member had access to or used the internet by province for 2016, shows that there is very low access to the internet at home. The province with the highest access to the internet at home is the Western Cape (**23.6%**), followed by Gauteng at **14.8%**. In all the other provinces, access to the internet at home was below 10%.

6.1.4 Government non-R&D investment in innovation support

Innovation depends on the availability of distinct regional resources that gives it a competitive advantage. Examples of regional innovation resources in South Africa include, but are not limited to, regional firms and industry associations, universities, public and private research centres, science parks, incubators, living labs, financial organisations and venture capitalists, and – of course – local talent and unique skills.

Entrepreneurs and innovators require enabling workspaces to enhance collaboration. Physical infrastructure is critical to provide innovators with space to engage, interact and network. Regular meetings, conferences and workshops can significantly reinforce the interaction between universities, businesses and government for the purposes of innovative development. Physical and digital environments are needed to support and enhance collaboration, co-learning, entrepreneurship and the creation of effective solutions to urban issues. Science parks, incubators and innovation labs provide physical spaces for interaction and the exchange of knowledge. In this subsection, specialised physical space that supports innovators at provincial level is presented.

Science parks

At regional level, science parks are important, especially in promoting the Triple Helix Model of Innovation. South Africa has a number of science parks located in the different provinces. The Innovation Hub was established as a joint initiative between the Gauteng Provincial Government and the University of Pretoria. Despite its slow start, the science park has become a hub for innovators. It has succeeded in attracting the paper-giant Sappi to build its research facility on its premises. Later, a biopark was built to house life science companies.

Another science park is located at the Vaal University of Technology (VUT) in Southern Gauteng. This park plays an important role because it is located next to a township and serves the marginalised community of Sebokeng. In the Eastern Cape, a science park is housed in the East London Economic Development Zone, and the Western Cape is home to the Technopark in Stellenbosch. Other provinces are planning to establish their own science parks.

TABLE 6.7: LIST OF SCIENCE PARKS AT REGIONAL LEVEL

Province	Science park
Eastern Cape	ELDZ-Science Park, East London
Free State	Science Park, Bloemfontein
Gauteng	Innovation Hub, Pretoria
VUT Science Park, Sebokeng	
Limpopo	Feasibility study underway
Mpumalanga	None
Northern Cape	None
North West	None
KwaZulu-Natal	None
Western Cape	Technopark, Stellenbosch

Sources: Various websites

Technology stations

The Technology Stations Programme was established to enable universities to provide technology development services to small, medium and micro enterprises (SMMEs). Located at the Technology Innovation Agency (TIA), the Technology Stations Programme is a management and systems-wide support unit responsible for all technology stations across the country. The TIA, as the implementing agency, provides financial support to technology stations to provide innovative science, engineering and technology solutions for complex engineering challenges within the relevant industrial sectors. Figure 6.1 shows the spatial distribution of the technology stations.

There are currently **18** technology stations (not all are shown on the map) distributed throughout the country. An attempt has been made to not only build stations in urban areas, but also in rural areas. The stations are therefore crucial infrastructure for supporting innovation in the regions.

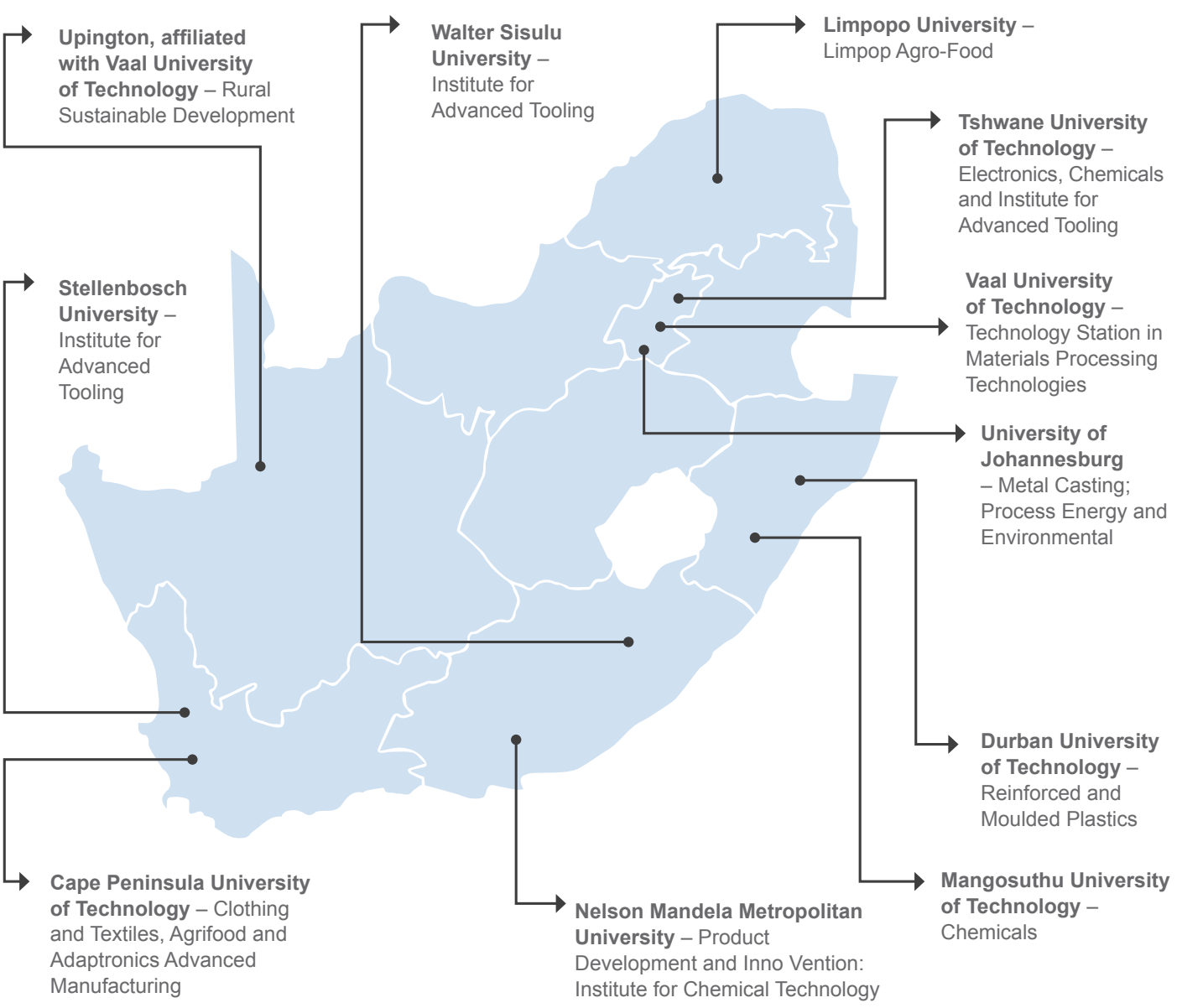


FIGURE 6.1: MAP OF TECHNOLOGY STATIONS IN SOUTH AFRICA

Source: Technology Innovation Agency

As shown in Table 6.8, some of the provinces, such as Mpumalanga and the North West, do not have technology stations at all, while others, such as Gauteng and the Western Cape, have several. It can be argued that this could limit the innovative performance of regions who lack this innovation support.

TABLE 6.8: TECHNOLOGY STATIONS AT VARIOUS HIGHER EDUCATION INSTITUTIONS

Gauteng	Limpopo	North West	Eastern Cape	Free State	Mpumalanga	Northern Cape	KwaZulu-Natal	Western Cape
Technology Station in Electronics – Tshwane University of Technology	Limpopo Agrifood Technology Station – University of Limpopo		Automotive Components Technology Station – Nelson Mandela Metropolitan University	Product Development Technology Station – Central University of Technology		Vaal University of Technology	Technology Station in Reinforced Material and Plastics – Durban University of Technology	Technology Station in Clothing and Textile – Cape Peninsula University of Technology
Metal Casting Technology Station – University of Johannesburg			Downstream Chemicals Technology Stations – Nelson Mandela Metropolitan University				Technology Station in Chemicals – Mangosuthu University of Technology	Agrifood Technology Station – Cape Peninsula University of Technology
Material Processing Technologies – Vaal University of Technology			Institute for Advanced Tooling, East London – Walter Sisulu University					Institute of Advanced Manufacturing – Stellenbosch University
Technology Station in Chemicals – Tshwane University of Technology								
Institute for Advanced Tooling, Soshanguve – Tshwane University of Technology								

Source: Technology Innovation Agency

Fabrication Labs

The DSI introduced the Fabrication Lab (FabLab) concept. A FabLab consists of a suite of off-the-shelf, industrial grade, digital fabrication tools, an electronics workbench, seven computers and programming tools, and is supported by open-source design software. In essence, a FabLab is a small-scale version of a production factory. While a FabLab cannot be used to manufacture thousands of assembly-line products, it can be used by individuals to create prototypes, from arts and crafts to engineering and architecture models. Computer-based design or drawing software, in most cases open-source software, is used to create designs that are automatically manufactured by an appropriate cutting, milling or forming machine. The distribution of the current FabLabs in South Africa is shown in Figure 6.2.

The FabLabs can also be used to enable grassroots inventions by providing a platform where communities can have access to advanced tools that can help people make products to address local needs. The strength of the FabLab initiative is that users get to complete the concept design fabrication process to make physical products, i.e. a fully "hands-on" experience. The environment created in the FabLab is that of peer-to-peer learning, which enables anyone with or without a technical background to learn and have a space to experiment and, as far as possible, make their imagination tangible. There are currently six fixed FabLabs and one mobile FabLab in South Africa.

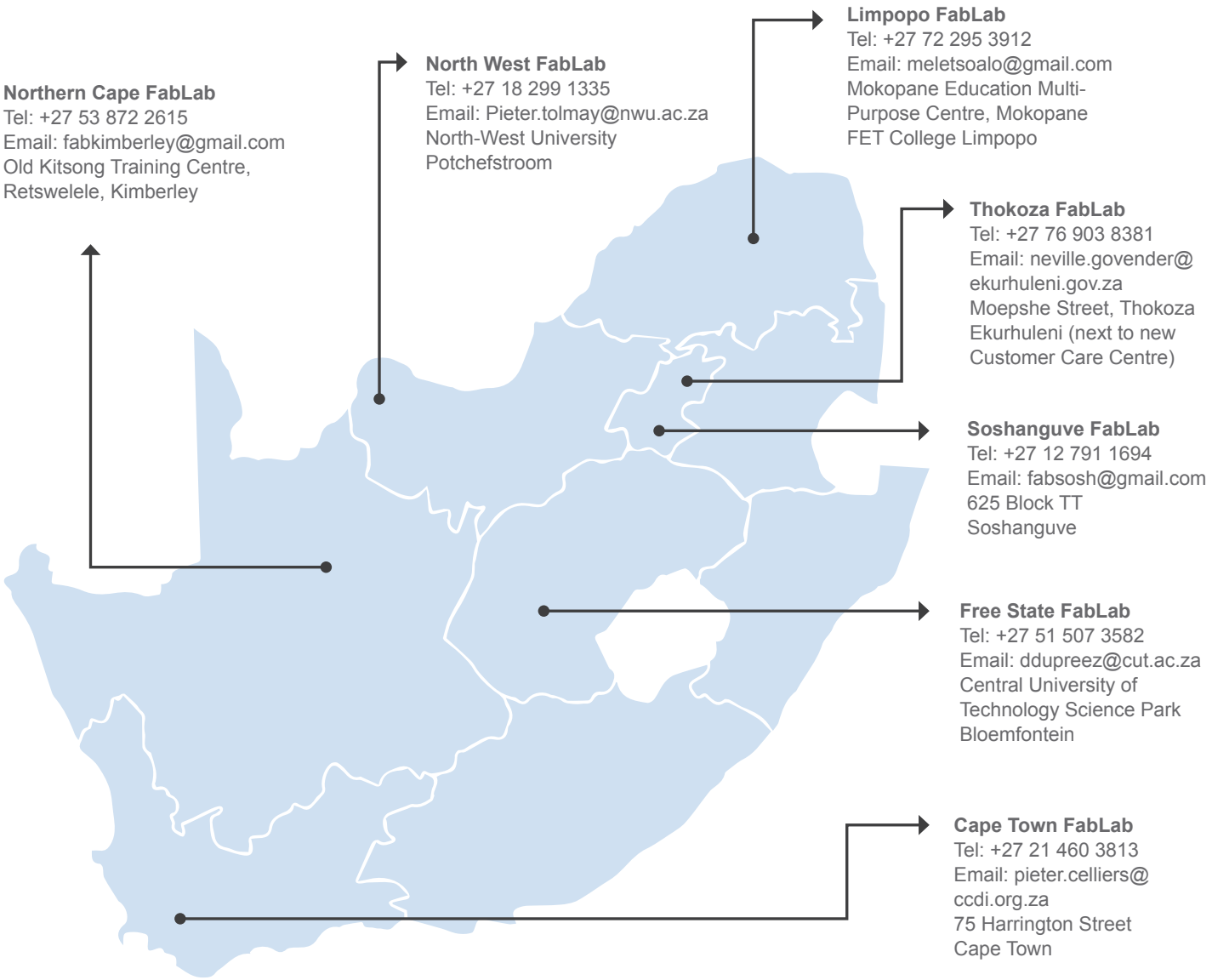


FIGURE 6.2: MAP OF FABLABS IN SOUTH AFRICA

Source: http://www.fablab.co.za/

Living labs

Living labs are open innovation environments in real-life settings, in which user-driven innovation is fully integrated within the co-creation process of new services, products and societal infrastructures in a regional, harmonised context. This encourages cooperative learning that involves stakeholders from diverse backgrounds and disciplines, and is aimed at addressing complex societal problems to develop sustainability in the South African society.

Living labs in South Africa that have been successfully running for several years are displayed in Figure 6.3. These living labs are mostly in rural communities in five provinces in South Africa.

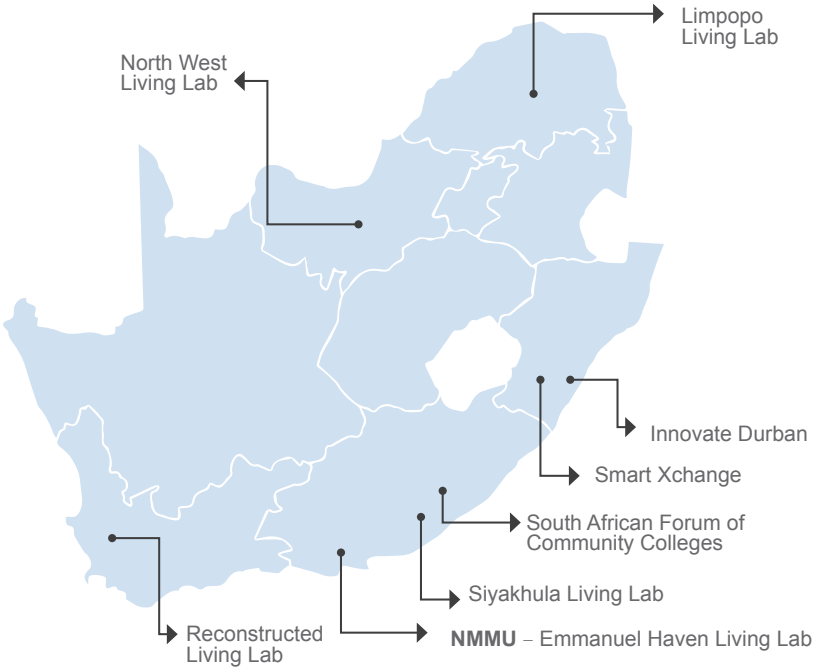


FIGURE 6.3: SOUTH AFRICA'S LIVING LAB ECOSYSTEM

Source: Several websites

Incubators

The Small Enterprise Development Agency (SEDA) is an agency of the Department of Small Business Development (DSBD). Its core mandate is to implement national government's small business strategy. To support SMMEs, it has set up an extensive network of incubators all over the country. Figure 6.4 illustrates the geographic distribution of the incubators.

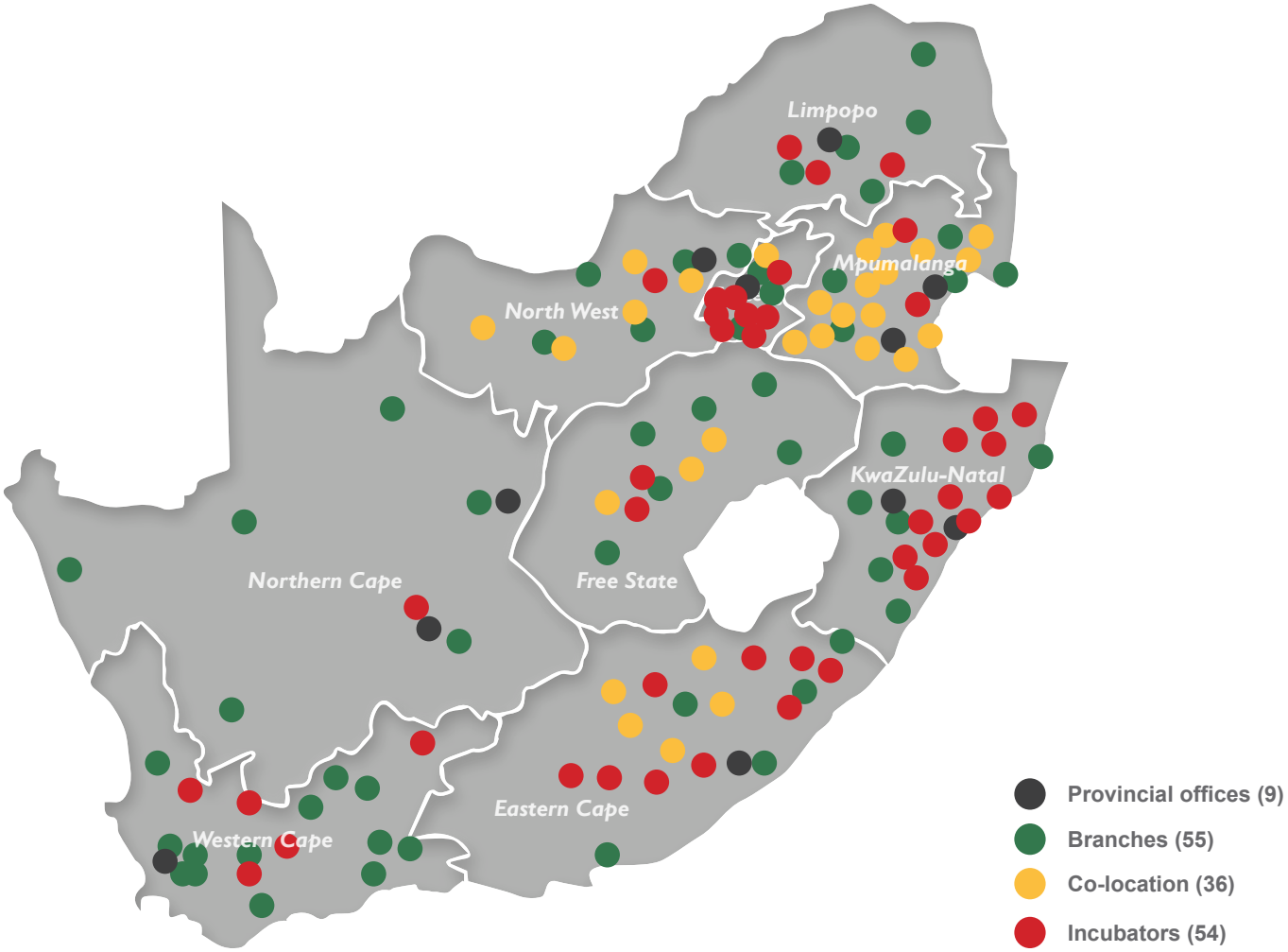


FIGURE 6.4: SEDA'S OFFICES AND INCUBATORS

Source: SEDA website

Table 6.9 summarises the number of specialised innovation spaces and support organisations that are located in the various provinces in South Africa. It illustrates the uneven distribution of the various innovation support organisations across the country.

TABLE 6.9: SUMMARY OF PROVINCIAL DISTRIBUTION OF INNOVATION SUPPORT ORGANISATIONS

Province	Science parks	Technology stations	FabLabs	Living labs
Eastern Cape	1	3	0	3
Free State	1	1	1	0
Gauteng	2	6	2	0
KwaZulu-Natal	0	2	0	1
Limpopo	0	1	1	1
Mpumalanga	0	0	0	0
Northern Cape	0	1	1	0
North West	0	0	1	1
Western Cape	1	3	1	1

6.2 Outputs and impact within the regional innovation systems

Technology output indicators such as publications, patents and the number of start-ups are not availabe at a provinvcial level. As a proxy, regional employment in high-technology manufacturing industries is utilised.

6.2.1 Employment in high-technology manufacturing industries

Table 6.10 and Figure 6.5 illustrate the employment levels in the high-technology manufacturing industry for 2008 and 2018 at provincial level. This is based on data supplied by Quantec. High-technology sectors are radio, television, instruments, watches and clocks.

With the exception of the Eastern Cape, employment in this sector increased. The Northern Cape showed the highest increase (**80.3%**), albeit from a low base.

TABLE 6.10: PROVINCIAL EMPLOYMENT IN HIGH-TECHNOLOGY SECTORS

Province	Number of employment		Changes in employment	Percentage change
	2008	2018		
Eastern Cape	978	927	-51	-5.21
Free State	491	585	94	19.14
Gauteng	10 702	12 415	1 713	16.00
KwaZulu-Natal	2 676	2 904	228	8.52
Limpopo	467	559	92	19.70
Mpumalanga	660	781	121	18.33
Northern Cape	132	238	106	80.30
North West	519	544	25	4.81
Western Cape	3 467	3 936	469	13.52

Source: Quantec

Figure 6.5 illustrates the trends in employment in the high-technology industrial sector. Gauteng is by far the largest employer in this industrial sector, followed by the Western Cape and KwaZulu-Natal. High-technology sectors are not significant contributors to employment in the rest of the provinces.

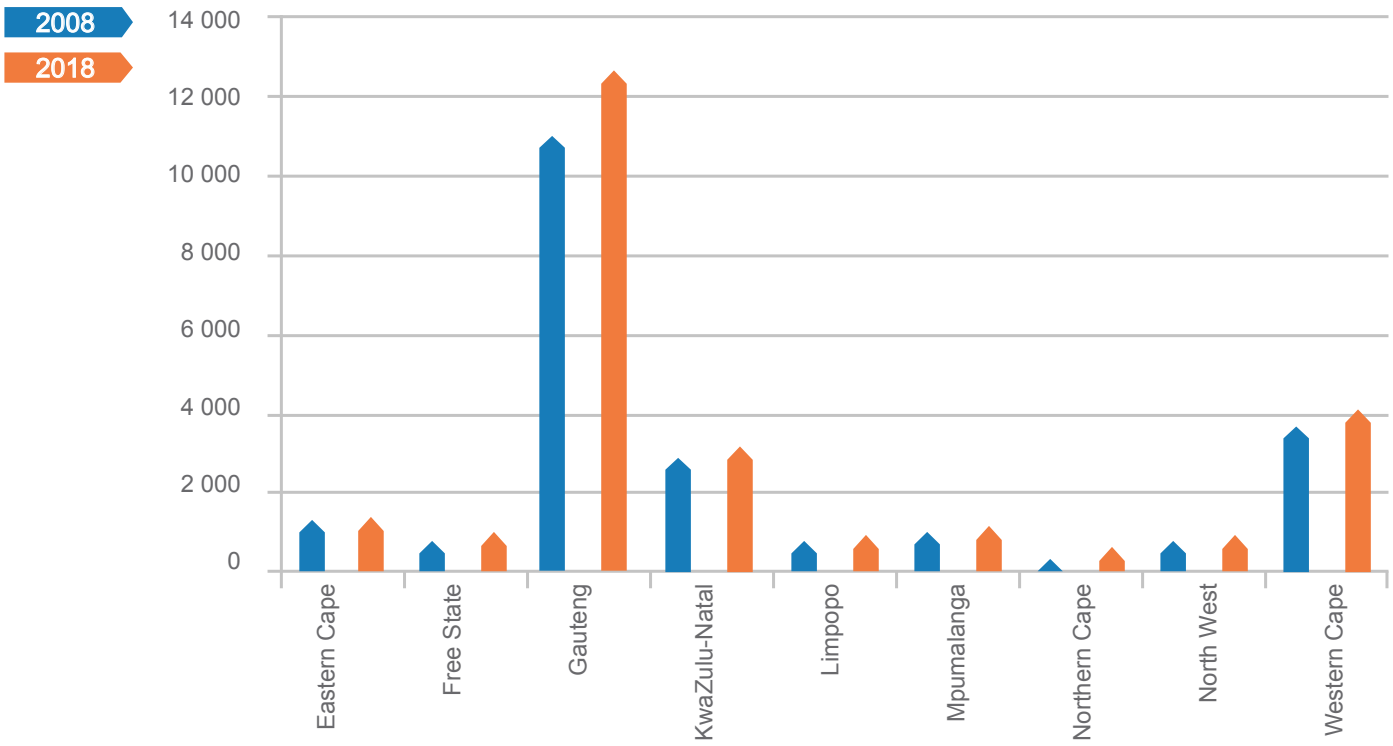


FIGURE 6.5: EMPLOYMENT IN HIGH-TECHNOLOGY MANUFACTURING SECTORS

Source: Quantec

6.2.2 Employment in medium-technology manufacturing industries

Table 6.11 and Figure 6.6 illustrate employment in the medium-technology sectors. Medium technology incorporates petroleum products, chemicals, rubber and plastic, other non-metal mineral products, metals, metal products, machinery and equipment, electrical machinery, and apparatus and transport equipment.

All the provinces have seen a decline in provincial employment in this sector. The provinces that experienced the highest decline are North West (**-21.45%**) and the Eastern Cape (**-20.65%**). Mpumalanga (**-2.14%**) and the Free State (**-5.48%**) experienced the lowest declines compared to the other provinces.

TABLE 6.11: PROVINCIAL EMPLOYMENT IN MEDIUM-TECHNOLOGY SECTORS

Province	Number of employment		Difference in employment	Percentage change
	2008	2018		
Eastern Cape	69 993	55 536	-14 457	-20.65
Free State	31 168	29 459	-1 709	-5.48
Gauteng	325 346	292 325	-33 021	-10.15
KwaZulu-Natal	144 221	128 769	-15 452	-10.71
Limpopo	33 955	30 713	-3 242	-9.55
Mpumalanga	52 646	51 522	-1 124	-2.14
Northern Cape	8 129	7 294	-835	-10.27
North West	46 070	36 190	-9 880	-21.45
Western Cape	120 120	113 458	-6 662	-5.55

Source: Quantec

Figure 6.6 illustrates the trends in employment in medium-technology sectors. Gauteng is the highest employer, followed by the Western Cape and KwaZulu-Natal.

Between 2008 and 2018, there has been an increase in high-technology employment in all the provinces, with the exception of the Eastern Cape. However, these increases are from a low base. On the other hand, employment in medium-technology sectors declined.

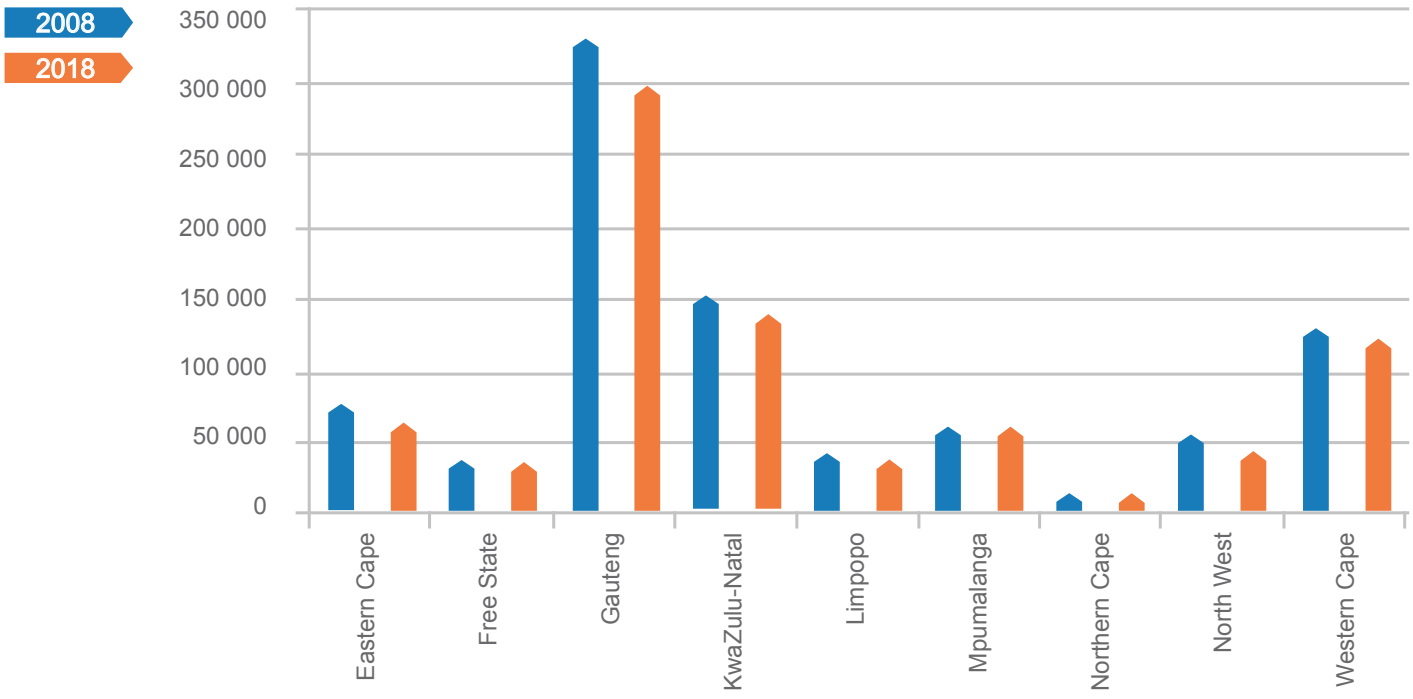


FIGURE 6.6: EMPLOYMENT IN MEDIUM-TECHNOLOGY MANUFACTURING SECTORS

Source: Quantec

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