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SOUTH AFRICAN SCIENCE, TECHNOLOGY AND INNOVATION

INDICATORS REPORT

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LIST OF ABBREVIATIONS

AI	Artificial Intelligence
AMITD	African Medicines Innovation and Technologies Development
AUDA	African Union Development Agency
AVCA	African Venture Capital Association
BBSRC	Biotechnology and Biological Sciences Research Council
BERD	Business Expenditure on Research and Development
BRIC	Brazil, Russia, India and China
BRICS	Brazil, Russia, India, China and South Africa
BSA	Biosafety South Africa
CNRS	Centre National de la Recherche Scientifique
CPGR	Centre For Proteomic and Genomic Research
CPUT	Cape Peninsula University of Technology
CREST	Centre for Research on Evaluation, Science and Technology
CSIR	Council of Scientific and Industrial Research
CUBIC	Cape Universities Body Imaging Centre
CUT	Central University of Technology
DBE	Department of Basic Education
DFG	German Research Foundation
DHET	Department of Higher Education and Training
DSBD	Department of Small Business Development
DSI	Department of Science and Innovation
DUT	Durban University of Technology
EC	Eastern Cape
ECSA	Engineering Council of South Africa
EGDI	E-Government Development Index
EPO	European Patent Office
ERC	European Research Council
ESRC	Economic Social Research Council
EU	European Union
FPL	Food Poverty Line
FS	Free State
FTE	Full Time Equivalent
GDB	Global Data Barometer
GDP	Gross Domestic Product
GERD	General Expenditure on Research and Development
GII	Global Innovation Index
GNI	Gross National Income
GP	Gauteng Province
GRDP	Gross Regional Domestic Product
GVA	Gross Value Added
HC	Head Count
HE	Higher Education

HEI	Higher Education Institute
HS	Harmonised System
HSRC	Human Sciences Research Council
ICT	Information and Communication Technology
IEB	Independent Examinations Board
III	Inclusive Internet Index
IMD	Institute of Management and Development
IP	Intellectual Property
IT	Information Technology
ITU	International Technology Union
JIF	Journal Impact Factor
KRISP	KwaZulu-Natal Research Innovation and Sequencing Platform
KZN	KwaZulu-Natal
LBPL	Lower-bound Poverty Line
LMIP	Labour Market Intelligence Partnership
LP	Limpopo Province
MHT	Medium and Higher Technology
MIMI	Municipal Innovation Maturity Index
MNCS	Normalised Mean Citation Score
MP	Mpumalanga Province
MRC	Medical Research Council
MUT	Mangusuthu University of Technology
NACI	National Advisory Council on Innovation
NC	Northern Cape
NDP	National Development Plan
NEP	National Equipment Programme
NF	National Facility
NIH	National Institutes of Health
NMP	National Metabolomics Platform
NMU	Nelson Mandela University
NNEP	National Nanotechnology Equipment Programme
NPC	National Planning Commission
NPHE	National Plan for Higher Education
NRF	National Research Foundation
NRIP	National Research Infrastructure Platform
NSB	National Science Board
NSC	National Senior Certificate
NSF	National Science Foundation
NSFC	National Natural Science Foundation of China
NSI	National System of Innovation
NT	National Treasury
NW	North West
NWU	North West University
OECD	Organisation for Economic Co-operation and Development
PATSTAT	Patent Statistical Database

PBR	Plants Breeders Right
PCT	Patent Corporation Treaty
PV	Photovoltaic
QER	Quantitative Evidence Research
RCA	Revealed Comparative Advantage
RFS	Relative Field Strength
RI	Research Infrastructure
RSA	Republic of South Africa
RU	Rhodes University
SA	South Africa
SAAO	South African Astronomy Observatory
SACNASP	South African Council for Natural Scientific Professions
SAEON	South African Environmental Observation Network
SAIB	South African Institute for Aquatic Biodiversity
SANSA	South African National Space Agency
SAPRS	South African Public Relationship with Science
SARAO	South African Radio and Astronomy Observatory
SARIR	South African Research Infrastructure Roadmap
SARS	South African Revenue Service
SAVCA	Southern African Venture Capital and Private Equity Association
SDG	Sustainable Development Goal
SEDA	Small Enterprise Development Agency
SET	Science, Engineering and Technology
SETA	Sector Education and Training Authority
SEZ	Special Economic Zone
SMME	Small, Medium and Micro Enterprise
SMU	Sefako Makgatho University
SPI	Social Progress Index
SPU	Sol Platjie University
SRE	Strategic Research Equipment
STEM	Science, Technology, Engineering and Mathematics
STFC	Science Technology Facilities Council
STI	Science, Technology and Innovation
STP	SEDA Technology Programme
SU	Stellenbosch University
TBP	Technology Balance of Payments
TIA	Technology Innovation Agency
TPP	Technology Platform Programme
TS	Technology Station
TSP	Technology Station Programme
TUT	Tshwane University of Technology
TV	Television
TVET	Technical and Vocational Education Training
UBPL	Upper-Bound Poverty Line
UCT	University of Cape Town

UFH	University of Fort Hare
UFS	University of the Free State
UJ	University of Johannesburg
UK	United Kingdom
UKRI	UK Research and Innovation
UKZN	University of KwaZulu-Natal
UL	University of Limpopo
UM	University of Mpumalanga
UN	United Nations
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNISA	University of South Africa
UNIVEN	University of Venda
UNIZULU	University of Zululand
UoT	University of Technology
UP	University of Pretoria
UPOV	International Union for the Protection of New Varieties of Plants
US	United States
USA	United States of America
USAID	United States Agency for International Development
USD	United States Dollars
USPTO	United States Patent and Trademark Office
UWC	University of the Western Cape
VC	Venture Capital
VUT	Vaal University of Technology
WC	Western Cape
WIDER	World Institute for Development Economics Research
WIID	World Income Equality Database
WIPO	World Intellectual Property Organization
WITS	University of the Witwatersrand
WOS	Web of Science
WSU	Walter Sisulu University

The 2024 South African Science, Technology and Innovation Indicators Report was compiled with the latest available data from a variety of institutions mandated to collect the data.

We welcome comments and suggestions that would enhance the value of the report. Report published by the National Advisory Council on Innovation, July 2024.

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Dr Mlungisi Cele
NACI CEO

FOREWORD BY THE CHAIRPERSON

As the Chairperson of the National Advisory Council on Innovation (NACI), I am pleased to present the 2024 South African Science, Technology, and Innovation (STI) indicators report. This report is a critical tool for assessing the performance of South Africa's national system of innovation (NSI), which is crucial for driving economic growth, addressing societal challenges, and improving the country's global competitiveness.

The report's findings are a testament to the progress made in various areas, including

- Increased scientific publications, with a growing share of women authors (45% in 2022) and Black academics (52% in 2022), indicating a more diverse and inclusive research community.
- Improved post-school education and training sector, with increased enrolments (12% increase in university enrolments between 2012 and 2021) and graduates (41% increase in graduates between 2012 and 2021), preparing a skilled workforce for the economy.
- A decent foundation for innovation, with 125 R&D technicians per million (2010-2017), comparable to Mauritius and Mexico. In 2020, there were 33,903 registered engineering professionals (92.5% men, 71% white, 21% black African) and 42 992 engineering candidates (75% men, 62% African, 24% White).
- Progress in skills development, with increased artisanal enrolments (from 21 849 in 2012 to 30 000 in 2018) and completions (19 536 individuals completed the programme in 2021 compared to 15 106 in 2020). The highest pass rate for trade tests was 54% for 25–34-year-old learners.
- Growing international collaboration in scientific publications (53% of publications involved international collaboration in 2022) and patent co-applications (12.6% of patent applications involved international collaboration in 2022), demonstrating South Africa's global research partnerships.
- Increased investment in national research infrastructure (R2.4 billion invested between 2015/16 and 2019/20).
- Public sector innovation advances with E-Government Development Index scores rising from 0.49 (2012) to 0.74 (2022), boosting global rankings from 101st to 65th (out

of 193). The Inclusive Internet Index also increased from 63rd (2018) to 74th (2022), enhancing internet accessibility and affordability.

- Notable performance in environmental sustainability and climate change, ranking second in biowaste-to-energy and geothermal energy technologies amongst the BRICS countries, showcasing South Africa's potential in green technologies.

While we celebrate these successes, we must also acknowledge the challenges that persist, including:

- Low R&D intensity (0.61%), indicating a need for increased investment in research and development.
- South Africa slipped to 58th in the 2023 IMD World Digital Competitiveness ranking from 48th in 2019, indicating low digital competitiveness.
- Decreased patenting activity (40% decline in international patent applications from South Africa between 2013 and 2022), indicating reduced innovation output.
- Decline in venture capital investments in 2021 and 2022, hindering entrepreneurship and job creation.
- Inequality in education and innovation outcomes across provinces, highlighting regional disparities. Gauteng accounted for 33% of national GDP in 2022, while Western Cape and KwaZulu-Natal followed with 16% and 14%, respectively.
- Low scores in the Municipal Innovation Maturity Index (average score of 2.0 out of 5 in 2022) and South Africa's Global Data Barometer (30 in 2021) indicate room for improvement in local innovation governance and harnessing data for the public good. In comparison, Brazil scored 40, India scored 47, and China scored 40, indicating South Africa trails behind its BRICS counterparts in harnessing data for the public good.
- Persistent poverty (62.6% poverty rate in 2022), unemployment (61.5% youth unemployment rate in 2022), and inequality (Gini coefficient of 66.92 in 2022), emphasising the need for inclusive growth.

As we move forward, it is essential that we prioritise inclusive innovation, address regional disparities, and foster collaboration among stakeholders to unlock South Africa's full potential.

I want to extend my gratitude to the experts, the NACI Secretariat, and all stakeholders who contributed to this report.

Mr Tilson Manyoni,
Chairperson, National Advisory Council on Innovation

1. EXECUTIVE SUMMARY

1.1 Purpose of the report

The 2024 Science, Technology and Innovation (STI) report monitors the annual performance of the South African National System of Innovation (NSI). This is achieved by consolidating STI data from reliable local and international sources. Where possible, drivers of observed trends are identified. This report aims to stimulate further investigation/research on selected topics of national interest.

1.2 The organising framework

An organising framework (**see Figure 1.1**) is derived from the monitoring and evaluation (M&E) framework adopted by the National Advisory Council on Innovation (NACI) in 2020. This framework has four components:

(a) Inputs and enablers (public and private investment and expenditure, human resources, infrastructure and equipment).

(b) Flows and linkages (mobility, research collaborations and networks).

(c) Outputs (scientific, technological and economic).

(d) Impact (scientific, technological and socio-economic).

The organising framework for this report is summarised below:

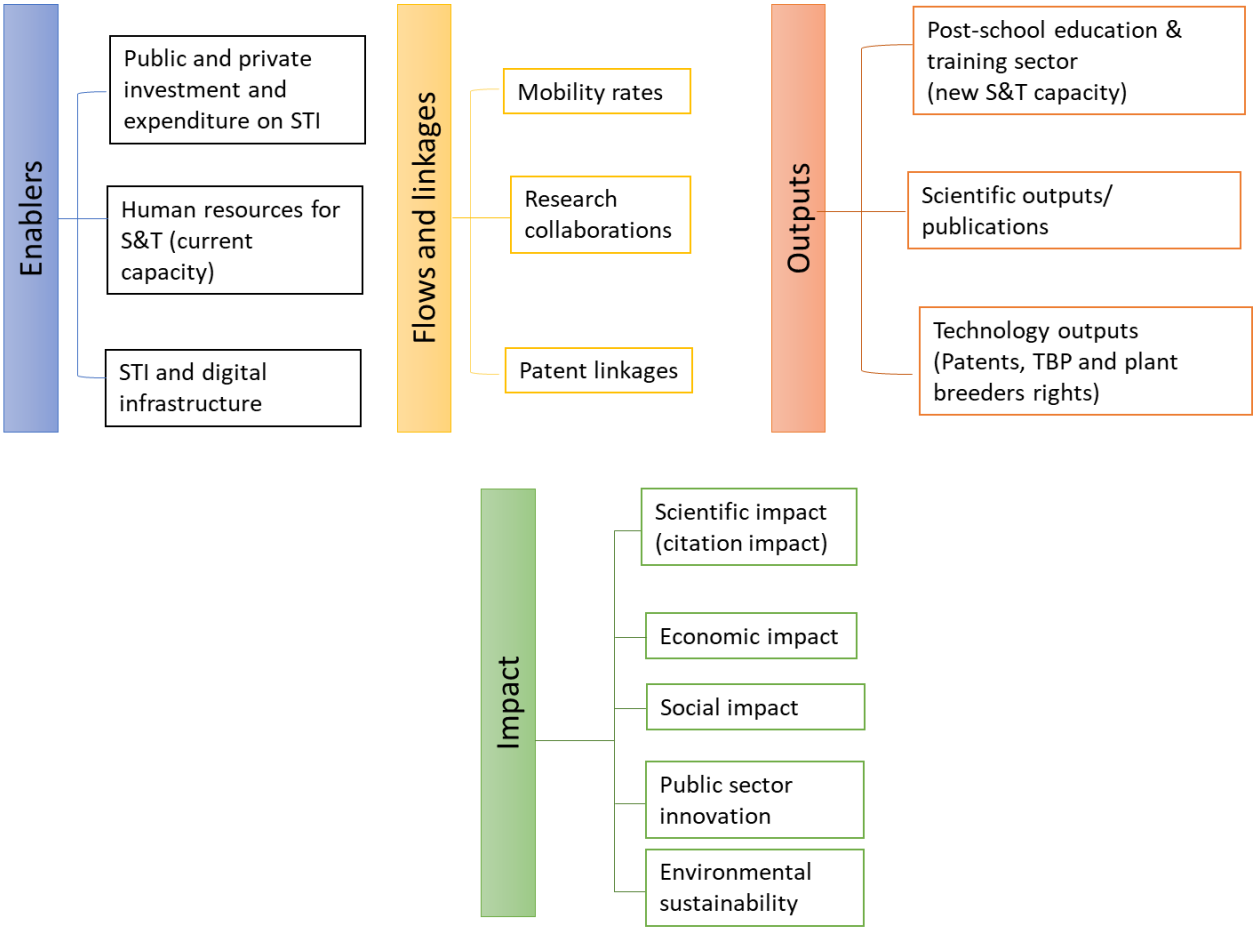


Figure 1.1: Organising framework for the STI indicators

Additionally, the theme of sectoral and provincial innovation systems has been added to the report.

1.3 Highlights of the key findings

1.3.1 Enablers

1.3.1.1 Global research and development expenditure trends

- About 75% of world research and development (R&D) spending is centred in a few nations like the United States, France, South Korea, Germany, Japan, China, India and the United Kingdom. The US and China account for 28% and 22% of global R&D expenditure, respectively. They are followed by Japan (7%), Germany (6%) and South Korea (4%).

- Countries leading the pack in R&D intensities are Israel (4.93%) and South Korea (4.64%), which happen to have higher R&D intensities than larger performers like the United States.
- On the African continent Kenya exhibits a greater R&D intensity at 0.98%, compared to South Africa at 0.61%.

1.3.1.2 South African research and development and innovation expenditures and funding

- South Africa had R&D spending of R39 billion in 2017, up from R22 billion in 2011, but it dropped primarily due to a decrease in business sector R&D expenditure.
- Despite a decrease in business sector R&D expenditure between 2017/18 and 2020/21, an annual increase of 26.4% was recorded in 2021/22. However, the business sector's share in general expenditure on research and development (GERD) remains well below that for most of the decade (44.3% in 2012/13 and 35% in 2021/22).
- The primary financiers for R&D are businesses, government and international sources with considerable parliamentary funding available to institutions under the Department of Science and Innovation (DSI) for specific projects in 2023/24. Foreign funding for business sector R&D fluctuated but increased to R1 455 656 in 2021/22, up from R1 400 577 in 2012/13.
- South African venture capital (VC) investments focus on ICT Fintech, Food and Beverage, and Manufacturing, with 48.5% of total investment by 2022. The value and the number of VC deals are concentrated in the Western Cape and Gauteng. VC investment growth occurred most quickly post-2015 but slowed in 2020. Thereafter, investments declined by 5.8% in 2021 and a further 4.4% in 2022. VC activity on the African continent has been snowballing and recently far more rapidly than in South Africa. In 2022, South Africa’s share was 14%, while Nigeria was the top country destination in Africa for the number of deals (22%).
- During 2019-2021, innovation-active enterprises primarily raised their funding from their sources (retained profits or income from asset disposal), representing 74.4% of total funding.
- About 6.8% of innovation-active enterprises applied for R&D tax incentives, with 5.3% accessing the incentives.

1.3.1.3 Science, technology and innovation human resources

- There had been a 0.5% increase in the population with post-secondary education between 2011 and 2020, and half of the population aged twenty years and above finished secondary education by 2020. Comparison of South Africa's population with tertiary education for the 35- to 64-year-olds with selected countries yields the following: South Africa (14%), India (13%), Brazil (21%), USA (51%), UK (51%) and South Korea (53%).
- 83% of learners passed the National Senior Certificate examination in 2023, with 40% obtaining a Bachelor pass. The performance patterns for different parts of the education system vary. On average, learners attending quintile 1, 2, 3 and 4 schools achieved similar pass rates (80% and 82%) and bachelor pass rates (36% and 39%). On average there is very little achievement variation among Q1 to 4 schools, who make up 84% of the school system. Sixteen percent of the learners who wrote the NSC examinations attended quintile 5 schools and achieved a 90% pass rate and a 55%Bbachelor pass rate.
- In terms of staff diversity, female representation among academic staff increased from 46% in 2010 to 52% in 2021. The share of Black African academic staff increased from 27% in 2010 to 43% in 2021.
- On average, the number of R&D technicians from 2010 – 2017 was 125 per million in employment. Two countries with a similar skill profile to South Africa were Mauritius and Mexico, with 130 and 140 R&D technicians per million in employment respectively. Malaysia and Egypt had higher numbers of R&D technicians, 233 and 370 per million respectively.
- Artisanal enrolments increased from 21 849 in 2012 to 30 000 in 2018. About 19 536 individuals completed the programme in 2021 compared to 15 106 in 2020. The highest pass rate on a trade test was 54% for 25–34-year-old learners.
- In 2020, there were 33 903 registered engineering professionals and 42 992 engineering candidates. Among the registered engineering professionals, 92.5% were men, 71% were white, and 21% were Black African. Furthermore, of the total engineering candidates, three-quarters were male, 62% were African, and 24% were White.

1.3.1.4 Science, technology, innovation and digital infrastructure

- Between 2015/16 to 2019/20, around R2.4 billion was invested in national research infrastructure. Nuclear science and biodiversity/earth observation received R504.6 million of this amount, while astronomy and geodetic sciences received R1.9 billion.
- The National Equipment Programme (NEP) received R1.2 billion from 2014/15 to 2022/23. However, the annual investment amount was reduced by 20%% from 2016/17 to 2022/23.
- The Technology Station Programme invested R670 million between 2017/18 and 2021/22, but funding was cut from R123 million in 2017/18 to R114 million in 2021/22.
- Investments in the Technology Platform Programme increased significantly from R1 million in 2018/19 to R75 million in 2022/23, totalling R374 million.
- Between 2018/19 and 2022/23, the SEDA Technology Programme received investments of R814 million. However, the annual funding decreased from R199 million to R159 million during this period.
- South Africa slipped to 58th in the 2023 IMD World Digital Competitiveness ranking from 48th in 2019, indicating low digital competitiveness.
- South Africa was ranked 86th in ICT infrastructure in 2014 and 70th in 2023, with internet use growing from 54% in 2016 to 73% in 2021. Notably, in 2022 South Africa had ICT prices that were usually higher than those of BRICS nations across various ICT baskets.

1.3.2. Flows and Linkages

1.3.2.1 Student mobility and research collaborations

- South Africa remains a destination for postgraduate studies, particularly doctoral studies. By 2021, 34% of doctoral students at South African public universities were international students, in contrast to 14% for Masters students, 6% for diploma students and 2.7% undergraduate students.
- Single-authored publications decreased by 20% from 2000 to under 10% in 2022. National collaboration has remained about 31% - 35% during the last five years and cooperation with African countries has increased gradually but steadily in recent years. Collaboration with nations outside Africa amounted to 53% in 2022, indicating growing global collaboration in scientific publications.

1.3.2.2 International patent applications and linkages

- There was a 40% decline in international patent applications from South Africa between 2013 and 2022, from 371 to 223.
- The percentage of patent co-applications with international partners increased from 10.5% in 2013 to 12.6% in 2022.
- The majority of patent co-applications with international partners, 53.8% in 2013 and 57.1% in 2022, involved private entities and local individuals.
- Universities also collaborated with international partners, slightly increasing from 2.6% in 2013 to 3.6% in 2022.
- Local patent co-applications declined from 19 in 2013 to 14 in 2022, indicating a decrease in local collaborations.

1.3.2.3 Innovation linkages

- According to the 2019-2021 Business Innovation Survey, the top barriers to innovation are high costs (35.5%), market competition (26.2%), and dominance by established enterprises (24.5%). In contrast, lack of information on technology, digital platforms, and prior innovations are less significant barriers.
- The 2019-2021 Business Innovation Survey also reveals that businesses prioritise different information sources depending on their collaboration approach. Activity-driven collaborators rely most on suppliers (66.1%) and internal sources (45.7%), while knowledge-driven collaborators prioritise customers (62.5%) and rely on internal sources (54.1%).

1.3.3 Outputs

1.3.3.1 Post-school education and training sector

- South Africa's public university sector saw a 12% increase in enrolments (0.95 million to 1.01 million) and a 41% increase in graduates (165,986 to 233,257) between 2012 and 2021. The throughput rate improved from 17.4% to 21.8%. However, SET fields remained below the 30% target, while humanities exceeded the 40% target.
- The TVET sector saw stable National Certificate (Vocational) (NC(V)) enrolments (150,000 per year), but a decline in National Accredited Technical Education Diploma (NATED) programme enrolments (360,000 to 417,000) after a 2015 peak (520,000).

Total TVET enrolment in 2021 was 590,000, short of the NDP target (2.5 million by 2030). Only 22,000 took NC(V) level 4 examinations, 16,456 took N3 engineering examinations, and 5,000 took N6 engineering examinations, with completion rates of 37% and 66% respectively.

1.3.3.2 Scientific publications

- South Africa's scientific publications have grown significantly, from 3 693 in 2000 to 27 208 in 2022, with a global share that peaked at 1% in 2018 before declining to 0.58% in 2022. The country ranks 29th in the world, with 27 208 publications in 2022, and has a publication output per million population that increased steadily from 2004 to 2021, but declined slightly in 2022.
- University publications have also shown significant growth, increasing at a compound annual growth rate of 7.4% between 2005 and 2022, with articles in accredited journals growing at 6.7%. The number of women authors has increased from 32% in 2005 to 45% in 2022, and the contributions of Black academics rose from less than 15% in 2005 to more than 52% in 2022. Per capita production of scientific journals has more than doubled, from 0.47 articles per permanent staff member in 2005 to 1.19 in 2022.

1.3.3.3 Technology Outputs

- South Africa's patenting activity has declined significantly over the past few years. Domestic patents granted decreased from 694 in 2019 to 513 in 2022, while patent applications abroad dropped from 1 457 in 2020 to 968 in 2022. Additionally, patents granted by the European Patent Office (EPO) decreased from 80 in 2020 to 38 in 2022. However, there was a slight increase in patents granted by the United States Patent and Trademark Office (USPTO), from 125 in 2021 to 150 in 2022.
- South Africa’s payments abroad for using Intellectual Property (IP) have declined significantly since 2017. In 2021, there was an increase over the previous year (21%), but this followed two earlier years of significant decline (-12% in 2019 and -16.6% in 2020). Payments abroad for IP use in 2022 were similar to the previous year and were significantly lower than a decade ago.
- Receipts from the sale of South African IP increased in 2021 compared to the previous year (6.6%). However, this followed significant decreases in the two previous years. Receipts from the sale of South African IP in 2021 were similar to a decade ago.

However, in 2022, there was a very significant increase compared to the previous year (53%).

- The number of South African plant breeders' rights (PBRs) applications shows some stagnation as there has not been a tangible growth in the number of applications between 2013 and 2022 (309 and 263, respectively). South Africa's world share of PBR has declined from 2.32% in 2015 to 0.97% in 2022.

1.3.4 Impact

1.3.4.1 Scientific impact

- South Africa's scientific publications have shown a positive trend in citation impact, with a Mean Normalised Citation Score (MNCS) consistently exceeding the world average over the last decade.
- The percentage of publications in the top 1% of most frequently cited papers ranges from 2.4% in agricultural sciences to 14.1% in natural sciences. Significant publications also fall within the top two journal quartiles, indicating prestige and quality.
- Overall, South Africa's publications perform slightly worse than the world average in some fields but consistently outperform in others, such as health sciences, humanities, and natural sciences.

1.3.4.2 innovation for economic and social impact

- On the economic front, South Africa lost manufacturing output at 524.8 Gross Value Added (GVA) in 2022 compared to the previous decade. However, manufacturing exports rose by 11.2%. Service exports varied but grew to USD 12.61 billion between 2013 and 2022. In 2021, the country's exports were limited to 116 manufactured and 200 competing products. The manufacturing sector employed 1 177 000 people in 2022, with medium and high technology (MHT) and MHT (excluding motor vehicles) comprising 33.1% and 29.0% of employment respectively, in the same year.
- On public engagement in science and technology, two-thirds of South Africa's population is interested in and proud of the country's achievements in these fields. Awareness of such accomplishments hovers at about 60%, but some fear rapid changes and possible job cuts. Trust is high among scientists and institutions (often universities and research organisations).

- After a decade of increasing the Social Progress Index (SPI), South Africa experienced a decline in all dimensions of the SPI. The SPI score declined from 70 in 2022 to 67 in 2024. As a result, it is now ranked 82 out of 172 countries, up from 69 in 2022.
- High income inequality persists in South Africa as evidenced by a Gini coefficient of 66.92 and a 62.6% poverty estimate in 2022. All age groups report rising unemployment, with 61.5% of youth aged 15 to 24 facing this challenge.

1.3.5 Public Sector Innovation

- The average Municipal Innovation Maturity Index (MIMI) score for participating municipalities was 2.0, where innovation is defined, but there is little evidence of its implementation. Mahikeng Local Municipality scored the highest at 3.7, followed by Ugu District Municipality at 3.0. On the other end, Nyandeni Local Municipality scored the lowest at 1.0.
- South Africa has made significant progress in leveraging Information and Communication Technologies (ICT) for public services, digital inclusion, and sustainable development, as shown by its improved E-Government Development Index (EGDI) and Inclusive Internet Index scores. South Africa’s EGDI score increased from 0.49 in 2012 to 0.74 in 2022, lifting the country's global ranking from 101st to 65th out of 193 countries.
- The country's Inclusive Internet Index (III) score has also shown a steady increase, rising from 63rd in 2018 to 74th in 2022, indicating progress in making the internet more accessible and affordable for its citizens. However, there is still room for improvement, particularly in harnessing data for the public good, as reflected in South Africa's lower Global Data Barometer (GDB) score of 30 in 2021, which trails behind other BRICS countries like Brazil (40), India (47), and China (40).

1.3.6 Environmental Sustainability and Climate Change

- South Africa ranks second in biowaste-to-energy (0.033 patents per million population) and geothermal energy (0.038 patents per million population) technologies and third in hydropower (0.362 patents per million population), solar photovoltaic (0.248 patents per million population), and wind energy (0.725 patents per million population) technologies.

- China leads in all technologies, with Brazil and India following behind. South Africa's performance is driven by its significant biomass energy consumption (10% of final energy consumption) and solar resources.

1.3.7 Sectoral and provincial systems of innovation

1.3.7.1 Bioeconomy sector

- R&D expenditure in biological sciences declined by 13.8% in 2020/21 and was 22% lower in 2021/22 compared to the 2013-2015 average.
- Biotechnology publications increased by 23% in 2019 but declined by 9.4% in 2022.
- Biotechnology patent applications and grants at the European Patent Office (EPO) plummeted from 6 in 2020 to 1 in 2022.
- Bioeconomy exports increased significantly by 27.8% in 2021 and 10% in 2022, with a marginal increase in unit value to $0.86 in 2022.
- Employment in the sector declined consistently after 2015 but saw a significant increase of 8.1% in 2022, still below the 2015 peak.
- The bioeconomy's share of total GDP remained marginal at 8.41% in 2022.

1.3.7.2 Emerging technologies and the South African manufacturing sector

- South Africa's patenting trends in emerging technologies have increased from 0 patents in digitalisation in 2011 to 4 patents in 2022, a compound annual growth rate of 19%.
- The country's share of global patents in emerging technologies remains low, at around 0.03% in 2022, with biotechnology having the highest share at 0.01%.
- Publications in emerging technology areas have grown significantly, with digitalisation growing from 171 publications in 2011 to 1 518 publications in 2022, and nanotechnology growing from 279 to 2 222 over the same period.
- Biotechnology dominates patent applications in manufacturing-related emerging technologies, with a share of 67.86% in 2022, followed by nanotechnology at 25%, and the Internet of Things at 8.70% over 2013-2022.
- Universities and science councils are the main drivers of patent applications in emerging technologies, with a combined share of 75.48% over 2013-2022, while the private sector contributed only 19.75% over the same period.

1.3.7.3 Provincial systems of innovation

- In 2022, 33% of the national Gross Domestic Product (GDP) was attributed to Gauteng, 16% to the Western Cape and 14% to KwaZulu-Natal.
- Between 2012/13 and 2021/22, Gauteng spent more than the other provinces on R&D, followed by Western Cape and KwaZulu-Natal.
- Gauteng province has the highest population level of 20 years and above with the NSC/Grade 12 attainment of 39.9%, followed by KwaZulu-Natal (38.2%) and Western Cape (34%). The Eastern Cape, Limpopo and Northern Cape have the lowest percentages of individuals who have attained NSC/ Grade 12 level.
- In 2023, the percentage of learners who achieved 50% and above (in Mathematics and Physical Science) remains very low, especially in the Eastern Cape, Mpumalanga and Limpopo. The Western Cape is the best-performing province at 47%, followed by Gauteng at 33.5%.
- Household internet access has been poor in all the provinces. Mobile access accounts for 69.6% of the nation's internet access.
- Gauteng has the highest number of innovation support organisations, with a total of 18 innovation support facilities, followed by Western Cape (14) and KwaZulu-Natal (11), out of 64 facilities across all provinces.
- Gauteng and Western Cape account for 66.7% of high-tech employment.
- Gauteng, KwaZulu-Natal, and Western Cape account for 64.5% of medium-tech employment.
- Gauteng, KwaZulu-Natal, and Western Cape account for 57.1% of low-tech employment.

2. SCIENCE, TECHNOLOGY AND INNOVATION ENABLERS

This chapter covers STI enablers such as funding, human capital and infrastructure.

2.1 Research and development expenditure trends in South Africa

R&D is recognised internationally as the fundamental cornerstone of economic growth, employment, international competitiveness and development.

The OECD (2012)[1] argues that R&D can help address urgent developmental challenges such as providing access to drinking water, eradicating neglected diseases, and reducing hunger.

In South Africa, the National Planning Commission states, “South Africa needs to sharpen its innovative edge and continue contributing to global scientific and technological advancement. This requires greater investment in R&D, better use of existing resources, and more nimble institutions that facilitate innovation and enhanced cooperation between public science and technology institutions and the private sector” (NPC, 2011: p23)[2].

Countries realise the importance of R&D and invest appropriately. The global R&D expenditures reached an estimated $2.4 trillion in 2019 (R48 trillion). This was a triple-fold increase from $726 Billion in 2010 (NSB, 2022)[3].

This section presents information related to R&D expenditures in South Africa over time and in an international context.

2.1.1 Global research and development expenditures

Global R&D performance is concentrated in a few countries. In 2019, the United States, China, Japan, Germany, South Korea, France, India, and the United Kingdom jointly accounted for about 75% of global R&D performance (see **Figure 2.1**).

R&D performance is concentrated geographically; the United States (28% of global R&D) and China (22%) lead R&D performance globally, jointly accounting for half of global R&D, followed by Japan (7%), Germany (6%), and South Korea (4%).

[1] OECD (2012) Innovation for Development. Organisation for Economic Development. Paris

[2] NPC (2011) National Development Plan. National Planning Commission. Pretoria.

[3] NSB (2022) Science and Engineering Indicators. National Science Board. Alexandria VA.

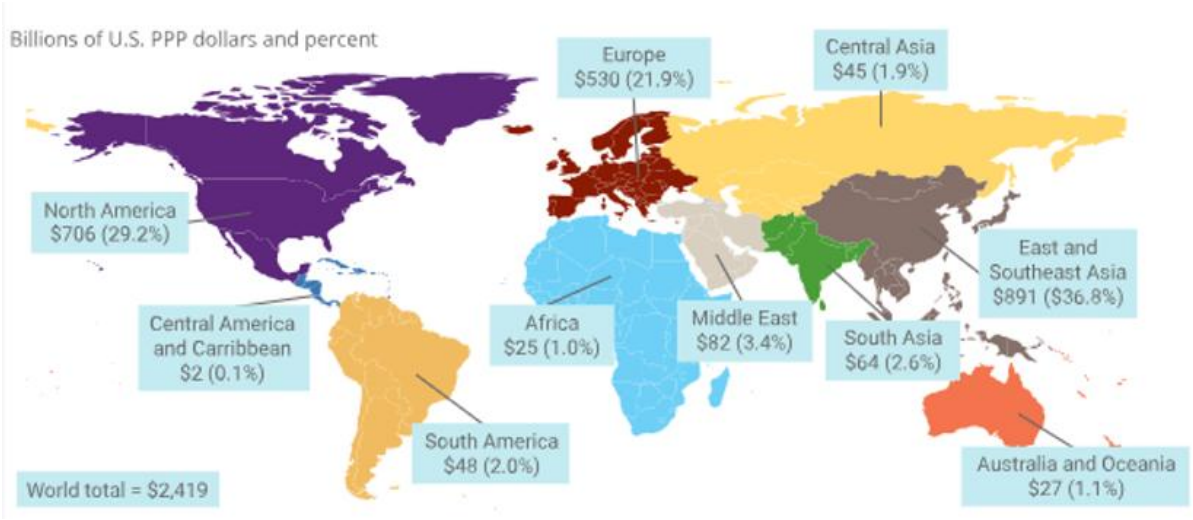


Figure 2.1: Global R&D Expenditures by Region

Source: NSB 2022

The global concentration of R&D performance is shifting from the United States and Europe to East-Southeast and South Asia. The USA contributed 23% to the growth in global R&D performance from 2000 to 2019, whereas countries in Southeast Asia and South Asia (China, Japan, Malaysia, Singapore, South Korea, and India) contributed 46% to the growth in global R&D during this period. China alone contributed 29% to increase in international R&D, buoyed by its high annual R&D growth (see **Figure 2.2**). There is an exciting debate on whether China will bypass the USA in the investment for R&D.

Several countries with small economies, including Israel and South Korea, have greater R&D intensities (R&D expenditures as a percentage of GDP) than the United States and other big contributors to R&D (**Table 2.1**). From 2000 to 2019, South Korea and China had the highest growth in R&D intensity, growing from 2.1% to 4.6% and from 0.9% to 2.2%, respectively. Israel has the highest intensity, 4.93%.

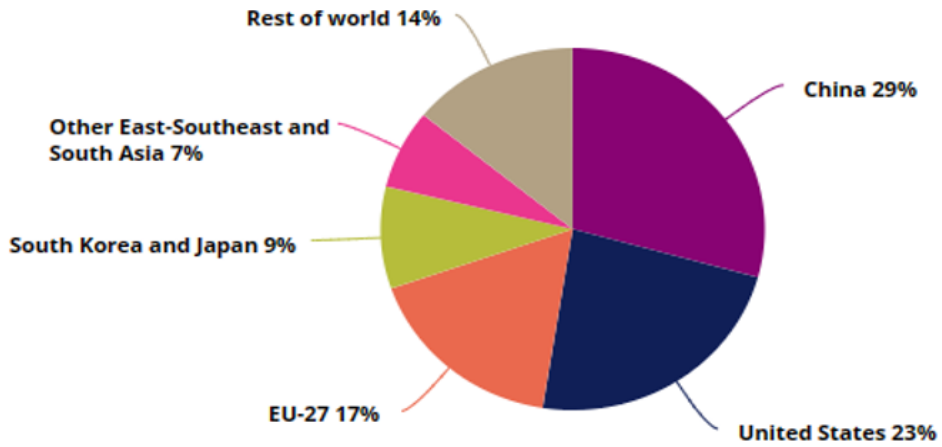


Figure 2.2: Contributions to Growth of Worldwide R&D Expenditures, by Selected Region, Country, or Economy: 2000–2019

Source: NSB 2022

Table 2.1 shows the research intensities of several countries and regions. It is interesting that several African countries have research intensities higher than South Africa's. South Africa is also at the bottom of the list of BRICS countries.

Table 2.1: Research Intensity- Top countries, Africa and BRICS

Top Countries[4]	Research Intensity		African Countries[5]	Research Intensity		BRICS[6]	Research Intensity
Israel	4.93		Kenya	0.98		China	2.14
S Korea	4.64		Egypt	0.95		Brazil	1.16
Sweden	3.39		Tunisia	0.74		Russia	1.10
Japan	3.20		Morocco	0.71		India	0.65
Germany	3.19		Ethiopia	0.62		South Africa	0.61
Switzerland	3.18		South Africa	0.61			
Belgium	3.17		Algeria	0.54		OECD	2.48
USA	3.13		Senegal	0.54		EU	2.12
Austria	3.13		Botswana	0.54		G20	2.09
			Namibia	0.40		World	1.92

Sources: NSB (2022), AUDA (2019), OECD Databases and UN database

2.1.2 South African research and development expenditures

Figure 2.3 shows the R&D expenditures per sector of performance in South Africa from 2011-12 to 2021-22. The figure also shows the total R&D expenditures per year (GERD). GERD touched R 39 billion during 2017 and then it declined. The figure reveals that the decline in GERD is the decline in the R&D expenditures in the business sector.

[4] NSB 2022
[5] AUDA 2019 and UN database
[6] OECD Databases

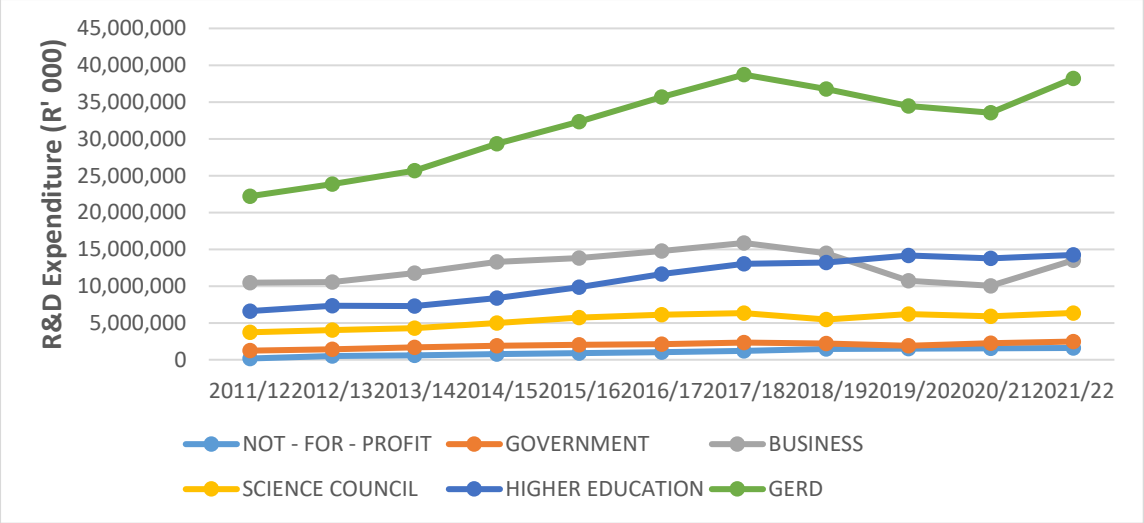


Figure 2.3: SA R&D Expenditures per Sector and Total GERD

Source: HSRC and DSI's National Survey of Research and Experimental Development, 2021/22

During the most recent period, the business sector in SA contributes 30% of the total GERD in the country (see **Table 2.2**). However, in most other countries, businesses are the main contributors to GERD. In 2017, the business sector accounted for approximately three-quarters of R&D funding in the leading Asian countries: Japan (78%), China (76%), and South Korea (76%). The business share of total R&D was lower but still significant in the United States (62%) and in leading European countries, with Germany at 66%, France at 56%, and the United Kingdom at 52%.

Table 2.2: R&D Percentage Expenditure Composition per Sector

	Government	Science Councils	Higher Education	Business
	%	%	%	%
2011/12	5.6	16.8	29.8	47.1
2012/13	6	16.9	30.7	44.3
2013/14	6.6	16.8	28.4	45.9
2014/15	6.5	17.1	28.5	45.3
2015/16	6.2	17.8	30.5	42.7
2016/17	5.9	17.2	32.7	41.4
2017/18	6	16.3	33.6	41
2018/19	6	14.8	35.8	39.3
2019/20	5.5	18	41.1	31
2020/21	6.7	17.6	41.1	30
2021/22	6.5	16.6	37.3	35.4

Source: HSRC and DSI's National Survey of Research and Experimental Development, 2021/22

Figure 2.4 shows the types of research undertaken in the country. Applied research has always been on top of the list. The decline in the R&D expenditures in the business sector has affected the ranking of experimental development. The latter is undertaken almost exclusively by the business sector and hence, its decline together with the sector's activities.

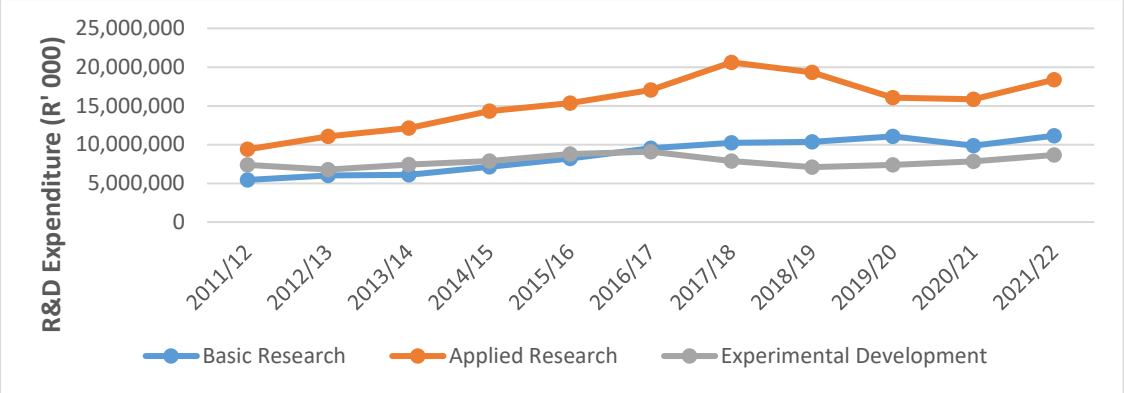


Figure 2.4: R&D Expenditure by Type of Research

Source: HSRC and DSI's National Survey of Research and Experimental Development, 2021/22

Figure 2.5 shows the main funders of businesses: higher education and Science Councils. Businesses fund mainly their own performance, and the government funds higher education and science councils. Foreign sources fund almost equally business and higher education.

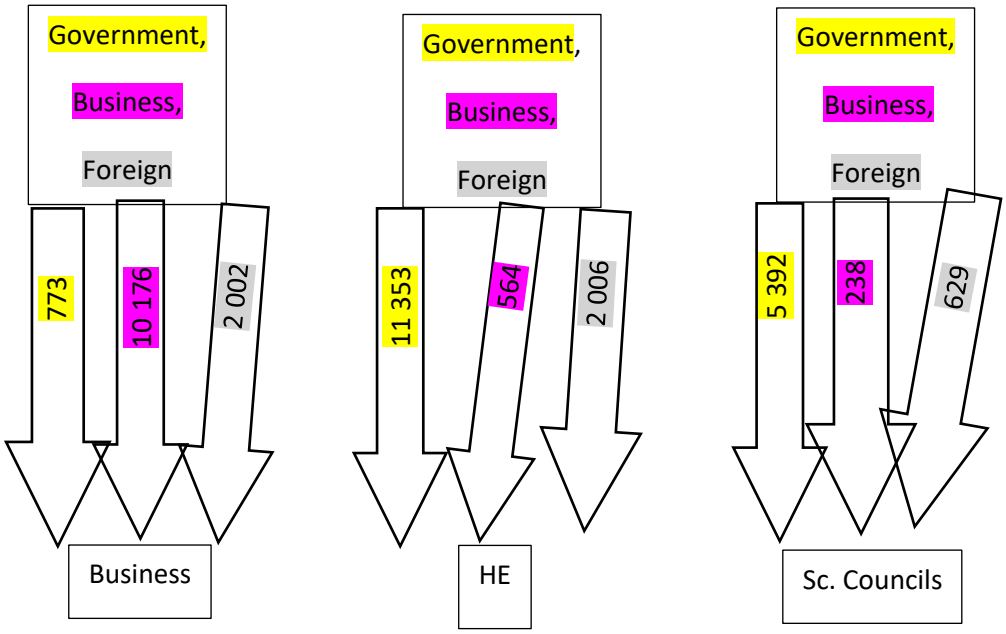


Figure 2.5: Main Funders of R&D, 2022

Table 2.3 shows the parliamentary grants the entities were budgeted to receive during 2023/24. In addition to the baseline parliamentary grants, the entities receive project funding to implement specific departmental projects. For example, the CSIR was to receive R1.03 billion for projects such as the Biomanufacturing Industry Development Centre, the Nanomaterials Industrial Development Facility, the National Recordal System, and the Waste Research, Development and Innovation Roadmap. Of the NRF's R4.78 billion

budgeted contract income, it received R3.87 billion as total contract income allocation from the DSI, most of which is for projects such as the South African Research Infrastructure Roadmap, the South African Research Chairs Initiative, the Centres of Excellence, the National Equipment Programme, Science Missions projects and Access to Global Infrastructure projects.

Table 2.3: Parliamentary Allocations to Entities Reporting to DSI, 2023/24

Entity	Baseline Allocation	Budget Contract Income	Other Income	Budgeted Total Revenue
	R' million			
ASSAf	34.0	0	3.6	37.6
CSIR	744.5	2 358.1	1.7	3 104.3
HSRC	322.3	214.0	34.6	570.9
NRF	1 001.3	4 782.2	297.3	6 080.81
SANSA	141.3	873.4	178.1	1 192.8
TIA	460.1	135.6	20.5	616.2
Total	**2 703.5**	**8 363.3**	**535.8**	**11 602.6**

Source: Entities' Annual Performance Plans (2023/24)

2.2 Business expenditure and funding in research and innovation

2.2.1 R&D expenditure and funding in the business sector

The business sector's R&D expenditure declined significantly from 2017/18 to 2020/21 (see **Table 2.4**).

In 2021/22, business R&D expenditure increased significantly by 26.4% year-over-year. As shown in Annexure F, this surge can be attributed to significant increases in research and development investments across various fields and industries.

In terms of research fields, investments in information, computer, and communication technologies have grown notably, now accounting for 25.4% of total business R&D expenditure, up from 15.9% in 2018/19. Similarly, medical and health sciences have significantly increased, rising from 19.8% to 23.9% over the same period. Additionally, material sciences have emerged as a growing area of interest, increasing from 0.4% to 4.4% of total business R&D expenditure.

The industry sectors driving this growth are manufacturing, financial intermediation, real estate, business services, and community, social, and personal services. Manufacturing continues to significantly contribute to business R&D expenditure, accounting for 29.9% of

the total in 2021/22. Financial intermediation, real estate, and business services have also seen a notable increase, rising from 42.3% in 2020/21 to 45.7% in 2021/22. Community, social, and personal services have also experienced growth, increasing from 4.7% to 5.2% over the same period.

These increases indicate a shift towards innovation in digital technologies, healthcare, and materials research and a growing focus on innovation in the manufacturing, financial, and social services sectors. This surge in business R&D expenditure is likely driven by companies seeking to stay competitive and capitalise on emerging opportunities in these fields. However, despite this increase, R&D expenditure by the business sector in 2021/22 remains substantially below the levels seen prior to 2018/19.

Table 2.4: R&D Expenditure by the Business Sector

	Constant 2015 Rand Values	Year-on-Year Changes %
2012/13	12 442 685	-3.5
2013/14	13 103 667	5.3
2014/15	14 028 004	7.1
2015/16	13 814 995	-1.5
2016/17	13 820 449	0
2017/18	14 058 812	1.7
2018/19	12 315 872	-12.4
2019/20	8 722 484	-29.2
2020/21	7 777 935	-10.8
2021/22	9 832 641	26.4

Source: HSRC and DSI's National Survey of Research and Experimental Development, 2021/22

As shown in **Table 2.5**, the business sector's share in Gross Expenditure on R&D (GERD) has been consistently declining. There was a very significant decline in 2019/20 and a further decline in 2020/21. In 2021/22, the share of the business sector in GERD increased to 35%. However, the share of the Business Sector in GERD remains well below that for most of the decade.

Table 2.5: Business Sector R&D Expenditure as % of GERD

2012/13	44.3
2013/14	45.9
2014/15	45.3
2015/16	42.7
2016/17	41.4
2017/18	41.0
2018/19	39.3
2019/20	31.0
2020/21	30.0
2021/22	35.0

Source: HSRC and DSI's National Survey of Research and Experimental Development, 2021/22

Business sector funding of R&D outside of the business sector itself is largely concentrated in higher education and the science councils (see **Table 2.6**). Business sector funding in both higher education and science councils declined significantly after 2016/17. In 2020/21, there was a significant increase in business sector funding of R&D in the science councils.

In 2021/22, business sector funding for R&D in higher education and the science councils declined. This is below the levels for most of the decade.

Table 2.6: Business Funded Real R&D Expenditure by Sector

	Total	Government	Science Councils	Higher Education	Business	Non-Profit
Constant 2015 Rand values (R'000s)						
2012/13	10 772 767	13 598	159 765	679 801	9 890 302	29 302
2013/14	11 805 910	1 956	466 490	654 578	10 623 546	59 340
2014/15	12 646 438	306	235 253	934 373	11 409 923	66 582
2015/16	12 576 499	41 109	326 648	770 448	11 384 710	55 585
2016/17	13 132 872	1 179	451 759	847 716	11 767 978	64 239
2017/18	14 242 899	460	314 540	602 417	13 264 539	60 942
2018/19	12 389 428	3 933	176 154	395 031	11 752 989	61 322
2019/20	7 625 940	34 765	156 059	423 595	6 960 215	51 306
2020/21	6 993 496	0	240 006	422 929	6 271 724	58 838
2021/22	8 054 419	7 484	173 405	410 075	7 397 455	66 000

Source: Data Supplied by CeSTII, Human Sciences Research Council.

Business sector funding for R&D has been largely concentrated in the business sector itself throughout the decade. The share has remained close to 90%. In 2021/22, the share was 91.8% (see **Table 2.7**).

Table 2.7: Proportional Business-funded R&D by Sector

	Government	Science Councils	Higher Education	Business	Non-Profit
	%				
2011/12	0.0	0.8	5.8	93.0	0.4
2012/13	0.1	1.5	6.3	91.8	0.3
2013/14	0.0	4.0	5.5	90.0	0.5
2014/15	0.0	1.9	7.4	90.2	0.5
2015/16	0.3	2.6	6.1	90.5	0.4
2016/17	0.0	3.4	6.5	89.6	0.5
2017/18	0.0	2.2	4.2	93.1	0.4
2018/19	0.0	1.4	3.2	94.9	0.5
2019/20	0.5	2.0	5.6	91.3	0.7
2020/21	0.0	3.4	6.0	89.7	0.8
2021/2022	0.1	2,2	5,1	91.8	0.8

Source: HSRC and DSI's National Survey of Research and Experimental Development, 2021/22

The capacity of the business sector to attract foreign funding for R&D declined significantly from 2015/16 to 2018/19, particularly in 2017/18 and 2018/19. However, there was a major year-on-year increase in 2019/20, followed by a further decline in 2020/21.

In real terms, foreign-funded R&D in the business sector in 2020/21 was less than half of what it was in the first half of the decade. However, in 2021/22, foreign-funded R&D in the business sector almost doubled compared to the previous year. In 2020/21, foreign-funded R&D in the business sector was at similar levels to the decade's first half.

Table 2.8: Foreign-funded Real R&D in the Business Sector

	Constant 2015 Rand values (R'000)
2012/13	1 400 577
2013/14	1 364 505
2014/15	1 497 504
2015/16	1 532 766
2016/17	1 251 645
2017/18	420 866
2018/19	341 369
2019/20	952 297
2020/21	757 835
2021/22	1 455 656

Source: Source: Data Supplied by CeSTII, Human Sciences Research Council.

After 2014/15, there was a very significant decline in the business sector's share of foreign-funded R&D in South Africa. In 2019/20, the business sector's share of foreign funding rose significantly. It declined year-on-year in 2020/21. There was a further significant increase in 2021/22. The business sector's share of foreign funding in 2021/22 is a little lower than in the early years of the decade.

Table 2.9: Business Sectors Share of Foreign Funding for R&D

	%
2012/13	38.2
2013/14	37.0
2014/15	39.8
2015/16	36.4
2016/17	32.1
2017/18	12.1
2018/19	10.0
2019/20	25.1
2020/21	21.9
2021/22	36.2

Source: HSRC and DSI's National Survey of Research and Experimental Development, 2021/22

There has been a steady increase in the share of financial intermediation, real estate and business services in business sector expenditure in R&D.

As financial intermediation, real estate and business services expanded its share, the shares of most other sectors tended to decline. Particularly significant has been the decline in the shares of mining and manufacturing.

Table 2.10: Proportional Business Sector R&D Expenditure by Industry

	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22
Agriculture, Hunting, Forestry and Fishing	3.1	3.5	3.5	3.2	2.5	3.9	6.6	6.6	4.5	3.4
Mining Quarrying	14.2	10.1	8.8	7.2	6.9	12.1	6.4	6.4	9.2	6.6
Manufacturing	32.2	33.9	32.2	27.8	28.2	21.9	32.3	32.3	28.8	29.9
Electricity, Gas and Water Supply	3	4.1	3.2	3.7	4	4.9	7.1	7.1	7.1	3.0
Construction	0.1	0	0	0	0	0.1	0.0	0	0	0.1
Wholesale and Retail	0.9	0.6	0.3	0.4	0.5	0.7	0.8	0.8	0.6	0.2
Transport, Storage and Communication	3.8	4.8	6.5	10.4	6.2	7.7	4.7	4.7	2.7	6.0
Financial Intermediation, Real Estate and Business Services	40.1	40.3	42.8	44.3	48.8	44.3	37.7	37.7	42.3	45.7
Community, Social and Personal Services	2.6	2.7	2.7	2.9	2.8	4.4	4.3	4.3	4.7	5.2
Total	100	100	100	100	100	100	100	100	100	100

Source: HSRC and DSI's National Survey of Research and Experimental Development, 2021/22

High-technology manufacturing's percentage share of R&D in total manufacturing increased in 2018/19, 2019/20, and significantly in 2020/21. However, the share declined in 2021/22. Overall, there is no clear tendency for the share of high-technology manufacturing to increase. The share of high-technology manufacturing in 2021/22 was lower than at the onset of the decade.

Table 2.11: Percentage Share of R&D Expenditure in the Manufacturing Sector by Technology Intensity

	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22
High technology	**18.9**	**19.6**	**15.7**	**12.8**	**15.3**	**14.0**	**15.4**	**15.6**	**19.6**	**13.6**
Radio, television, watches, instrument and clocks	18.9	19.6	15.7	12.8	15.3	14.0	15.4	15.6	19.6	13.6
Medium technology	**67.7**	**66.4**	**71.2**	**73.7**	**73.8**	**72.7**	**65.1**	**68.5**	**69.4**	**76.2**
Petroleum products, chemicals, rubber and plastic	32.8	33.1	40.8	40.5	41.3	37.8	25.3	33.7	37.9	42.1
Other non-metal mineral products	1.4	1.4	1.1	0.6	0.9	0.6	1.4	0.6	1.2	0.6
Metals, metal products, machinery and equipment	16.8	16.4	13.5	14.9	12.6	13.0	16.6	15.9	14,6	17.2
Electrical machinery and apparatus	9.0	6.7	6.7	8.6	11.1	14.2	11.8	7.3	10.4	10.5
Transport equipment	7.7	8.8	9.1	9.1	7.8	7.1	10.0	11.0	3.3	5.8
Low technology	**13.4**	**14.1**	**13.1**	**13.5**	**10.9**	**13.3**	**19.5**	**16.0**	**13.1**	**10.3**
Food, beverages and tobacco	9.2	9.0	8.1	8.5	8.0	10.2	15.7	13.1	9.4	5.9
Textiles, clothing and leather goods	0.1	0.8	0.8	0.2	0.2	0.5	0.4	0.3	0.6	0.7
Wood, paper, publishing and printing	1.5	1.6	1.6	2.2	2.1	2.0	2.4	2.3	2.7	2.6
Furniture & other Manufacturing	2.7	2.6	2.6	2.7	0.6	0.6	1.0	0.3	0.3	1.1

Source: HSRC and DSI's National Survey of Research and Experimental Development, 2021/22

In 2021/2, medium technology sectors accounted for more than three-quarters of manufacturing R&D. The most significant industry is petroleum products, chemicals, rubber and plastics. This sector has had a very considerable increase in its share since

2018/19. In 2021/22, it accounted for 42% of all R&D in manufacturing. The share of the low technology sectors in total manufacturing R&D tended to increase over the decade. However, the share of low-technology sectors declined after 2018/19. Food, beverages and tobacco, which constitute a very large part of the R&D in low technology, have seen very considerable declines in their share since 2018/19, with a particularly strong decline in 2021/22.

Overall, R&D data for the manufacturing sector for the decade do not suggest any clear tendency towards a higher technology intensity. The increase in the share of high-technology manufacturing in total manufacturing R&D evident in 2018/19 – 2020/21 was reversed in 2021/22. R&D in medium technology is increasing, reducing the shares of both high-technology and low-technology manufacturing.

Business Expenditure on R&D at the Firm Level

To provide more insight into the factors that account for the low and declining trend in BERD, NACI commissioned a study of R&D at the level of the firm. Of particular concern was understanding which firms engaged in R&D and the intensity and persistency of their engagement in R&D. The study's main findings are listed below.

This research utilised the administrative tax data from the South African Revenue Service-National Treasury (SARS-NT) database. Given data limitations, the analysis is restricted to firms with a real sales value of R20 million or above (in April 2013 prices). This excludes many small firms that engage in R&D. However, as the research shows, the large firms account for a very high share of BERD.

The tax data corroborates the trend shown by BERD. Aggregate expenditure on R&D by the sample of SARS-NT firms declined from 2010 to 2019. The principal reason for this decline is that fewer firms engaged in R&D activities. More firms exit from R&D than new firms enter into R&D. The exit of large firms from R&D activities had a particularly pronounced impact. Manufacturing firms have been the main contributor to the decline in BERD, but engagement in and expenditure on R&D activities by firms in other sectors have also fallen.

While there is considerable variation (heterogeneity) as between firms, R&D firms differ from other firms. Compared to other firms, R&D firms:

- Are larger in terms of sales, with larger firms more likely to persist in R&D
- Have higher levels of fixed capital.
- Employ more workers and pay higher wages.
- Are more likely to have foreign ownership and be part of a multinational enterprise (local or foreign-owned).
- Are more productive and profitable.
- Are far more integrated into global markets (more likely to be exporters and/or importers and have higher values of exports and export varieties).
- Are particularly important for the export of technologically sophisticated products.

Firms that enter into exporting are more likely to engage in R&D and higher exports are, in turn, more likely to follow engagement in R&D. While this virtuous circle between R&D and exporting applies to relatively few firms, the decline in numbers of R&D firms may have contributed towards the stagnation of aggregate exports and high-tech exports over the past decade.

As expected, R&D firms are significantly more productive than other firms, even after controlling for other firm characteristics. In addition to R&D, the external acquisition of technology through in-licencing of know-how and technology embodied in high-technology imports are essential sources of firm productivity. Indeed, the external acquisition of knowledge is more widespread than R&D and plays a more significant role than R&D in enhancing firm-level productivity, with firms increasingly spending more on royalties and license fees than on R&D. There is a solid complementary relationship - the productivity-enhancing effects of R&D are stronger in firms that also in-licence know how.

2.2.2 R&D personnel in the business sector

Reflecting declining expenditure on R&D in the business sector, the numbers employed in R&D in the business sector declined by a little more than one-fifth (-20.44%) in 2019/20 compared with the previous year. However, in 2020/21, there was a significant increase (16.7%). There was a further increase (15.1%) in 2020/21. By contrast with the R&D expenditure by the business sector in 2021/22, which remains substantially below earlier levels, the numbers employed in R&D in the business sector in 2021/22 are comparable to those employed in earlier years.

Table 2.12: R&D Personnel Full-Time Equivalents in the Business Sector

2012/13	11 322
2013/14	11 877
2014/15	12 928
2015/16	12 458
2016/17	12 549
2017/18	12 953
2018/19	11 691
2019/20	9 301
2020/21	10 860
2021/22	12 505

Source: HSRC and DSI's National Survey of Research and Experimental Development, 2021/22

In summary, the declining trend in both R&D expenditures and personnel in the business sector was reversed in 2021/22. There was a significant increase in R&D expenditure in 2021/22. However, R&D expenditure by the business sector in 2021/22 is still substantially below that earlier in the decade. The share of the business sector in GERD has remained well below that for most of the decade. Foreign-funded R&D in the business sector in 2021/22 almost doubled compared to the previous year. Foreign-funded R&D in the business sector is at similar levels to the decade's first half. There was a significant increase in R&D personnel in the business sector in 2021/22. Employment is approaching the levels earlier in the decade.

Overall, R&D data for the manufacturing sector for the decade do not suggest any clear tendency towards a higher technology intensity. The increase in the share of high-technology manufacturing in total manufacturing R&D evident in 2018/19 – 2020/21 was reversed in 2021/22. R&D in medium technology is increasing, reducing the shares of both high and low-technology manufacturing.

2.2.3 Venture capital investment and financial support to the businesses

Venture Capital

Venture Capital (VC) is an important source of funding for new enterprises – particularly for innovative and technology-based small firms. More than half of all VC deals support new ventures (**Table 2.13**). Early-stage funding i.e. prior to Series A funding, when investment is made in a start-up that has shown progress in building its business model and its potential to generate revenue, constituted more than half of all deals (56.8%). Only a small share of active deals is for buy out, rescue, turnaround and replacement capital (2.6%).

Table 2.13: Venture Capital Investments Contribution by Stage of Deal, all deals still valid, 2022

	Investment by Value (%)	Investment by No. of Deals %
Pre-Seed	0.5	2.3
Seed	4.2	15.3
Pre-Series A	31.6	39.2
Series A	19.9	15.1
Series B	38.6	23.1
Series C	1.4	0.4
Buyout Capital	1.2	1.1
Rescue/Turnaround	2.4	0.9
Replacement Capital	0.2	0.6

Source: SAVCA "2023 Venture Capital Industry Survey"

South African start-ups are active in a broad range of economic activities. In 2022, ICT Fintech, Food and Beverage, Fintech, Manufacturing, ICT (Software) and Consumer Products and Services were the leading sectors by value, accounting for almost half (48.5%) of VC investments. These sectors, together with Business Products and Services (9.8%), accounted for over half (50.9%) of the deals.

Table 2.14: Venture Capital Investment by Sector, for all deals still invested, 2022

	By Value %	By No of Deals %
ICT (Fintech)	12.3	12.6
Food and Beverage	10.7	5.1
Manufacturing	9.3	6.4
ICT (Software)	8.9	10.1
Consumer Products and Services	7.3	6.9
Healthcare (Medical Devices)	6.6	5.2
Healthcare (Other)	5.7	5.7
Business Products and Services	5.1	9.8
Energy	5.0	3.0
ICT (Telecommunications)	4.0	3.2
ICT (AgriTech.)	3.9	2.4
Agriculture (not AgriTech)	3.1	3.3
Health Care (Biotechnology)	2.7	3.1
ICT (Electronics)	2.3	2.8
ICT (Media)	2.2	1.1
ICT (Other)	1.9	2.1
ICT (Security)	1.4	2.2
ICT (online Markets)	1.3	1.6
ICT (eCommerce)	1.3	2.4
Distribution and Logistics	1.3	2.6
Financial Services (non-Fintech)	1.1	2.8
ICT (Ed Tech)	0.8	2.2
ICT (Edtech)	0.9	1.7
Materials and Resources	0.7	0.9
Mining. Minerals and Chemicals	0.4	1.1
ICT (Hardware)	0.3	0.7
Healthcare (Life Sciences)	0.3	0.1
Retail	0.1	0.3

Source: SAVCA "2023 Venture Capital Industry Survey"

South African VC investments are highly concentrated in the Western Cape and Gauteng (**Table 2.15**). Indeed, there is very little VC activity outside of these two regions. In 2022, the Western Cape had the highest share by value (53.7%) and by number of deals (54.3%).

Table 2.15: Business Location of all Deals Still Invested, 2022

	No. of Deals %	Value of Deals %
Western Cape	54.3	53.7
Gauteng	34.8	33.6
KwaZulu-Natal	2.3	1.5
Rest of South Africa	3.8	4.4
Non-South Africa	4.8	6.8

Source: SAVCA "2023 Venture Capital Industry Survey"

Over the last decade, there has been a steady increase in the value of VC investments in South Africa and in the number of deals, with the growth rate rising most rapidly after 2015 (see **Table 2.16**). However, the growth rate slowed in 2020. Thereafter, the value of investments declined, by 5.8% in 2021 and by a further 4.4% in 2022. After 2019, the number of deals continued to rise, but at a slower rate.

Table 2.16: Venture Capital Investments per Annum

Investments	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Value (R millions)	288	183	273	372	933	968	1 067	1 225	1 387	1 306	1 117
Number of deals	8	19	67	69	116	147	134	162	167	186	195

Source: SAVCA "2023 Venture Capital Industry Survey"

VC activity on the African continent has been snowballing, and recently far more rapidly than in South Africa. The total volume of deals in Africa rose from 319 in 2020 to 650 in 2021 and 853 in 2022. In 2014-2020, over one-fifth (21%) of the number of VC deals on the African continent were in Southern Africa. In 2021, Southern Africa's share of VC deals on African content fell to 17%. In 2022, Southern Africa's share of VC deals fell further to 15% - with South Africa's share at 14%. In 2022, Nigeria was the top country destination in Africa for the number of deals (22%). Egypt (15%) and Kenya (13%) have also rapidly increased their shares (AVCA 2023:11).

There is also a pronounced difference in the success rate of start-ups. Over the past five years, Nigeria has produced five technology unicorns, while South Africa has produced none. A significant number of high-potential South African start-ups have left South Africa altogether, including Gyft, Yola, Yoco, and Clickatell.

As VC in continent Africa has expanded more rapidly, South Africa lost its former dominance. “South Africa’s grip on the venture ecosystem has loosened in the face of increased macroeconomic stability, competition, entrepreneurial innovation, and investment elsewhere on the continent, resulting in a drop-in regional activity for Southern Africa.” (AVCA 2023:17)[7]

Innovation Financial Support to the Businesses

Adequate financing is essential for businesses to fund their growth and innovation. The 2019-2021 business innovation survey reveals innovation-active enterprises' different funding models. Despite this, considerable interest is still in obtaining government financial support, especially during the Covid-19 pandemic. Understanding how businesses access and use different funding sources is critical to their financial health and innovation capacity.

Figure 2.6 demonstrates that during 2019-2021, innovation-active enterprises primarily raised their funding from their sources (retained profits or income from asset disposal), representing 74.4% of total funding. About 9.4% of funding sources were debt funding, including loans or credit facilities. Equity finance, or selling company shares to investors, provided 8.2% of the funding. Other sources of funding besides public funding, including crowdfunding, accounted for 4.3% of total sources. The findings imply that innovation-active enterprises are a little dependent on external financing since a significant part of their funding source is their resources. This indicates that these enterprises are financially stable and self-sufficient and do not have to depend on outside innovation funding sources.

[7] African Venture Capital Association (AVCA) (2023). Venture Capital in Africa Report 2022.

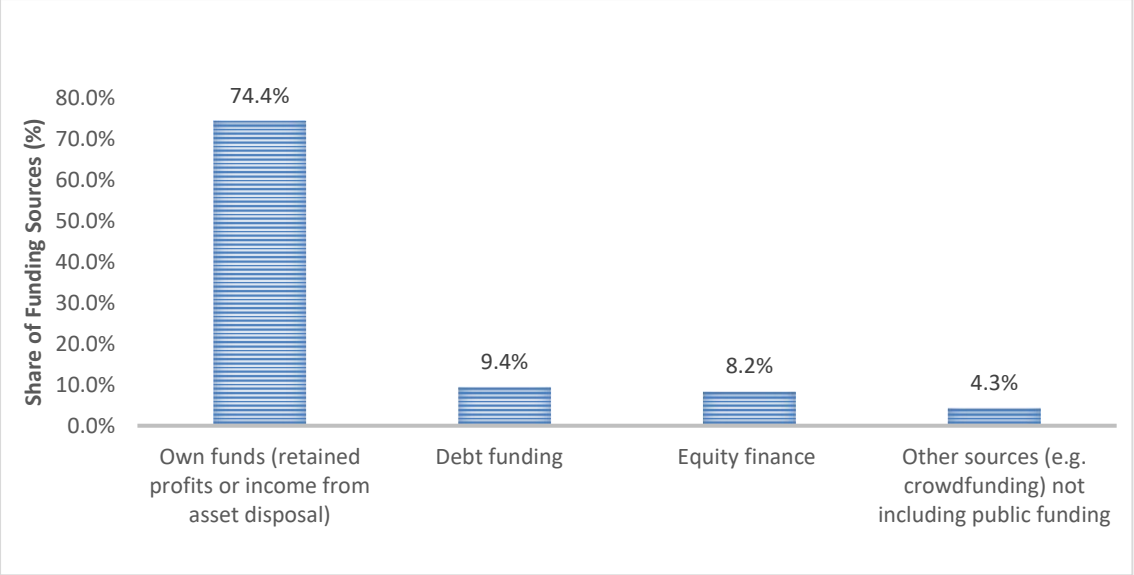


Figure 2.6: Funding Sources for Innovation-Active Enterprises, 2019-2021

Source: HSRC and DSI's Business Innovation Survey, 2019-2021

Figure 2.7 shows the share of innovation-active enterprises applying for and receiving government financial support from 2019-2021. For instance, 26.7% of enterprises applied for COVID-19 grants/support packages, and 23.1% obtained the grants. In addition, 6.8% of enterprises applied for R&D tax incentives, with 5.3% accessing the incentives. Furthermore, 6.1% of enterprises applied for other financial support, with 4.5% obtaining the support. The data highlight a keen interest by businesses in accessing government financial support during the pandemic.

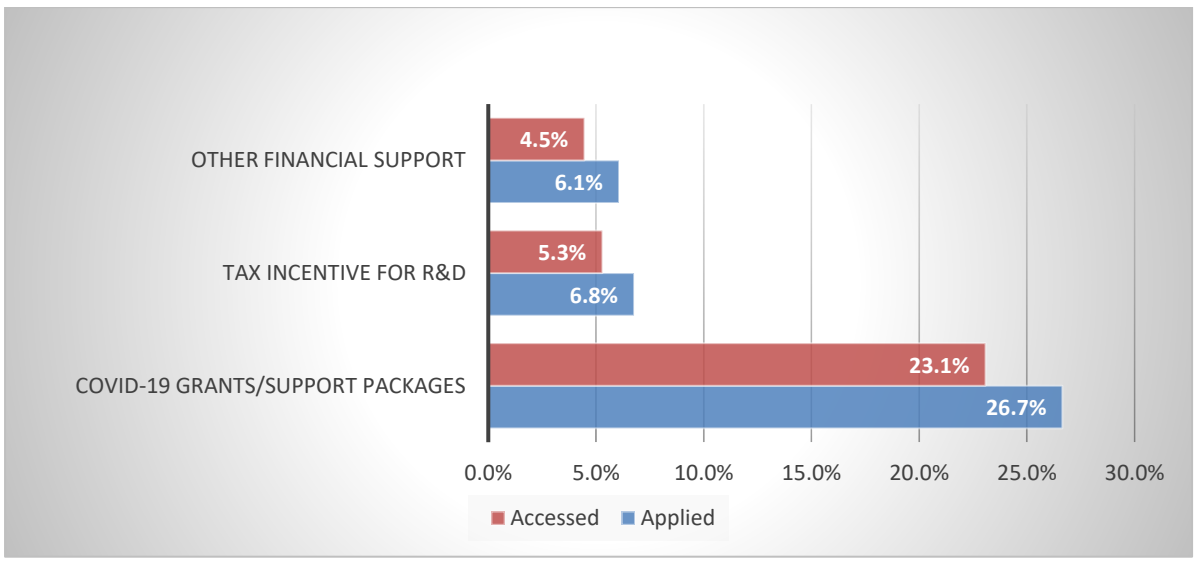


Figure 2.7: Percentage of Innovation-Active Enterprises that Applied and Accessed Government Financial Support

Source: HSRC and DSI's Business Innovation Survey, 2019-2021

In conclusion, even though many innovative enterprises raise funds from within themselves, there is still a keen interest in government financial support in times of crisis such as COVID-19. Understanding and using different funding sources is critical for business financial health and innovation potential.

2.3 Science, technology and innovation human resources

In this section, we report, firstly, on the educational levels in the country; secondly, we drill down on the education and skills pipeline from the schooling sector; and thirdly, we provide a demographic profile of higher education academic staff, R&D technicians, artisans and engineering personnel.

Education continues to be one of the country's top priorities. Figure 2.8 illustrates the level of educational attainment in the country in 2022 and the improvements in educational attainment for adults aged 20 years and older since 2011.

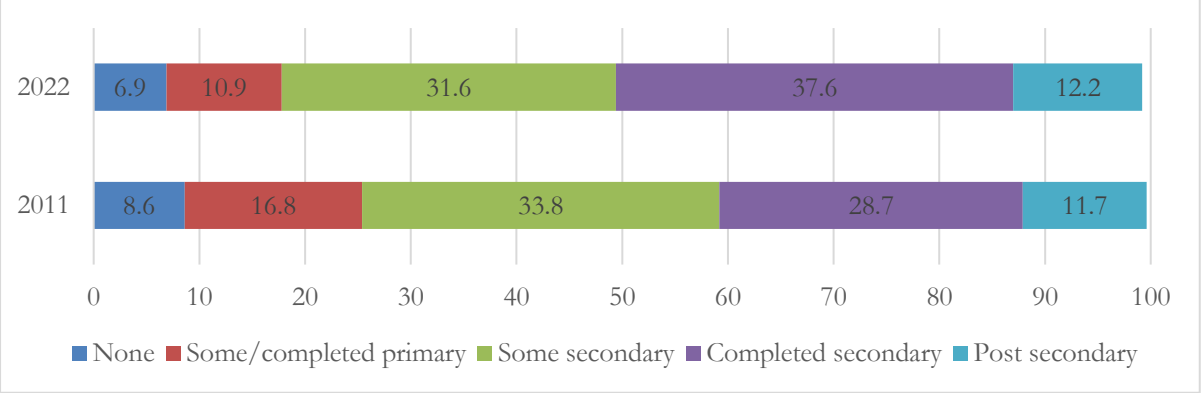


Figure 2.8: Educational Attainment for Individuals Aged 20 Years and Older in 2011 and 2022 (percent)
Source: StatsSA (2023)

In 2022, half of the population aged 20 years and older completed a secondary school education (StatsSA, 2023), an improvement by ten percent from 2011. However, the educational level of the population with post-secondary education increased by only 0.5 percent from 11.7% to 12.2% over the same period[8]While the improvement in secondary education completion is commendable, the level of post-secondary educational attainment is concerning and falls short of the skills needed for society, an efficient NSI, and a thriving economy. The shape of economies is rapidly changing, with an ever-increasing demand for high and specialised skills.

[8] This may not be a supply issue, but due to a net exit of skills from the country.

Comparative country statistics for 25-to 64-year-olds with a tertiary education are: South Africa (14%), India (13%), Brazil (21%), Mexico (21%), USA (50%), UK (51%) and Korea (53%) (OECD, 2023)[9].

In the following sections, we drill down on the education and skills pipeline from the schooling sector, the researchers' profiles, and technicians, artisans, and engineering personnel.

2.3.1 National Senior Certificate human capital pipeline

This section focuses on those who completed secondary school and acquired the grade 12 (or matriculation certificate), those who achieved a Bachelor pass in that examination (i.e. those eligible to enter tertiary education institutions), and the quality of passes in mathematics subjects (a proxy for analytical skills). It also provides a provincial profile of the education and skills of the school system, which could support the regional system of innovation.

The schooling system is extensive, with close to 13 million learners, the majority of who attended public schools while five percent attended independent schools (DBE, 2022)[10]. Of those who wrote the grade 12 examinations, 663 162 learners sat for the National Senior Certificate (NSC) and 15 180 for the Independent Examinations Board (IEB). The analysis here is focused on learners in public schools who took the NSC.

South Africa is a highly unequal society with an unequal educational system. Schools are categorised into five quintiles, denoting a school's poverty index. Quintile 1 are the most under-resourced schools in the most economically disadvantaged communities, and Quintile 5 are the most resourced schools, generally in the more affluent communities[11].

Figure 2.9 provides learner performance in the NSC 2023 examinations by the poverty index of the schools. Overall, 83% of the learners passed the NSC examination, and 40% achieved a Bachelor pass, allowing them access to tertiary studies. The performance patterns for different parts of the education system vary. On average, learners attending

[9] OECD (2023), Education at a Glance 2023: OECD Indicators, OECD Publishing, Paris, https://doi.org/10.1787/e13bef63-en.

[10] Department of Basic Education (2022) School Realities Report 2022. Published by the Department of Basic Education. https://www.education.gov.za/Portals/0/EMIS/School%20Realities%20December%202022.pdf?ver=2022-12-12-112304-000. Accessed February 2023.

[11] Learners in Quintile 1, 2 and 3 schools do not pay school fees, called no-fee schools, while learners in Q4 and 5 schools pay fees, and these are called fee-paying schools.

quintile 1, 2, 3 and 4 schools achieved similar pass rates (80% and 82%) and Bachelor pass rates (36% and 39%). On average there is minimal achievement variation among Q1 to 4 schools, who make up 84% of the school system. Sixteen percent of the learners who wrote the NSC examinations attended quintile five schools and achieved a 90% pass rate and a 55% Bachelor pass rate.

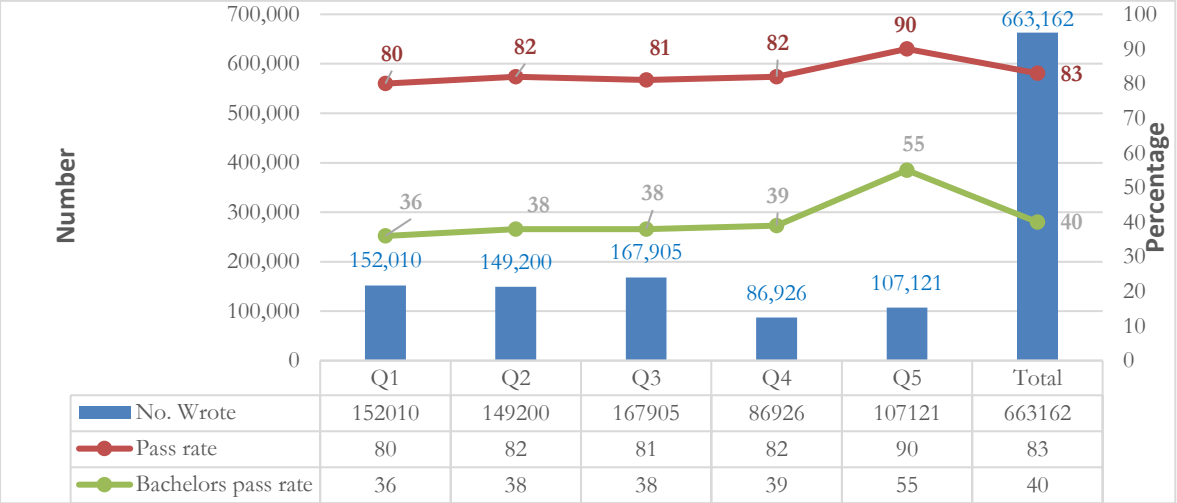


Figure 2.9: Performance in NSC 2023 by the Poverty Index of the School

Source: Own calculations from DBE (2024) data[12]

There is a gender imbalance in the number of girls and boys who wrote the NSC examination – the 2023 cohort comprised 44% male and 54% female learners. There is a high dropout of males, especially those with weaker academic performance, from schooling, creating a potential problem of young boys without adequate education, skills or employment.

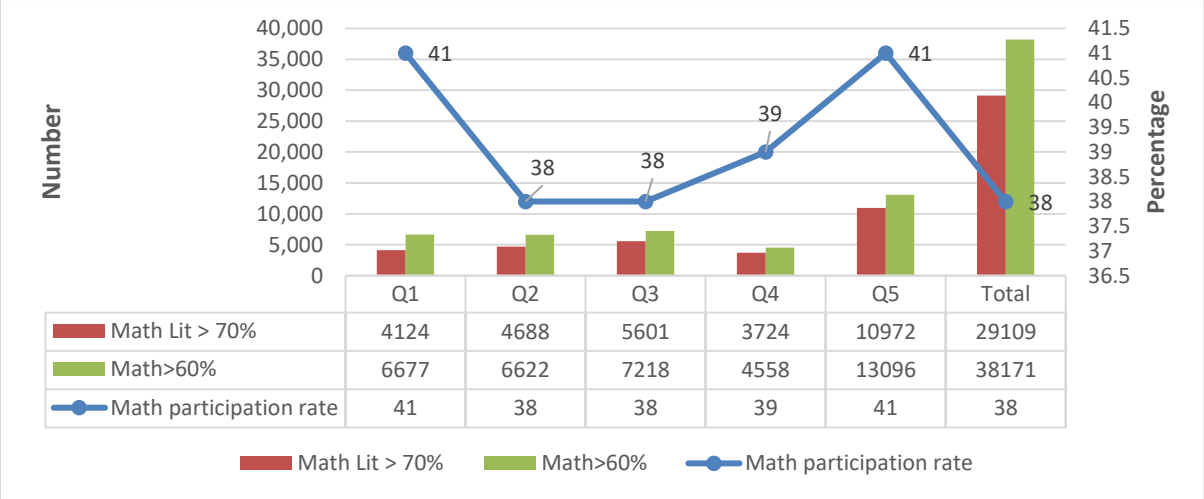
Summary of Mathematics Performance in NSC 2023

Numerical, mathematical, and scientific skills are key competencies for personal development, a modern society, and an increasingly knowledge—and technology-based economy. Mathematics and Science achievement at school signals the future ability of learners to continue studying technical subjects in post-secondary education and training institutions. Those with sound Mathematics and Science skills are considered to possess abilities that make them more trainable in several jobs.

[12] DBE (2024) 2023 NSC Exam Results Technical Report. https://www.education.gov.za/Portals/0/Documents/Reports/2021NSCReports/NSC23%20Technical%20Report.pdf?ver=2024-01-18-161615-123

Given the importance of school mathematics, we report on the participation rates and performance in the NSC 2023 examinations. All learners follow the same Mathematics curriculum until the end of Grade 9. In Grade 10, learners take academic Mathematics or Mathematical Literacy courses. Most Science, Technology, Engineering and Mathematics (STEM)-based tertiary qualifications require learners achieving at least 60% in Mathematics, while learners with 70% or higher in Mathematical Literacy may be eligible for some STEM tertiary qualifications.

For an insight into the pool of potential Grade 12 graduates who are eligible to study the qualifications that are in higher demand in the workplace, Figure 2.10 illustrates the participation rate in Mathematics (vis-à-vis Mathematical Literacy) and the number of learners who passed Mathematics with a score higher than 60% and Mathematical Literacy with a score higher than 70%.



	Q1	Q2	Q3	Q4	Q5	Total
Math Lit > 70%	4124	4688	5601	3724	10972	29109
Math>60%	6677	6622	7218	4558	13096	38171
Math participation rate	41	38	38	39	41	38

Figure 2.10: Mathematics Participation and Performance in NSC 2023 by the Poverty Index of the School

Source: DBE (2024) data

Overall, 262 016 learners (i.e. 38%) who wrote the NSC 2023 examinations took the Mathematics examination, while 62% opted for Mathematical Literacy. The Mathematics cohort comprised 58% female and 42% male learners. The Mathematics participation rates in the different quintiles are similar, and, surprisingly, quintile five schools have the same participation rate as quintile one schools.

A total of 38 171 learners scored above 60% in the Mathematics examination, while 29 109 achieved higher than 70% in Mathematical Literacy. This means slightly over 67 000 learners, with a strong mathematical foundation, are potentially eligible to participate in STEM-related tertiary qualifications. Just over a third (36%) of these learners attended

quintile five schools, while just over half (52%) attended no-fee schools (Q1, 2 and 3). There is the potential for these outcomes to continue improving – with higher performance expected in the better-resourced quintile five schools and more support offered to learners in quintile one to four schools to increase performance.

Trends in NSC Performance from 2014 to 2023

To better understand the state of the schooling system, it is informative to examine the education trend over the last ten years (i.e. from 2014 to 2023) concerning the following indicators from the matriculation examination: pass rates, Bachelor pass rates, shares of matriculants who took Mathematics rather than Mathematical Literacy and the numbers who achieved higher than 60% for Mathematics (**Table 2.17**).

Table 2.17: Trends in Matriculation Participation and Performance

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Number that wrote the NSC exams	532 860	644 536	610 178	534 484	512 735	504 303	578 468	704 021	725 146	691 160
Pass rate	75.8	70.7	72.5	75.1	78.2	81.3	76.2	76.4	80.1	82.9
Number of Bachelors passes	150 752	166 263	162 374	153 610	172 043	186 058	210 820	256 031	278 814	282 894
Bachelor pass rate	28.3	25.8	26.6	28.7	33.6	36.9	36.4	36.4	38.4	40.9
Number that took mathematics	255 458	263 903	265 810	245 103	233 858	222 034	223 315	259 143	269 734	262 016
Percent mathematics participation	47.9%	40.9%	43.6%	45.9%	45.6%	44%	38.6%	37%	37%	38%
Number that achieved >60% for mathematics	30 226	31 760	33 832	32 323	28 118	23 763	30 706	34 380	33 733	38 171

Source: Information extracted from DBE (2024) data

From 2014 to 2023, the number of learners that wrote the NSC examinations fluctuated between half and three-quarters of a million learners, with the lowest numbers recorded in 2019 (504 303) and the highest numbers in 2022 (725 146). Pass rates generally increased, from 71% in 2015 to 83% in 2023. The number of Bachelor passes steadily increased from 150 752 in 2014 to 282 894 in 2023 – an increase of 88%. The Bachelor pass rate over the same period increased from 28% in 2014 to 41% in 2023. Both the matriculation pass rate and Bachelor pass rate signal that educational outcomes are improving.

Learner choices of Mathematics or Mathematical Literacy as a senior secondary subject is concerning. Over the last ten years, the share of learners who took NSC Mathematics steadily declined from 48% in 2014 to 38% in 2023 – a decrease by ten percent. The reason for this decline is uncertain: either because learners cannot cope with academic Mathematics or schools pushing learners to Mathematical Literacy or learners choosing

Mathematical Literacy to achieve a higher overall pass? It is important to stop the decline and encourage higher participation in Mathematics.

Over the same period, the number of learners achieving a Mathematics pass of over 60% increased slightly from 30 226 in 2014 to 38 171 in 2023 – this represents an average annual increase of 2.6%. This slow pace of improvement is concerning since the demand for STEM skills is rapidly increasing, while the supply from the schooling system is not keeping pace.

Provincial Performance and Potential Skills for Regional Systems of Innovation

Socio-economic conditions differ from province to province. With the focus on building the regional systems of innovation, an analysis of the NSC 2023 examination is provided, together with the Gross Regional Domestic Product (GRDP) for each province, for an insight into the supply of skills at the provincial level (see **Table 2.18**). In the table, the top three provinces on each indicator are indicated using blue shading and the bottom three provinces using yellow shading.

Table 2.18: Participation and Performance in NSC 2023 by Province

Province	Provincial GDP (2019) per capita (Rands)	Number that wrote NSC	NSC pass rate	Bachelor pass rate	Math participation rate	Math achieve >50%	Math Skills Index
Eastern Cape	55 000	95 697	81.4	39.6	45	21.8	981
Free State	80 000	34 451	89	44.7	37.3	29.2	1 089
Gauteng	110 000	127 697	85.4	44.3	33.5	33.5	1 122
KwaZulu-Natal	66 000	157 911	86.4	45.7	38.6	27.2	1 050
Limpopo	59 000	93 533	79.5	36.4	47.9	24.6	1 178
Mpumalanga	78 000	65 534	76.9	33.3	42.8	24.3	1 040
North-West	77 000	41 418	81.6	36.4	26.9	26.8	721
Northern Cape	80 000	12 842	75.8	30	21.2	21.7	460
Western Cape	98000	62 077	81.5	42.2	25	43	1 075

There is a wide variation between provinces but not a consistent pattern. The most industrialised provinces, Gauteng and Western Cape, are the wealthiest provinces while the Eastern Cape, Limpopo and KwaZulu-Natal have the lowest GDP per capita. The size of the provincial educational systems, and hence the number of learners who wrote the NSC 2023 varied from 12 842 learners in the Northern Cape to 157 911 learners in KwaZulu-Natal. The three provinces with the highest pass rates and Bachelor pass rates were the Free State, KwaZulu-Natal and Gauteng provinces, while the lowest pass rates were in the Limpopo, Mpumalanga and Northern Cape provinces. The pass rates varied from 75.8% (Northern Cape) to 89% (Free State).

There was a surprising pattern for Mathematics participation. The provinces with the highest Mathematics participation rates, the Eastern Cape, Limpopo and Mpumalanga, also had the lowest Regional GDP. The Northwest, Northern Cape and Western Cape provinces had the lowest Mathematics participation. We created a Mathematics High Skills Index by multiplying the Mathematics participation rate by Mathematics achievement over 50% to rank the Mathematics capability of the provinces. The provinces producing the highest mathematics skills were Limpopo, Gauteng and Free State, and the provinces with the lowest Mathematics skills were the Eastern Cape, Northwest and Northern Cape provinces.

2.3.2 Higher education academic staff

The trend in academic capacity at public universities shows that there has been a steady increase in the number of permanent instructional/research personnel between 2010 and 2016 (see **Figure 2.11**). However, in terms of headcount and full-time equivalent (FTE), the trend since then shows a plateauing of the numbers and an evident decline over the past year or two. This illustrates that the academic capacity at public universities is now in stagnation and declining.

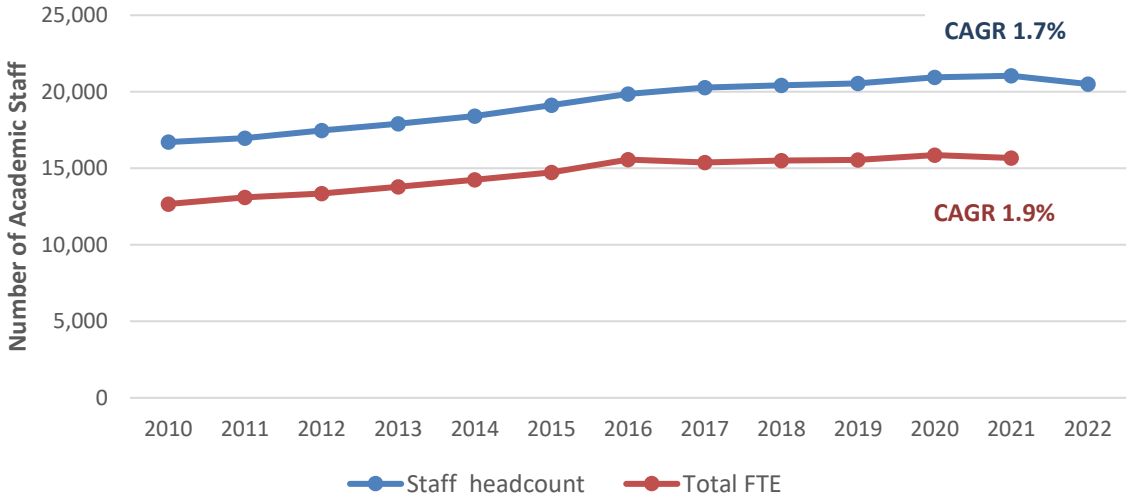


Figure 2.11: Growth in Permanent Academic Staff (HC and FTE)
Source: CREST

Public universities in South Africa remain constrained by the slow growth in their academic staff capacity, especially compared to the development of postgraduate students. **Figure 2.12** shows that over the last decade, the number of permanent academic staff has grown at a compound average growth rate of 2.1%, whereas postgraduate enrolments grew at 2.7%. Undergraduate enrolments grew at an equally slow rate of 1.5%. This higher rate of

growth in the number of postgraduate enrolments contributes to the already heavy supervisory burden experienced by South African academics.

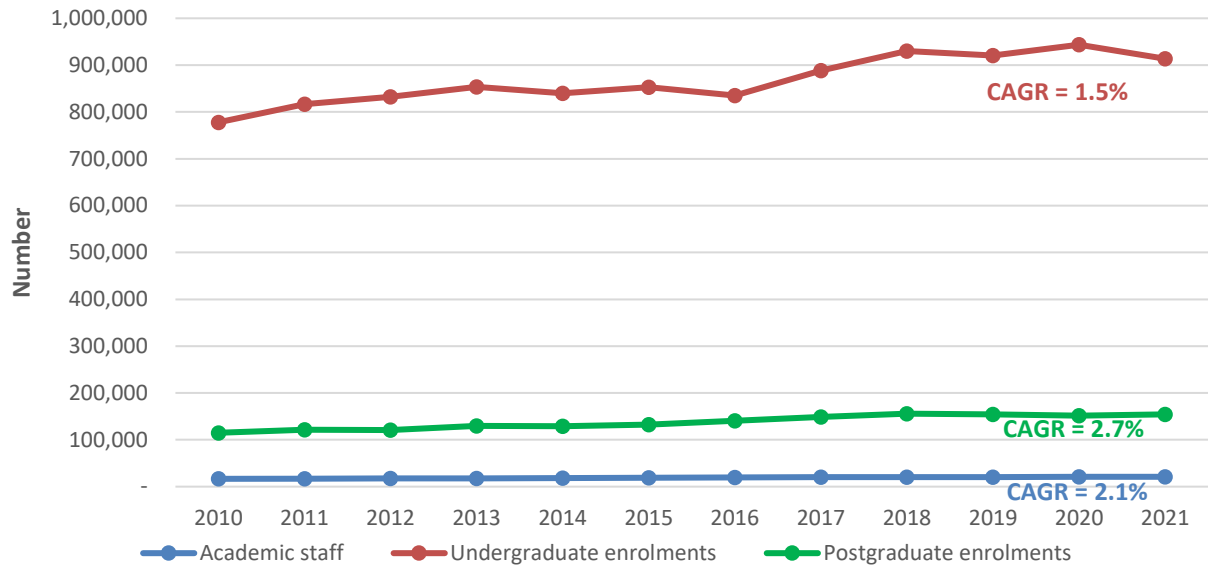


Figure 2.12: Growth in Number of Permanent Academic Staff, Undergraduate and Postgraduate Enrolment

Source: CREST

Figure 2.13 shows that academic staff at public universities has gradually become more inclusive of women academics. The percentage of South African female permanent instructional research staff increased from 46% in 2010 to 52% in 2021 and reached parity with male staff in 2016. Although there is no specific target set in any South African policy document against which this trend can be assessed, the graph shows a positive trend regarding the general transformation imperative to make academic staff capacity more inclusive and to improve the representation of female academics in the sector.

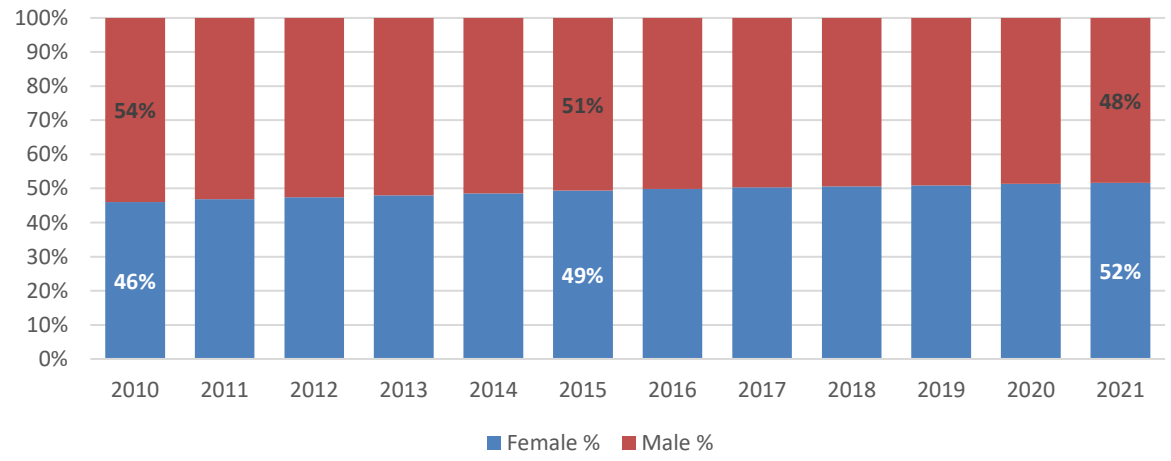


Figure 2.13 Percentage Male and Female Permanent Academic Staff

Source: CREST

The trend over the past 12 years (**Figure 2.14**) shows that there has been a substantial increase in the percentage of Black South African academic staff at South African universities. The share of Black African academic staff increased from 27% in 2010 to 43% in 2021. At the same time, the share of Indian and Coloured staff also increased over the reported period, where South African Black staff (including Black African, Coloured, and Indian) constituted 60% of all South African academic staff in 2021. Conversely, the percentage of white staff has decreased significantly from 58% in 2010 to 40% in 2021.

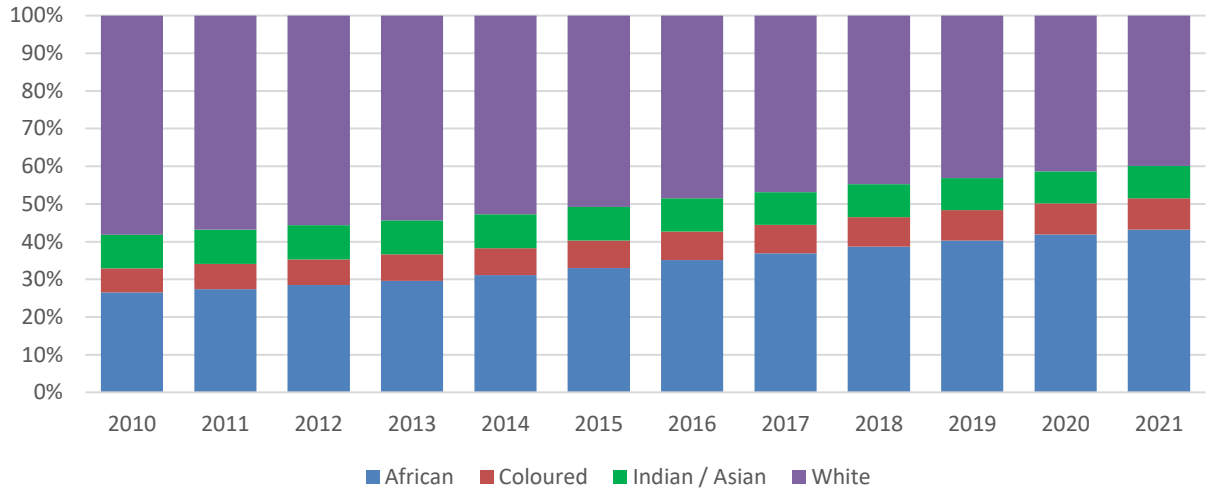


Figure 2.14: Permanent Academic Staff by Race (SA only)
Source: CREST

Figure 2.15 shows that there has been a steady increase in the percentage of permanent academic staff with doctoral degrees – from 36.0% in 2010 to 48.7% in 2021. National policy documents, such as the National Development Plan (2030) and STI Decadal Plan (2021 – 2031), have set as a target that 75% of all permanent academic staff at traditional universities and 40% at universities of technology should have a Doctoral degree by 2030. By 2021 approximately half of all staff had PhDs.

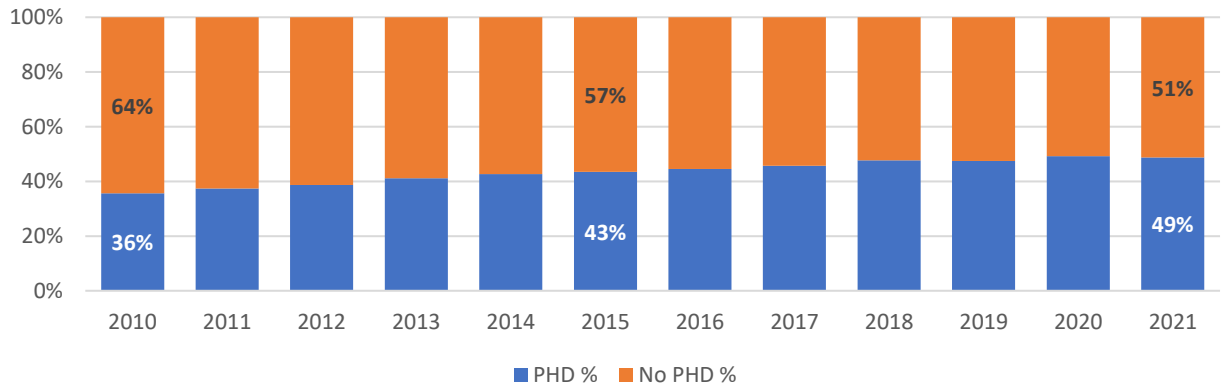


Figure 2.15: Percentage of Permanent Academic Staff with a PhD

Source: CREST

It is worth pointing out that this sector average should be understood against the considerable differentiation in the university sector. The top research universities record percentages in the mid- to high sixties, whilst the universities of technology record substantially lower percentages of staff with a Doctoral degree (see **Table 2.19**). Additionally, it is important to emphasise that the trend displayed in this graph represents the general picture across all scientific fields. A breakdown by scientific field and discipline will reveal large differences.

Table 2.19: Percentage of Permanent Academic Staff with a PhD by University

University	2010	2015	2020	2021
UP	39.6%	62.4%	69.7%	71.2%
WITS	53.0%	61.3%	66.5%	67.8%
SU	52.7%	56.7%	62.7%	63.6%
RU	55.8%	54.0%	60.2%	63.3%
UWC	48.5%	55.8%	58.4%	61.9%
UCT	61.2%	66.8%	60.6%	61.5%
UKZN	39.8%	47.2%	60.1%	61.1%
UJ	22.4%	44.2%	53.7%	55.8%
SPU	-	30.0%	48.5%	55.3%
NWU	48.6%	49.6%	48.2%	55.2%
UFS	44.1%	46.9%	52.2%	55.1%
UNIVEN	32.4%	33.6%	44.2%	49.0%
UM	-	2.2%	45.7%	47.6%
UNIZULU	33.6%	38.3%	48.0%	47.4%
UFH	32.5%	41.5%	46.8%	47.1%
NMU	38.0%	43.7%	45.8%	46.2%
CUT	26.9%	31.9%	40.1%	41.5%
TUT	19.1%	26.7%	34.1%	36.7%
UL	19.9%	26.4%	33.8%	35.1%
DUT	11.3%	21.7%	31.7%	34.5%
CPUT	12.4%	23.2%	31.3%	31.4%
UNISA	31.9%	42.6%	53.0%	25.9%
SMU	-	15.1%	20.4%	24.1%
WSU	10.9%	13.6%	19.9%	23.9%
MUT	5.9%	13.0%	21.0%	21.1%
VUT	14.3%	16.1%	20.7%	20.8%

Source: CREST

2.3.3 Profile of technicians supporting research and development

Technicians supporting research and development (which we will refer to as R&D technicians) perform scientific and technical tasks involving the application of concepts and operational methods, generally under the supervision of researchers. They require technical knowledge and experience in engineering, physical and life sciences, or social science and humanities. The NACI's 2022 STI Indicators Report highlighted the shortage of R&D technicians. To understand the shortage, this sub-section describes the trend in

R&D technician participation in the workforce and the demographic profile of the R&D technician sector.

On average, the number of R&D technicians over 2012 - 2021 was 129 per million people. Two countries with a similar skill profile to South Africa were Mauritius and Mexico, with 130 and 140 R&D technicians per million people respectively. Malaysia and Egypt had higher numbers of R&D technicians, with 233 and 370 per million people respectively, while India had 73 R&D technicians per million people (UNESCO Institute of Statistics).

Table 2.20: Number of R&D Technicians (FTE) per Million People

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Number of R&D technicians per million people	125	129	142	139	135	130	123	118	116	129

Source: The South African National Survey of Research and Experimental Development: Statistical Report: 2021/202

Secondly, this sub-section reports the demographic profile of R&D technicians by gender, highest educational qualification, and population group for 2019 to 2021.

R&D personnel comprise the following occupational categories: researchers, technicians and other R&D personnel. **Table 2.21** reports the number of R&D researchers and technicians for the 2019 to 2021 period and the proportion of researchers to technicians. For this period, the headcounts of researchers and technicians have remained stable. On headcounts, there are six researchers per R&D technician. This ratio changes when calculated by FTEs – there are four researchers per R&D technician.

Table 2.21: R&D Personnel, in Headcounts and Full-time Equivalents, by Occupation

	2019		2020		2021	
	Headcounts	FTEs	Headcounts	FTEs	Headcounts	FTEs
Researchers	62 002	28 358	61 406	27 698	63 122	27 763
Technicians	10 080	6 880	9 870	6 847	10 221	7 657
Proportion and Ratio: Technicians to Researchers	16% 1:6	24% 1:4	16% 1:6	25% 1:4	16% 1:6	28% 1:4

Source: The South African National Survey of Research and Experimental Development: Statistical Report: 2021/2022; 2020/2021; 2019/2020

As shown in **Table 2.22**, over the period 2019-2021, there were more male than female R&D technicians, although this gap is closing.

Table 2.22: Demographic Profile of R&D Technicians

	2019		2020		2021	
	Headcounts (10 080)	Percent	Headcounts (9 870)	Percent	Headcounts (10 221)	Percent
By gender						
Male	5 710	57	5 617	57	5 434	53
Female	4 370	43	4 253	43	4 787	47
By population group						
Africans	4 911	49	4 814	49	4 693	46
Coloured	1 129	11	1 090	11	1 094	11
Indian/Asian	705	7	680	7	733	7
White	3 039	30	3 020	31	3 428	34
Non-SA	296	3	268	3	273	3
By educational qualifications						
Doctoral degree or equivalent	310	3	305	3	450	4
Masters, Honours, Bachelor or equivalent	3 837	38	3 921	40	4 376	43
Diplomas	5 933	59	5 644	57	5 395	53

Source: The South African National Survey of Research and Experimental Development: Statistical Report: 2021/2022; 2020/2021; 2019/2020

There was a growing number of African R&D technicians and a decreasing number of White R&D technicians, although this trend reversed slightly in 2021. In 2021, 46% of the R&D technicians were African, followed by Whites (34%), Coloureds (11%) and Indian/ Asian (7%). Forty-seven percent of the R&D technician workforce had a Bachelor degree or higher qualification, with four percent with a doctoral degree. The rest of the workforce had a diploma qualification.

2.3.4 The artisanal sector: Enrolments and completions

The Skills Development Act (1998) defines an artisan as a person certified as competent to perform a listed trade. Artisanal skills are important in supporting economic growth. Hence, artisanal skills development is a priority area. To be certified as an artisan, a person must complete the theory component, a practical training component, structured workplace training and trade testing.

Between 1985 to 1995, the number of artisans in training decreased from an annual high of 33 000 in 1985 to just over 22 000 in 1994 (Mzabalazo Advisory Services, 2022)[13]. The

[13] Mzabalazo Advisory Services (2022). *Supply and Demand of Artisans in South Africa*. Labour Market Intelligence research programme, Department of Higher Education. and Training.

NDP set a target for the country to produce 30 000 artisans per year. On average, from 2012 to 2021, the country produced 18 000 qualified artisans per year.

Over the 2012 to 2021 period, there were close to a quarter million registrations for artisanal training programmes. The number of registrations increased from 21 849 in 2012 to a high in 2017 and 2018, with nearly 30 000 registrations each year (**Table 2.23**). In 2020, there was a drastic decrease in registrations to 10 302 (perhaps due to the COVID-19 pandemic). There was a slight increase in registrations to 14 379 in 2021. The net change in the annual registrations from 2012 to 2021 showed a decrease from 21 849 to 14 379 registrations – a decrease of 34%. The highest drop in registrations was at Indelela Trade Test Centre, the Manufacturing, Engineering and Related Service Sector Education and Training Authority (MerSeta) and the Services SETA (DHET, 2023)[14].

Over the 2012 to 2021 period, there were 184 558 completions of the artisanal programme. In 2012, 15 277 students completed the programme. There was a general increase in completions, with slightly more than 24 000 completions in 2019 (see **Table 2.23**). Artisanal completions dropped to 15 106 in 2020 and rose again to 19 536 in 2021. In 2021, the highest number of completions was reported by Merseta (25%), followed by the Construction Education and Training Authority (14%) and Energy and Water SETA (13.2%) (DHET, 2023).

Table 2.23: Number of Enrolments and Completions of the Artisanal Learning Programme

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Enrolments	21 849	27 670	28 302	28 640	30 817	32 330	29 982	16 218	10 302	14 379
Completions	15 277	18 110	14 389	16 114	21 198	21 151	19 627	24 050	15 106	19 536

Source: DHET, 2023

Artisanal training is offered in 124 trades (e.g. panel beater, carpenter, vehicle painter, refrigeration mechanic). There are 15 trades identified as 'scarce skills', and within the scarce skills list, a quarter of the registrations were for the electrician trade. The three trades with the lowest registrations are: carpenter/ joiner (0), joiner (1) and pipe fitter (17).

The demographics of the artisans who have qualified are: 54% of the trade test passes were in the 25- —to 34-year-old category; 71% were African and 81% male. The 25- —to 44-year-old category accounted for 87% of all trade test passes, indicating that most

[14] Department of Higher Education and Training (DHET) (2023) Statistics on Post-School Education and Training. Published by Department of Education and Training, Pretoria.

qualifying artisans are older youth. This is different from most other countries, where people generally pass the trade test around 20 to 21 years of age (Mzabalazo Advisory Services, 2022).

While artisanal skills have been identified as a priority skill, over a ten-year period, 30 844 artisans registered on an unemployment database. The trade with the largest number of unemployed artisans was the electrician trade (18.5%), followed by boilermaker (13.7%), bricklayer (13%), rigger (12.2%), plumber (10.1%), and carpenter (7%) (Mzabalazo Advisory Services, 2022).

2.3.5 Registered engineering professionals and candidates

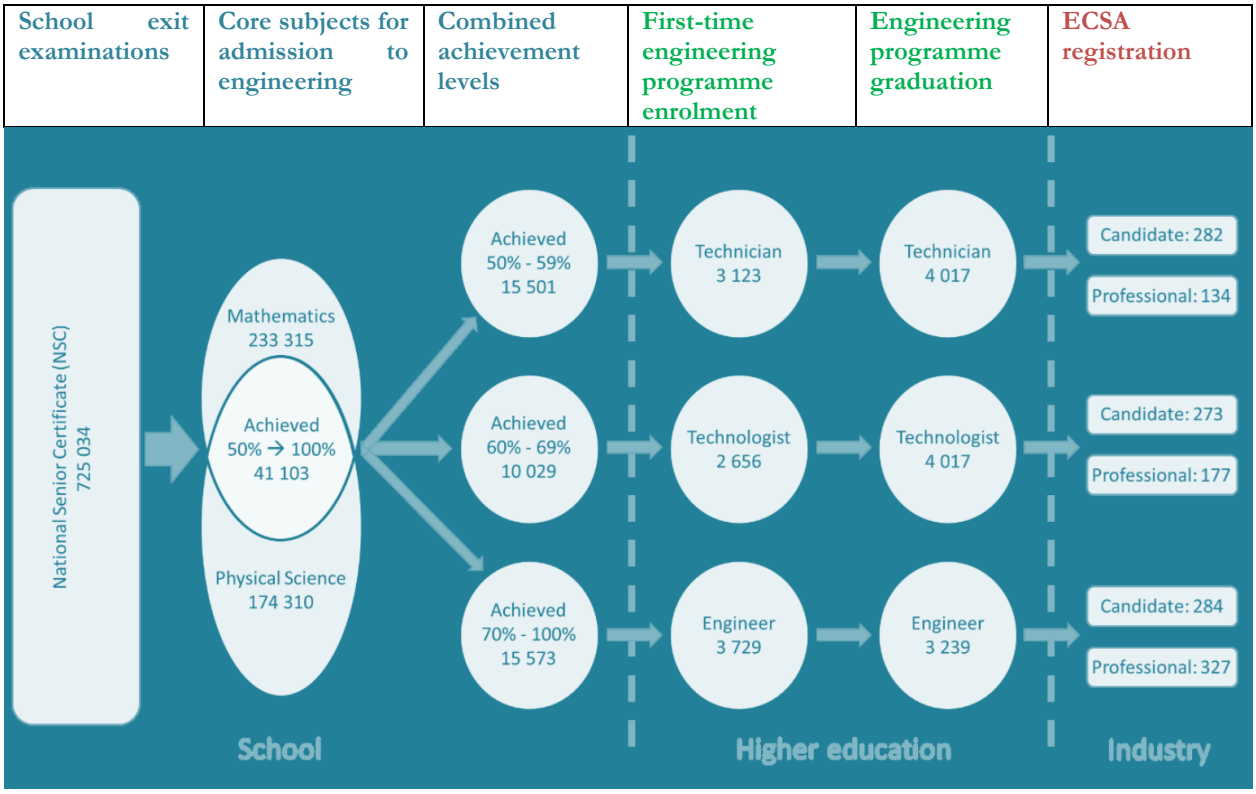
There is a shortage of engineering skills in South Africa and globally. Engineering qualifications are versatile and attractive to several industrial sectors. The Labour Market Intelligence Partnership project reported that close to one-third of engineering graduates were employed in the financial service sector in 2014 and 2018, and this increased to 43% in 2021 (Reddy et al., 2016; Khuluvhe et al.,2022).

Engineering graduates who work in engineering jobs must register with the Engineering Council of South Africa (ECSA). The Engineering Professions Act of 2000 empowers ECSA to register persons applying for registration across all professional and candidate categories. ECSA has three registers: professional engineers, professional engineering technologists, and professional engineering technicians. To be eligible to register as an engineering professional, a person must have successfully completed a qualification at an ECSA-accredited higher education institution and demonstrated competence in a variety of areas.

The pipeline to practise as an engineer in South Africa consists of three phases: completion of schooling and higher education (TVET colleges, Universities of Technology, Traditional and Comprehensive Universities) and then a professional registration with ECSA.

ECSA presented a high-level snapshot for 2020 to illustrate the number of students moving through the different pipeline stages until they had registered with ECSA[15]. **Figure 2.16** quantifies the pipeline of potential engineering professionals as they move through the education system and proceed to professional registration with ECSA.

In 2020, just over three-quarters of a million learners took the National Senior Certificate (NSC) examination. In this cohort, 41 103 students achieved results that made them eligible to enter one of the engineering programmes,[16] with 15 501 eligible to study for the engineering diploma to become a technician, 10 029 for the Bachelor of Technology to be a technologist and 15 573 for the Bachelor of Engineering to become engineers. In the same year, the total first-time engineering enrolments for these university pathways was 9 508, with 3 123 enrolments for the technician route, 2 656 technologist enrolments and 3 729 enrolments for engineers[17]. There were 11 323 engineering graduates: 4 017 with a diploma, 4 017 with a Bachelor of Technology (Eng) and 3 239 with a Bachelor of Engineering.



[15] ECSA (2022) Engineering Skills Pipeline. Produced by ECSA. https://www.ecsa.co.za/ECSADocuments/Shared%20Documents/Engineering%20Skills%20Pipeline.pdf. Accessed 16 February 2024

[16] Learners need to achieve at least 50% in both mathematics and physical science for eligibility to a tertiary engineering programme.

[17] This analysis does not include entrants to the TVET Nated programmes.

Figure 2.16: Summary of Pipeline from School Exit Examinations to Professional Registration, 2020

Source: Reproduced from ECSA (2022)

Those who took jobs as professional or candidate engineers, technicians or technologists need to obtain their professional registrations with ECSA. In 2020, there were 839 new engineering candidates and 638 new engineering professional registrations.

Number of Engineering Professionals and Candidates Registered on the ECSA Database

The registration process has been slow and ECSA has embarked on campaigns encouraging registrations. **Table 2.24** presents the number of engineering professionals and candidates for the four occupations (engineers, technologists, certificated engineers and technicians).

At the start of 2020, there were 55 393 engineering professional and candidate registrations and 21 502 new registrations. The database at the end of 2021 had 77 441 registrations.

Table 2.24: Number of Engineering Professionals and Candidates in Four Occupations, 2020

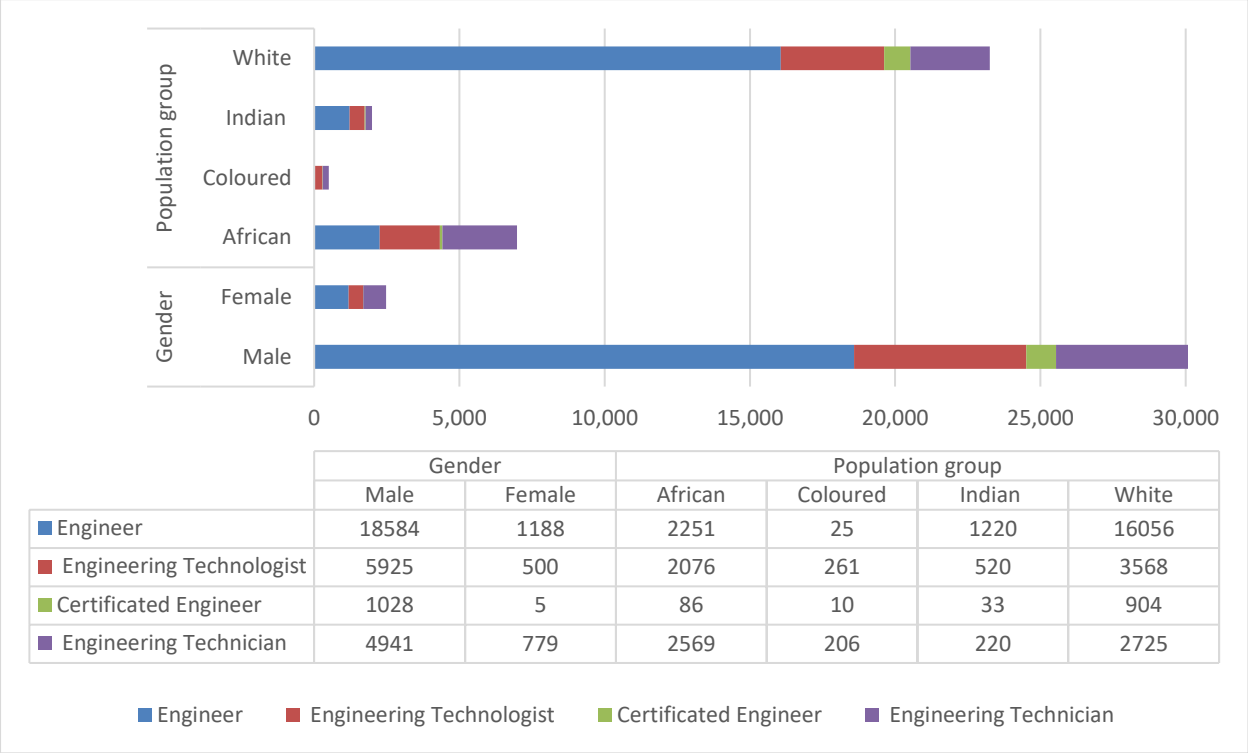
	Engineers		Technologist		Certificated Engineer		Engineering Technician	
	Registrations to 2020	New Registrations	Registrations to 2020	New Registrations	Registrations to 2020	New Registrations	Registrations to 2020	New Registrations
Professionals	19 772	488	6 425	231	1 033	15	5 720	219
Candidates	9785	8 829	5 688	5 053	279	227	6 691	6 440
Total for 2020	**29 557**	**9 317**	**12 113**	**5 284**	**1 312**	**242**	12 411	6 659

Source: Extracted from ECSA Annual Report, 2020/2021

Profile of Engineering Professionals

By 2020, 32 950 professional engineers, technologists, technicians, and certificated engineers were registered on the ECSA registration database. In the same year, 953 new registrations across the four categories were made, giving a total of 33 903 registered engineering professionals.

Of the registered engineering professionals, 92.5% were male, 71% were White and 21% were Black African.



	Gender		Population group			
	Male	Female	African	Coloured	Indian	White
Engineer	18584	1188	2251	25	1220	16056
Engineering Technologist	5925	500	2076	261	520	3568
Certificated Engineer	1028	5	86	10	33	904
Engineering Technician	4941	779	2569	206	220	2725

Figure 2.17: Profile of Registrations for Engineering Professional Occupations, by Gender and Population Group, 2020

Source: Data extracted from ECSA Annual Report 2020/2021

The age structure highlights the changing population group profile. There is a higher proportion of younger Black African engineering professionals, while most of those over age 50 were White (see **Table 2.25**).

Table 2.25: Age Structure of Engineering Professionals by Population Group, 2020

Age groups	African	Coloured	Indian	White
20-39	3 291	243	768	2 403
40-49	2 736	279	744	2 567
Over 50	955	198	476	12 400

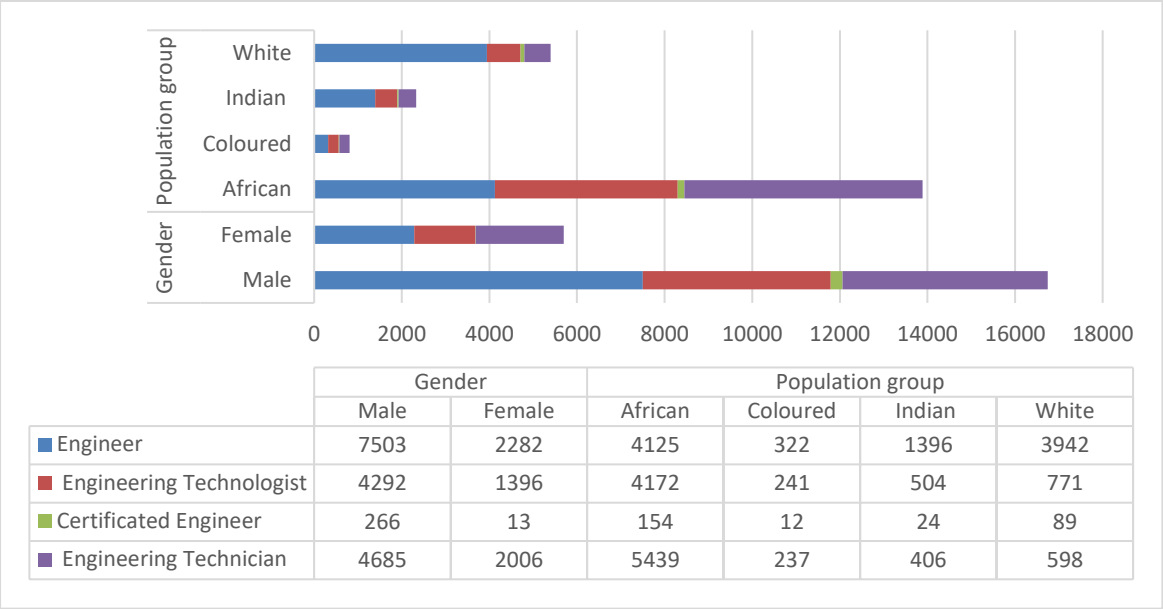
Source: Data extracted from ECSA Annual Report 2020/2021

Profile of Engineering Candidates

Within three years of graduation, a person with one of the four engineering qualifications can register as a candidate engineer. **Figure 2.18** paints the demographic profile, by gender and population group, of the engineering candidates registered on the ECSA database.

By 2020, the ECSA registration database had 22 443 candidate engineers, technologists, technicians, and certificated engineers. In the same year, there were 20 549 new registrations across the four categories, giving a total of 42 992 registered engineering candidates.

Of those that are registered as engineering candidates, three quarters are male, 62% are African and 24% are White. With candidates registering soon after graduation, the expectation is that most candidates will be under the age of 40 years (or 30 years).



	Gender		Population group			
	Male	Female	African	Coloured	Indian	White
Engineer	7503	2282	4125	322	1396	3942
Engineering Technologist	4292	1396	4172	241	504	771
Certificated Engineer	266	13	154	12	24	89
Engineering Technician	4685	2006	5439	237	406	598

Figure 2.18: Profile of Registrations for Candidate Engineering Occupations by Gender and Population Group, 2020

surprised. Surprisingly, the age structure of registered engineering candidates revealed that 16% of engineering candidates are over 40, of which 3.5% are over 50.

Table 2.26: Age Structure of Candidate Engineers by Population Group

Age groups	African	Coloured	Indian	White
20-29	4 370	296	850	1 484
30-39	7 406	413	1 172	2 738
40-49	1 852	80	263	587
Over 50	262	23	44	450

2.4 Science, technology and innovation infrastructure

The provision and access to research, technology, and innovation infrastructure is a key enabler of globally competitive research, development, and innovation. This infrastructure is an essential and vital ingredient for the development of a competitive national system of

innovation. The overall aim of this section is to understand and take stock of existing infrastructure and the investments the government has made.

Table 2.27 lists the main national infrastructure programmes that are covered in this report.

Table 2.27: List of Research, Technology and Innovation Infrastructure Programmes

Category	Name of Programme	Implementing Agency	Responsible National Department
Research Infrastructure	National Facilities Infrastructure Platform National Equipment Programme	National Research Foundation	Department of Science and Innovation
Technology Infrastructure	Technology Station Programme	Technology Innovation Agency	Department of Science and Innovation
Innovation Infrastructure	Small Business Development Agency-Technology Programme	Small Business Development Agency	Department of Small Business Development

2.4.1 Research infrastructure

According to the SARIR report (2016), research infrastructure (RI) includes facilities, resources, and services used by the scientific community across all disciplines to conduct cutting-edge research for the generation, exchange, and preservation of knowledge. It includes major facilities, equipment or sets of instruments, collaborative networks and knowledge-containing resources such as collections, archives and data- and biobanks. Research Infrastructure may be “single-sited”, “distributed”, or “virtual” (the service is provided electronically) (SARIR, 2016).

The two main research infrastructure programmes in South Africa are National Research Infrastructure Platforms (NRIP) and the National Equipment Programme (NEP).

National Research Infrastructure Platforms

The National Research Infrastructure Platforms incorporate the five national research facilities in the thematic areas of nuclear sciences, biodiversity and environmental sciences, astronomy, and geodetic sciences. Table 2.28 displays the research clusters and national facilities.

Table 2.28: NRF’s Portfolio of Research Infrastructure Platforms and National Facilities

Name of Research Infrastructure Platforms/National Research Facility	Science Domain/Discipline	NRF Cluster

NRF-iThemba Laboratory of Accelerator-Based Science (iThemba Labs)	Nuclear Sciences	Nuclear Sciences
South African Environmental Observation Network (SAEON)	Long-term Ecological Monitoring	Biodiversity and Environmental Sciences
NRF-South African Institute for Aquatic Biodiversity (SAIAB)	Aquatic Biodiversity Science	Biodiversity and Environmental Sciences
NRF-South African Radio and Astronomy Observatory (SARAO)	Radio Astronomy	Astronomy and Geodetic Sciences
NRF-South African Astronomy Observatory (SAAO)	Optical/ Infrared Astronomy	Astronomy and Geodetic Sciences

Source: NRF Annual Report, 2021/22

Total investment in the national research facilities from 2016/17 to 2019/20, as expressed by total annual expenditure by the NFs, is shown in **Table 2.29**.

Table 2.29: Total Investment in National Research Facilities – Rand million

Research Cluster	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	Total
	R' million							
Nuclear Sciences	331.6	310.1	303.7	320.9	309.7	434.1	476.9	2 487.0
Biodiversity and environmental sciences	106.1	162.4	152.9	193.2	134.3	156.2	211.2	1 116.3
Astronomy and geodetic sciences	1 071.5	1 152.7	827.6	764.1	756.9	1 225.1	1 477.1	7 275.0
Total Expenditure (Opex and Capex)	1 509.1	1 625.2	1 284.3	1 278.3	1 200.9	1 815.4	2 165.2	10 878.3
Operational Expenditure (Opex)	913.7	954.3	1 044.9	1 116.2	1 037.0	1 349.0	1 770.1	8 185.2
Opex % Contribution	*60.5%*	*58.7%*	*81.4%*	*87.3%*	*86.3%*	*74.3%*	*81.8%*	*75.2%*
Capital Expenditure (Capex)	595.4	670.9	239.3	162.0	163.9	466.4	395.1	2 693.1
Capex % Contribution	*39.5%*	*41.3%*	*18.6%*	*12.7%*	*13.7%*	*25.7%*	*18,2%*	*24.8%*

Source: NRF

As shown in the table, the total investment in the national research facilities, expressed as total expenditure by the NFs (operational and capital expenditure) over the seven years 2016/17 to 2022/23 is R10.9 billion. Over the seven years, 75% of the NFs total expenditure was on operational expenditure (Opex) while 25% was on capital expenditure (Capex). Overall, total investment has increased across all three scientific domains, although a minor decline was seen in 2020/21 due to the Covid-19 pandemic. The marked increase in investment in Nuclear Sciences in 2021/22 was mainly due to expenditure towards the South African Isotope Facility (SAIF) project, which was completed in 2023. The initial high investment in the Astronomy and geodetic sciences cluster was due to high expenditure concerning the SKA project, which was completed with the successful delivery

of the fully operational MeerKAT radio telescope at the end of March 2018. Astronomy cluster expenditure increased again from 2021/22, with the implementation of the MeerKAT extension project, which has a total estimated project cost of R555 million and is expected to be completed by the end of the 2024/25 financial year.

It should be noted that fluctuation in investment over the years is not necessarily due to under-investment in the years of lower expenditure (except for 2020/21 due to COVID-19), but due to the nature of infrastructure projects which are long term and include varying annual project milestones. Most of the critical projects require specialised procurement, and those that include construction are prone to delays. In some cases, delays are attributed to the recruitment of staff and the identification and preparation of sites to procure and deploy equipment (NRF Annual Report, 2022/23). Amidst the reality of the annual fluctuations, the NRF has successfully delivered on its critical infrastructure projects, particularly MeerKAT and the SAIF.

The maintenance of the infrastructure at the national facilities has been sub-optimal due to financial constraints for several years and, more recently, the impact of the Covid-19 pandemic and the energy crisis. Total maintenance costs over the seven years were R353.8m, which is 3.3% of the total investment of R10.9 billion for the same period. This is way below the norm of ~10%, which is regarded as acceptable considering the high value and scientific nature of assets to ensure relevance and world-class research.

National Equipment Programme

The NEP provides grants for state-of-the-art research infrastructure to South African research institutions. The targeted beneficiaries of the NEP include universities, science councils, national research facilities and museums. The NEP also supports the National Nanotechnology Equipment Programme (NNEP) and Strategic Research Equipment. The Strategic Research Equipment (SRE) bridges the gap between NEP investments and the investments proposed in the South African Research Infrastructure Roadmap (SARIR, 2016). It supports acquiring or developing large research infrastructure that facilitates internationally competitive research.

As shown in **Figure 2.19**, the total amount allocated to the NEP was R1.2bn from 2014/15 to 2022/23. The data reveals that funding declined from R189m in 2016/17 to R152m per annum in 2021/22 during this period, which is a decline of about 20%. In addition, it must

be noted that from 2019/20, the NEP grants are only awarded biennially, with the last awards made in 2021/22.

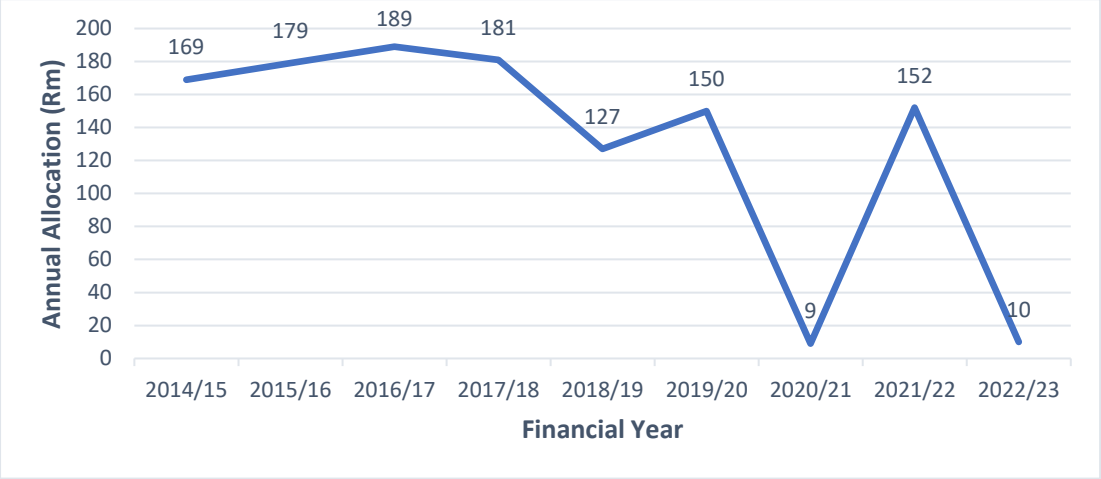


Figure 2.19: NEP Investment by Financial Year

Source: DSI NEP Evaluation Report, 2022, NRF Annual Report 2021/22 and 2022/23

Figure 2.20 compares the number of applicants against grants awarded each year. In total, 202 equipment grants were allocated from 2014/15 to 2022/23. Since this is a competitive grant scheme, not all applicants are successful.

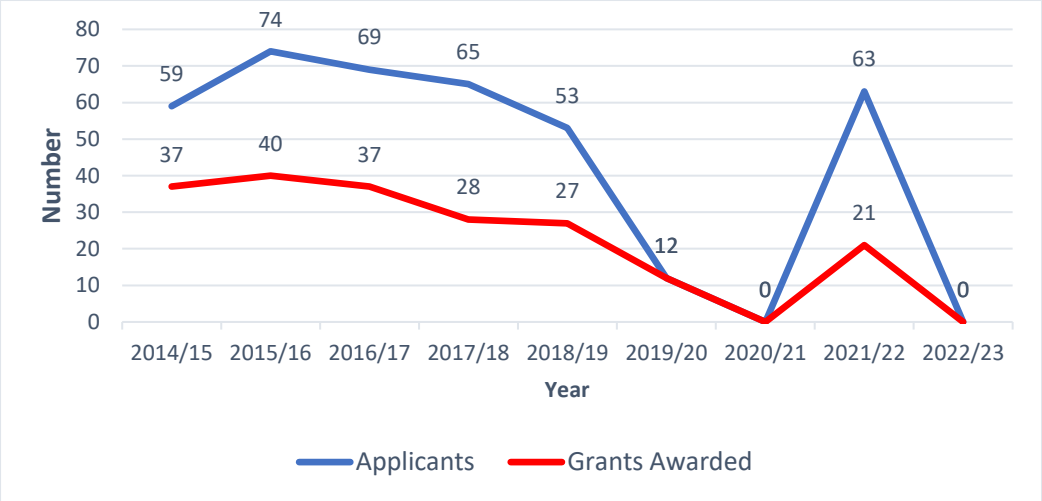


Figure 2.20: Number of Grants Awarded Per Year

Source: DSI Evaluation Report, 2022, NRF Annual Report 2021/22 and 2022/23

The research organisations which benefit the most from the grants are located in Gauteng and Western Cape. According to the DSI evaluation report (DSI, 2022), almost half of the grant value was allocated to institutions within the Gauteng province (43%), followed by the Western Cape (26%), as shown in **Figure 2.21**. This is expected because most of the research-intensive universities and science councils are located in these two provinces.

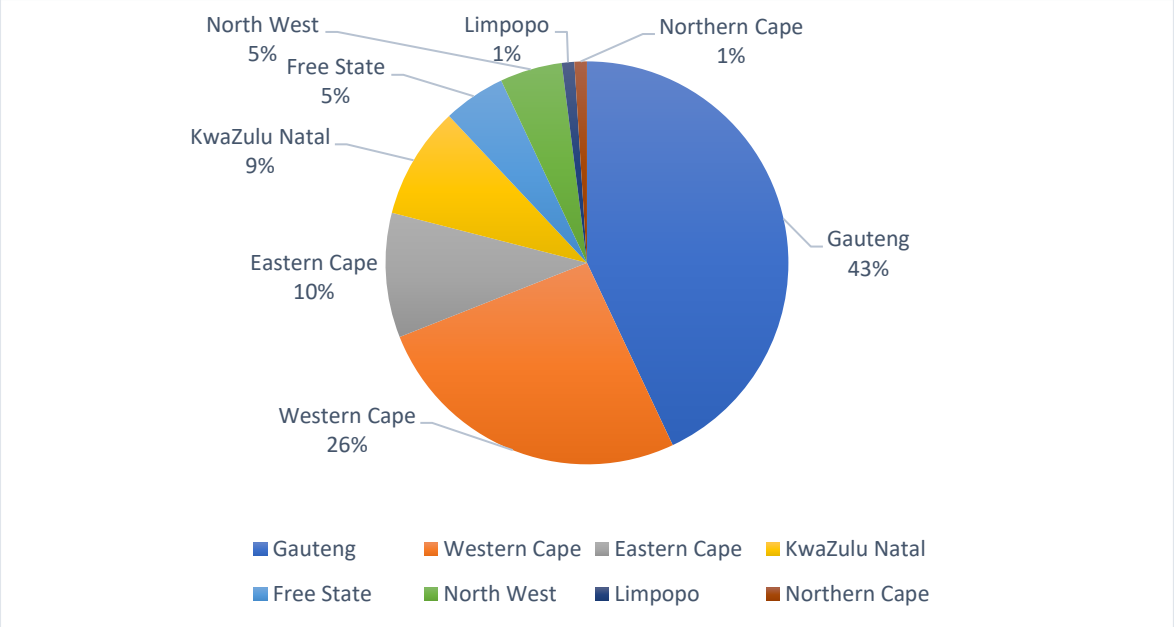


Figure 2.21: Percentage Grant Value Awarded by Province

Source DSI Evaluation Report, 2022, NRF Annual Report 2021/22 and 2022/23

2.4.2 Technology infrastructure

Technological infrastructure is important for enabling innovators to transfer and commercialise their innovations. For technology development, industry, especially Small and Medium-Sized Enterprises, require access to the right technology infrastructures to quickly develop and test their innovations and successfully enter the market (EU Technology Infrastructures, 2019).

Technology infrastructures are understood as the facilities, equipment, capabilities, and support services required to develop, test, and upscale technology to advance from validation in a laboratory *to higher Technology Readiness Levels (TRLs) prior to competitive market entry.*

The DSI has established and invested in two critical technology infrastructure programmes: the Technology Stations Programme (TSP) and the Technology Platform Programmes (TPP).

Technology Station Programme

The core goal of the TSP is to contribute towards improving the competitiveness of the industry through the application of specialised knowledge and technology. Furthermore, the programme facilitates the interaction between industry (especially SMEs) and academia to enable innovation. Its specific objective as an instrument is to provide

technology support, infrastructure and services to local enterprises with a primary focus on small and medium enterprises (SMEs). In particular, the Technology Stations provide product and process improvements, prototype development, training and technology absorption services. The services are delivered by Technology Stations (TS) which are located mainly at Universities of Technology (UoT).

The following table shows that about R670 m was invested under the TSP between 2017/2018 and 2021/22. As shown in Figure 2.22, the investment has fluctuated but declined from R123m in 2017/18 to R114 in 2021/22.

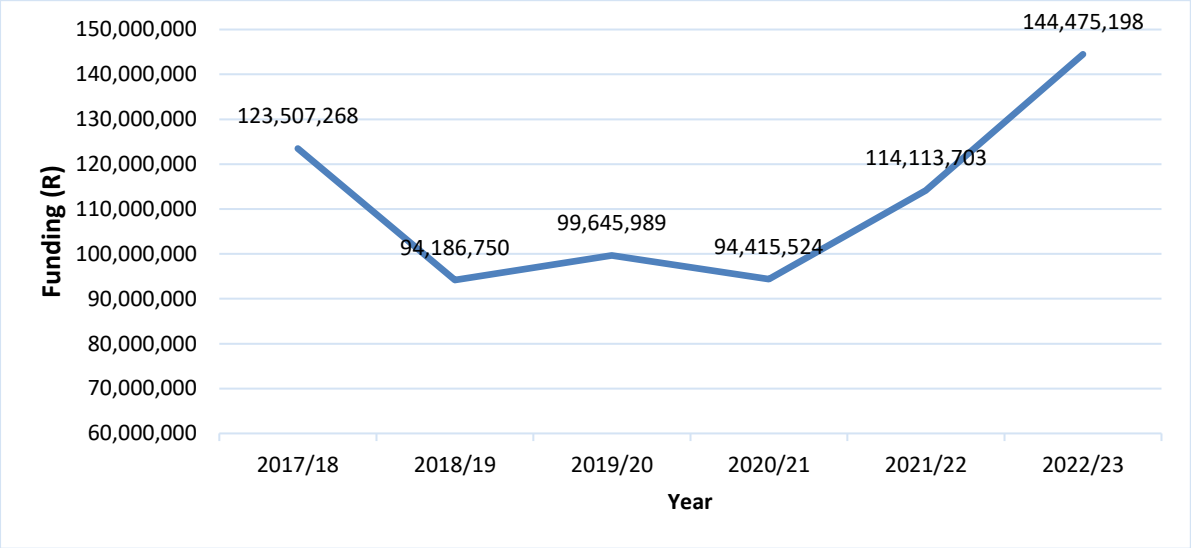


Figure 2.22: Investment in Technology Stations Programme

Source: TIA Annual Workplans

According to TSP reports from TIA, there has been a substantial funding gap between the funding requirements and available funds from DSI. For example, in 2018/19, the gap was 29% but decreased to 15% in 2021/22. To complement the funding from DSI and to become sustainable, the TSP raises additional revenues through recoveries from its clients.

Because the TSP leverages existing infrastructure at HEI, i.e. UoTs, the capital expenditure is deficient and most of the funds are used for salaries and the provision of services. For example, in 2022/23, the budgeted capex was only R6m of the total required investment for the programme. However, one of the challenges the programme faces is the maintenance and replacement cost of obsolete equipment at the various institutions that host the stations.

Geographic Distribution of Technology Stations

The programme is implemented through a network of 16 regionally distributed TSs. To provide access to innovators and entrepreneurs across the country, the Technology Stations are distributed in six provinces in South Africa. **Figure 2.23** illustrates the TS geographic footprint throughout South Africa and the industrial sectors they focus on.

The figure shows that the TS are unevenly distributed, with most located at the major industrial hubs Gauteng (three stations), Western Cape (two stations) and KwaZulu-Natal (two stations).

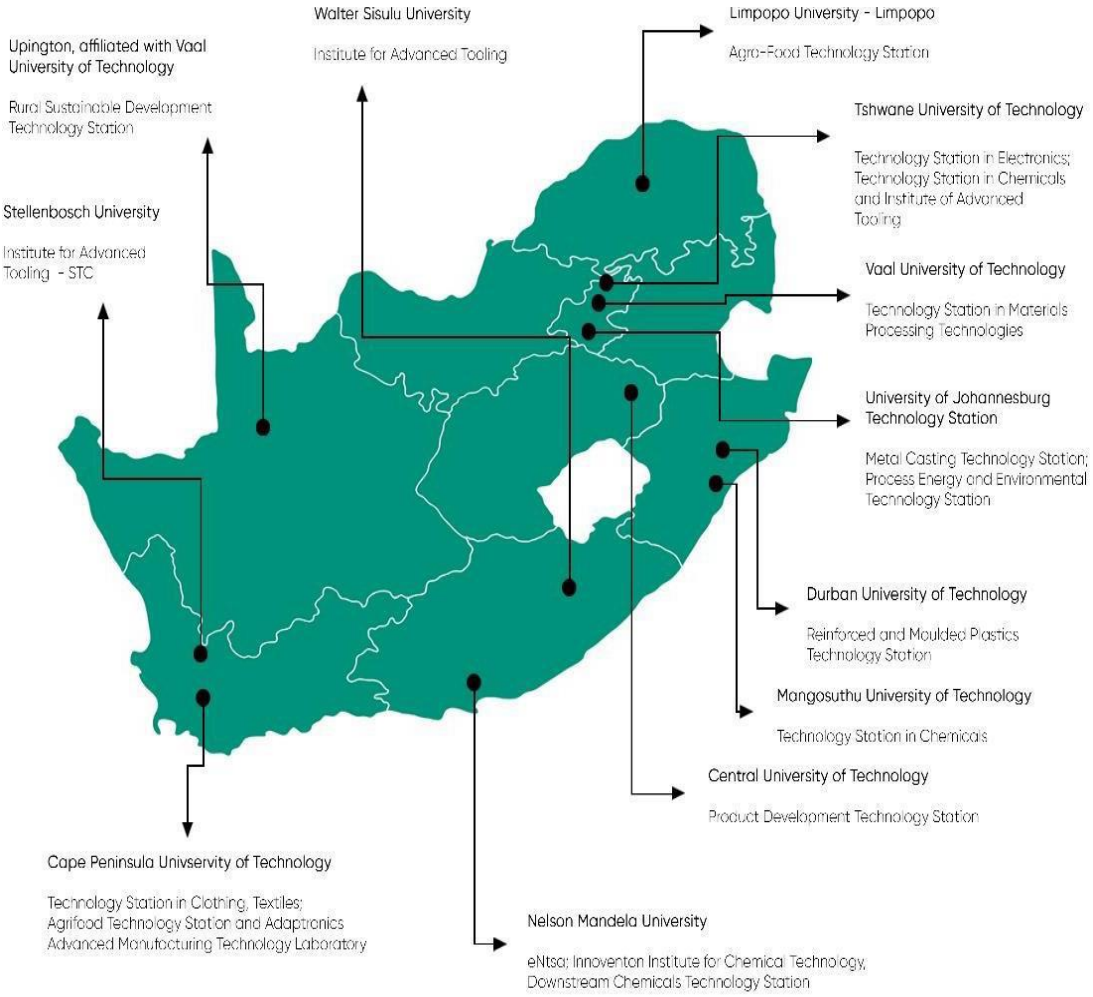


Figure 2.23: Technology Stations and Geographical Footprint

Source TIA Workplans, 2021/22

Note: VUT and Upington Stations have been terminated.

Technology Platform Programme

As mentioned above, the TPP is the second technology infrastructure that TIA implements to support the implementation of the Bio-economy strategy. The TPP aims to facilitate

access to cutting-edge technological capabilities by investing in and supporting entities to acquire appropriate technologies and expertise that lower the barriers to innovation. At present, TIA provides funding to eight technology platforms across South Africa. The programme enables providing technology development services from the proof-of-concept stage up to commercialisation; and specialised training and capacity development opportunities for role-players in multiple value chains.

Table 2.30 shows the names, capabilities and locations of the various technology platforms.

Table 2.30: Names of Technology Platforms

	Strategic Objective	Location
African Medicines Innovation and Technologies Development (AMITD)	To promote the establishment and long-term growth of the pharmaceutical industry based on SA's indigenous knowledge base and biodiversity	University of Free State, Free State
Biosafety South Africa (BSA)	To support the development of successful innovators, effective regulation and confident consumers through supporting and ensuring the sustainability of bio-based products	Cape Town, Western Cape
Cape Universities Body Imaging Centre (CUBIC)	To provide a 3T Siemens Skyra full-body magnetic resonance imaging scanner and a positron emission tomography system	University of Cape Town, Western Cape
Centre For Proteomic and Genomic Research (CPGR)	To provide integrated genomic and proteomic technologies with biocomputational pipelines	University of Cape Town, Western Cape
Holistic Drug Discovery and Development (H3D) Centre	To provide integrated drug discovery and development in tuberculosis, malaria, and anti-microbial resistance	University of Cape Town, Western Cape
KwaZulu-Natal Research Innovation and Sequencing Platform (KRISP	To provide genetic sequencing platforms to enable and support world-class genomics research and diagnostics services in Africa.	University of KwaZulu-Natal, KwaZulu-Natal
National Metabolomics Platform (NMP)	To exploit the application of metabolomics techniques and modelling to alleviate inherited health disorders and disorders	North West University, North West
Bioprocessing Platform (TBP)	To provide bioprocessing suites for fermentation process development and downstream processing. It also houses the Institute for Diagnostic Research	Umbongintwini, KwaZulu-Natal

Source: TIA Technology Platform Brochure

Figure 2.24 shows the investments that have been made between 2019/18 and 2022/23.

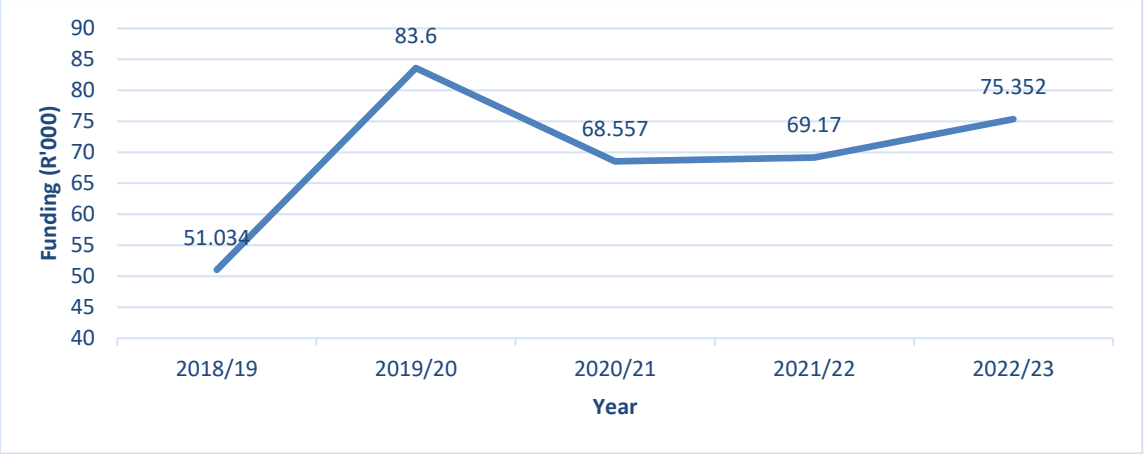


Figure 2.24: Investment in Technology Platform Programme

Source: TIA Annual Reports

In total, R374m Rands was invested, and the investment has increased from R51m in 2018/19 to R75m in 2022/23. However, this is lower than the highest investment of R83m in 2019/20.

2.4.3 Innovation infrastructure

Innovation Infrastructure is also a critical element of the national system of innovation. There is currently no commonly accepted definition of 'innovation infrastructure. For this report we define this infrastructure as 'facilities and assets that enable the development, demonstration and delivery of innovative (new to market) products, services or processes in business, public services, or non-profit sectors. It comprises a set of inter-related manufacturing, consulting, educational and informational structures designed to implement innovations. It includes the following elements: special economic zones (SEZ), industrial zones, science/technology parks (Technopark's) and business incubators.

Business incubators, which are the focus of this report, are one of the infrastructures used to promote and support entrepreneurs throughout the world to support the realisation of innovative ideas. The business incubator programme is one of the critical interventions in South Africa.

SEDA Technology Programme

The Department of Small Business and Development (DSBD) established the SEDA Technology Programme (STP).

The aim of the incubation programme is to provide support to existing and aspiring small, medium, and micro enterprises (SMME) entrepreneurs. These entrepreneurs get access

to both basic services (e.g., physical space, infrastructure, and shared services) and advanced services (e.g., networking opportunities, access to specialised knowledge, and access to finance). Incubation programmes aim to improve the early-stage survival and long-term growth prospects of SMMEs.

In 2021 the programme consisted of 110 incubation centres across the nine provinces. The programme supports SMMEs in various industrial sectors operating in economic sectors such as biotechnology, mining, agro-processing, construction, jewellery, automotives, metals and renewable energy, amongst others.

Between 2018/19 and 2022/23, SEDA invested a total of R814 in the STP programme. However, the annual allocation has been declining from R199m to R159m during this period. This includes operational and capital expenditures.

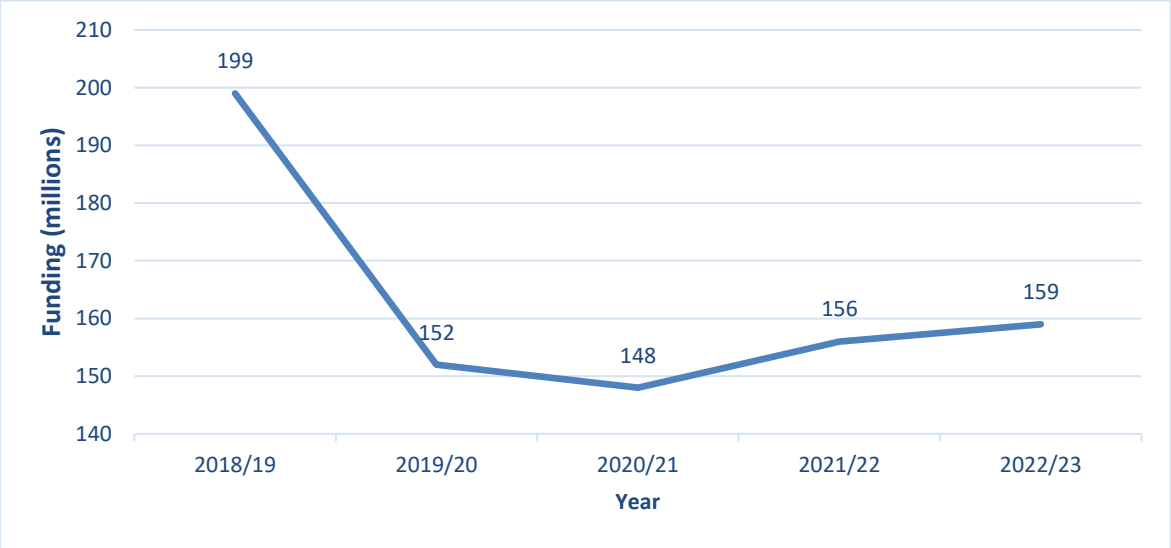


Figure 2.25: Investment in SEDA Technology Programme

Source: SEDA Annual Reports

Capital expenditure in the incubator programme refers to all purchases recorded on incubators' financial statements, including land and buildings, computer equipment, plant equipment, farm equipment and office equipment. A previous review of the STP incubator programme showed that capital expenditure was only 9% (SEDA Technology Incubators, 2014) of allocated funds for the programme. Recent annual reports and annual performance plans do not state the capital expenditure for the STP.

Summary/Key Messages

A national system of innovation requires a comprehensive research, technology, and innovation infrastructure to provide support across the innovation value chain. As shown in this report, despite financial constraints, South Africa has invested over the years in this infrastructure to support research and innovation.

The research infrastructure requires significant investment. Specifically, the astronomy and geodetic sciences domains require significant investment compared to the nuclear and biodiversity domains. It is vital that the scientific and social impact of the investments are evaluated to justify such investments.

The upkeep and maintenance are below the acceptable norm of 10% of fixed assets; This funding gap needs to be addressed to ensure the relevance of the facilities.

The NEP's funding has declined significantly, from R237 m in 2014/15 to R135m in 2021/23. This has been attributed to budget cuts and a flat increase in DSI funding allocation over the years.

A long-term financial commitment should underpin the Research Infrastructure strategy. Research Infrastructure investments require a dedicated and long-term strategy to steer dedicated and sustainable funding.

Investment in technology and innovation infrastructure is far below investment in research infrastructure. Unlike research infrastructure, there is no national roadmap for investment in these later stages of the Technology and Market Readiness Levels, which are important for commercialisation. It is important to identify infrastructure gaps and priority areas in order to inform investment decisions.

2.5 Digital Infrastructure and Access

Digital capabilities are essential to ensure a country’s growth and economic resilience and is a key enabler to innovators and entrepreneurs. Access to affordable digital infrastructure has become indispensable to society's functioning and citizens' quality of life. Although there is no single definition of digital infrastructure, it comprises the physical resources necessary to enable the use of data, computerised devices, methods, systems and processes.

This section presents selected indicators of South Africa’s digital competitiveness, development of digital infrastructure including its ranking, access and enablers.

2.5.1 Digital competitiveness of South Africa

Since 2017, the Institute of Management and Development (IMD) World Digital Competitiveness Ranking has been ranking the digital competitiveness of 64 economies. The IMD World Competitiveness Center aims to measure the capacity and readiness to adopt and explore digital technologies as a key driver for economic transformation in business, government and wider society.

Table 2.31 compares South Africa's ranking from 2018 to 2023 with other BRICS countries. Between these years, South Africa's ranking has declined sharply from 48th in 2019 to 58th in 2023. The lack of significant improvement from the previous years is of concern. The data shows South Africa has been ranked below the BRICS countries during these years. Moreover, South Africa trails far behind the leading country in this economic bloc, China (ranked 19th) in 2023.

Table 2.31: Digital Competitiveness Ranking Comparison with BRICS

	2018	2019	2020	2021	2022	2023
South Africa	49	48	60	60	58	58
Brazil	55	57	57	51	52	57
China	31	30	22	16	17	19
India	51	48	44	48	44	49
Russia	42	40	38	43	N/A	N/A

Source: IMD World Digital Competitiveness Reports, 2018-2023 (Russia was not ranked in 2022 and 2023)

To analyse digital competitiveness further, the IMD ranks countries according to how they fare in the following three factors: knowledge, technology and future readiness. The knowledge factor refers to intangible infrastructure that enables the discovery, understanding and learning of new technologies, leading to digital transformation. This factor includes three sub-factors: talent, training and education and scientific concentration.

The technology factor assesses the overall context facilitating the development of digital technologies. The sub-factors that are included under this domain are regulatory framework, capital and technological framework. This includes criteria that assess the impact of regulation in encouraging innovation in the private sector, the availability of capital for investments and the quality of the technological infrastructure.

The future readiness factor examines the degree to which technology is adopted by governments, businesses, and society at large. The sub-factors examined are adaptive attitudes, business agility, and IT integration. This factor includes indicators such as the

diffusion of e-commerce, industrial robots, and data analytics tools in the private sector, as well as the strength of cyber-security measures in place.

Table 2.32 shows the six-year rankings of the knowledge, technology and future readiness factors. It is apparent that South Africa performs poorly across all factors. Furthermore, between 2018 and 2023, South Africa's performance has declined across the board. Of concern is that there has been a slight decline in the knowledge and technology factors except for the slight improvement in the future readiness factor.

Table 2.32: Factor Level Performance of South Africa

	2018	2019	2020	2021	2022	2023
Knowledge • Talent • Training and Education • Scientific Concentration	52	54	60	62	54	58
Technology • Regulatory Framework • Capital • Technological Framework	52	51	55	59	58	59
Future readiness • Adaptive Attitudes • Business Agility • ICT Integration	43	44	57	59	59	56

Source: IMD Digital Competitiveness Reports, 2018-2023

2.5.2 ICT ranking of South Africa

The Global Innovation Index (GII) considers ICT as a key innovation input for innovation performance. As a result, the GII ranks countries' ICT infrastructure, access and use in its annual innovation performance reports. As **Table 2.33** shows, South Africa's overall ICT infrastructure has improved from a ranking of 86 in 2014 to 70 in 2023.

Table 2.33: GII Ranking of South Africa's ICT Infrastructure, access and use

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
ICT infrastructure	86	91	84	76	81	67	67	74	67	70
ICT access	78	80	74	76	76	80	87	89	74	67
ICT use	72	75	73	68	80	81	83	75	83	88
Number of countries	143	141	128	127	126	129	131	132	132	132

Source: Global Innovation Index Reports, 2014-2023

However, the overall ranking has slightly declined between 2022 (67) and 2023 (70). Access to ICT has also improved from 78 in 2014 to 67 in 2023. What is concerning is the significant decline in ICT use during this period (72 in 2014 and 88 in 2023). Table 2.34 compares the ranking of South Africa's ICT infrastructure with that of other BRICS countries.

As the GII data shows, South Africa and India are ranked far behind other countries, with China having the most highly ranked infrastructure among this economic bloc. It is interesting to note that in 2014, China was ranked 73 and has since moved to a ranking of 18 in 2023.

Table 2.34: Comparison of ICT Infrastructure Ranking with BRICS Countries

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
South Africa	86	91	84	76	81	67	67	74	67	70
Brazil	41	43	42	41	46	36	38	49	45	36
Russia	28	35	35	36	37	29	29	36	34	49
India	99	86	86	80	83	75	74	86	72	82
China	73	54	53	48	45	46	45	34	20	18

Source: Global Innovation Index Reports, 2014-2023

2.5.3 Digital infrastructure, access and enablers

Accessible and affordable access to ICT infrastructure is the cornerstone of the digital economy. South Africa's digital development was assessed using the International Technology Union (ITU) ICT indicators. The ITU is a UN institution that measures ICT development globally. The measurement framework measures three indices: infrastructure and access, internet use and enablers and barriers.

Infrastructure and Access

The following table compares South Africa's network coverage to that of other BRICS countries. As **Table 2.35** shows, overall mobile network coverage in South Africa is almost 100% for both 3G and 4G networks and is one of the highest among the BRICS countries.

Table 2.35: Network Coverage

	Population Covered by a mobile network	Population Covered by a 3G mobile network	Population Covered by 4G mobile network
South Africa	100%	100%	98
Brazil	93	92	92
Russia	99	97	93
India	99	99	99
China	100	100	100

Source: ITU Digital Development Dashboards

Table 2.36 compares mobile ownership in South Africa with Brazil and Russia. In 2019, mobile cell ownership was 78%, with female mobile ownership slightly higher than male ownership. However, as the table shows, mobile phone ownership in South Africa is still below Brazil and Russia. It must be noted that the data on mobile ownership in South Africa is for 2019.

Table 2.36: Mobile Cell Ownership

	Individuals owning mobile phones	Female mobile phone ownership as % of total female population	Male mobile phone ownership as a % of total male population
South Africa (2019)	78%	80%	77%
Brazil (2022)	88%	89%	87%
Russia (2022)	99%	99%	99%
India	N/A	N/A	N/A
China	N/A	N/A	N/A

Source ITU Digital Development Dashboards

Table 2.37 shows ICT access among BRICS countries. As the data shows, in 2019, 77% of households in South Africa had internet access at home, but only 27% of households had a computer. Access to the Internet was also significantly lower (62%) in rural homes compared to urban households (84%).

Table 2.37: ICT Access at Home

	Households with internet access	Households with a computer	Households with Internet , rural	Households with Internet, urban
South Africa (2019)	77%	27%	62%	84%
Brazil (2022)	80%	39%	71%	83%
Russia (2022)	87%	73%	78%	86%
India (2018)	24%	11%	N/A	N/A
China	N/A	N/A	N/A	N/A

Source: ITU Digital Development Dashboards

The data shows that in most of the access to ICT indicators, South Africa trails behind Brazil and Russia.

Table 2.38 shows subscriptions according to ITU classifications. These are 1) mobile and fixed telephone subscriptions and 2) mobile and fixed broadband subscriptions. South Africa has high mobile cellular subscriptions and active mobile broadband subscriptions. On the other hand, fixed telephone subscriptions are low.

Table 2.38: Subscriptions According to Classifications

	Mobile and fixed telephone subscriptions		Mobile and Fixed broadband subscriptions		
	Mobile cellular subscriptions per 100 inhabitants	Fixed telephone subscriptions per 100 inhabitants	Active mobile broadband subscriptions per 100 inhabitants	Fixed broadband per 100 inhabitants	International bandwidth per internet user
South Africa	167	2	135	3	56
Brazil	99	13	93	21	29
Russia	169	16	108	24	63
India	81	2	56	2	103
China	125	13	108	41	61

Source: ITU Digital Development Dashboards

Internet Use

Access to the internet is crucial for connecting people and businesses to the information and knowledge they need in an increasingly digital world. The data in **Table 2.39** shows that internet use in South Africa increased from 54% in 2016 to 73% in 2021. Between 2020 and 2021, internet use increased slightly. Overall, internet use in South Africa is the third highest (tied with China) among the BRICS countries and is well above India, which has the lowest internet use.

Table 2.39: Percentage Population Using the Internet

	2016	2017	2018	2019	2020	2021
South Africa	54	56	62	68	70	73
Brazil	61	66	70	74	81	81
Russia	73	76	81	83	85	88
India	17	18	20	29	43	46
China	53	54	59	64	70	73

Source: International Telecommunication Union Data Hub

Enablers and Barriers

ICT Prices

Affordable high-speed broadband is an important enabler for competitiveness across many areas. The ITU has developed a framework for price statistics, which refer to ICT price baskets, which are internationally comparable units of ICT services.

Table 2.40 depicts trends in ICT costs for the various baskets of services in South Africa between 2018 and 2022. The data shows a vast difference in cost between fixed broadband costs and the mobile cellular basket. However, there has been a gradual decline in cost for the various baskets of services as measured by the percentage of GNI per capita.

Table 2.40: Trend in ICT Prices in South Africa

	2018	2019	2020	2021	2022
Fixed broadband basket as a % of GNI p.c.	6.5	6.5	4.7	4.8	3.9
Mobile data and voice basket (high consumption) as a % of GNI p.c.	7.3	7.3	5.6	5.4	3.5
Mobile data and voice basket (low consumption) as a % of GNI p.c.	3.1	3.1	2.5	2.4	1.8
Mobile broadband basket as a % of GNI p.c.	4.4	4.0	2.4	2.3	1.6
Mobile cellular basket as a % of GNI p.c.	1.5	1.6	1.4	1.4	0.8

Source: International Telecommunication Union, Digital Development Dashboard

Note: p.c -per capita

As shown in **Table 2.41**, ICT prices in South Africa are very high compared to other BRICS countries. For example, the fixed broadband basket is five times higher in South Africa than in Russia, which has the lowest cost. With the exception of South Africa, the cost of mobile internet in BRICS countries is lower than the global average (International Trade Centre BRICS Digital Economy Report, 2022).

Table 2.41: Benchmarking of ICT Prices

	SA	Brazil	Russia	India	China
Fixed broadband basket as a % of GNI p.c. (2022)	3.9	3.1	0.7	2.8	1.0
Mobile data and voice basket (high consumption) as a % of GNI p.c. (2022)	3.5	0.9	0.7	1.1	0.6
Mobile data and voice basket (low consumption) as a % of GNI p.c. (2022)	1.8	0.9	0.7	1.1	0.4
Mobile broadband basket as a % of GNI p.c. (2022)	1.6	0.9	0.7	1.1	0.4
Mobile cellular basket as a % of GNI p.c. (2022)	0.8	0.9	0.3	1.1	0.3

Source: ITU Digital Development Dashboards

3. SCIENCE, TECHNOLOGY AND INNOVATION FLOWS AND LINKAGES

The NSI is premised on innovation collaboration, flows and linkages within and across the sectors. These are considered as significant multiplier effects at the system level. Hence, the purpose of this chapter is to assess the STI flows and linkages in terms of students' mobility, research collaborations, as well as international patent applications and linkages.

3.1 Students mobility (inbound and outbound) rates

South Africa remains an attractive destination for postgraduate studies, especially at a doctoral level. **Figure 3.1** shows that the largest share of foreign enrolments at public universities is at the doctoral level, whereas in 2021, 36% of Doctoral students were international students. This compares to 14% Masters students and 6% of Honours students. At the undergraduate level, the data show that in 2021, 2.7% of all enrolments were international students. Across all levels, we have seen a slow decline in the proportional share of international students since 2017.

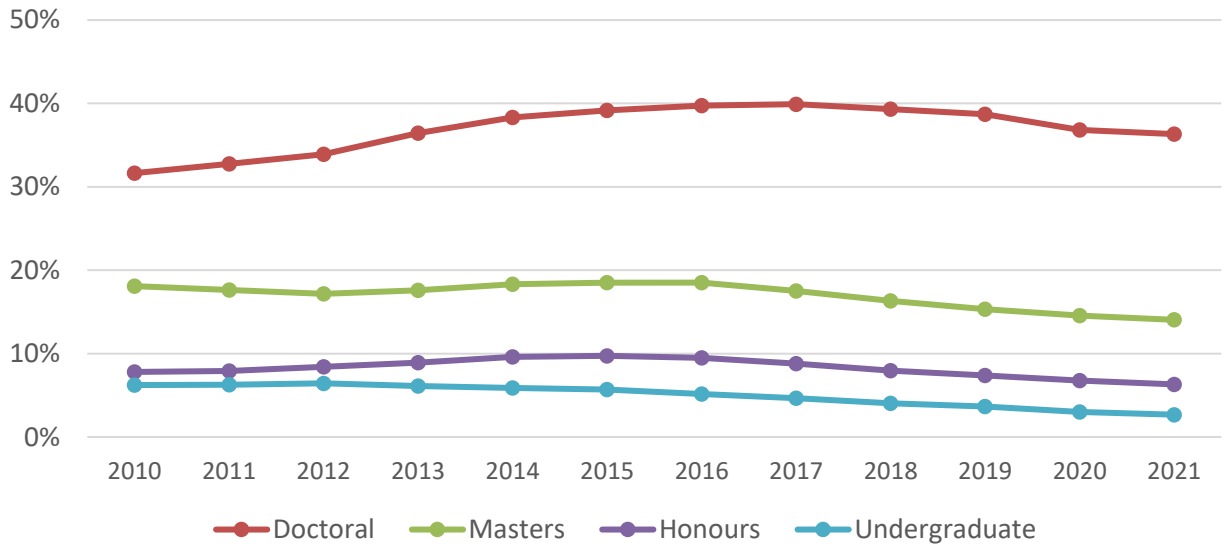


Figure 3.1: Percentage Foreign Student Enrolments at Public Universities by Academic Level
Source: CREST

3.2 Research collaborations

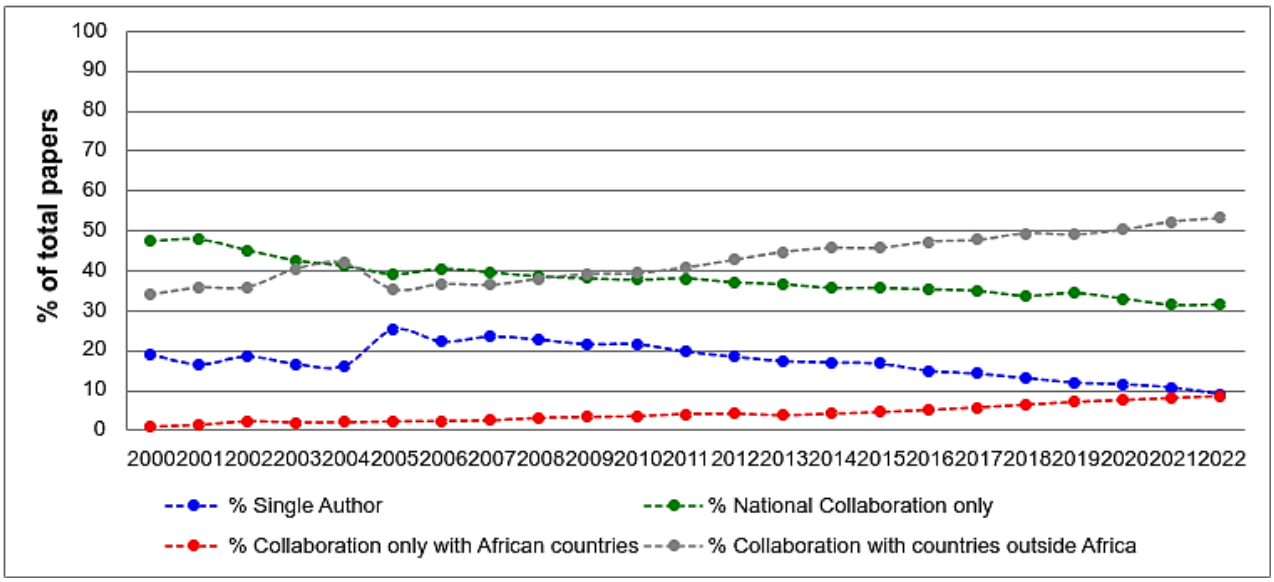
In bibliometric analyses, it is standard to define “research collaboration” between researchers, research centres, institutions, and countries regarding the co-authorship relations between the contributing authors in scientific publications. However, it is widely acknowledged that this indicator is merely a partial indicator as it does not capture other dimensions of research collaboration, such as joint proposal writing, joint funding, and joint mentoring of young scholars. Nevertheless, owing to the standardised structure of bibliometric databases such as the CAWeb of Science and Scopus, the pertinent data related to co-authorships and affiliations is readily accessible, facilitating the analyses presented in this section.

Indicator	Historical benchmarking
Trends in research collaboration (three categories of co-authorship)	Trend between 2013 and 2022 (Source CAWeb of Science)
Trends in research collaboration (four categories of co-authorship)	Trend between 2013 and 2022 (Source CAWeb of Science)
Trends in research collaboration (three categories of co-authorship) by main science domain	Trend between 2013 and 2022 (Source CAWeb of Science)
Trends in research collaboration (three categories of co-authorship) by citation impact	Trend between 2013 and 2022 (Source CAWeb of Science)

The trend in research collaboration between South African authors and authors from other countries and regions is presented in **Figure 3.2**. The data source is the CAWeb of Science and the document types are articles and review articles. Four categories of research collaborations are presented in the figure, which are: (1) no collaboration or single-authored publications; (2) national collaboration (South African authors only); (3) collaboration with Africa only (at least one author from an African country other than South Africa and no author from outside Africa); and (4) collaboration with countries outside of Africa (at least one author comes from outside Africa). Please note that these four categories are defined based on the field of address in scientific publications.

The figure shows a continuing decline in single-authored publications, which fell from nearly 20% in 2000 to less than 10% in 2022. Further disaggregation by scientific field shows that most single-authored papers are found in humanities and arts. The percentage share of national collaboration has been similarly decreasing in favour of international collaboration. However, it stabilised at around 31%-35% over the past five years. The collaboration with African countries has been increasing but at a slow rate. The

collaboration with countries outside Africa has risen over the last two decades and reached a high of 53% in 2022.



F

Figure 3.2: Trends in Research Collaboration (4 categories of co-authorship)

Source: CREST, Stellenbosch University

The collaboration of African countries and collaboration with countries outside Africa can be grouped together to form a single category, “foreign collaboration” or “International collaboration”. **Figure 3.3** shows that international collaboration has increased, from one-third of all scientific publications in 2000 to more than 60% in 2022. This increase has occurred with commensurate declines in single-authored and nationally collaborative publications. It is worth noting that these trends summarise collaborative authorship in all scientific fields. In some fields, such as health sciences, astronomy and high-energy physics, foreign collaboration is much higher.

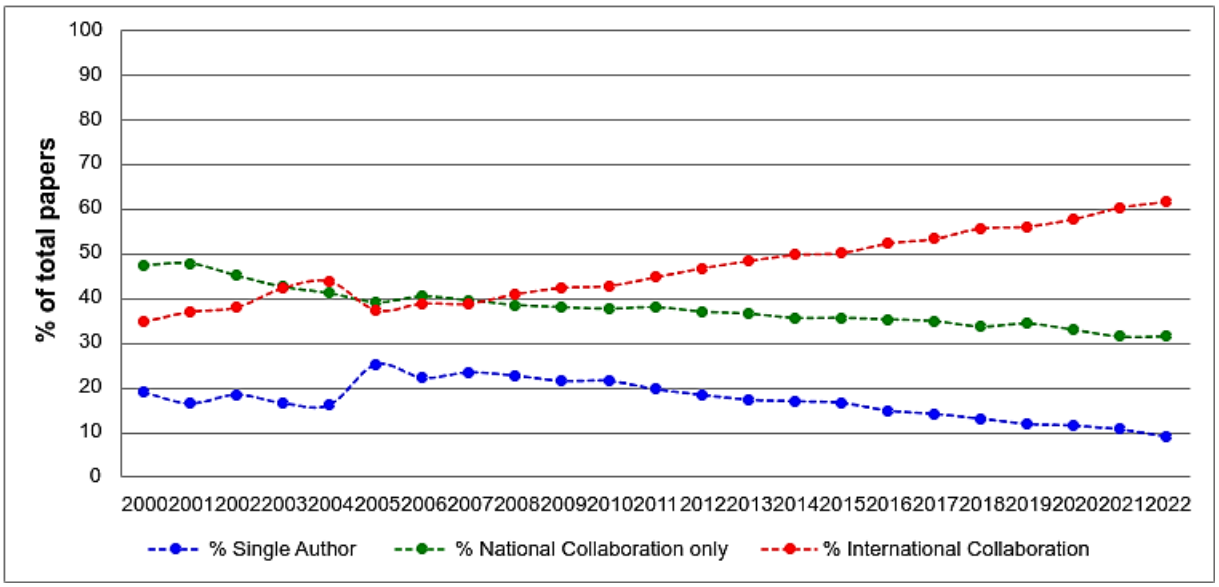


Figure 3.3: Trends in Research Collaboration (3 categories of co-authorship)

Source CREST, Stellenbosch University

The research collaboration at the country level is presented in **Figure 3.4** and **Figure 3.5** for two different periods. A comparison between the two maps shows that South African scientists have increased their collaborations with the USA, Germany, the UK, and Australia (dark brown), as well as BRICS countries, Canada, and several European countries (dark red). Except for the increased collaboration with Egypt, Nigeria, Morocco, and some eastern and southern African countries, collaboration with African countries remains low.

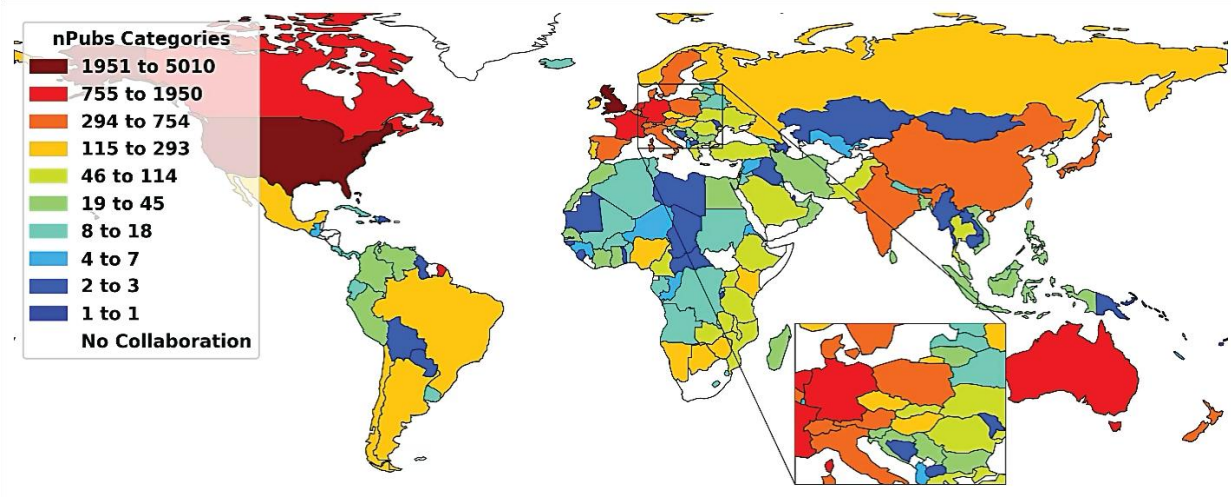


Figure 3.4: Collaboration Intensity between South Africa and Other Countries between 2000 and 2007

Source: CREST, Stellenbosch University

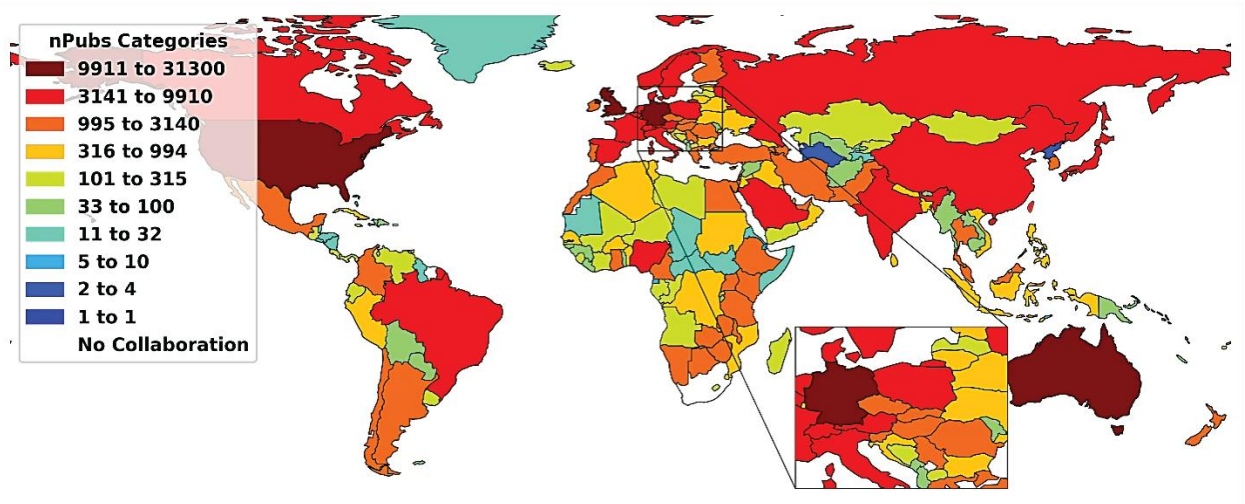


Figure 3.5: Collaboration Intensity between South Africa and Other Countries between 2015 and 2022

Source: CREST, Stellenbosch University

3.3 International patent applications and linkages

This section aims to reveal the characteristics of patent cooperation treaty (PCT) patent applicants with at least one applicant residing in South Africa. In the context of the declining number of patents granted to South Africans over the years, this analysis facilitates an understanding of the changing technology development landscape in South Africa over a decade. This section also shows technology linkages through an analysis of co-applications among various sectors, provincially and with international partners. The individual patent applications are also analysed in terms of gender. Unless stated, the rounded-off fractional count of patent applications is used.

3.3.1 Patents application by various actors

The analysis involves 371 PCT patent applications in 2013 and only 223 in 2022, a 40% decline in the last decade. As **Figure 3.6** shows, the proportion of patent applications by individuals decreased from 2013 (45.6%) to 2022 (36.8%), whereas the institutions increased in their proportion from 54.4% in 2013 to 63.2% in 2022. This trend shows a move towards institutionalisation of technology management, especially by the founders of the small start-ups that constitute a bulk of individual patent applications. In some instances, the individual applicants are the local technology transfer agents who are acting on behalf of international invention owners for a specific country.

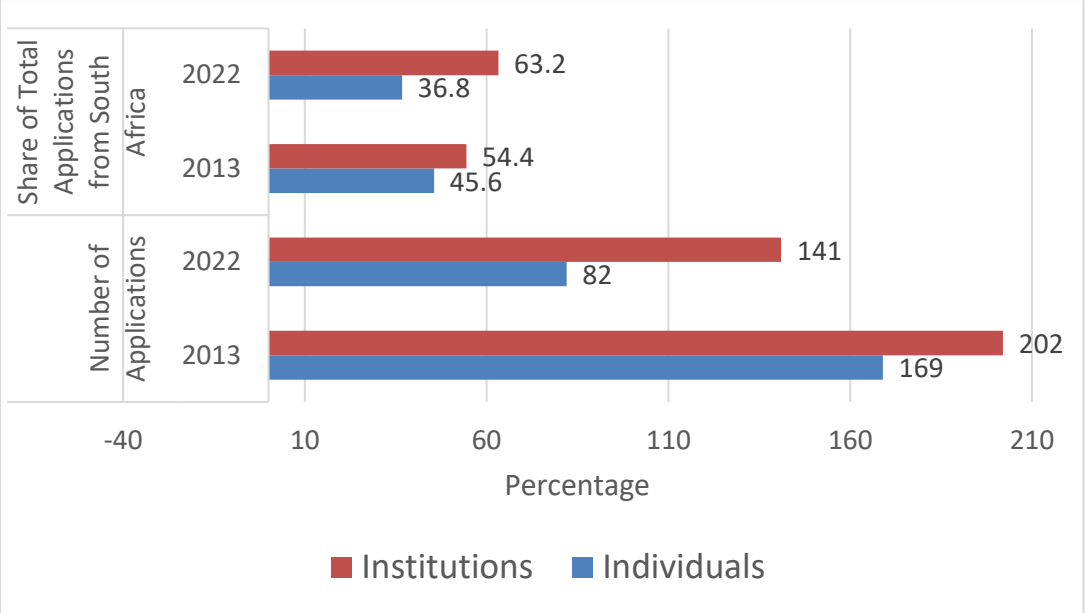


Figure 3.6: Institutional and Individual International Patents Application from South Africa

Source: computed from WIPO "Patentscope"

The majority of the individual applicants are males, although there has been an improvement of female applicants from 4.3% in 2013 to 13.8% in 2022 (see **Figure 3.7**).

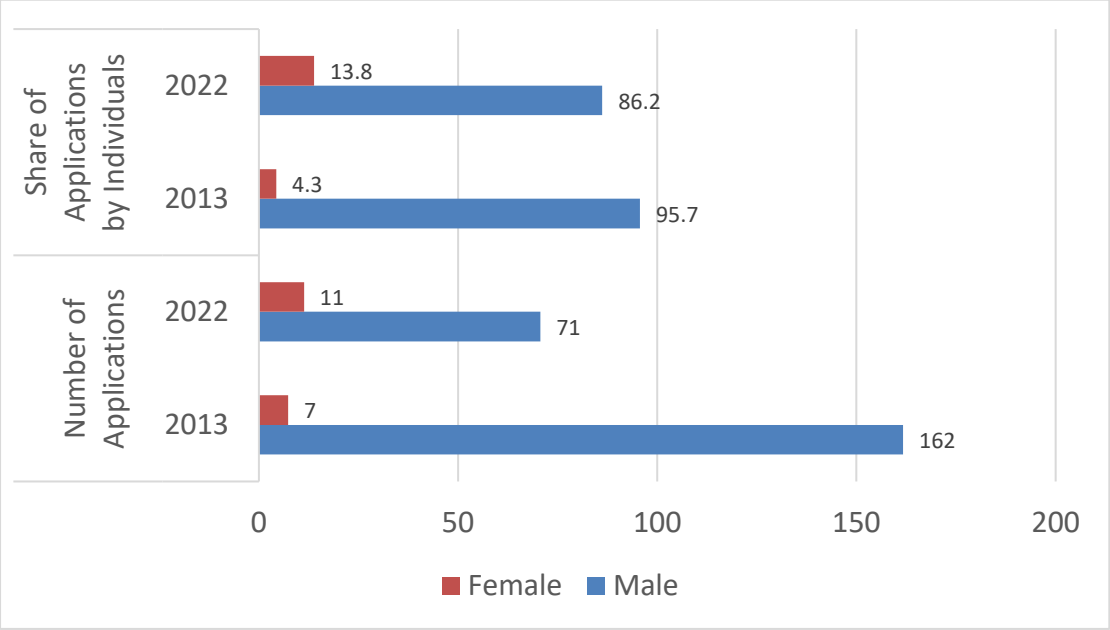


Figure 3.7: Distribution of Individual Patents Application from South Africa

Source: computed from WIPO "Patentscope"

The proportional distribution of the institutional applicants has not changed much from 2013 to 2022 (see **Table 3.1**). The private entities increased their share of South African PCT patent applications from 37.7% in 2013 to 42.7% in 2022, although their share of

institutional applications decreased from 69.3% in 2013 to 67.5% in 2022. An observed trend is a massive decline in patent applications by the large companies such as Sasol (from 13 applications in 2013 to nothing in 2022). Sasol's patenting activities are still high in their joint ventures in the United States and Germany.

Table 3.1: Distribution of Institutional Patents Application by Sector

	Number of Applications		Share of Applications by Institutions		Share of Total Applications from South Africa	
	2013	2022	2013	2022	2013	2022
Private Entity	140	95	69.3	67.5	37.7	42.7
University	49	37	24.0	26.2	13.1	16.6
Science Council	10	5	4.7	3.2	2.6	2.0
Family Trust	1	3	0.5	2.1	0.3	1.3
Public Entity	3	1	1.5	0.9	0.8	0.6

Source: computed from WIPO "Patentscope"

Second, after the private entities are the universities, with a decrease in PCT patent applications from 49 in 2013 to 37 in 2022 but an increase in a proportional share of applications from the institutions (from 24.0% in 2013 to 26.2% in 2022). The South African university with the most patent applications in 2022 was Stellenbosch University (11), followed by the University of Cape Town (9, one shared with an international university) and the University of Pretoria (4). Similar to the University of South Africa, the University of KwaZulu-Natal had two patent applications (one shared with the University of Zululand). Other universities with a single patent application are the University of the Witwatersrand and the University of Venda.

All the five science councils' international patent applications in 2022 are from the CSIR (one shared with the University of Pretoria). In 2013, the CSIR also had five patent applications, Mintek had four and the South African Medical Research Council had one (shared with the University of Cape Town).

In 2013, the public entities/state-owned enterprises that filed PCT patent applications are Eskom (shared with the UKZN), PetroSA, Technology Innovation Agency, and Japan Oil, Gas, and Metals National Corporation (shared with Platreef Resources Proprietary Limited).

Table 3.2 shows the distribution of South African patent applications by province. The majority originate from Gauteng (52.2% and 53.8% share in 2013 and 2022, respectively), followed by the Western Cape and KwaZulu-Natal.

Table 3.2: Distribution of Provincial Patents Application from South Africa

	Number of Applications		Share of Applications by Provinces	
	2013	2022	2013	2022
Gauteng	194	120	52.2	53.8
Western Cape	97	51	26.2	23.0
KwaZulu-Natal	29	16	7.8	7.2
Eastern Cape	10	9	2.6	4.0
Free State	3	6	1.1	2.7
Mpumalanga	3	4	0.8	1.6
North West	10	2	2.7	0.9
Limpopo	4	1	1.1	0.4
Northern Cape	2	0	0.4	0.0
International	20	14	5.4	6.3

Source: computed from WIPO "Patentscope"

The patent co-application of local actors shows a decrease in co-applications (from 19 in 2013 to 14 in 2022). In contrast, their share of total patent applications from South Africa increased from 5.1% in 2013 to 6.3% in 2022 (see **Table 3.3**).

Local Patents Co-Application from South Africa

Number of Local Co-Applications		Share of Total Patent Applications	
2013	2022	2013	2022
19	14	5.1	6.3

Source: computed from WIPO "Patentscope"

Table 3.4 shows that most of these local patent co-applications are from individuals (78.9% and 71.4% in 2013 and 2022, respectively). Some of these individual co-applications originate from family members. In general, there is a lack of patent co-applications among various institutions.

Table 3.4: Distribution of Local Patents Co-Application from South Africa

	Number of Co-Applications		Share of Local Co-Applications	
	2013	2022	2013	2022
University – University	1	1	5.3	7.1
Private Entity - Private Entity	0	1	0.0	7.1
Individual – Individual	15	10	78.9	71.4
University - Science Council	1	1	5.3	7.1
Private Entity - Individual	2	1	10.5	7.1

Source: computed from WIPO "Patentscope"

Similar to the institutions, there is a lack of provincial patent co-applications (see **Table 3.5**). From these small pockets of co-applications, Gauteng, Western Cape and KwaZulu-Natal are at the centre.

Table 3.5: Distribution of Provincial Patents Co-Application from South Africa

Provincial Partners	Number of Applications		Share of Local Co-Applications	
	2013	2022	2013	2022
Gauteng and Eastern Cape	1	0	5.3	0.0

Gauteng and Western Cape	0	1	0.0	7.1
Gauteng and KwaZulu-Natal	2	1	10.5	7.1
Western Cape and Mpumalanga	0	1	0.0	7.1
Western Cape and KwaZulu-Natal	0	1	0.0	7.1

Source: computed from WIPO "Patentcope"

In both 2013 and 2022, there were relatively more patent co-applications with international partners than local co-applications. As Table 3.6 shows, the share of patent co-applications with international partners in total patent applications increased to 12.6% in 2022 from 10.5% in 2013.

Table 3.6: Patents Co-Application with International Partners

Number of Applications		Share of Total Patent Applications	
2013	2022	2013	2022
39	28	10.5	12.6

Source: computed from WIPO "Patentcope"

Table 3.7 shows the distribution of these patent co-applications with international partners. Most of these co-applications involve an international private entity and local individuals. As stated, most of these collaborations involve the local technology transfer agents managing an invention to be protected by an international patent in specific countries.

Table 3.7: Distribution of Patents Co-Application with International Partners

		Number of Applications		Share of International Co-Applications	
International Partner Applicants Category	Local Partner Applicants Category	2013	2022	2013	2022
Private Entity	Individual	21	16	53.8	57.1
Private Entity	Private Entity	5	3	12.8	10.7
Individual	Individual	7	4	17.9	14.3
University	University	1	2	2.6	7.1
University	Private Entity	1	1	2.6	3.6
Private Entity	University	1	0	2.6	0.0
University	Individual	1	0	2.6	0.0
Private Entity	Private Entity and Individual	1	1	2.6	3.6
Private Entity and Individual	Individual	1	0	2.6	0.0
Private Entity	Public Entity	0	1	0.0	3.6

Source: computed from WIPO "Patentscope"

3.4 Innovation linkages

3.4.1 Barriers to innovation

The data from the business innovation survey 2019 - 2021 reveals some of the barriers innovators face in the business landscape. Identifying and addressing these barriers will

help businesses navigate the complexities of the innovation landscape and boost their competitiveness.

Figure 3.8 shows that over 2019-2021, innovators consistently cited high barriers imposed by innovation costs being too high, market competition and dominance by established enterprises ranging from 35.5% to 26.2%. In contrast, barriers to lack of information on technology, digital platforms, and no need due to prior innovations were perceived as lower (ranging from 9.4% to 9.1%). These findings highlight the challenges and relatively low concerns among innovators across various innovation areas between 2019 and 2021.

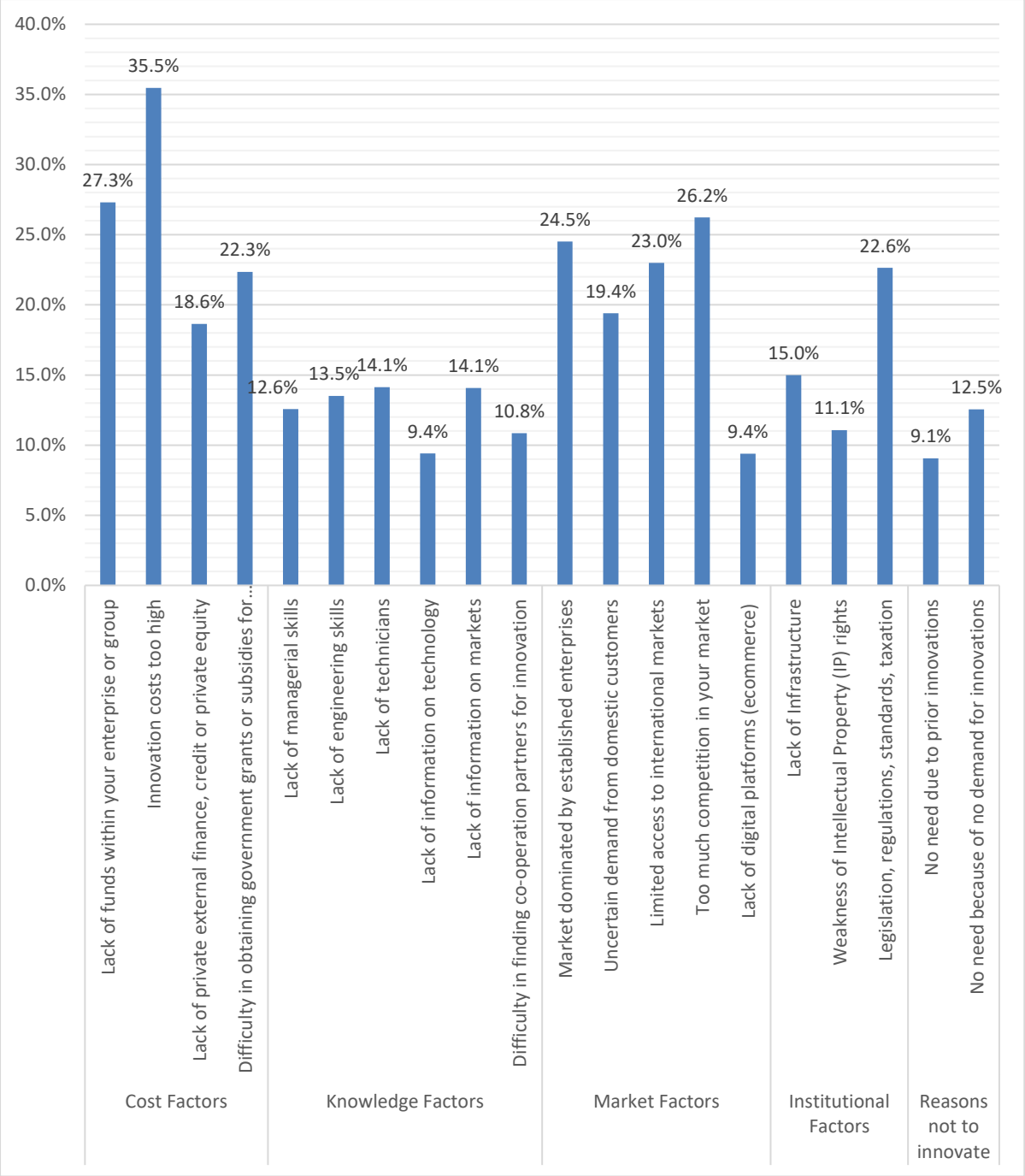


Figure 3.8: Percentages of innovators that indicated that barriers were highly important, 2019-2021

Source: HSRC and DSI's Business Innovation Survey, 2019-2021

In conclusion, the identified barriers to innovation emphasise the significance of implementing barrier removal strategies for businesses to adapt to the ever-changing business landscape and foster growth.

3.4.2 Sources of innovation

The 2019-2021 business innovation survey reveals preferences for information sources among knowledge-driven and activity-driven businesses regarding collaboration and non-collaboration. Highlighting the differences in priorities between these types of businesses gives insight into how businesses collaborate, innovate, and build relationships within their ecosystems.

Figure 3.9 shows that during the period 2019-2021, activity-driven collaborators considered suppliers of equipment, materials, components, or software an important information source (66.1%). By contrast, knowledge-driven collaborators prioritised clients or customers (62.5%). In addition, knowledge-driven collaborators value internal sources (54.1%), whereas activity-driven collaborators also value internal sources (45.7%).

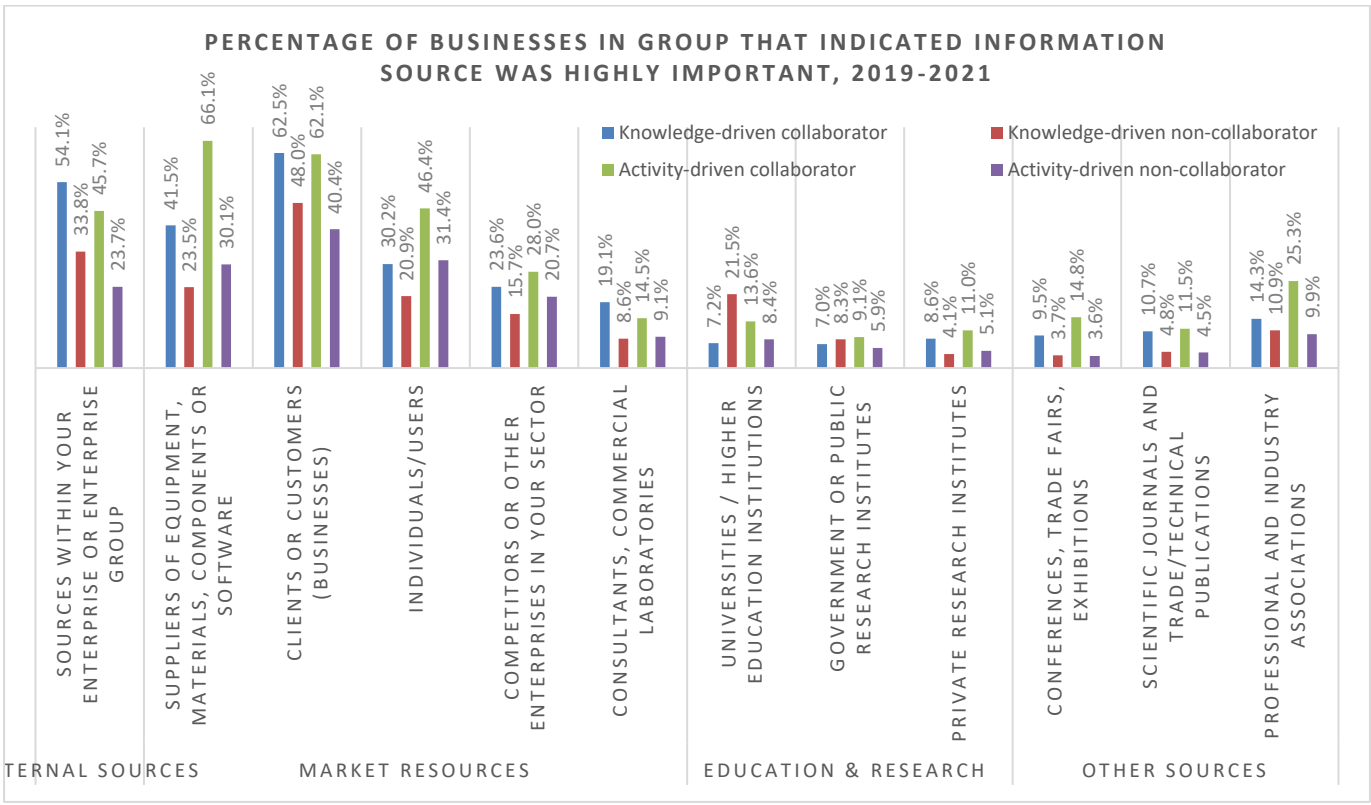


Figure 3.9: Percentage of Businesses in Group that Indicated Information Source was Highly Important, 2019-2021

Source: HSRC and DSI's Business Innovation Survey, 2019-2021

This distinction demonstrates the different focal areas and priorities of the two collaboration types: knowledge-driven collaborators focus on customer relationships, whereas activity-driven collaborators focus on their supply chain and material inputs. Combining internal and external information sources is important for both collaborator types in driving innovation and success in their fields.

4. SCIENCE, TECHNOLOGY AND INNOVATION OUTPUTS

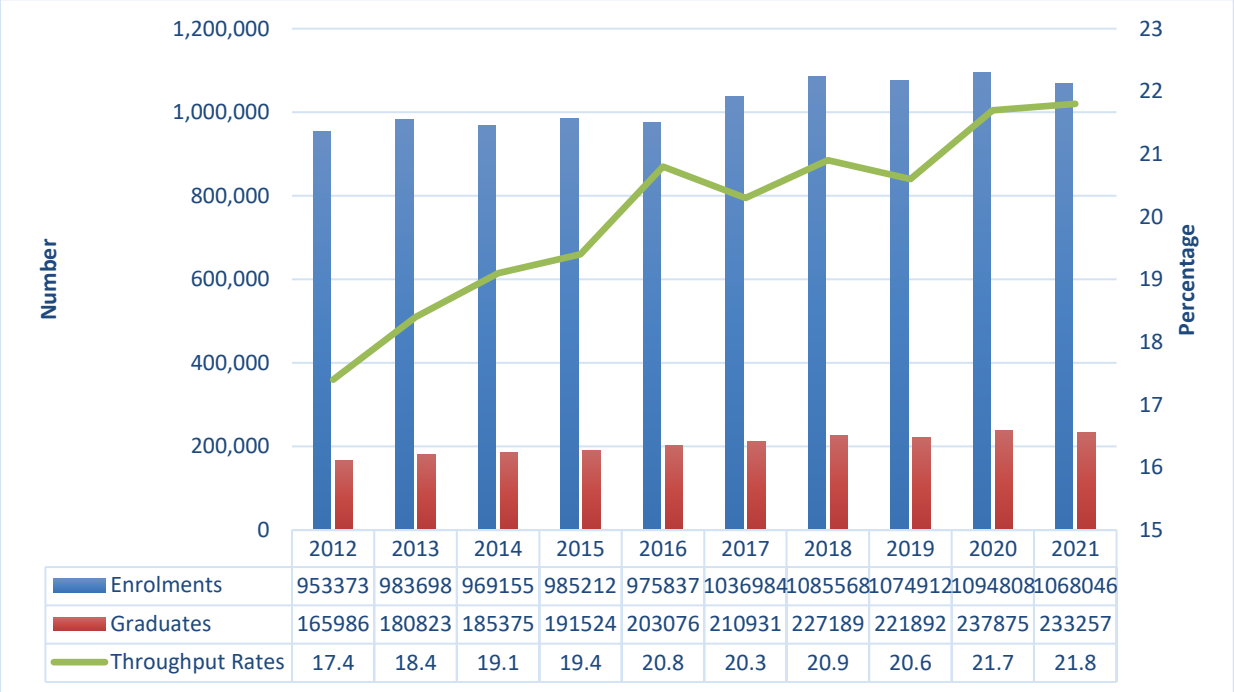
The STI outputs in this chapter are intended to cover the whole value chain from the outputs of science, such as publications, to technology outputs, such as patents and finally, the innovation outputs, such as technology balance of payments.

4.1 The post school education and training sector

The leading institutions offering post-secondary qualification programmes are the higher education institutions (public and private) and public Technical and Vocational Education and Training (TVET) colleges.

4.1.1 Public university sector

The university sector comprises 26 public universities and more than 200 accredited private higher education institutions. Eighty-five percent of all higher education students are enrolled in public institutions, so we report trends for these institutions (see **Figure 4.1**).



	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Enrolments	953373	983698	969155	985212	975837	1036984	1085568	1074912	1094808	1068046
Graduates	165986	180823	185375	191524	203076	210931	227189	221892	237875	233257
Throughput Rates	17.4	18.4	19.1	19.4	20.8	20.3	20.9	20.6	21.7	21.8

Figure 4.1: Enrolment and Graduation Trends in Public Universities

Source: DHET (2023) "Statistics on Post School Education and Training in South Africa, 2021". Own calculations for throughput rates

The public university sector enrolments increased from 0.95 million students in 2012 to slightly over one million students in 2021 – an increase of 12% over the ten years. Over the same period, the number of graduates increased from 165 986 to 233 257– an increase of 41%. The university throughput rates[18] has shown a steady increase, with a throughput rate of 17.4% in 2012 and 21.8% in 2021 (DHET, 2023)[19]While the increasing number of graduates and throughput rates are a positive sign, it is highly unlikely that South Africa

[18] Number of enrolments for the year divided by the number of graduates for the same year.
[19] DHET (2023) Statistics on Post School Education and Training in South Africa, 2021. Published by Department of Higher Education and Training.

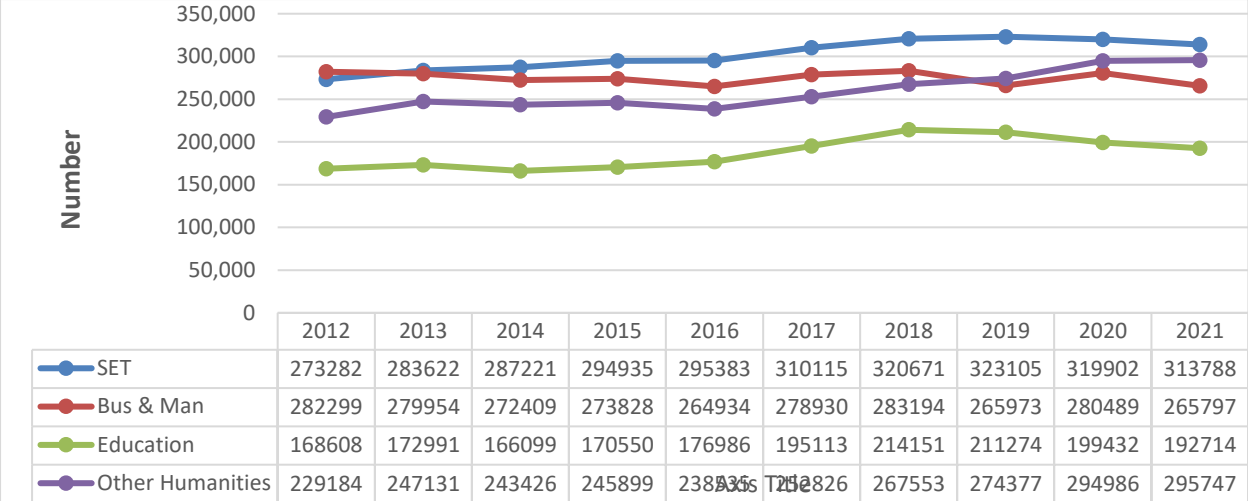
will be able to meet its National Development Plan (NDP) target of 1.6 million enrolments by 2030.

Drilling down on enrolments, we report the major fields of study students enrolled in (**Figure 4.2**). In 2021, the enrolment shares by the three major fields of study were 29.4% for Science Engineering and Technology (SET), 24.9% for Business and Management sciences, and 45.7% for Humanities (made up of 18% for Education and 27.7% Other Humanities). The National Plan for Higher Education (NPHE) (2002)[20] recommended the enrolment share targets for the SET: Business and Management Science: Humanities fields of study to be the ratio of 30: 30: 40. Presently the humanities enrolments, at 46%, are higher than the target of 40%.

Over the period 2012 to 2021, the SET enrolments increased by 15%, Education by 14% and Humanities by 29%. In 2016, to respond to the skills demand in the country, the Labour Market Intelligence Partnership (LMIP) project recommended that the NPHE targets be reviewed to increase the shares of SET enrolments in university courses from 30% to 35%, especially in the areas of Engineering and Health professions. Concomitantly, the LMIP recommended a decrease in the Humanities target from 40% to 35% (Reddy, et al; 2016)[21]. This analysis indicates that Humanities enrolments, rather than SET enrolments have been increasing. This trend could exacerbate technical skills shortages in the workplace.

[20] Ministry of Education (2001) Draft National Plan for Higher Education in South Africa. Ministry of Education. https://www.dhet.gov.za/HED%20Policies/National%20Plan%20on%20Higher%20Education.pdf

[21] Reddy, V., Bhorat, H., Powell, M., Visser, M. and Arends, A., (2016) Skills Supply and Demand in South Africa, LMIP Publication, Human Sciences Research Council, Pretoria.

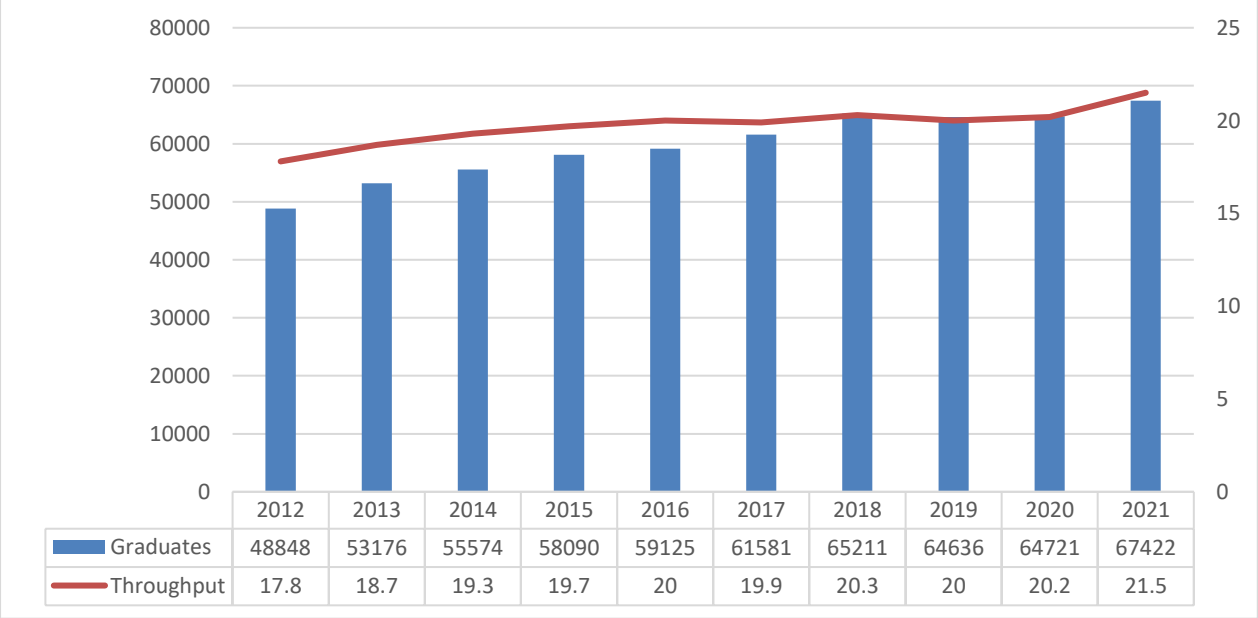


	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
SET	273282	283622	287221	294935	295383	310115	320671	323105	319902	313788
Bus & Man	282299	279954	272409	273828	264934	278930	283194	265973	280489	265797
Education	168608	172991	166099	170550	176986	195113	214151	211274	199432	192714
Other Humanities	229184	247131	243426	245899	238435	252826	267553	274377	294986	295747

Figure 4.2: Number of Students Enrolled in Public HEIs by Major Field of Study

Source: DHET (2023) Statistics on Post-School Education and Training in South Africa, 2021

Over the same period, the number of SET graduates and graduation rates have been increasing (Figure 4.3). In 2021, there were close to 18 500 more graduates than in 2012. This represents a 38% growth in SET graduates over the ten years. The SET graduation throughput rates also increased from 17.8% in 2012 to 21.5% in 2021.



	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Graduates	48848	53176	55574	58090	59125	61581	65211	64636	64721	67422
Throughput	17.8	18.7	19.3	19.7	20	19.9	20.3	20	20.2	21.5

Figure 4.3: Number of SET Graduates and Throughput Rates

Source: DHET (2023) Statistics on Post School Education and Training in South Africa, 2021; Own calculations for throughput rates.

4.1.2 Technical and vocational education and training sector

The TVET sector comprises 50 public and 296 private institutions, with 80% of TVET students registered at public institutions. We therefore focus on public sector TVET

institutions. The focus of TVET colleges is the National Certificate (Vocational) NC(V)[22] and National Technical Education (NATED) Report 191[23] Qualifications, with a smaller focus on occupational and skills programmes.

This section reports the NC(V) and NATED qualifications to illustrate the intermediate skills pipeline, which is the economy's engine. **Figure 4.4** presents the NC(V) and NATED enrolments, as well as the total TVET enrolments, for the period 2012 to 2021. The National Development Plan (NDP) aims to massify the TVET college sector by 2.5 million enrolments by 2030.

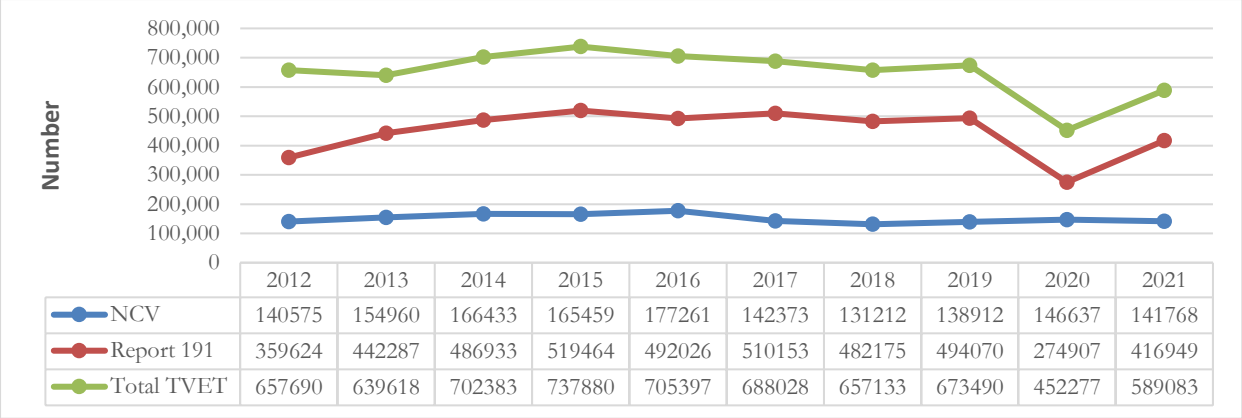
The NC(V) enrolments have been stable over the last ten years, with an average of 150 000 students each year. These small enrolments for students registering for the technical matriculation qualification are concerning as the NC(V) pathway was designed to offer a workplace skills programme. Attracting more students to this pathway should be a priority.

The NATED Report 191 programme enrolments increased from 360 000 in 2012 to a peak of close to 520 000 in 2015, and thereafter enrolments dropped with the 2021 numbers close to 417 000.

The total TVET enrolment in 2021 was close to 590 000 students – a long way from the NDP target of 2.5 million enrolments by 2030. This low enrolment has implications for the much-needed intermediate skills required to mitigate the skills shortages.

In addition to the low enrolment, the completion rates at TVET colleges are low. Just over 22 000 students took the matriculation equivalent NC(V)4 examinations, and 16 456 students took the Engineering N3 examinations. Around half of these students completed their qualifications – adding only a further 19 000 to the pool of students who completed secondary education.

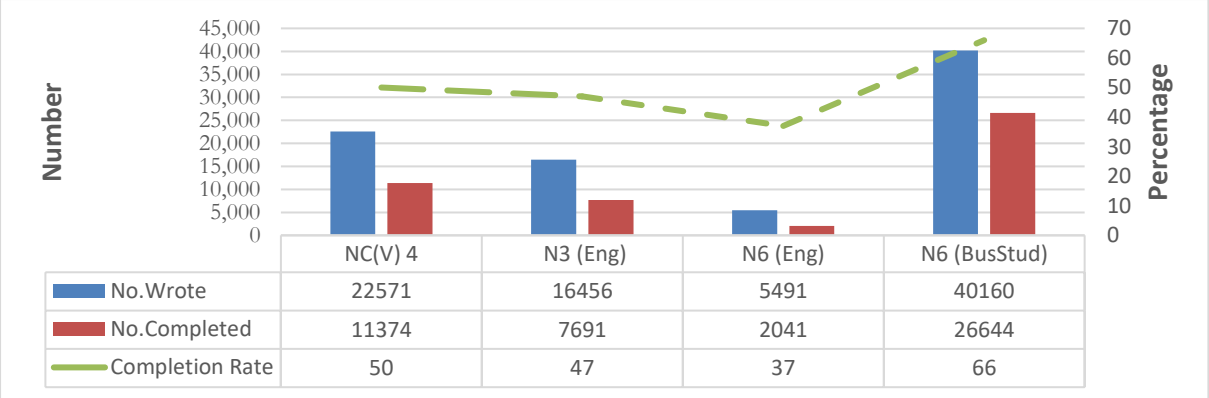
[22] This programme offers workplace-based skills sets in various career fields. The NCV4 is equivalent to a matriculation certificate.
[23] NATED courses are designed to train students for the workplace. N3 is equivalent to a matriculation certificate and N4, 5 and 6 are post matriculation qualifications. NATED programmes are offered at 6 different levels (N1 to N6) for Engineering programmes and three levels (N4 to 6) for Business Studies programmes.



	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
NCV	140575	154960	166433	165459	177261	142373	131212	138912	146637	141768
Report 191	359624	442287	486933	519464	492026	510153	482175	494070	274907	416949
Total TVET	657690	639618	702383	737880	705397	688028	657133	673490	452277	589083

Figure 4.4: Total Enrolments and Enrolments in NC(V) and NATED Programmes

Just over 5 000 students took the N6 Engineering examinations, while just over 40 000 students took the N6 Business Studies examinations. The completion rates were 37% and 66% respectively. Engineering skills are in high demand in the economy, but there are fewer enrolments and completions for these important qualifications at the TVET colleges. TVET college enrolments should be increased generally, and in particular, in qualifications that respond to the needs of the labour market.



	NC(V) 4	N3 (Eng)	N6 (Eng)	N6 (BusStud)
No.Wrote	22571	16456	5491	40160
No.Completed	11374	7691	2041	26644
Completion Rate	50	47	37	66

Figure 4.5: Completions for NC(V) 4 and N3 and N6 Programmes

4.2 Scientific outputs (publications)

4.2.1 South Africa's scientific publications

The annual publication of South African scientific publications and its world share are presented in **Figure 4.6,** which shows that South Africa has maintained its strong annual growth in publication output: an increase from 3 693 publications in 2000 to 27 208 in 2022. However, despite this sustained increase in publications, the country's world share seems to have peaked at around 1% by 2018 and, since then, remained the same and even began to decline over the past two years. This means that other countries (most notably, countries such as China and India) have increased their output at an even higher rate. Significantly,

Clarivate Analytics added the Emerging Sources Citation Index to its standard set of citation indexes in 2015 to improve its coverage of developing countries. South Africa has benefitted from this decision, as the continued increase in the country's publications since 2015 has been partly driven by the inclusion of more than 40 South African journals in the Web of Science.

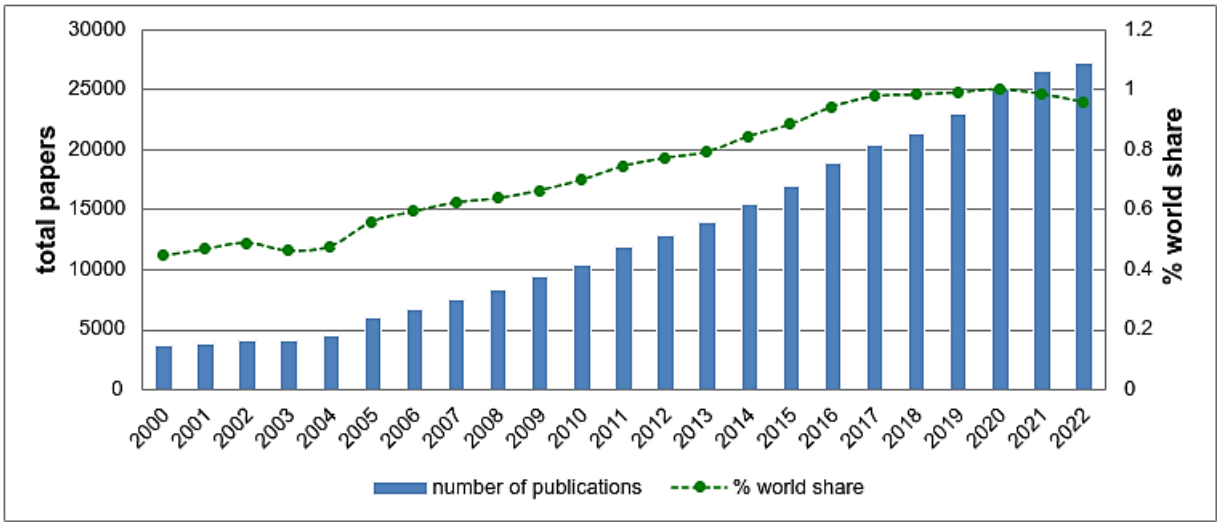


Figure 4.6: Number of Articles and Reviews (full-paper counting) and World Share
Source: CREST, Stellenbosch University

A significant driver of the increasing trend in South African scientific publications is South Africa's participation in large international scientific programs such as the European Organization for Nuclear Research and Global Health. It is typical for publications of such programmes to have a very high number of authors. In this case, the number of South African authors is proportionally smaller when compared to the number of authors from larger science systems in the world. The data presented in **Figure 4.7** is based on full paper counting at the country level. This means that irrespective of the number of countries listed in the address field of a scientific publication, each country is counted only once. However, when fractional counting is applied at the country level to the same dataset, the number of publication units (fractionalised) is lower per year, as **Figure 4.7** shows. The figure also shows that South Africa's share of the world is also lower, and it will be around 0.58 % in 2022.

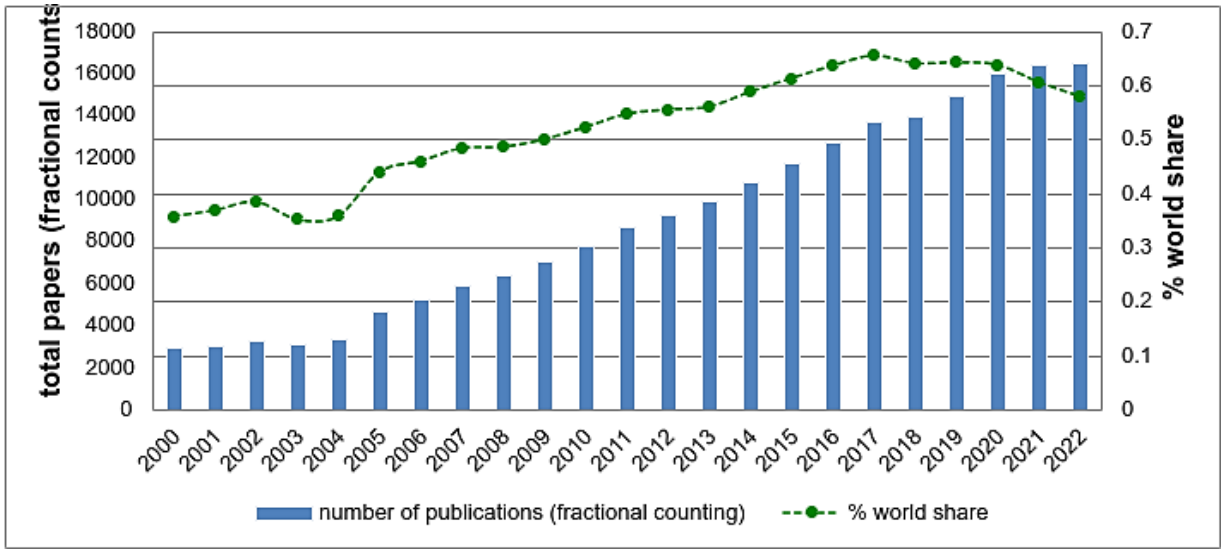


Figure 4.7: Number of Articles and Reviews (fractional counting) and World Share

Source: CREST, Stellenbosch University

Countries can be ranked based on the annual publication output. **Figure 4.8** presents South Africa's ranking in terms of the number of scientific publications produced annually. South Africa obtained its best rank (24th in the world) in 2016. In 2022, the country was ranked 29th in the world.

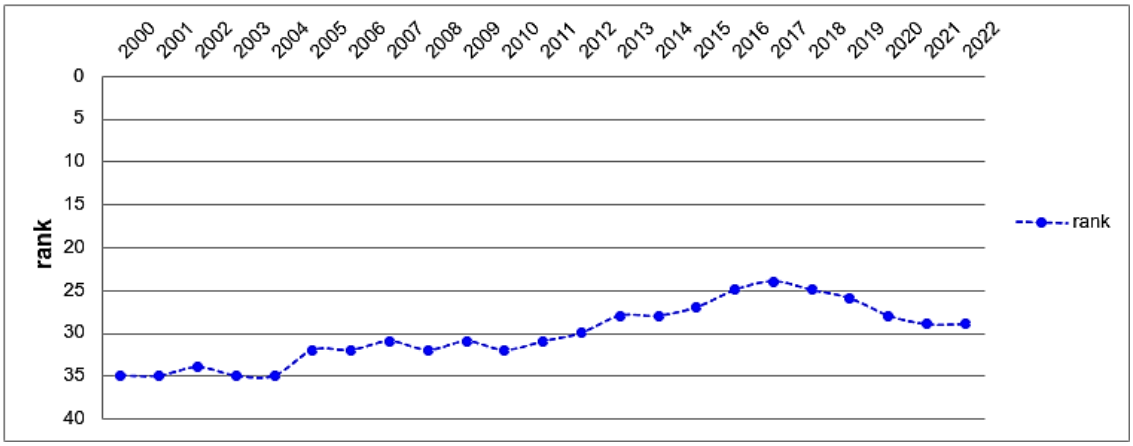


Figure 4.8: South Africa World Rank According to the Annual Number of Articles and Review Articles

Source: CREST, Stellenbosch University

Table 4.1 compares South Africa's publication output to the 28 countries that ranked above it in 2022. South Africa occupies the second-highest position of all African countries behind Egypt.

Table 4.1: Number of Articles and Review Articles by Country, 2022

Country	Number of Articles and Review Articles
China	797 350
USA	555 145
India	175 922

England	164 949
Germany	154 598
Italy	114 518
Japan	109 555
Canada	105 635
Australia	104 567
Spain	96 647
France	94 885
South Korea	86 798
Brazil	75 747
Iran	65 939
Turkey	65 412
Russia	64 353
Netherlands	59 284
Saudi Arabia	55 458
Poland	47 632
Switzerland	45 185
Sweden	41 326
Egypt	36 694
Pakistan	35 931
Belgium	32 731
Malaysia	29 030
Denmark	28 665
Portugal	27 621
South Africa	27 208

Source: CREST, Stellenbosch University

The absolute numbers reported in the previous figures do not normalise for any appropriate system-related characteristics of the South African system. Given the large differences between countries, it is useful to report on the number of scientific articles per million of the population. **Figure 4.9** shows that the South African science system is productive when the number of publications is divided by millions of the population, except for 2022, which witnessed a slight decrease. The science system has a sharp increase since 2004. The increase over the past 22 years is a positive trend suggesting that despite the financial and other constraints, the South African science system continues to be increasingly productive. However, the decline in 2022 is cause for concern.

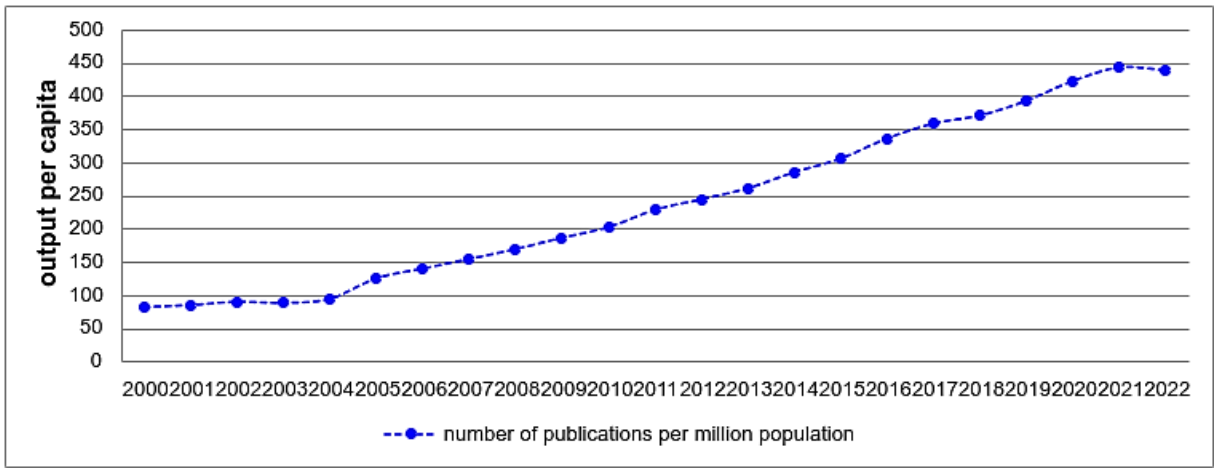
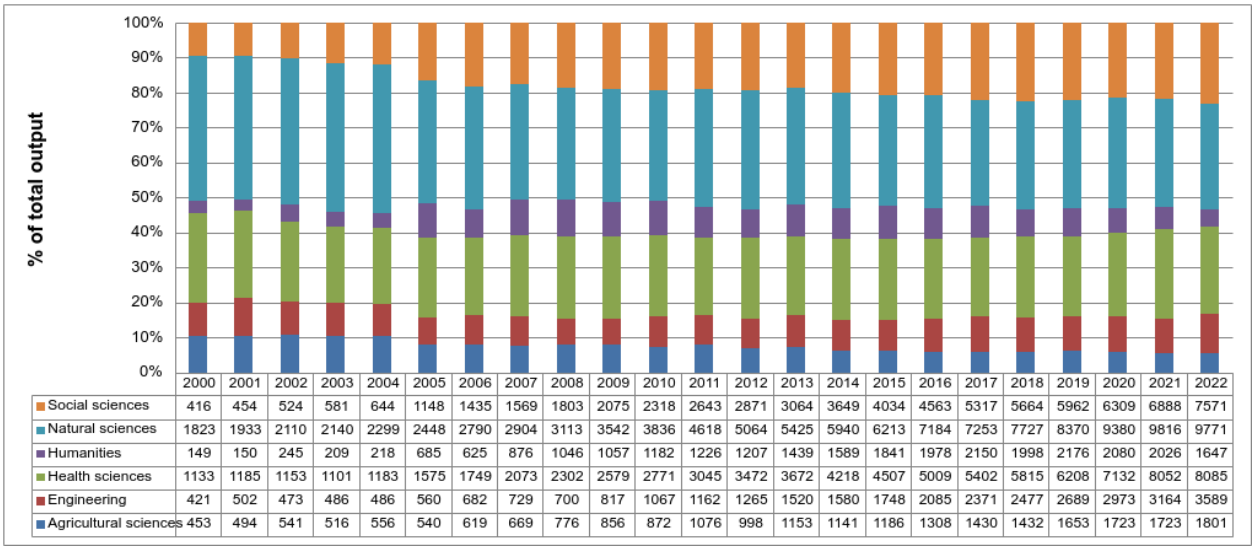


Figure 4.9: South African Publications per Million of Population

Source: CREST, Stellenbosch University

The distribution of scientific knowledge production across the six main scientific domains can provide insight into the fields in which the country intensifies scientific publication. The publications are assigned to six main science domains based on the subject categories of the journals in which they are published. However, given a small degree of overlap between some categories, the sum of publications in each year exceeds the numbers reported in earlier graphs. **Figure 4.10** reveals the stability of the disciplinary breakdown of the publications in the science system. The fields that have consistently contained the largest number of South African publications are health sciences and natural sciences.

Over the reporting period, there has been a slight decline in the relative contribution of the agricultural sciences, with a concomitant increase in the relative share of the social sciences. The context for this trend is that, over this period, the Web of Science has increased its indexing of South African journals by a factor of more than threefold, and most of the additional journals fall under humanities and social sciences. The two larger fields have also increased their output substantially, even though their relative share has not changed substantially due to a concurrent increase in the publications of other fields. The number of publications in health sciences increased by more than seven-fold over the reporting period, and the number of publications in natural sciences increased by more than five-fold over the reporting period.



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Social sciences	416	454	524	581	644	1148	1435	1569	1803	2075	2318	2643	2871	3064	3649	4034	4563	5317	5664	5962	6309	6888	7571
Natural sciences	1823	1933	2110	2140	2299	2448	2790	2904	3113	3542	3836	4618	5064	5425	5940	6213	7184	7253	7727	8370	9380	9816	9771
Humanities	149	150	245	209	218	685	625	876	1046	1057	1182	1226	1207	1439	1589	1841	1978	2150	1998	2176	2080	2026	1647
Health sciences	1133	1185	1153	1101	1183	1575	1749	2073	2302	2579	2771	3045	3472	3672	4218	4507	5009	5402	5815	6208	7132	8052	8085
Engineering	421	502	473	486	486	560	682	729	700	817	1067	1162	1265	1520	1580	1748	2085	2371	2477	2689	2973	3164	3589
Agricultural sciences	453	494	541	516	556	540	619	669	776	856	872	1076	998	1153	1141	1186	1308	1430	1432	1653	1723	1723	1801

Figure 4.10: The Distribution of Articles and Review Articles by Main Scientific Fields

Source: CREST, Stellenbosch University

The specialisation or activity index is a standard bibliometric indicator employed in studies to assess the strength of a country, region, or institution in a specific field. We refer to this indicator as the "relative field strength (RFS) index" because it measures the "relative" strength of a particular field or discipline compared to others. An RFS value of 1 in a field or discipline indicates a "neutral" situation, meaning there is no relative strength in that field. When the RFS index is greater than 1, the country is said to be strong in that field at the expense of other fields for which the index is less than 1. The results for the South African science system are presented in **Figure 4.11**, which compares the values on the RFS index for two periods (2000 – 2007) and (2015 – 2022). The figure shows above-average activity and relative strength in agricultural science, social sciences, and humanities. In comparison to the world publications in engineering and health sciences, the RFS values indicate that these fields are under-represented in South Africa, whereas the South African performance in natural sciences is aligned with the world average (having RFS value close to 1.0), which suggests the neutrality of natural sciences in South Africa (not an area of strength or weakness).

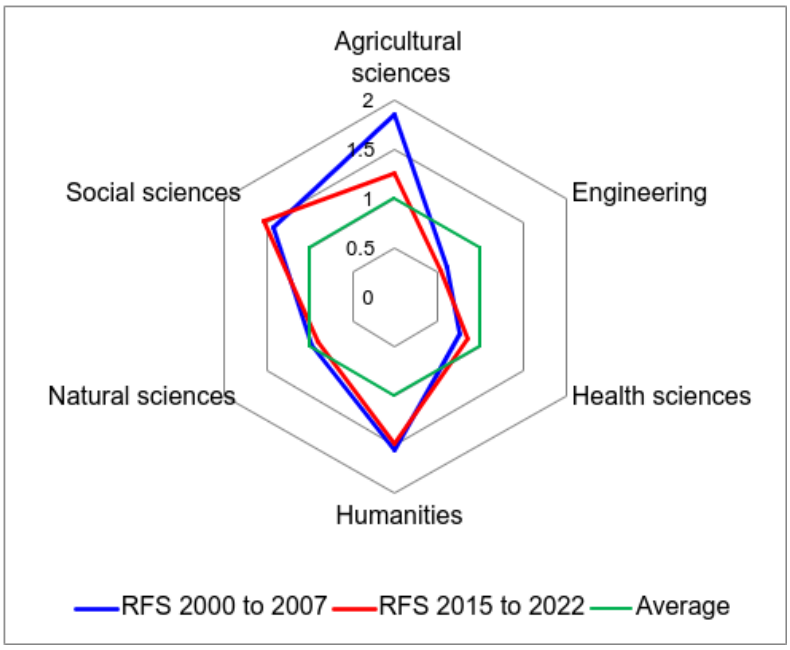


Figure 4.11: Relative Field Strength (relative activity index)

Source: CREST, Stellenbosch University

4.2.2 Publications by SA universities

The production of scientific publications of all document types increased at a healthy compound growth rate of 7.4% between 2005 (7 230 publications units) and 2022 (24 403), as illustrated in **Figure 4.12**. The consistent linear trend attests to the achievement of one of the main goals of the DHET's Publication Output Policy, i.e. to increase the quantity of university publications.

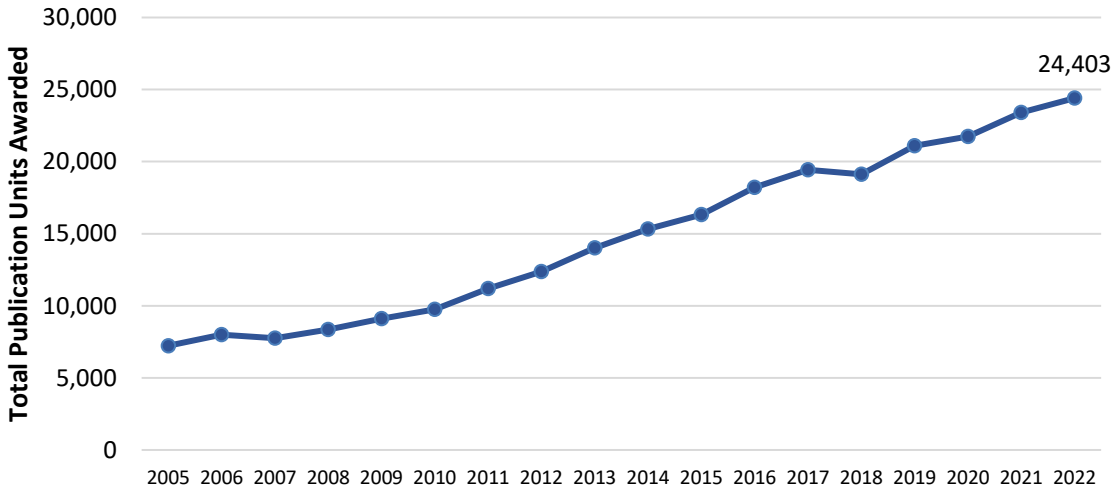


Figure 4.12: Total Publication Subsidy Units Awarded

Source: CREST, Stellenbosch University

The overall trend in the production of articles in accredited journals shows a clear linear increase. This increase became steeper from 2010 onwards but has continued on a year-

to-year basis ever since. The compound annual growth rate for the sixteen-year period is 6.7%.

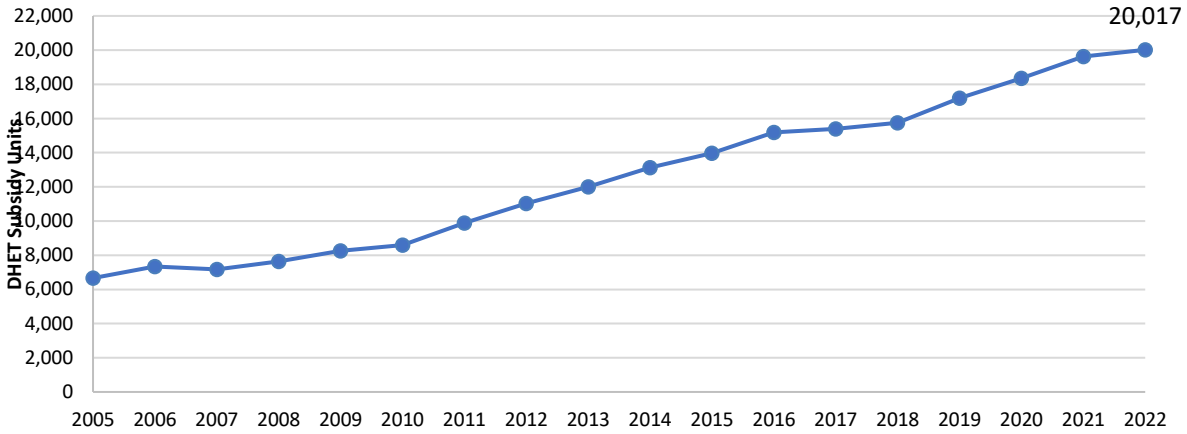


Figure 4.13: Number of Subsidy Units Awarded to Journal Articles

Source: CREST, Stellenbosch University

The disaggregation of article output by broad scientific domains shows high productivity in the natural and health sciences, particularly over the last two years (see **Figure 4.14**). Across all domains, except for the humanities and arts, there has been consistent growth in the number of subsidy units awarded for research articles.

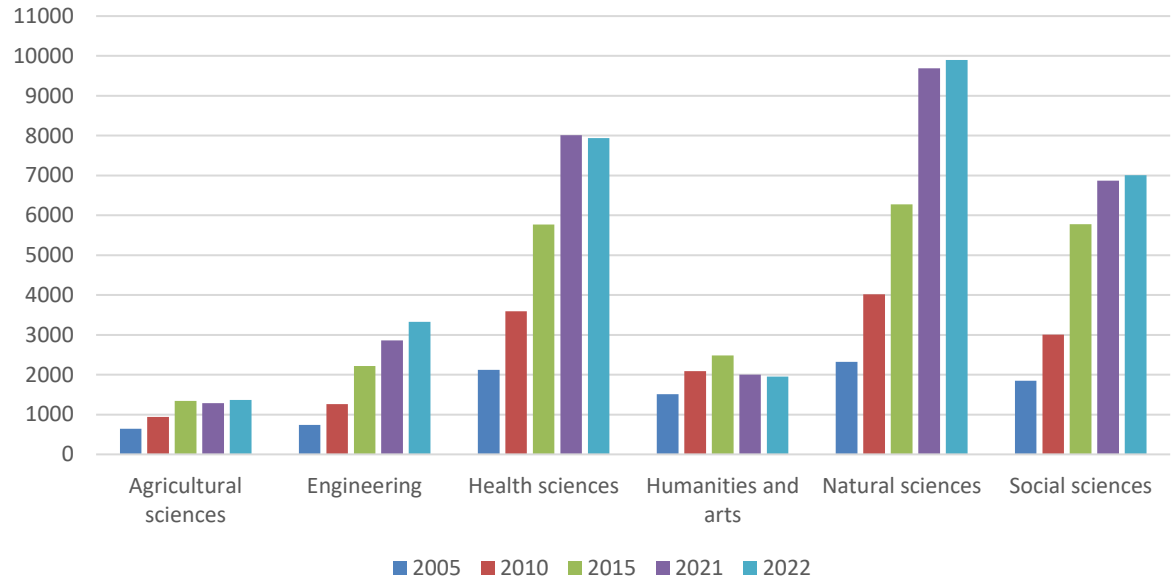


Figure 4.14: Articles and Units Awarded by Main Science Domain

Source: CREST, Stellenbosch University

The trend in the production of published conference proceedings between 2005 and 2022 (**Figure 4.15**) can be divided into three quite different periods. Between 2005 and 2009 there was no real growth in annual output. From 2010 onwards, and especially between 2012 and 2013, we witness a much steeper increase. Close inspection of university-

specific output will show that three or four universities primarily drove this steep increase. Between 2013 and 2019, annual output 'stabilised' at around 1,200 units per year. The large drop in 2002 is explained by the withholding of subsidy units in cases where questionable publication behaviour has been identified, whereafter, the number of published conference proceedings slowly increased to 1 066 in 2022.

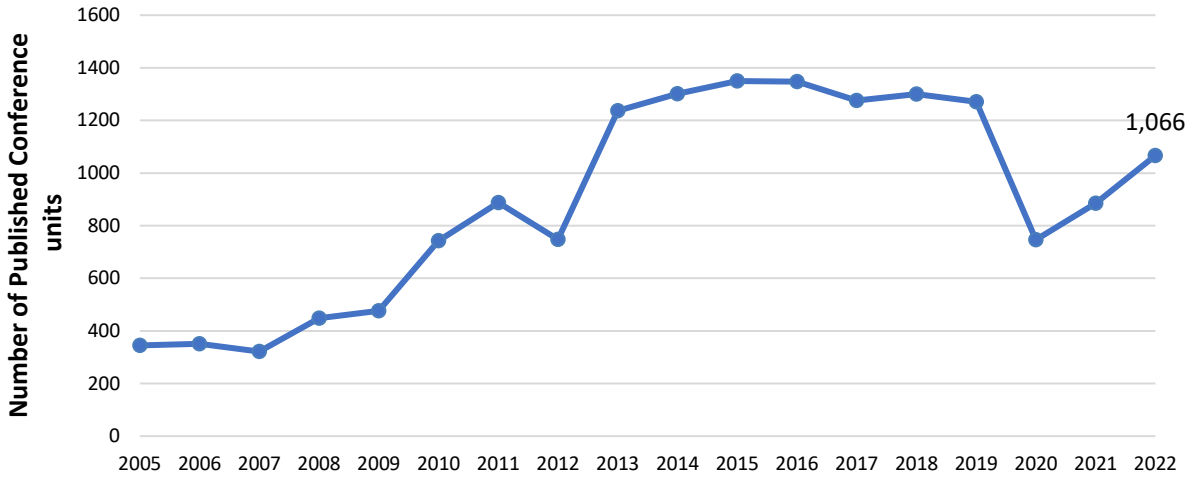


Figure 4.15: Number of Published Conference Subsidy Units Awarded
Source: CREST, Stellenbosch University

The trend over the past 17 years (**Figure 4.16**) shows a steady linear increase in the contribution of women authors from 32% in 2005 to 45% in 2022.

Although no specific target is set in any South African policy document against which this trend can be assessed, the general transformation imperative is to make the production of knowledge as inclusive as possible. It is important to emphasise that the trend displayed in this graph represents the general picture across all scientific fields. A breakdown by scientific field and discipline will reveal large differences.

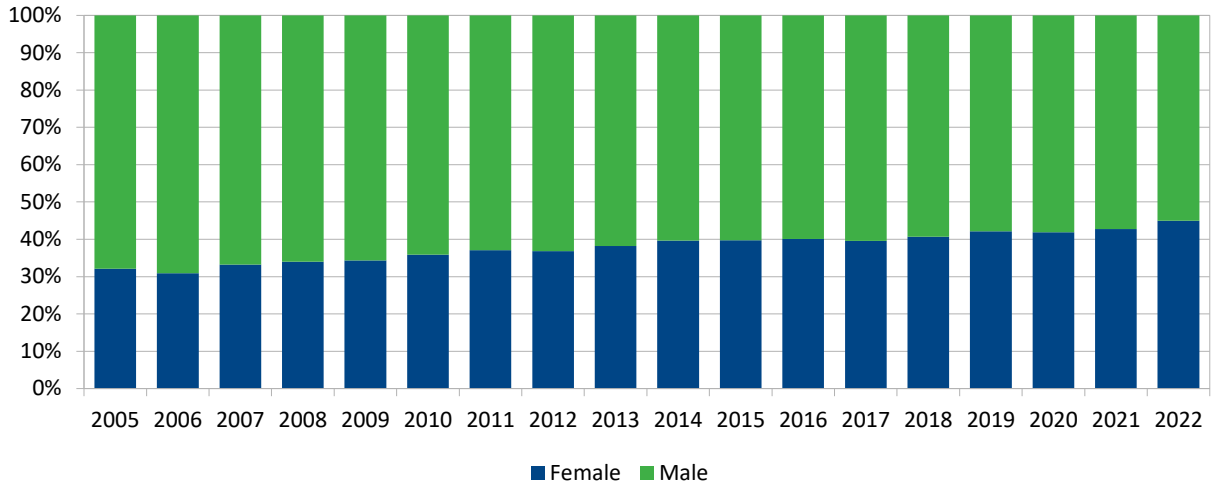


Figure 4.16: Percentage Female Authored Articles

Source: CREST, Stellenbosch University

The trend over the past 17 years (**Figure 4.17**) shows a linear and substantial increase in the relative contributions of Black academics (Black African, Indian/Asian and Coloured combined) between 2005 and 2022. In 2005 articles authored by Black academics constituted less than 15% of all output. By 2022, this percentage had increased to more than 52%, with the largest increase amongst Black African authors (from only 5% in 2005 to 35% in 2022). It is again important to emphasise that the trend displayed in this graph represents the general picture across all scientific fields. A breakdown by scientific field and discipline will reveal significant differences.

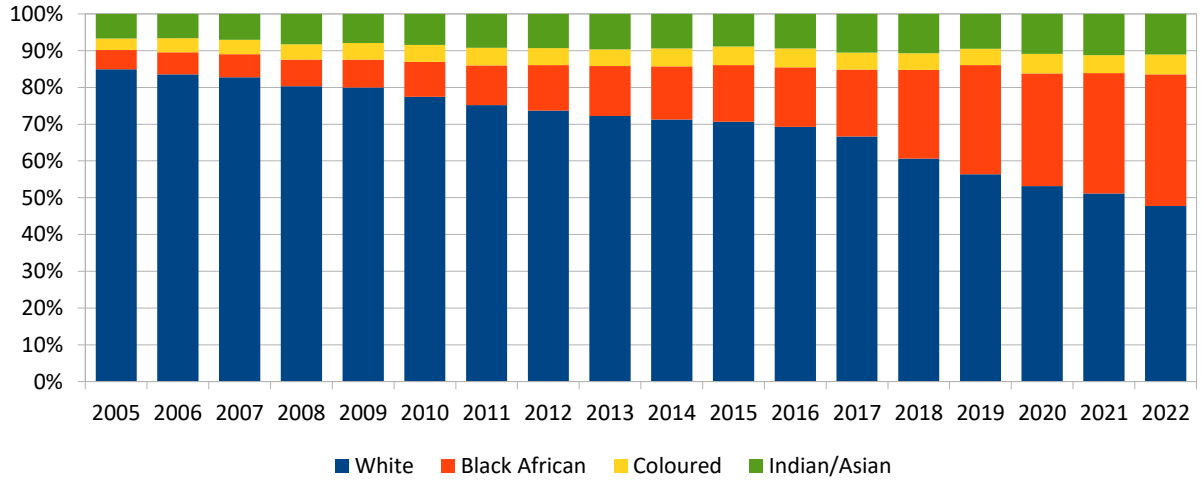


Figure 4.17: Percentage South African Black Authored Articles

Source: CREST, Stellenbosch University

Over the past 17 years (see **Figure 4.18**), the per capita production of scientific journals has more than doubled from 0.47 articles (on average) per permanent staff member in

2005 to 1.19 in 2022. This is a laudable achievement as it attests to the increased productivity of university staff and students.

The normalised weighted research output is a measure of the 'knowledge productive' performance of university academics at South African universities as it calculates the total number of publications (all document types) plus graduate (Masters and Doctoral students) that is produced by the average instructional and research staff. The trend displayed in the graph shows a steady (and increasingly steep since 2012) increase in the knowledge productivity of the average South African academic. For the latest years, the data show that South African academics produce on average at least two 'knowledge outputs' per year.

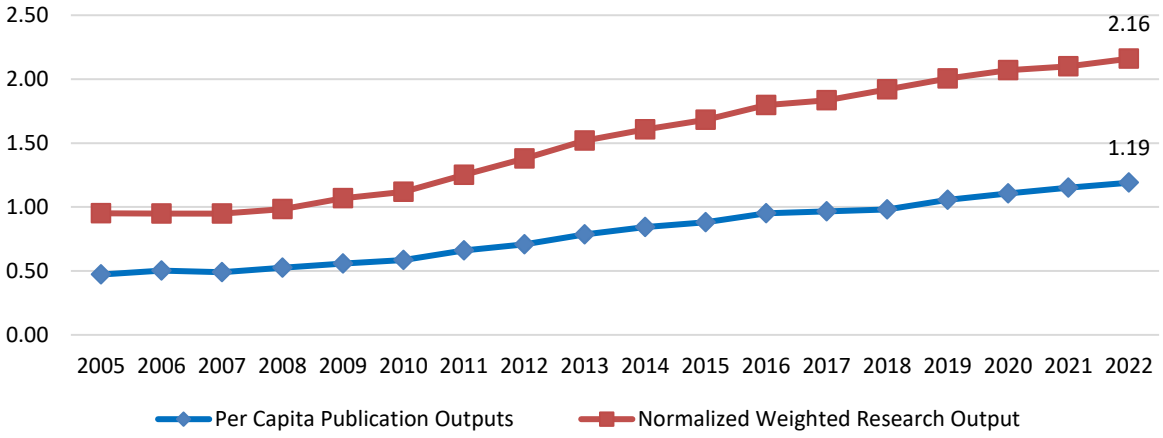


Figure 4.18: Per Capita Article Output and Normalised Weighted Research Output
Source: CREST, Stellenbosch University

4.3 Technology outputs

The technology outputs covered under this section are the patents, technology balance of payments and the plant breeders' rights.

4.3.1 Patents

Domestic Patents

Patents granted to South African residents in South Africa were on a downward trend for much of the decade (see **Table 4.2**). Over the last few years, the number of patents granted has fluctuated considerably – rising sharply in 2019 (54%); then declining equally sharply (-55%) in 2020 and increasing very significantly in 2021, (81%). In 2022, patents granted to residents declined (-9%).

Table 4.2: Domestic Patent Grants, Foreign and Resident (direct and PCT national phase entries)

	Resident	Non-Resident	Total	Resident (%)
2013	474	4 282	4 756	10.0
2014	445	4 620	5 065	8.8
2015	453	4 046	4 509	10.0
2016	403	3 852	4 255	9.5
2017	595	4 940	5 535	10.7
2018	451	4 295	4 746	9.5
2019	694	5 468	6 162	11.3
2020	313	3 153	3 466	9.0
2021	565	5 542	6 107	9.3
2022	513	10 754	11 267	4.6

Source: WIPO "Statistics Database"

There was no clear trend until 2019 regarding patents granted in South Africa to non-residents. There was a sharp fall in 2020 (-42%), followed by significant increases in 2021 (76%) and again in 2022, when patents granted to non-residents almost doubled year-on-year (94%).

Table 4.3: Domestic Patent Grants to China and India

Year	China	India
2018	490	129
2019	725	122
2020	770	126
2021	3 077	183
2022	5 797	622
2033	4 283	566
Total	15 142	1 748

Source: Adams and Adams

The increase in patent applications by China and India accounts for much of the increase in non-resident applications. China, and to a much lesser extent India, have significantly increased the number of patent applications that they have filed in South Africa in recent years. The Chinese government offers incentives whereby a Chinese entity can receive a considerable sum for each patent application filed. Since filing in South Africa is very cheap, well below the incentive, this has encouraged filing on behalf of Chinese entities.[24]

The share of patents granted to South African residents has tended to decline over the decade. In 2022, principally as a result of the major increase in non-resident patents, the

[24] https://www.adams.africa/intellectual-property/curbing-enthusiasm-for-junk-patents-in-south-africa/

share of patents granted to South African residents (4.6%) was less than half the share in 2021.

Patents Abroad

South African patent applications abroad have declined over most of the past decade. In 2020 there was a small increase (3%), followed by a further small increase in 2022 (2%). In 2022, South African patent applications abroad were about one-third lower than a decade earlier.

Table 4.4: Total Patent Applications, South Africa (direct and national phase entries)

	Resident	Abroad	Total
2013	638	1 577	2 215
2014	802	1 520	2 322
2015	889	1 197	2 086
2016	704	1 316	2 020
2017	728	1 461	2 189
2018	657	1 204	1 861
2019	567	950	1 517
2020	542	915	1 457
2021	1 804	947	2 751
2022	1 651	968	2 619

Source: WIPO "Statistics Database"

In 2013, patent applications abroad accounted for 71% of all patent applications filed by South Africans. In 2022, patent applications abroad accounted for 37% of all patent applications filed by South Africans.

South African patent grants abroad declined for the first half of the decade and then increased in 2018. Since 2018, there has been a significant decline. In 2022, South African patent grants abroad declined further (–11%). In 2022, South African patent grants abroad were 30% lower than a decade earlier.

In 2013, patents granted abroad accounted for more than two-thirds of the total patents granted to South Africans (67%). In 2022, patents granted abroad accounted for a little over one-half of the total patents granted to South Africans (56%).

Table 4.5: Total Patent Grants, South Africa (direct and national phase entries)

	Resident	Abroad	Total
2013	474	966	1 440
2014	445	890	1 335
2015	453	773	1 226
2016	403	674	1 077
2017	595	835	1 430

2018	451	992	1 443
2019	694	861	1 555
2020	313	710	1 023
2021	565	748	1 313
2022	513	662	1 175

Source: WIPO "Statistics Database"

The US and Europe

Patents granted in large markets with extensive examination procedures are one index of a country's progress at the global technology frontier. Patents from the United States Patent Office (USPTO) and the European Patent Office (EPO) are used most widely.

Patents granted at the USPTO to South Africa have fluctuated but have tended to decline. In 2021, patent grants declined (-19%) but increased in 2022 (20%). The level of patent grants remains notably lower than for much of the decade. While there was some increase in 2022, South Africa's share of total patents at the USPTO has tended to decrease.

Table 4.6: South Africa Patents Granted in the United States Patent Office

	Number	Share of Total (%)
2015	166	0.055
2016	181	0.059
2017	182	0.056
2018	145	0.047
2019	182	0.051
2020	155	0.043
2021	125	0.037
2022	150	0.045
TOTAL	1286	0.049

Source: USPTO

In contrast to South Africa, the other BRIC countries—China, India, Russia, and Brazil—have all increased their patents at the USPTO. The contrast between South Africa and Brazil, arguably at a similar stage of development, is particularly noteworthy.

Table 4.7: BRICS Patent Grants at the USPTO

	2015	2016	2017	2018	2019	2020	2021	2022	TOTAL
China	8 117	10 469	13 247	14 485	19 213	21 476	23 784	27 434	138 255
India	3 355	3 658	4 161	4 225	5 378	5 863	5 939	6 304	38 883
Russia	440	511	541	533	622	677	657	674	4 655
Brazil	323	310	374	371	425	494	489	493	3 729
South Africa	166	181	182	145	182	155	125	150	1 286

Source: USPTO

The number of South African patents granted at the European Patent Office (EPO) has fluctuated over the decade. The number of South African patent grants peaked in 2020. In 2021, the number of South African patents granted at the EPO declined significantly

compared to the previous year (-36%). There was a further significant decline in 2022 (-25%). The indications are that there will be an increase in patent grants in 2023, but the numbers will remain considerably below the peak and the average for the decade. South Africa's share of total patent grants at the EPO has declined over the decade.

Table 4.8: South African Patent Grants at the EPO

	Number of Patent Grants	Share of Total Patents sGrants
	(per country of residence of the first named applicant)	
2013	54	.08
2014	50	.07
2015	59	.09
2016	70	.07
2017	50	.05
2018	73	.06
2019	69	.05
2020	80	.06
2021	51	.05
2022	38	.05
2023 (estimate)*	52	-

Source: EPO database
*Correspondence with PATSTAT.

There were large increases in the granting of patents by the EPO in 2015 – 2019 as the EPO sought to reduce the stock of pending patents. Variations in the activity of the EPO in granting patents may account for some of this decline in South African patent grants. Patent applications at the EPO are, accordingly, a better indicator of innovative activity. [25]

The number of South African patent applications at the EPO and the South African share of applications peaked in 2017 and then declined. The number of patent applications slightly increased in 2022 compared with the previous year.

Table 4.9: South Africa Patent Applications at the EPO

	Number of Patent Applications	Share of Total Applications
	(per country of residence of the first named applicant)	
2013	107	0.07
2014	112	0.07
2015	99	0.06
2016	96	0.06
2017	118	0.07
2018	105	0.06
2019	88	0.05
2020	91	0.05
2021	85	0.04
2022	87	0.04

Source: EPO database
Correspondence with PATSTAT.

[25] Correspondence with EPO PATSTAT 04-01- 2024

Table 4.10 lists the top South African applicants for patent protection filed under the Patent Cooperation Treaty (PCT) in 2019 – 2022. Patent applications in this period were dominated by the universities.

Table 4.10: PCT Top Applicants (per country of residence of the first named applicant)

	2019	2020	2021	2022
Stellenbosch University	17	6	6	8
Detnet South Africa (Pty) Ltd	1	11	7	5
University of Cape Town	18	7	7	5
University of Pretoria	5	9	3	5
Council for Scientific and Industrial Research	-	1	-	4
Onespark (Pty) Ltd	-	-	-	3
Innovative Mining Products (Pty) Ltd	-	-	5	2
Northwest University	2	-	2	2
University of South Africa	-	4	2	2
VDM Supply Chain Solutions (Pty) Ltd	-	-	1	2
African Rainbow Minerals	-	2	-	2
Maverick International (Pty) Ltd	-	-	-	2
Rocbolt Technologies (Pty) Ltd	-	-	-	2
Seal Chemistry (Pty) Ltd	-	-	-	2

Source: WIPO "Statistics Database"

There were very few firms engaged and even fewer firms that made applications in more than one year. Most of the firms filing patents at the PCT were engaged in mining and mining-related activities.

In summary, while there are some fluctuations, there is overall a generally consistent pattern across the different patent data. South African patenting activity has been in decline over the last few years. The number of firms making applications at the PCT is very limited.

4.3.2 Technology balance of payments

South Africa's payments abroad for IP use have declined significantly since 2017 (see **Table 4.11**). This decline reflects lower levels of investment as economic growth has slowed. In 2021, there was an increase over the previous year (21%). However, this followed two earlier years of significant decline (-12% in 2019 and -16.6% in 2020). Payments abroad for IP use in 2022 were similar to the previous year and were significantly lower than a decade ago.

Table 4.11: Charges for the Use of Intellectual Property (current US$)

	Payments	Receipts
	($ billion)	($ 000)
2012	2.02	135 297

2013	1.94	135 485
2014	1.73	136 803
2015	1.64	126 114
2016	1.83	139 258
2017	1.88	157 684
2018	1.54	182 504
2019	1.36	150 760
2020	1.20	126 359
2021	1.45	135 304
2022	1.45	207 073

Source: World Bank "World Development Indicators"

Receipts from the sale of South African IP increased in 2021 (6.6%) compared to the previous year. However, this followed significant decreases in the two previous years. Receipts from the sale of South African IP in 2021 were similar to what they were a decade ago. However, in 2022, there was a very significant increase compared with the previous year (53%).

Brazil, Argentina, and South Africa all saw declines in their receipts from the sale of their IP in 2018-2020However, for both Brazil and Argentina, receipts in 2021 were significantly higher than in 2016. By contrast, for South Africa, receipts from the sale of IP were lower in 2021 than in 2016 (-3%). However, in 2022, receipts from the sale of IP increased far more rapidly in South Africa (53%) than in Brazil (6%), while Argentina's receipts from the sale of IP were static.

Compared with all middle-income countries, South Africa's share of receipts declined significantly and consistently from 3.3% in 2016 to 0.7% in 2021. South Africa's share of receipts of Middle-Income Countries increased significantly in 2022 compared to the previous year. However, South Africa's share receipts of Middle-Income Countries was still considerably lower in 2022 than in 2016.

Table 4.12: Charges for the Use of Intellectual Property Receipts, South Africa, and Selected Countries

	2016	2017	2018	2019	2020	2021	2022
Current $US 000							
Argentina	168 807	356 50	321 051	284 486	209 353	204 996	204 705
Brazil	650 834	642 16	825 475	641 114	634 292	705 262	745 138
South Africa	139 258	157 684	182 504	150 761	126 359	135 304	207 073
Current $US billion							
Middle Income	4.67	9.1	10.67	11.92	14.4	18.52	20.33
South Africa Share of Middle-Income Countries	3.0	1.7	1.7	1.3	0.9	0.7	1.0

Source: World Bank "World Development Indicators"

4.3.3 Plant Breeders' Rights (PBR)

The number of South African PBR applications shows some stagnation as there has not been a tangible growth in the number of applications between 2013 and 2022 (see **Figure 4.19**). To illustrate this observation numerically, the compound annual growth rate for this period under review is -0.02%, whereas the average annual growth rate for the number of PBRs' applications is -0.26%. The challenge in the growth of the PBR applications filed in South Africa is evident when looking at the world share of PBR applications. It has declined from 2.32% in 2015 to 0.97% in 2022.

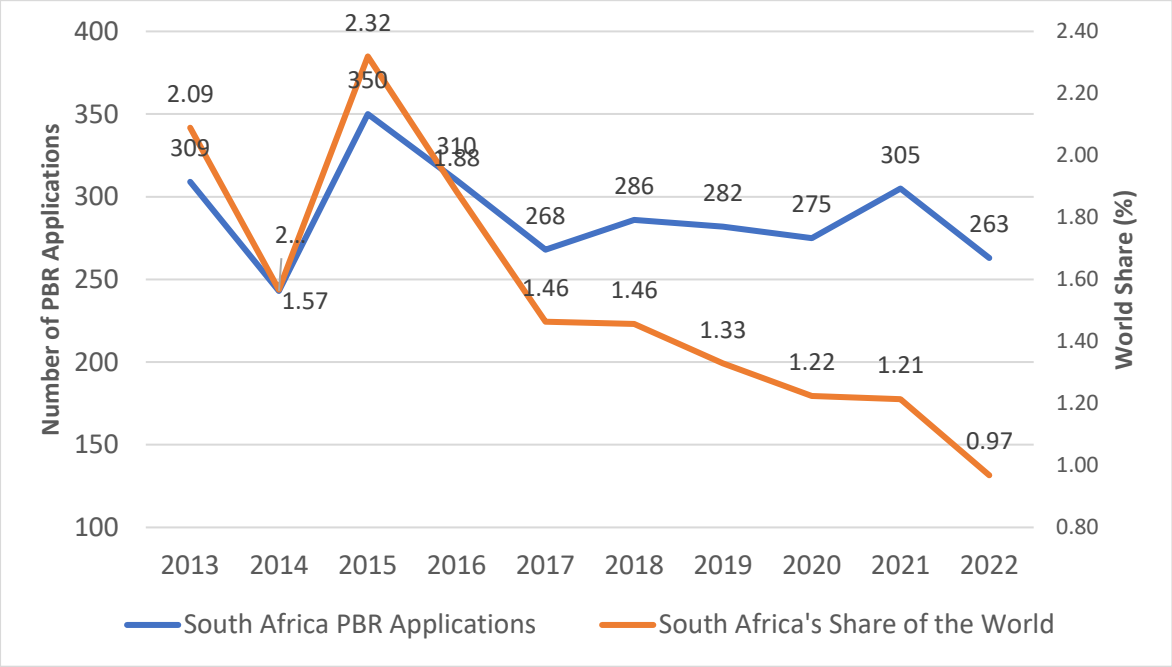


Figure 4.19: Trend of Plant Breeders Rights Applications in South Africa

Source: UPOV "Plant Variety Protection Data and Statistics"

A benchmarking in **Table 4.13** shows that among the four BRICS member countries, China is showing a high growth rate (from 1 510 applications in 2013 to 13 027 applications in 2022). Russia and Brazil-based PBR applications are growing at a low rate but better than South Africa-based applications.

Table 4.13: Benchmarking of Annual Plant Breeders Rights Applications

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
South Africa	*309*	*243*	*350*	*310*	*268*	*286*	*282*	*275*	*305*	*263*
Brazil	326	344	355	326	339	327	283	335	325	400
China	1 510	2 026	2 342	2 923	4 465	5 760	7 834	8 960	11 195	13 027
Russia	555	722	743	772	807	780	765	800	672	865
African Intellectual Property Organization	0	0	0	0	4	-	12	-	17	15
European Union	3 296	3 625	3 111	3 299	3 422	3 554	3 525	3 427	3 480	3 193
Egypt	-	-	-	-	-	-	-	34	48	87

Kenya	95	69	71	75	71	-	65	63	62	92
Morocco	56	76	50	64	101	109	80	63	74	82
South Korea	599	661	757	966	748	765	695	729	625	557
Tanzania	0	0	0	0	40	5	10	6	7	3
Tunisia	n/a	7	31	62	-	27	10	18	25	22
United Kingdom	37	36	20	54	183	328	187	130	409	1702
United States	1 889	1 567	1 634	1 604	1 557	1 609	1 590	1 432	1 902	1 375
World Total	14 788	15 511	15 091	16 455	18 306	19 643	21 222	22 471	25 133	27 166

Source: UPOV "Plant Variety Protection Data and Statistics"

In comparison to other African countries, South Africa is leading in terms of PBR applications filed, and the growth rate in other African countries is also stagnant, which is also the case with select developed countries and the world's total number of PBR applications.

South Africa is unique among the four founding members of BRICS in that its share of residents' PBR applications is low (18.87% in 2022, from 29.45% in 2013). That said, the other African countries also show a low share of resident applications of PBRs, although Egypt is experiencing some growth trajectory (from 29.41% in 2020 to 43.68% in 2022).

China consistently had a high share of residents' applications during the period 2013 – 2022 (94.67% in 2022 vis-à-vis 92.72% in 2013). In developed countries, countries such as South Korea and European Union member countries (on average) also have a high share of resident applications. In 2022, Europe increased its number of PBRs drastically, and most came from residents.

Table 4.14: Benchmarking of Proportion of Residents' Annual Plant Breeders Rights Applications

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
South Africa	29.45	18.11	26.00	11.94	15.30	22.03	25.53	14.18	8.85	17.87
Brazil	65.03	61.05	58.31	61.35	59.00	57.80	53.36	54.03	56.31	66.00
China	92.72	95.56	89.24	91.89	89.68	90.66	93.48	92.96	94.14	94.67
Russia	78.20	74.38	85.20	79.40	73.98	79.74	75.56	62.75	71.13	68.09
African Intellectual Property Organization	-	-	-	-	0.00	-	16.67	-	17.65	0.00
European Union	83.56	75.37	77.79	79.45	80.74	79.66	80.94	81.27	74.97	79.64
Egypt	-	-	-	-	-	-	-	29.41	27.08	43.68
Kenya	9.47	11.59	32.39	17.33	26.76	-	15.38	4.76	1.61	15.22
Morocco	3.57	17.11	0.00	1.56	9.90	0.00	11.25	0.00	4.05	2.44
South Korea	85.14	84.11	82.03	89.03	83.96	77.25	84.89	86.69	84.80	77.56
Tanzania	-	-	-	-	95.00	0.00	0.00	83.33	28.57	0.00
Tunisia	-	14.29	19.35	1.61	-	7.41	0.00	5.56	12.00	0.00
United Kingdom	51.35	50.00	40.00	31.48	22.40	10.37	14.97	14.62	41.32	90.19
United States	46.85	47.67	54.90	50.62	52.79	55.94	56.67	51.12	65.72	52.36

Source: UPOV "Plant Variety Protection Data and Statistics"

In order to normalise the PBRs numbers for population difference, **Table 4.15** shows the PBRs per million population. This indicator highlights the strength of South Africa among the African countries and its competitiveness among the BRICS member countries and developed countries such as the United States. However, the lack of growth of the PBR applications filed in South Africa is shown by it trailed behind China (9.14%) and Russia (5.98%).

Table 4.15: Benchmarking of Annual Plant Breeders Rights Applications per Million Population

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
South Africa	5.74	4.44	6.26	5.49	4.73	4.99	4.85	4.68	5.14	4.39
Brazil	1.62	1.69	1.73	1.58	1.63	1.56	1.34	1.57	1.52	1.86
China	1.10	1.46	1.68	2.09	3.17	4.06	5.51	6.29	7.85	9.14
Russia	3.86	5.00	5.14	5.32	5.55	5.36	5.25	5.49	4.63	5.98
African Intellectual Property Organization	0.00	0.00	0.00	0.00	0.01	-	0.03	-	0.04	0.04
European Union	7.45	8.17	7.00	7.40	7.67	7.95	7.88	7.65	7.78	7.14
Egypt	-	-	-	-	-	-	-	0.32	0.44	0.78
Kenya	2.12	1.51	1.52	1.57	1.45	-	1.28	1.21	1.17	1.70
Morocco	1.66	2.22	1.44	1.82	2.84	3.03	2.20	1.72	2.00	2.19
South Korea	11.96	13.07	14.84	18.83	14.52	14.80	13.42	14.06	12.06	10.75
Tanzania	0.00	0.00	0.00	0.00	0.71	0.09	0.17	0.10	0.11	0.05
Tunisia	-	0.61	2.68	5.31	-	2.26	0.83	1.48	2.04	1.78
United Kingdom	0.58	0.56	0.31	0.82	2.77	4.94	2.80	1.94	6.08	25.21
United States	5.91	4.87	5.03	4.90	4.72	4.84	4.76	4.26	5.64	4.06

Source: computed from UPOV "Plant Variety Protection Data and Statistics"

5. INNOVATION IMPACTS

This chapter assesses STI impacts through indicators such as citations in scientific publications and select economic and social impact indicators. Additional indicators introduced are public relations with science, environmental sustainability, and climate change.

5.1 Scientific impact

The number of times a publication is cited is often used as a measurable proxy for quality or impact. While the strength of this proxy is debatable, the number of citations is an indicator of visibility and recognition. Citation practices differ vastly between scientific disciplines; therefore, the number of citations received by publications across different disciplines cannot be compared. A common indicator that overcomes this problem is the normalised mean citation score (MNCS), which accounts for the differences in scientific disciplines and the elapsed years since the publication was published. An MNCS value of 1 is aligned with the world average citation impact; an MNCS value above 1.0 suggests a better performance than the world average in terms of citation impact, and an MNCS value less than 1.0 suggests under-performance. **Figure 5.1** shows the trend in the citation impact of South Africa's scientific publications as measured by the MNCS over the last two decades. The figure shows an overall positive trend, with the citation impact of South Africa's publications consistently exceeding the world average over the last decade.

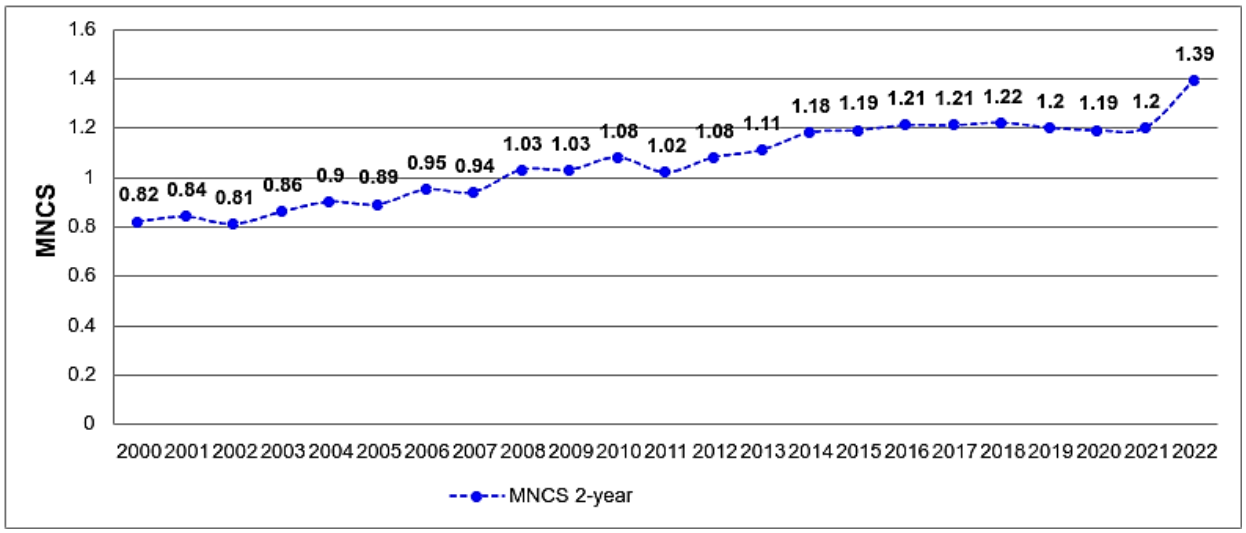


Figure 5.1: Trends in Citation Impact (MNCS: 2-year window)

Source: CREST, Stellenbosch University

In addition to the MNCS score as an indicator of citation impact, three other related citation indicators are used. These are the PP (top 1%), PP (top 5%) and the PP (top 10%)

indicators. The PP (top 1%) indicator measures the percentage of a country's scientific publications that fall within the top 1% of the most frequently cited publications in the same year and field. Similarly, PP (top 5%) and PP (top 10%) can be defined. Because the citation density (relative citation rate) differs significantly across scientific fields, these three indicators are calculated for scientific fields separately. The results are presented in **Annexure B**. The results are positive, showing that the South African-authored publications are well represented in the three percentiles. The trend over time is consistent. As expected, the highest percentage of publications in the top 1% of most-cited papers are in natural, health and engineering sciences.

Journal quartiles reflect the prestige and ranking of journals within a particular scientific field. Journals are categorised into four groups (called quartiles) based on their journal impact factor (JIF). Journals with the highest JIF belong to the first quartile (Q1), representing the top 25%, while the last quartile (Q4) includes the bottom 25% of journals with the lowest JIF. The distribution of a country's publications across these journal quartiles indicates prestige and, to some extent, the perceived quality of its research output. The distribution of the South African publications across the six main scientific fields is provided in **Annexure C**. In general, significant proportions of the South African publications are in the top two quartiles Q1 and Q2 across all fields which are the two quartiles containing journals with the highest JIF.

The citation impact as measured by MNCS is presented for the six scientific fields in **Annexure D**. In general, across all fields, the MNCS is either close to 1.0 or above, which suggests that South Africa’s publications perform slightly worse than the world average performance in the worst case. This suggests that South Africa’s publications do not drop significantly below the world’s average performance even at their lowest level. In health sciences, humanities, and natural sciences, South Africa’s publications consistently outperform the world average except for very few isolated years when the performance dropped slightly below the world average. The performance in agricultural sciences, engineering and social sciences lag but not by a substantial margin.

5.2 Innovation for economic impact

The economic impacts outlined are for output, employment and exports.

5.2.1 Gross value added in the manufacturing sector

Manufacturing output, measured by Gross Value Added (GVA), in 2022 decreased marginally (see **Table 5.1**). Manufacturing GVA in 2022 was lower than a decade ago.

The GVA of medium and high technology (MHT) manufacturing increased by 4.4% in 2021, and that excluding motor vehicles increased by 6.7%. Output for both MHT and MHT excluding motor vehicles in 2022 remained the same as the previous year. The GVA of both MHT and MHT excluding Motor Vehicles was lower in 2022 than it was a decade ago.

Over the decade, there has been a tendency for the output shares of both MHT and MHT excluding Motor Vehicles in manufacturing GVA to decline slowly, with a more pronounced decline after 2016.

Table 5.1: Manufacturing and Medium and High Technology Manufacturing Gross Value Added

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
	R' billion (constant 2015 prices)									
Manufacturing	558.0	554.4	553.4	555.9	554.8	563.3	559.3	493.7	526.7	524.8
MHT	158.1	157.8	157.9	159.9	156.0	156.3	148.4	130.3	136.3	136.1
MHT less motor vehicles	137.7	137.0	136.5	138.7	135.4	132.0	125.6	113.4	121.0	119.4
MHT (%)	28.32	28.47	28.54	28.76	28.17	27.46	26.52	26.39	25.89	25.94
MHT less motors (%)	24.67	24.71	24.66	24.96	24.40	23.43	22.46	22.96	22.96	22.75

Sources: Quantec & Stats SA

Regarding the different sectors within MHT, percentage shares of GVA have generally been stable over the last decade. Special Purpose Machinery increased its share after 2016. The share of motor vehicles increased through much of the decade, but declined in the last two years. There are no MHT sectors that show significant and sustained increases in their relative share over the decade.

Table 5.2: Medium and High Technology Sectors % Share of Gross Value Added at Constant 2015 Prices

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Basic chemicals	11.71	12.27	12.49	14.21	13.36	12.98	11.67	15.62	15.41	15.54
Other chemical products	20.31	20.40	20.39	20.68	19.82	18.53	16.84	18.52	17.21	16.72
General purpose machinery	11.86	10.89	9.87	9.51	10.06	10.29	10.80	10.47	10.54	11.31
Special purpose machinery	13.67	13.56	13.28	12.65	13.75	14.12	14.53	13.77	13.86	13.40
Household appliances	1.60	1.62	1.49	1.35	1.41	1.47	1.57	1.46	1.53	1.64

Office, accounting, computing machinery	0.83	0.85	0.77	0.69	0.71	0.72	0.91	0.92	0.89	1.01
Electric motors, generators, transformers	1.89	2.08	2.13	2.32	2.02	1.99	2.10	2.30	2.25	2.09
Electricity distribution and control apparatus	1.22	1.11	1.17	1.14	1.25	1.15	1.17	0.98	1.04	0.92
Insulated wire and cables	1.41	1.36	1.34	1.36	1.46	1.38	1.40	1.23	1.26	1.28
Other electrical equipment	3.47	3.30	3.77	3.56	3.10	2.93	3.23	3.26	3.10	3.37
Radio, television and communication apparatus	1.26	1.54	1.43	1.65	1.82	1.98	2.30	2.52	2.51	2.24
Professional equipment	3.08	3.29	3.25	3.30	3.73	3.58	3.55	3.53	3.69	3.95
Motor vehicles	12.89	13.19	13.60	13.23	13.41	14.68	15.33	13.01	11.28	12.29
Parts and accessories	10.45	10.16	10.51	10.02	9.33	9.66	9.34	8.64	11.69	10.40
Other transport equipment	4.33	4.38	4.52	4.33	4.79	4.55	5.23	3.77	3.74	3.84

Sources:

5.2.2 Merchandise and service exports

Manufacturing Exports by Technological Intensity

As **Table 5.3** shows, manufacturing exports have been on a declining trend since 2016. Manufacturing exports increased (11.7%) in 2021 and increased further (11.2%) in 2022. In 2022, manufacturing exports were 9% higher than in 2013.

MHT and MHT high-technology exports follow the same trajectory as Manufacturing exports—declining after 2016 but with significant increases in 2021 and 2022. In 2022, MHT exports were 12.2%, and MHT excluding Motor vehicles was 11.5%, higher than in 2013.

Table 5.3: Manufacturing Exports, Medium and High Technology Exports

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
	R' billion (constant 2015 prices)									
Manufacturing	509.4	530.6	543.7	547.0	531.7	550.0	527.9	462.1	499.9	555.8
MHT	234.6	248.4	266.1	266.7	253.8	262.3	63.5	225.8	238.3	263.2
MHT excl. motor vehicles	174.8	179.8	178.2	182.8	173.1	175.4	178.8	171.3	180.8	194.8
	% share of total									
MHT %	46.05	46.81	48.94	48.58	47.74	47.95	49.91	48.86	47.66	47.36
MHT excl. motor vehicles	34.31	33.89	32.77	33.16	32.56	32.07	33.86	37.06	36.17	33.05

Sources: Quantec & Stats SA

By comparison with 2013, 2022 MHT, as a share of manufacturing exports, was marginally higher, MHT excluding m,otor vehicles, as a share of manufacturing exports, was marginally lower.

Service Exports

Service exports have tended to lower since 2013. As shown in **Table 5.4** service exports declined significantly in 2019 (-7%) followed by a major decline in 2020 (-46%) – largely the result of reduced earnings from tourism as a consequence of the pandemic. In 2021, service exports (5%) and increased significantly in 2022 (38%). However, in 2022, service exports were still significantly lower (-26%) than in 2013.

Table 5.4: South African Exports Total and Service Exports

	BoP Current US$ billions	
	Total	Services
2013	113.64	17.12
2014	110.44	17.20
2015	96.35	15.56
2016	91.48	14.97
2017	104.17	16.53
2018	111.37	17.08
2019	105.83	15.91
2020	94.06	8.65
2021	130.88	9.11
2022	136.11	12.61

Source: World Bank "World Development Indicators"

5.2.3 Composition and diversity of exports

Tables 5.5 and **5.6** show export values, the number of exporters, the number of products exported, the number of export destinations, and the number of export transactions.[26]

Table 5.5: Total Exports Characteristics (excluding gold)

	Number of Exporters	Number of Products	Number of Destinations	Number of Transactions
2010	32 928	4 247	218	862 463
2011	33 756	4 243	224	949 979
2012	39 606	4 234	219	1 041 537
2013	41 412	4 216	221	1 062 464
2014	41 530	4 219	227	1 094 901
2015	42 096	4 222	220	1 111 467
2016	42 392	4 217	220	1 116 578
2017	40 652	4 202	227	1 117 537
2018	37 716	4 199	226	1 097 850
2019	35 595	4 192	227	1 056 977
2020	35 964	4 178	218	967 516
2021	37 379	4 187	220	1 016 213

Source: Data supplied by Professor Lawrence Edwards

[26] All data for this section supplied by Professor Lawrence Edwards. Data differs slightly from last year's report. Data were updated to include CPC codes H68 (Outright Export of goods manufactured in an Excise Warehouse) and others. The exclusion of these resulted in an under-estimate of vehicle and food and beverage exports.

Table 5.6: Manufacturing Exports Characteristics

	Number of Exporters	Number of Products	Number of Destinations	Number of Transactions
2010	30 826	3 529	217	778 606
2011	31 677	3 527	221	862 942
2012	36 865	3 518	216	939 991
2013	38 605	3 502	215	959 266
2014	38 799	3 505	223	990 823
2015	39 354	3 506	215	1 006 994
2016	39 499	3 501	216	1 006 221
2017	37 849	3 488	224	1 011 669
2018	35 170	3 487	221	1 013 427
2019	33 266	3 484	224	997 123
2020	33 631	3 470	217	875 225
2021	35 071	3 478	220	922 487

Source: Data supplied by Professor Lawrence Edwards

Total exports and manufacturing exports have followed the same trajectory. Following the Global financial crisis, the number of exporters expanded rapidly from 2010 to 2012. The rate of growth then tapered off. After 2016, the number of exporters declined. 2020 registered a small increase (4%), followed by a similar increase in 2021. The number of exporters in 2021 is some 12% lower than the number of exporters in 2017.

The number of export transactions follows a similar trend—reaching a peak in 2016 and 2017 and declining thereafter. There was a significant decline in the number of export transactions in 2020. In 2021, the number of export transactions rose for both total and manufactures (5%) compared to 2019. The number of transactions in 2021 is some 9% lower than in 2017.

The number of products, both for all exports and manufacturers, has been on a slow declining trend over the entire decade. For both total and manufactured exports, the number of export products was 1.5 % lower in 2021 compared with 2010.

From the perspective of innovation, the decline in the number of exporters and the decline in the number of export products is of particular concern. Increasing levels of innovation would find expression in a rising number of exporters and new export products.

Changes in exports can be decomposed into two categories. The first category, referred to as the intensive margin, refers to changes in the value of exports by established exporters exporting existing products to established markets. The second category, referred to as the extensive margin, refers to changes in the value of exports arising from

the entry/exit of new or continuing exporters, exporting new products or existing products to new destinations.

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

Table 5.7 and **Table 5.8** decompose the contribution of the extensive and intensive margin to changes in export values.

Table 5.7: Decomposition of Change in Total Exports: Extensive and Intensive Margin

	Extensive Margin % Contribution	Intensive Margin % Contribution	Total % Change
2011-12	1.6	-9.9	-8.3
2012-13	1.5	-3.0	-1.5
2013- 14	2.8	-5.9	-3.1
2014- 15	-0.7	-13.0	-13.7
2015-16	-0.2	- 5.4	-5.6
2016-17	2.7	12.7	15.4
2017-18	0.1	6.6	6.7
2018-19	-1.5	-2.4	- 3.9
2019-20	-0.6	-8.0	- 8.6
2020-21	6.6	32.8	39.4

Source: Data supplied by Professor Lawrence Edwards

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

Over the decade, price changes accounted for some three-quarters of the annual growth in the intensive margin from 2011 to 2019. The intensive margin is dominated by the strong growth in exports in 2021. This is principally a result of higher prices for established mineral products, not increases in export volumes.

Table 5.8: Decomposition of Change in Manufactured Exports: Extensive and Intensive Margin

	Extensive Margin % Contribution	Intensive Margin % Contribution	Total % Change
2011	1.3	4.4	-5.7
2012	1.3	-3.6	-2.4
2013	0.3	-2.6	-2.4
2014	1.5	-0,0	1.5

2015	-0.5	-5.3	-5.8
2016	-1.2	-3.0	-4.2
2017	0.9	4.3	5.2
2018	1.7	2.4	4.2
2019	-0.7	-2.2	-3.0
2020	-0.8	-8.5	-9.4
2021	1.4	11.5	12.9

Source: Data supplied by Professor Lawrence Edwards

Growth in export volumes on the part of established firms exporting established products to established. Over the decade, markets have only made a minor contribution to aggregate growth in export value.

South Africa's exports have become increasingly less diversified. The number of manufactured products and the number total products in which South Africa is competitive has declined consistently since 2012 (see **Table 5.9**). Moreover, the rate of decline has accelerated since 2017, with particularly significant decreases in 2020 and 2021. The number of manufactured products in which South Africa is competitive is 42% lower in 2021 as compared to 2012; for all products the number is 37% lower.

Table 5.9: The Diversity of South African Exports; Manufactured Products and All Products

	Manufactured Products	All Products
2012	201	318
2013	199	307
2014	194	303
2015	195	306
2016	175	281
2017	177	280
2018	169	275
2019	153	248
2020	129	219
2021	116	200

Source: The Growth Lab, Harvard University

Note: The data is for HS products with a revealed comparative advantage (RCA) that is greater than 1; i.e., products that South Africa exports by more than its "fair share" of the products' global share of exports.

5.2.4 Medium- and high-technology manufacturing employment

As shown in **Table 5.10**, formal employment in manufacturing declined significantly in 2020 (-4.3%) and in 2021 (-1.0%). There was an increase in manufacturing employment in 2022 (5%). The numbers for formal employment in manufacturing in 2022 are 5% higher than they were in 2013.

Employment in MHT declined in 2020 (-2%) and in MHT excluding motor vehicles declined in 2020 and in 2021. There were marginal increases in employment in MHT and in MHT excluding motor vehicles in both 2021 and 2022. Formal employment in MHT and in MHT excluding motor vehicles has tended to grow, albeit slowly. Employment in MHT and employment in MHT excluding motor Vehicles are 8% higher in 2022 than in 2013.

Table 5.10: Manufacturing, Medium and High Technology Manufacturing Employment and % Share

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Manufacturing employment ('000)	1 168	1 161	1 174	1 188	1 200	1 221	1 234	1 180	1 168	1 177
MHT employment ('000)	360	355	354	365	369	384	391	383	386	389
% Share of MHT employment	30.8	30.6	30.2	30.7	30.7	31.4	31.7	32.5	33.0	33.1
MHT employment, excl. motor vehicles ('000)	316	312	310	318	320	335	341	335	337	341
% Share of MHT employment, excl. motor vehicles	27.0	26.9	26.4	26.8	26.7	27.4	27.6	28.4	28.9	29.0

Sources: Quantec & Stats SA
Note: The data are for formal employment

There has been an increase in the employment shares of both MHT and MHT excluding motor vehicles, particularly since 2017.

As regards the different sectors within high- and medium technology manufacturing, percentage shares of employment have been largely stable over the last decade. Special purpose machinery has exhibited a slight increase in the share of employment over the decade.

Table 5.11: Medium and High Technology Sectors Employment % Share

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Basic chemicals	7.49	6.94	6.39	5.93	6.09	6.09	5.88	5.79	5.5	5.73
Other chemical products	15.37	15.39	16.01	15.96	16.63	17.30	15.97	16.23	15.68	15.57
General purpose	12.80	12.54	11.89	11.83	12.19	12.44	12.52	12.72	12.50	12.48
Special purpose	14.81	15.26	15.27	14.96	15.74	16.11	16.55	16.85	16.58	16.37
Household appliances	1.90	2.08	1.99	2.02	1.99	1.73	1.65	1.87	1.88	1.90
Office, accounting, computing machinery	1.44	1.24	1.15	1.22	1.23	1.14	0.95	0.93	0.92	0.88
Electric motors, generators, transformers	3.97	4.48	4.49	4.38	3.95	3.99	3.97	4.65	5.23	4.57
Electricity distribution and control apparatus	1.54	1.61	1.87	1.86	1.89	1.84	1.81	1.73	1.75	1.69
Insulated wire and cables	1.51	1.46	1.45	1.41	1.35	1.22	1.24	1.20	1.18	1.16
Other electrical	4.98	4.68	4.59	4.54	3.04	3.87	4.32	4.07	4.11	4.90
Radio, television and communication apparatus	1.82	1.95	1.92	1.94	1.92	1.79	1.71	1.73	1.79	1.88
Professional equipment	2.97	3.00	2.96	3.11	3.28	3.29	3.37	3.34	3.30	3.18

Motor vehicles	12.19	12.19	12.33	12.76	13.09	12.60	12.83	12.43	12.61	12.49
Parts and accessories	13.23	13.0	13.39	13.54	13.09	12.11	12.62	12.43	12.94	13.04
Other transport	3.97	4.13	4.29	4.55	4.53	4.47	4.61	4.03	3.95	4.17

Sources: Quantec & Stats SA

5.2.5 Turnover of innovative active businesses and non-innovative active businesses

The 2019-2021 business innovation survey reveals how innovation impacts innovative and non-innovative active businesses across turnover size categories and identifies possible trends and differences in performance.

Figure 5.2 demonstrates that over the period 2019-2021, innovative active businesses were dominant in medium (8.3%) and small (25.8%) turnover size categories compared to non-innovative active businesses (medium 7.6%, small 22.4%). Large businesses are consistent (6.7%) across innovative and non-innovative active businesses. The distribution in very small, small, and medium size classes appears to drive differences in turnover size between innovative and non-innovative active businesses.

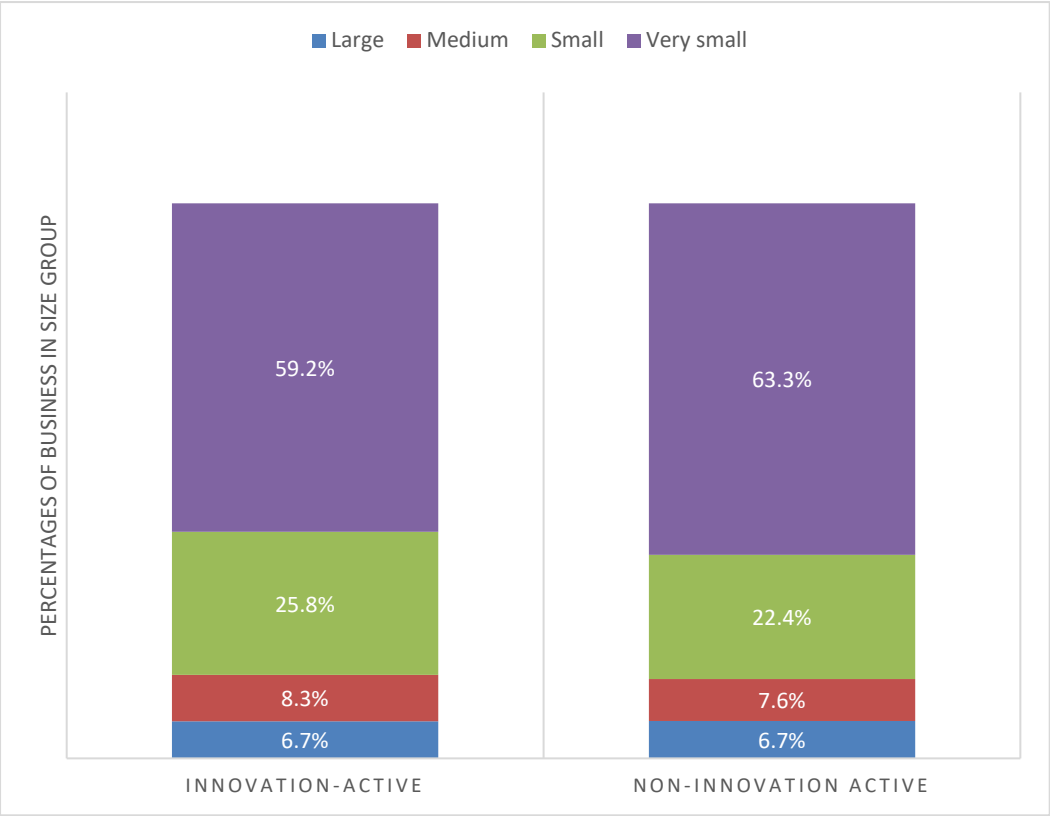


Figure 5.2: Differences in Turnover Size Class in Innovation-Active and Non-Innovation Active Businesses

Source: HSRC and DSI's Business Innovation Survey, 2019-2021

In conclusion, the results suggest that innovation may play a role in contributing to higher turnover figures for businesses across different turnover size categories. The consistent performance of large businesses across innovative and non-innovative active businesses suggests that size might not be a significant determinant of turnover.

5.2.6 Outcomes of innovation

Innovation plays a crucial role in shaping the outcomes and impacts of businesses across various sectors. The 2019-2021 business innovation survey sheds light on the diverse results of innovation efforts among businesses.

Figure 5.3 shows that over the period, 2019-2021, 53% of innovators regarded improved working conditions, health, and safety of their personnel as a significant outcome of their innovation(s). This was followed by meeting governmental regulatory requirements at 51.8% and improving the quality of goods or services at 51.3%. Innovations also contributed to enhanced quality of life or well-being (45.4%), business resilience, and adaptability to change (44.9%), along with public health and safety (40.1%).

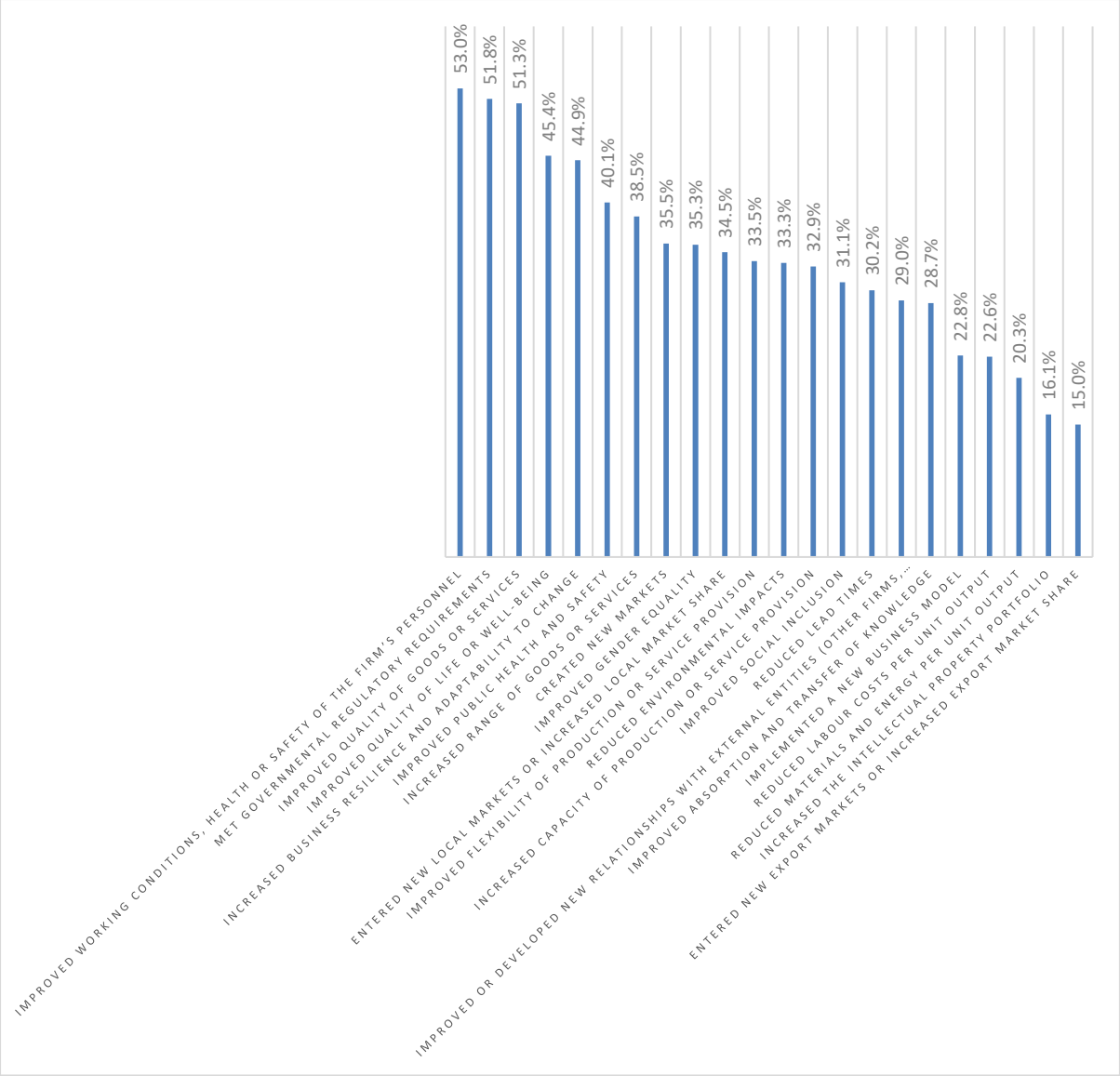


Figure 5.3: Highly Important Innovation Outcomes for All Innovators, 2019-2021

Source: HSRC and DSI's Business Innovation Survey, 2019-2021

Other outcomes include 38.5% providing additional goods or services, 36.5% creating new markets, and 35.3% achieving gender equality - reflecting the diverse nature of innovation outcomes across innovators. The least reported outcome for innovators during this period was expansion into new export markets or an increase in export market share (only 15.0% of innovators considered this an achievement).

In conclusion, the 2019-2021 business innovation survey demonstrates that the outcomes of innovation are multifaceted and can have wide-ranging impacts on both businesses and society. Innovation could enhance worker safety or develop new markets. It can also resolve crucial problems facing businesses. As businesses innovate and change to new

environments, it is essential to consider innovation's outcomes and the effect on business success and growth.

5.3 Innovation for social impact

This section covers the public's perception of science as well as the broader indicators of the STI's impact on society.

5.3.1 South African Public's Relationship with Science

Since the 1960s, many governments and societies have recognised the role of the public and society in informing a science and technology (S&T) agenda. The global S&T research agenda has expanded to include understanding what happens when science interfaces with society.

From its earliest days, the democratic South African state recognised the importance of the relationship between the public and science. The 1996 White Paper recognised that for the NSI to be effective and successful, all South Africans should participate in shaping its evolution. Thus, the government embarked on science awareness and science engagement initiatives that sought to develop a society that is literate, knowledgeable, optimistic about and trusting of science and can form independent opinions about scientific issues.

To measure the distance the country has travelled on its journey towards that society, the South African Public Relationship with Science (SAPRS) survey was conducted with adults 16 years and older in 6 000 nationally representative households selected from around the country. Some of the views of the public about science[27] are shared in this section.

The Public's Awareness, Interest in, and Pride in South African S&T

There is broad acknowledgement that S&T contributes to both social and economic development. The public's awareness and support of these developments could contribute to greater recognition of S&T. **Figure 5.4** reports the public's awareness of, interest in and pride in South African S&T.

[27] DSI (2024) The South African public relationship with science 2022 survey results. Published by the Department of Science and Innovation. Pretoria.

Two thirds of the public are interested in and proud of South African science and technology achievements. Sixty per cent are aware of S&T's achievements.

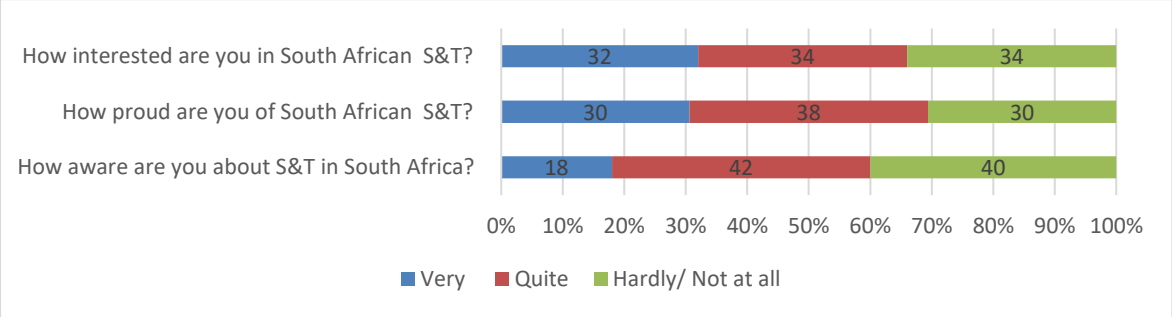


Figure 5.4: Awareness of, Interest in and Pride in South African S&T Achievements

Attitudes of Promise and Reservation towards Science

The attitudes of promise (i.e. potential benefits) and reservation (concerns) towards science provides the signal of the relationship between science and society. **Figure 5.5** reports the South African attitudes of promise and reservation towards science.

The South African public acknowledged both the promises of, as well as concerns, towards S&T. Three-quarters of the public agreed that S&T is making our lives easier, but at the same time, a comparable share was concerned that S&T makes our way of life change too fast. While three-quarters agreed that S&T will make work more interesting, almost two-thirds were concerned that new technologies will result in people losing jobs. Overall, close to 60% of the public agreed that S&T will create more opportunities for the future, that the benefits of S&T are greater than the harmful effects and that S&T careers are suitable for women.

However, close to two-thirds of the public were concerned that S&T advances would contribute to further inequality and that scientific advances tended to benefit the rich more than the poor. Comparable shares were concerned that we depend too much on science and not enough on faith.

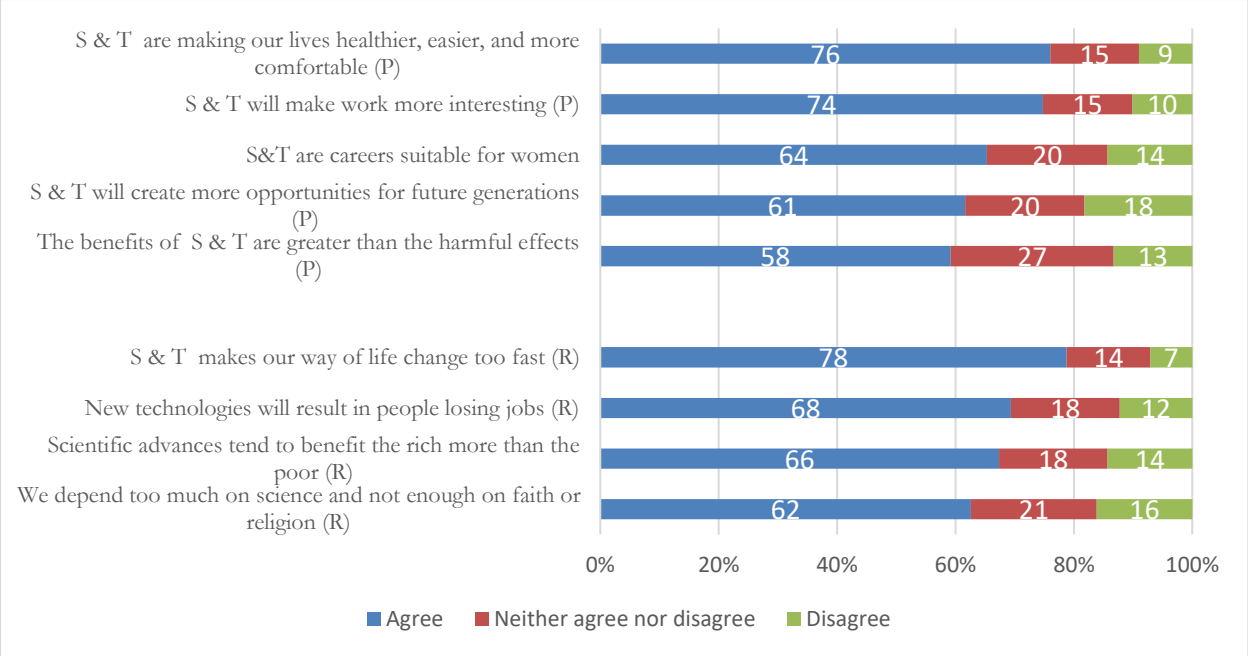


Figure 5.5: Attitudes of Promise and Reservation towards Science

In addition to a positive view of the promise of modern science, more than 60% of the South African public were, at least somewhat, knowledgeable about and interested in traditional S&T. They were moderately positive of the promise of traditional S&T, with close to two-thirds agreeing that traditional knowledge and traditional small-scale farming can benefit society. Slightly less than half the public recognised the role of traditional medicine and traditional healers.

Trust in Scientists and Science Institutions

Science and scientists provide information, evidence and advice to inform decisions. For the advice to be heard, the public must be willing to trust scientists and science institutions that produce knowledge.

In general, two-thirds of the South African public reported that they trusted the work of scientists. While three-quarters of the public reported that the work of scientists made life better for people and generated knowledge that explained the world we live in, half the public was concerned about the honesty of the work of scientists and just over 60% were concerned that scientists kept their work secret and sometimes harmed people and animals.

The universities and research organisations were the most trusted institutions for S&T information, with 71% of the public reporting they trusted their information. This level

dropped to below 50% in the case of all other institutions (not necessarily knowledge producers) listed in **Figure 5.6**. Forty-five percent of the public trusted S&T information from the corporate world, while 42% trusted religious leaders for S&T information. The public had the lowest trust in S&T information from government institutions: national government (38% trusted), local government (33% trusted) and traditional leaders (36% trusted).

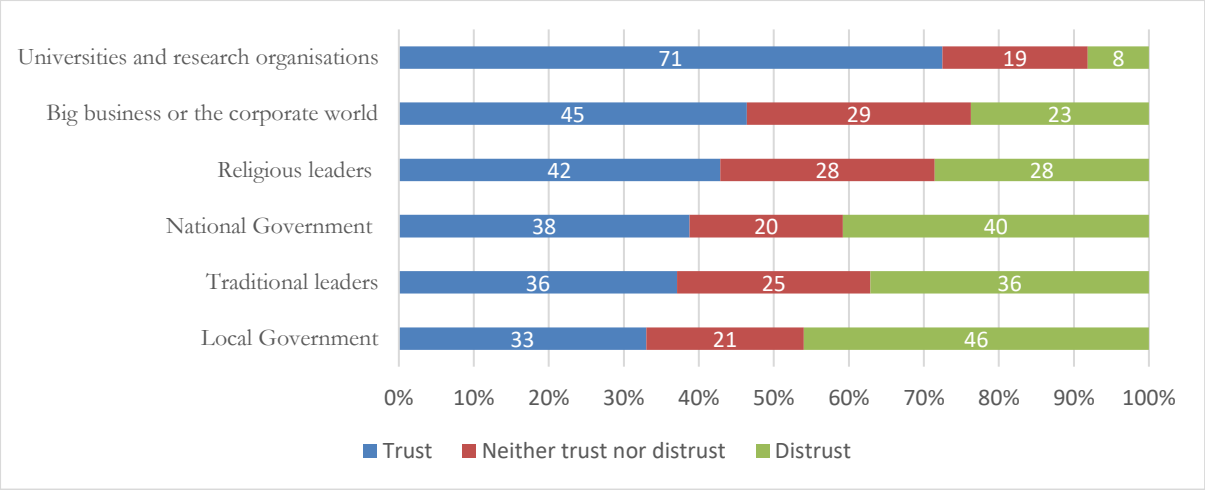


Figure 5.6: Trust in S&T information from different institutions

5.3.2 Impact of science, technology and innovation on social dimensions

The National Development Plan aims to eliminate income poverty by 2030. In other words, it is to reduce the proportion of households with a monthly income below R419 per person (in 2009 prices) (equivalent to R907 in 2023 prices) from 39 percent to zero and reduce inequality, as measured by the Gini coefficient, from 0.69 to 0.60 by 2030[28].

The NDP acknowledges that rapid economic growth has the potential to widen opportunities for all and generate the resources required to improve all the other social sectors, such as education, health, water and sanitation, ICT access, and safety and security. Similarly, improved education leads to higher employment incomes, while an active citizenry is key to strengthening democracy, accountability, and development. Overall, the socio-economic conditions must be conducive for this vibrant society to emerge.

The quality of interactions between the inputs and STI, capabilities, and conditions (with a zero-tolerance to corruption approach) will deliver improved health, improved education

[28] National Development Plan 2030: Our future – make it work

outcomes, the eradication of poverty, and the reduction of inequality and unemployment. The achievement of these goals presages and signals the attainment of rising living standards and, consequently, social cohesion.

Poverty, Inequality and Growth Rates

The ambition of the United Nations' Sustainable Development Goal (SDG) 1 is to eradicate extreme poverty by 2030 for all people everywhere, using a threshold of less than $1.25 a day per person per day. In the SDG Country report, South Africa (2023) reports that efforts to combat poverty are being hampered by the adverse economic environment, high unemployment, and the negative impact of load-shedding.

The food poverty line is R760 (in April 2021 prices) per person per month. This refers to how much money an individual will need to afford the minimum required daily energy intake. This is also commonly referred to as the “extreme” poverty line:

- Lower-bound poverty line is R1 058 (in April 2021 prices) per person per month. This refers to the food poverty line plus the average amount derived from non-food items of households whose total expenditure is equal to the food poverty line;
- Upper-bound poverty line is R1 558 (in April 2021 prices) per person per month. This refers to the food poverty line plus the average amount derived from non-food items of households whose food expenditure is equal to the food poverty line.

Table 5.12 shows that the upper-bound poverty line increased by R566 from its 2015 value to R1 558 in 2023 and the lower bound by R319 from R441 in 2015 to R760 in 2023.

Table 5.12: Poverty Lines and their Rand Values in 2015 and 2023

	2015-line values	2023-line values	Change values, 2015-2023
	Rands		
Food poverty line (FPL)	441	760	319
Lower-bound poverty line	647	1 058	411
Upper-bound poverty line	992	1 558	566

Source: SDG Country Report, 2023

Table 5.13 shows the upward trend in the values of the food poverty line and the lower-bound and upper-bound lines. About 55.5 percent (30.3 million people) of the citizens of South Africa are living below the national upper poverty line of R992; while a total of 13.8 million people (25 percent) are experiencing food poverty[29].

[29] Poverty and Equity Brief: South Africa, World Bank, April 2020

Table 5.13: Inflation-adjusted National Poverty Lines

	Food Poverty Line	Lower-bound Poverty Line (LBPL)	Upper-bound Poverty Line (UBPL)
	per person per month in Rands		
2012	366	541	834
2013	386	572	883
2014	417	613	942
2015	441	647	992
2016	498	714	1 077
2017	531	758	1 138
2018	547	785	1 183
2019	561	810	1 227
2020	585	840	1 268
2021	624	890	1 335

Source: National Poverty Lines, Stats SA, 2021
Unless otherwise indicated, the reference is March prices for the respective year

South Africa is touted as the most unequal country in the world. The country ranks first out of 164 countries in the World Bank's global poverty database. The country recorded the highest rate of inequality in the world, with a poverty estimate of 62.6% in 2022 using an upper-middle-income country poverty line[30]. In 2022, South Africa recorded a Gini Index of 66.92 which is higher than the Sub-Saharan Gini index of 61.43[31]. The most commonly used tool to measure inequality is the Gini Index. The Gini coefficient assumes values between zero and one, where zero represents perfect equality (where all people have equal incomes) and one (or 100%) represents total inequality in which one person has all the income. Therefore, the closer the Gini index is to zero, the more equal the society is, and the closer it is to one, the more unequal the society is. A country with a Gini coefficient above 50.0 is considered very unequal. A Gini Index below 30.0 is considered low[32]. An alternative to the Gini coefficient is the Palma index. The Palma index focuses on the tails of inequality as the ratio takes the richest 10% of the population's share of the gross national income and divides it by the poorest 40% of the population's share[33]. Higher values of the Palma ratio are indicative of higher inequality.

Table 5.14 shows that the peak of inequality was in 2004, when the Gini Index for South Africa was recorded at 72.48. For the past 20 years, it has remained above 50.0,

[30]World Bank (2022). Inequality in Southern Africa: An Assessment of the Southern African Customs Union
[31] Wider, UNU: https://www4.wider.unu.edu/?ind=1&type=table&year=70&byCountry=false&slider=buttons&avg=precomputed&yearRange=0,70

[32] Trapeznikova (2019)
[33] Cobham and Sumner (2013).

representing a very unequal society. The highest value of the Palma Ratio for South Africa was recorded at 15.41 in 2005. The Palma Ratio has hovered around the 10.0 value in the past eight years. GDP growth rate reached a peak of 4.28 in 2006. Since then, it has been on a rapid decline, which was exacerbated by the outbreak of the COVID-19 pandemic to record a rate of -7.92 in 2020 (See **Table 5.14**).

Table 5.14: Inequality and Growth Rates

	Gini Index	Palma Ratio	GDP growth rate
2000	67.80	10.41	2.74
2001	67.22	10.01	1.34
2002	68.97	11.10	2.40
2003	70.72	12.34	1.70
2004	72.48	13.76	3.29
2005	74.23	15.41	3.98
2006	72.73	14.45	4.28
2007	71.23	13.52	4.01
2008	69.33	12.62	1.82
2009	72.46	14.14	-2.90
2010	72.88	15.14	1.55
2011	69.76	12.22	1.61
2012	66.64	9.96	0.79
2013	66.85	10.02	0.85
2014	67.06	10.09	-0.18
2015	67.27	10.16	-0.22
2016	67.10	10.11	-0.81
2017	66.92	10.05	-0.27
2018	66.92	10.05	0.11
2019	66.92	10.05	-1.20
2020	66.92	10.05	-7.62

Source: World Income Equality Database (WIID), World Institute for Development Economics Research (WIDER), United Nations University

Unemployment Rate

Just like poverty and inequality, unemployment has remained intractable and stubborn, largely affecting women the most. The pattern, as shown in Table 5.15, reflects an upward trend in unemployment from 2017 to 2022 (with a slight dip in 2018). The unemployment rate for both sexes in 2022 was 33.5%, compared to 27.5% in 2017. The expanded rate for 2022 was 43.8%.

Table 5.15: Unemployment Rate by Sex

	Year						% change
	2017	2018	2019	2020	2021	2022	2022-2017
Men	25.7	25.3	27.0	28.0	32.4	31.8	6.1
Women	29.6	29.3	30.7	31.2	36.6	35.6	6.0
Total	27.5	27.1	28.7	29.4	39.3	33.5	6.1

Source: StatsSA, (2023) Labour Dynamics in South Africa

Unemployment Rate by Age Group

Table 5.16 shows that the age group 15-24 is the most affected by unemployment recording an unemployment rate of 61.5%. For 2017-2022, the situation has worsened for all age groups, as shown by the positive percentage changes. The age group 15-24 posted the highest percentage change with 8.1 percentage points, followed by the age group 25-34 with 7.9 percentage points mainly affecting the youth.

Table 5.16: Unemployment Rate by Age Group

Age Group	Year	Rate	Change
	2017	27.5	6.1
	2022	33.5	
55-64	2017	9.5	3.4
	2022	12.9	
45-54	2017	15.9	5.1
	2022	21.0	
35-44	2017	22.0	6.5
	2022	28.5	
25-34	2017	33.1	7.9
	2022	40.9	
15-24	2017	53.4	8.1
	2022	61.5	

Source: StatsSA, (2023) Labour Dynamics in South Africa

The least percentage increase in the unemployment rate was recorded for the age group 55-64 at 3.4 percent in 2022 as compared to 2017.

Figure 5.7 reveals the extent of spatial inequality concerning the spatial distribution of jobs in the country's three largest city regions. Many areas are pockets of unemployment, with most areas having less than the average of 1 000 jobs. The bottom panel of this figure groups sub-places within each urban region into two categories:

- Below average: the average number of jobs is below the city region's average
- Above average: the average number of jobs is above the city region's average

In the Cape Town city region, 74% of sub-places have a total number of jobs below the city's average. In the eThekwini city region, this figure is 77%, and 72% in the Johannesburg city region. This trend underscores the extent of spatial inequality, where even within large urban centres, a substantial portion of the population remains excluded from the benefits of the formal economy.

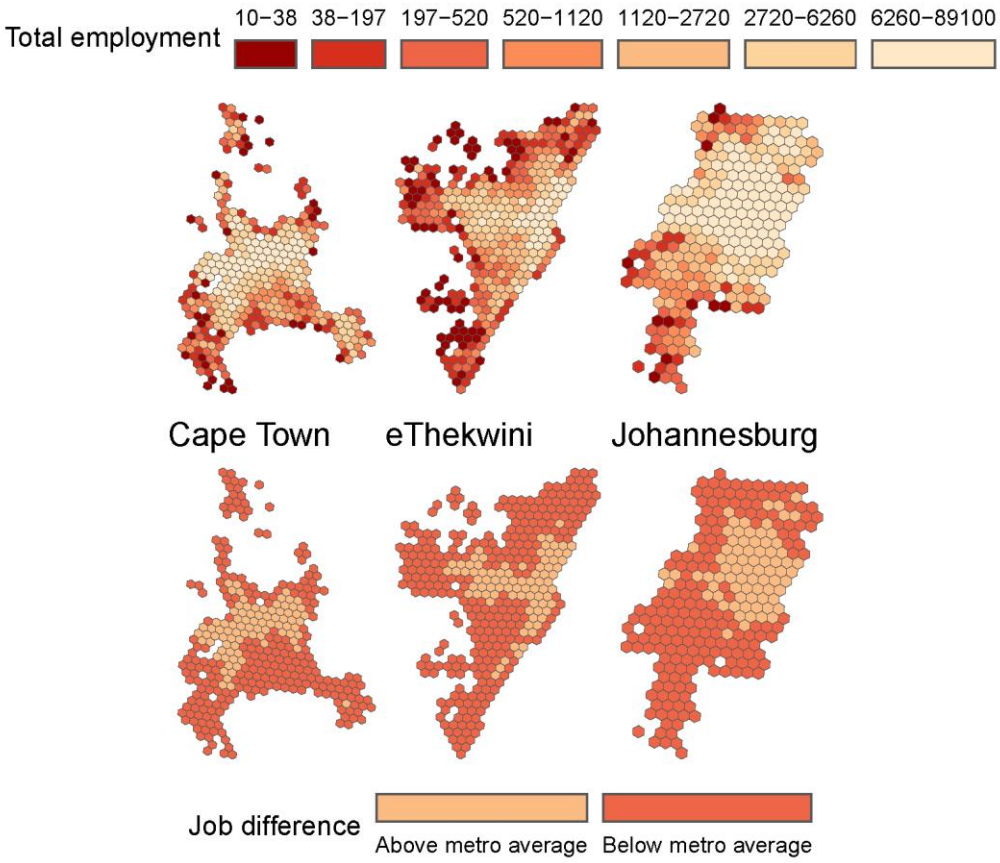


Figure 5.7: Total Employment in Metro Sub-places, 2022

Source: Authors' calculation based on Nell & Visagie, Spatial Tax Panel (2014-2022) data

Note: The top panel shows the total employment and the bottom panel shows the difference in employment compared to a metropolitan average

Trends in Social Progress Index

Social Progress Index (SPI) measures the extent to which countries provide for their citizens' social and environmental needs. It ranks countries based on 60 indicators grouped into three dimensions: Basic human needs, foundations of well-being and opportunity. After a decade of increase in SPI, South Africa experienced a decline in all dimensions of SPI (see **Figure 5.8**). The SPI score declined from 70 in 2022 to 67 in 2024. As a result, it is now ranked 82 out of 172 countries, from 69 in 2022.

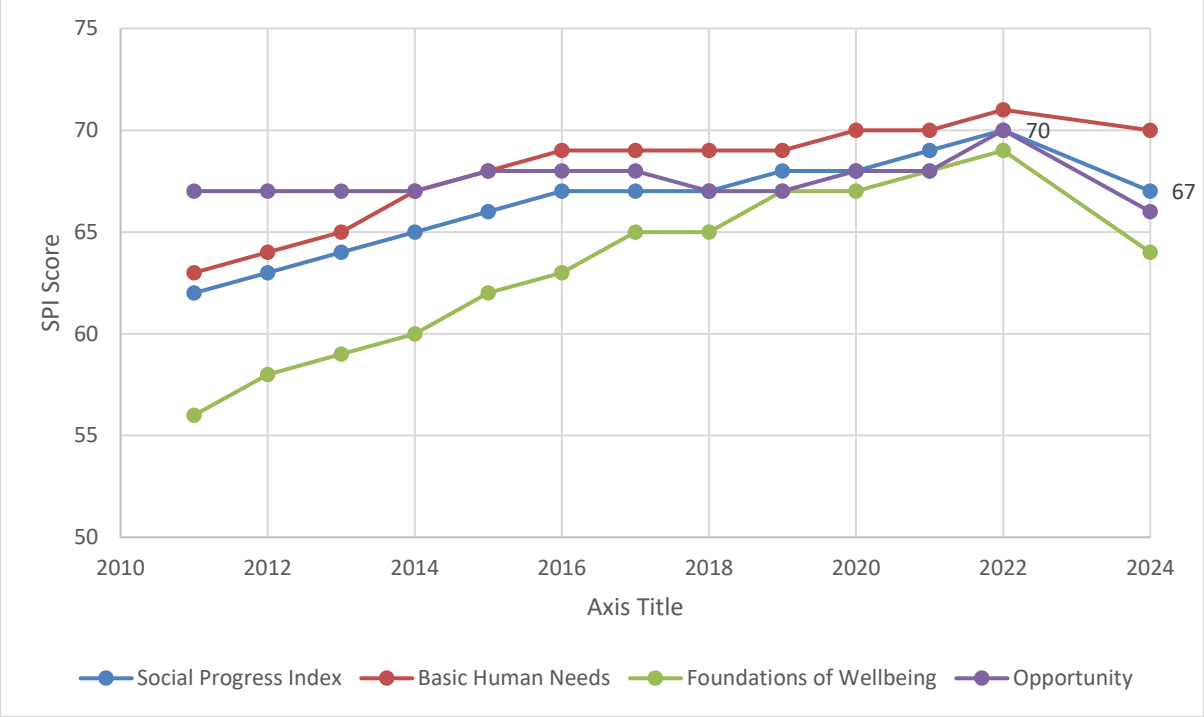


Figure 5.8: Trends in Social Progress Index

Source: The Social Progress Imperative (2024)

Impact of Innovation on the Households

Table 5.17 shows progress made in other areas related to living standards. From 1996, the proportion of people living in formal dwelling structures has increased by 24%. The share of people with no piped water has decreased from 39% in 1996 to 17% in 2022. Similarly, the proportion of households with access to formal sanitation (flush toilets) has improved from 52% in 2001 to 71% in 2022.

Table 5.17 also shows assets related to innovation and important in the digital world. For example, there is now almost universal access to cellphones, while the proportion of those having no access to the internet has declined to 21%. The worrying trend is the low percentage (25%) of households that own computers.

Table 5.17: Socio-economic Indicators, 1996-2022

Item	1996 (%)	2001 (%)	2011 (%)	2022 (%)
Formal dwelling	65.1	68.8	77.6	88.5
No piped water inside yard	39.3	38.7	26.7	17.6
Access to formal sanitation		51.9	60.1	70.8
Access to electricity	58.1	70.2	84.7	94.7
Refuse collection by local authority	52.1	55.4	62.1	66.3
Asset: Refrigerator		53.8	68.4	83.2
Asset: TV		52.6	74.5	79
Asset: Cell phone		32.3	88.9	92.1
Asset: Computer			21.4	24.7
No access to internet			64.8	21.1

Source: Statistics South Africa Census 2022

5.5 Public sector innovation

5.5.1 Municipal innovation maturity index

The Municipal Innovation Maturity Index (MIMI) is a decision support tool designed to measure municipalities' innovation capabilities, practices, and readiness to adopt innovation(s) to improve the delivery of basic services. The tool measures the capabilities of individual employees and municipalities to learn, implement, adopt, and institutionalise innovations that can enhance the delivery of basic services. It measures innovation based on three constructs:

- Municipal enablers of innovation
- Managers support for innovation
- Individual innovation behaviour (of participant officials) within municipalities

Based on the above constructs, the MIMI framework classifies municipalities into six different innovation maturity levels. The six levels are described in **Table 5.18**.

Table 5.18: MIMI Maturity Levels

Maturity Level 1	Maturity Level 2	Maturity Level 3	Maturity Level 4	Maturity Level 5	Maturity Level 6
Limited, if any, awareness or evidence of innovation on the part of individual officials or the organisation.	Innovation is defined. Officials understand innovation principles and there are innovation strategies in place, but there is little, if any, evidence of innovation implementation.	Innovation is applied. There is evidence of innovation implementation in certain departments of the municipality. Innovation is repeatable, but irregular.	Innovation is managed. Innovation occurs on an on-going basis and the relevant processes are well managed in the municipality.	Innovation principles and practices are entrenched throughout the municipality. Innovation officials seek to optimise and evaluate solutions, and continuously improve on these for internal benefit.	Innovation is open and outward-looking. New knowledge is applied creatively, based on evidence, in different contexts and shared with others outside of the organisation.

The results of the state of innovation for 2023 are shown in **Table 5.19**. The average MIMI score for municipalities that participated was two (2).

Table 5.19: MIMI Score, 2023/2024

Entity	MIMI Overall Score	Municipal Enablers of Innovation	Management Support for Innovation	Individual Innovation Behaviour
National Average	**2.0**	**1.7**	**1.8**	**2.2**
Mahikeng Local Municipality	3.7	4.0	4.0	3.0
Ugu District Municipality	3.0	3.0	2.0	4.0
Namakwa District Municipality	2.7	2.0	3.0	3.0
City of Tshwane Metropolitan Municipality	2.3	2.2	2.2	2.4
Okhahlamba Local Municipality	2.0	1.8	2.2	2.0
Beaufort West Local Municipality	2.0	2.0	2.0	2.0
Buffalo City Metropolitan Municipality	1.9	2.0	2.0	1.7
eThekwini Metropolitan Municipality	1.8	1.7	1.7	2.2
Waterberg District Municipality	1.8	1.6	2.2	1.6
Emalahleni Local Municipality	1.8	1.4	1.7	2.3
Central Karoo District Municipality	1.8	1.7	1.7	2.0
uMzinyathi District Municipality	1.7	1.0	2.0	2.0
Knysna Local Municipality	1.7	1.0	1.0	3.0
Gert Sibande District Municipality	1.7	1.0	1.0	3.0
City of Mbombela Local Municipality	1.7	1.0	1.5	2.5
City of Ekurhuleni Metropolitan Municipality	1.7	1.6	1.8	1.6
Msunduzi Local Municipality	1.5	1.0	1.5	2.0
uMngeni Local Municipality	1.3	1.0	1.0	2.0
Lephalale Local Municipality	1.3	1.0	2.0	1.0
Dr Ruth Segomotsi Mompati District Municipality	1.3	1.0	1.0	2.0
Cape Winelands District Municipality	1.2	1.0	1.0	1.5
Nyandeni Local Municipality	1.0	1.0	1.0	1.0

Source: Municipal Innovation Maturity Index Results (2023/24)

Regarding MIMI maturity levels, the average municipality is in level 2, which can be interpreted as: "I*nnovation is defined. Officials understand innovation principles and*

there are innovation strategies in place, but there is little, if any, evidence of innovation implementation".

5.5.2 ICT usage by the government and inclusive internet

E-Government *Development* Index

Figure 5.9 shows the trends in E-Government Development Index (EGDI). EGDI is the global index used to measure how countries are using innovative technologies in ICT for inclusive development. EGDI uses three indices to calculate the overall index: online services, telecommunication infrastructure and human capital. In 2022, the South African EGDI was 0.74 and this score has improved from 0.49 in 2012.

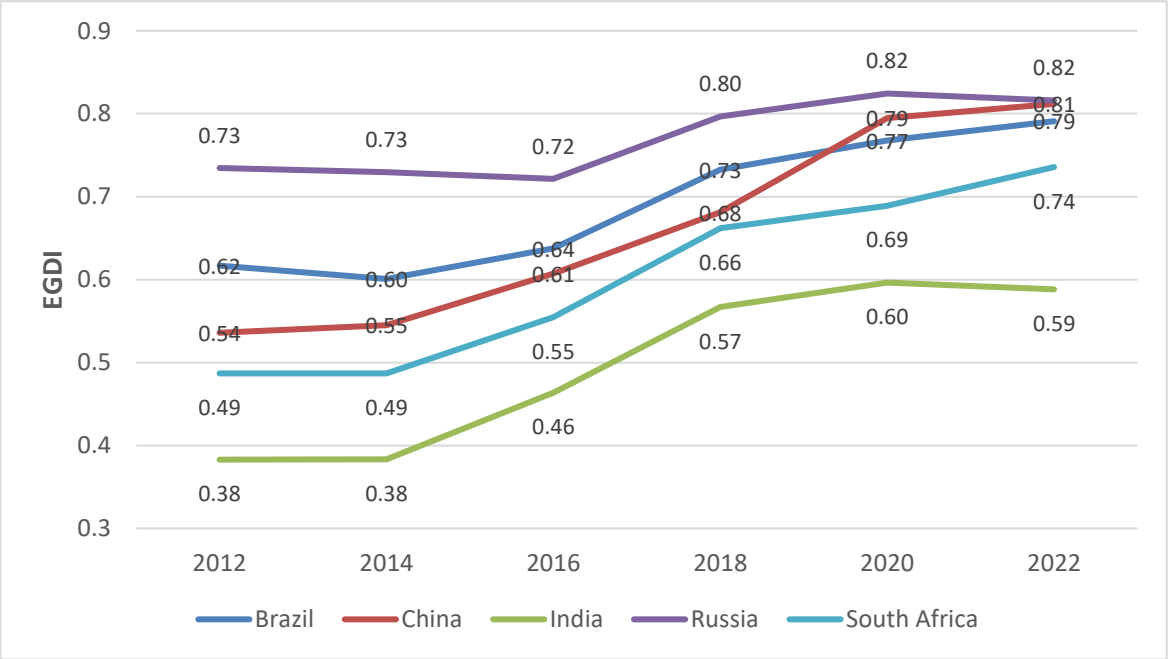


Figure 5.9: E-Government Development Index
Source: United Nations "e-Government Knowledgebase"

Table 5.20 shows other sub-indices of EGDI of South Africa in relation with other countries. South Africa improved its position globally, ranking 101st in 2012 to 65th out of 193 countries in 2022.

Table 5.20: E-Government Development Index

	Rank		Overall Index		e-Participation	Online Services	Human Capital	Tele Infrastructure
	2022	2012	2022	2012	2022	2022	2022	2022
Denmark	1	4	97	0.89	0.89	0.98	0.96	0.98
Finland	2	9	95	0.85	0.95	0.98	0.96	0.91
South Korea	3	1	95	0.93	0.94	0.98	0.91	0.97
USA	10	5	92	0.87	0.91	0.93	0.93	0.89
Russia	42	27	82	0.73	0.60	0.74	0.91	0.81
China	43	78	81	0.54	0.86	0.89	0.74	0.81
Brazil	49	59	79	0.62	0.90	0.90	0.80	0.68
South Africa	65	101	74	0.49	0.59	0.75	0.77	0.69
India	105	125	59	0.38	0.59	0.79	0.58	0.40

Source: United Nations "e-Government Knowledgebase"

Inclusive Internet Index

The Inclusive Internet Index (III) aims to measure the level of internet accessibility and affordability and its role in enabling social and economic goals. It focuses on four sub-categories to construct the overall index:

- Availability
- Affordability
- Relevance
- Readiness

As indicated in **Table 5.21**, South Africa had a III score of 74th in 2022 and has been relatively improving from 63rd in 2018.

Table 5.21: Benchmarking of Inclusive Internet Index

	Overall Index		Availability	Affordability	Relevance	Readiness
	2022	2018	2022	2022	2022	2022
Singapore	86	75	90	89	81	72
United States	84	73	80	87	91	76
United Kingdom	83	72	79	90	82	77
China	80	68	78	83	87	68
Brazil	80	66	72	86	93	68
South Africa	74	63	70	80	75	74
India	74	62	62	86	82	71
High income	80	77	78	85	81	72
Upper-middle income	70	67	65	79	73	63
Lower-middle income	63	59	55	75	65	57
Low income	48	44	35	62	52	50

Source: Economist Impact

Compared with other countries, South Africa is ranked 49th out of 100 countries and has a higher III score (74th) than the average of upper-middle-income countries (see

Table 5.21). Furthermore, South Africa scored higher in sub-categories: availability, affordability, relevance, and readiness.

Global Data Barometer

The Global Data Barometer (GDB) tracks the governments' use of data for public good, inclusive development and SDGs. It focuses on four themes to build the GDB score:

- Capabilities
- Governance
- Availability
- Use and impacts

Figure 5.10 shows the 2021 GDB score for South Africa in relation to other countries. South Africa scores relatively lower compared to other countries, with a score of 30. It ranks lower than other BRICS countries: Brazil (40), India (47), and China (40).

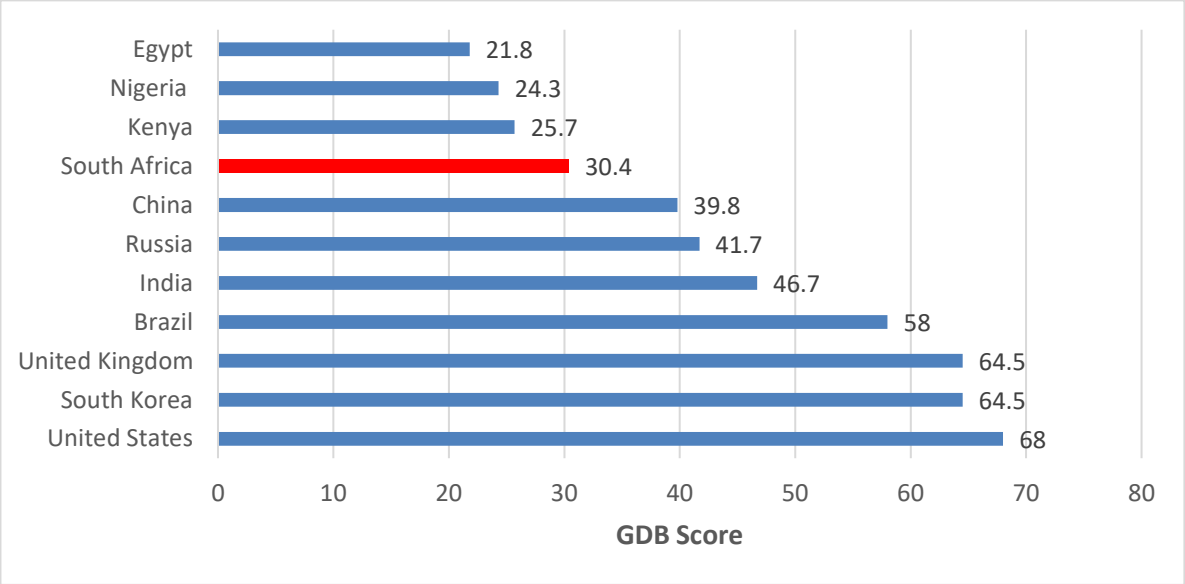


Figure *5.10:* Benchmarking of Global Data Barometer Scores, 2022
Source: 2022 Global Data Barometer

Table 5.22 shows the individual scores of the GDB, and South Africa needs to improve in all categories, especially on climate action and land.

Table 5.22: The Global Data Barometer Score

	GDB Score	Capability	Governance	Public Finance	Public Procurement	Health & Covid-	Company	Land	Climate Action	Political Integrity
USA	68	73	38	83	73	85	24	74	94	82
UK	65	78	63	57	61	60	83	33	73	60
South Korea	64	88	79	85	81	76	58	63	49	35
Brazil	58	59	68	71	78	73	53	55	75	45
India	47	57	50	47	42	55	65	36	29	38
India	47	57	50	47	42	55	65	36	29	38
Russia	42	61	35	79	82	22	33	60	24	32
China	40	63	35	36	60	28	45	61	30	26
South Africa	30	48	32	93	33	32	29	11	0	23
Ghana	28	49	32	70	1	17	45	5	32	6
Kenya	26	30	46	59	38	34	9	0	25	17

Source: 2022 Global Data Barometer

5.6 Environmental sustainability and climate change

Renewable energy patent analysis is used in this section as a measure of the extent to which renewable energy is playing a role in supporting BRICS countries to transition to a sustainable energy future that is taking into consideration country commitments to a low carbon economy and climate resilient society as part of operationalising commitments under climate change conventions.

Renewable Energy Patent Analysis

China is leading the biowaste to energy patent landscape, followed by South Africa, Brazil and India (see **Table 5.23**). It is not surprising that South Africa is above Brazil and India as its renewable energy share in final energy consumption is 10%, where around 85% is from biomass[34]. There has been an increase in waste-to-energy systems installed in rural and previously underserviced municipalities in South Africa.

[34] IEA Bioenergy Country Reports
https://www.ieabioenergy.com/wp-content/uploads/2021/11/CountryReport2021_SouthAfrica_final.pdf

Table 5.23: Patents per Million Population Filed in BRICS Countries for Biowaste to Energy Technology

	Brazil	India	China	South Africa
2011	0.025	0.000	0.101	0.033
2012	0.030	0.000	0.085	0.033
2013	0.015	0.000	0.081	0.033
2014	0.015	0.001	0.090	0.033
2015	0.000	0.000	0.125	0.000
2016	0.005	0.000	0.241	0.017
2017	0.005	0.000	0.305	0.017
2018	0.005	0.000	0.302	0.017
2019	0.028	0.000	0.453	0.000
2020	0.000	0.000	0.486	0.017

Source: computed from International Renewable Energy Agency data

China has a growing number of patents filed among the four BRICS countries for geothermal renewable energy technology, followed by South Africa and India (see **Table 5.24**). The trend in an increase in the number of patents filed by China for geothermal technology could be attributed to the abundant geothermal resources that account for about one-sixth of the global total and present great potential for development and utilisation [35].

Table 5.24: Patents per Million Population Filed in BRICS Countries for Geothermal Energy Technology

	Brazil	India	China	South Africa
2011	0.025	0.000	0.101	0.038
2012	0.030	0.000	0.085	0.038
2013	0.015	0.000	0.081	0.037
2014	0.015	0.001	0.090	0.037
2015	0.000	0.000	0.125	0.000
2016	0.005	0.000	0.241	0.018
2017	0.005	0.000	0.305	0.018
2018	0.005	0.000	0.302	0.017
2019	0.028	0.000	0.453	0.000
2020	0.000	0.000	0.486	0.017

Source: computed from International Renewable Energy Agency data

China had many patents filed among the BRICS countries for hydropower energy technology, followed by Brazil and South Africa. India had the least (see **Table 5.25**).

Global data reveals that hydropower accounted for 17% of China's total installed power generation capacity and 16% of total power generation in 2021[36].

[35] https://www.thinkgeoenergy.com/wgc2023-in-beijing-china-highlights-global-geothermal-growth-and-potential/
[36] https://www.power-technology.com/data-insights/hydropower-in-china/

Table 5.25: Patents per Million Population Filed for BRICS Countries for the Hydropower Technology

	Brazil	India	China	South Africa
2011	0.252	0.000	0.767	0.362
2012	0.335	0.008	0.711	0.132
2013	0.248	0.008	0.712	0.167
2014	0.162	0.020	0.834	0.292
2015	0.239	0.007	1.060	0.179
2016	0.184	0.000	1.136	0.089
2017	0.177	0.001	1.359	0.106
2018	0.109	0.000	1.341	0.087
2019	0.165	0.000	1.470	0.103
2020	0.023	0.000	1.715	0.017

Source: computed from International Renewable Energy Agency data

China had the highest number of patents per million population filed among the BRICS countries for ocean energy technology, followed by South Africa, Brazil, and India (see **Table 5.26**).

Table 5.26: Patents per Million Population Filed in BRICS Countries for the Ocean Energy Technology

	Brazil	India	China	South Africa
2011	0.156	0.000	0.320	0.534
2012	0.160	0.006	0.364	0.169
2013	0.129	0.002	0.384	0.297
2014	0.074	0.014	0.467	0.238
2015	0.078	0.009	0.422	0.215
2016	0.077	0.000	0.559	0.124
2017	0.077	0.000	0.563	0.141
2018	0.033	0.000	0.607	0.070
2019	0.038	0.000	0.594	0.155
2020	0.014	0.000	0.732	0.068

Source: computed from International Renewable Energy Agency data

Global renewable energy consumption data reveals that China is the leading consumer of hydropower, with over three times the consumption of other leading countries such as Canada and Brazil[37]To this end, China has developed an Ocean Energy Development Five Year Plan (2016-2020) as part of its contribution to achieving a global energy transition and leveraging the ocean's potential towards this goal.

China had a growing number of patents per million population filed among the four BRICS countries for the PV thermal hybrid energy technology, followed by South Africa, Brazil and India (see **Table 5.27**).

[37] https://www.statista.com/statistics/237090/renewable-energy-consumption-of-the-top-15-countries/

Table 5.27: Patents per Million Population Filed in BRICS Countries for the PV Thermal Hybrid Energy Technology

	Brazil	India	China	South Africa
2011	0.131	0.000	0.808	0.286
2012	0.160	0.009	0.888	0.207
2013	0.134	0.002	0.873	0.371
2014	0.128	0.023	1.132	0.238
2015	0.146	0.005	1.481	0.125
2016	0.077	0.000	1.962	0.124
2017	0.144	0.000	1.525	0.265
2018	0.071	0.000	0.860	0.262
2019	0.047	0.000	0.859	0.138
2020	0.000	0.000	0.896	0.051

Source: computed from International Renewable Energy Agency data

China had the highest and fastest-growing number of patents per million population filed among the BRICS countries for solar photovoltaic energy technology, followed by South Africa, Brazil, and India (see **Table 5.28**).

Table 5.28: Patents per Million Population Filed in BRICS Countries for the Solar Photovoltaic Energy Technology

	Brazil	India	China	South Africa
2011	0.120	0.000	0.762	0.248
2012	0.148	0.008	0.843	0.182
2013	0.125	0.002	0.835	0.331
2014	0.120	0.021	1.089	0.215
2015	0.139	0.005	1.434	0.116
2016	0.074	0.000	1.910	0.116
2017	0.139	0.000	1.493	0.248
2018	0.069	0.000	0.847	0.248
2019	0.046	0.000	0.848	0.132
2020	0.000	0.000	0.887	0.050

Source: computed from International Renewable Energy Agency data

China also has growing number of patents per million population filed among the four BRICS countries for the solar thermal energy technology, followed by South Africa, Brazil and India (see **Table 5.29**).

Table 5.29: Patents per Million Population Filed in BRICS Countries for the Solar Thermal Energy Technology

	Brazil	India	China	South Africa
2011	0.790	0.001	5.345	1.026
2012	0.739	0.048	5.870	1.539
2013	0.596	0.009	5.630	1.059
2014	0.439	0.092	7.082	1.059
2015	0.490	0.034	9.053	0.828
2016	0.485	0.000	12.091	0.596
2017	0.647	0.000	15.368	0.430
2018	0.550	0.000	17.388	0.761
2019	0.471	0.000	14.855	0.596
2020	0.028	0.000	18.170	0.199

Source: computed from International Renewable Energy Agency data

China has a high and growing number of patents per million population filed among the four BRICS countries for wind renewable energy technology, followed by Brazil, South Africa, and India (see **Table 5.30**). This is no surprise, as China has had a steep acceleration in the rollout of wind capacity since 2021[38].

Table 5.30: Patents per Million Population Filed in BRICS Countries for the Wind Energy Technology

	Brazil	India	China	South Africa
2011	1.292	0.002	2.979	0.725
2012	1.345	0.050	2.910	1.374
2013	1.150	0.026	2.336	1.281
2014	0.865	0.125	2.453	1.608
2015	0.833	0.062	3.092	1.521
2016	1.073	0.000	4.155	0.691
2017	0.969	0.000	5.703	0.441
2018	1.071	0.000	6.151	0.401
2019	0.562	0.000	6.049	0.482
2020	0.070	0.000	7.603	0.204

Source: computed from International Renewable Energy Agency data

This trend is not a surprise as renewable energy in makes up 10% of total energy supply in China in 2019, with final energy consumption of 15% when taking into consideration the unused energy from power plants. Of this energy supply and consumption, one third is from biomass and waste[39]. Renewable energy in South Africa makes up 6.6% of total energy supply in South Africa.

6. SECTORAL AND PROVINCIAL SYSTEMS OF INNOVATION

This section analyses sectoral and provincial innovation systems to examine how NSI performance translates at the sectoral and regional levels.

6.1 Bioeconomy sector

The South African Bioeconomy Strategy was approved in January 2014[40]To avoid yearly fluctuations, the bioeconomy's performance since the strategy's adoption is assessed against a base— three-year average of the period 2013-2015.

[38] https://www.reuters.com/markets/commodities/china-widens-renewable-energy-supply-lead-with-wind-power-push-2023-03-01/

[39] IEA Bioenergy Country Reports https://www.ieabioenergy.com/wp-content/uploads/2021/11/CountryReport2021_China_final.pdf

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

R&D expenditures in the field of Biological Sciences have been on a consistently downward trend since 2012/13 (see **Table 6.1**). In 2020/21, there was a significant decline (-13.8%). In 2021/22, there was a light increase (4%). In 2021/22, expenditures were 22% lower than in the base. Biological science's share of research expenditures in all fields has also tended to decline. It declined further in 2021/22 and was substantially lower than the share in the base years.

Table 6.1: R&D Expenditures in the Field of Biological Sciences and Expenditures in Biological Sciences as a Share of R&D Expenditures in All Research Fields

	R&D Expenditure R'000s (constant 2015 rands)	Share of Total R&D Expenditures (%)
2012/13	1 830 422	6.5
2013/14	1 755 467	6.2
2014/15	1 476 185	4.8
2015/16	1 452 763	4.5
2016/17	1 324 383	4.0
2017/18	1 384 769	4.0
2018/19	1 347 213	4.3
2019/20	1 375 769	4.9
2020/21	1 186 522	4.6
2021/22	1 222 711	4.4
Base: 2013/14 -2015/16	1 561 471	5.2

Source: HSRC and DSI's National Survey of Research and Experimental Development. Statistical Report 2021/22

By contrast with the decline in resources committed to R&D in the iological ciences, there has been an increase in the number of Biotechnology publications since adopting the Bioeconomy strategy. As **Table 6.2** shows, there was a particularly significant increase in publications in 2019 as compared to 2018 (23%). However, since 2019, there has been a decline in the number of publications. In 2022, publications declined by 9.4% as compared with 2021. Despite the recent declines, the number of publications remains higher than at the time of adopting the Bioeconomy strategy.

South Africa's global share of Biotechnology publications tended to increase until 2019. However, after 2019, South Africa's share of world publications steadily declined. There was a further decline in 2022. The world share of South African publications was only marginally higher in 2022 than at the time of the adoption of the Bioeconomy strategy.

Table 6.2: South Africa Number and World Share of Biotechnology and Applied Microbiology Publications (articles and reviews only)

	Number of Publications	World Share (%)
2013	187	0.64
2014	243	0.79
2015	183	0.59
2016	221	0.74
2017	235	0.73
2018	238	0.77
2019	283	0.88
2020	279	0.80
2021	265	0.76
2022	240	0.68
Base: 2013 -15	204	0.67

Source: CREST, Stellenbosch University version of the Clarivate Analytics Web of Science

By contrast with publications, the number of South African patents abroad has decreased. Biotechnology patent applications and patent grants at the European Patent Office (EPO) have declined significantly in recent years (see **Table 6.3**). The decline in patent grants is particularly striking.

The Bioeconomy strategy has three key economic objectives: to increase the economy's contribution to GDP through high growth, create more employment, and make the country more competitive. The data presented here are for what has been identified as the 'core' of the bioeconomy. The "core" bioeconomy consists of the following: SIC1, SIC30, SIC321-SIC326, SIC391, SIC392 - SIC395.

Output declined in 2019 and 2020. In 2021, there was a significant increase in output over the previous year (7%). There was a marginal decline in output in 2022. There has been no consistent tendency for the bioeconomy to grow its share of total South African output since the adoption of the Bioeconomy strategy. In 2020 and 2021 there was some increase in the share of the Bioeconomy. But, in 2022, the share of the Bioeconomy in total GDP declined.

Table 6.3: South Africa Biotechnology Patent Applications and Patent Grants at the EPO

	Applications	Grants
2013	2	4
2014	3	1
2015	0	6
2016	7	3
2017	7	3
2018	10	4
2019	3	7
2020	5	6

2021	2	2
2022	3	1
Base: 2013 -15	2.67	3.67

Source: EPO, PATSTAT

Table 6.4 shows, in 2022, the share of the Bioeconomy in total GDP (8.41%) was only marginally higher than at the onset of the strategy (8.0%).

Table 6.4: Bioeconomy GDP Output and Share of Total South African GDP

	Bioeconomy GDP Output (R' million at constant 2015 prices)	Bioeconomy's Share of Total GDP (%)
2013	308 490	7.96
2014	319 083	8.11
2015	316 434	7.95
2016	311 091	7.75
2017	331 680	8.17
2018	335 945	8.14
2019	330 490	7.99
2020	326 816	8.31
2021	350 152	8.58
2022	349 733	8.41
Base: 2013-15	314 669	8.00

Source: Quantec & Stats SA

The bioeconomy's employment numbers declined consistently after 2015. In 2022, there was a significant increase (8.1%), but employment numbers were still well below their peak in 2015. The bioeconomy's share of total South African employment in 2022 is the same as it was at the onset of the strategy (10.9%).

Table 6.5: Bioeconomy Sector Employment+

	Bioeconomy Employment	% Total SA Employment
2013	1 605 942	10.7
2014	1 572 579	10.3
2015	1 821 920	11.6
2016	1 781 840	11.3
2017	1 750 643	10.9
2018	1 728 388	10.6
2019	1 718 497	10.6
2020	1 588 817	10.6
2021	1 545 589	10.7
2022	1671 333	10.9
Base: 2013 -15	1 666 814	10.9

Source: Quantec & Stats SA

+Note: Total Employment = Formal and Informal Employment

A key objective of the bioeconomy strategy is to increase exports and South Africa's competitiveness in global markets. In addition to increasing total bioeconomy exports, the strategy aims to increase the value of South Africa's bioeconomy exports. As a result of

enhanced technological change and innovation, exports should be more sophisticated and, hence, of higher value.

While there were fluctuations, until 2020, there was no tendency for Bioeconomy exports to increase. However, in 2021, Bioeconomy exports increased significantly (27.8%). There was a further increase in 2022 (10%). As a result, exports in 2022 were significantly higher than at the onset of the Bioeconomy strategy.

Over the decade, there has been no tendency for the bioeconomy share of total South African exports to increase. The Bioeconomy share of total South African exports in 2022 (16.2%) was below its share of total South African exports (17.5%) at the onset of the Bioeconomy strategy.

Table 6.6 shows that the US$ unit value of Bioeconomy exports has declined since 2017. However, the US$ unit value of Bioeconomy exports rose significantly in 2021. It increased marginally in 2022. In 2022, the unit value (US$0.86) was marginally above the average for 2013-15. (US$0.84)

Table 6.6: Bioeconomy Sector's Exports

	Bioeconomy Exports (current US$ millions)	% of Total SA Exports	Unit Value US$
2013	16 362	17.2	0.78
2014	15 945	17.2	0.89
2015	14 526	18.0	0.85
2016	14 162	18.6	0.87
2017	15 954	18.0	0.88
2018	16 656	17.7	0.85
2019	14 554	16.3	0.74
2020	14 654	17.2	0.77
2021	18 142	14.8	0.85
2022	19 961	16.2	0.86
Base: 2013-15	15 611	17.5	0.84

Source: Quantec & Stats SA

In summary:

- The number of biotechnology publications has increased since adopting the Bioeconomy strategy. However, the number has been declining since 2019.
- South Africa's world share of publications peaked in 2019 and declined thereafter. South Africa's world share of publications in Biotechnology is only marginally higher than at adopting the Bioeconomy strategy.
- The number of global patent applications and grants has declined.

- There was a marginal decline in Bioeconomy output in 2021.
- There has been no consistent tendency for the bioeconomy to grow its share of total South African output since adopting the bioeconomy strategy. However, there was some increase in the share of the Bioeconomy output in 2020 and 2021. The Bioeconomy's share of total GDP is marginally higher in 2022 than at adopting the bioeconomy strategy.
- Employment in the bbioeconomy has been declining consistently since 2015. In 2022, there was a significant increase in employment. The bioeconomy's share of total employment has not increased since the adoption of the Biotechnology strategy.
- There were significant increases in Bioeconomy exports in 2021 and 2022. However, the bioeconomy share of total South African exports will be lower in 2022 than at the adoption of the bioeconomy strategy.
- The US$ unit value of Bioeconomy exports in 2022 is only marginally higher than at the adoption of the Bioeconomy strategy andhas tended to decline since 2017.
- The relatively strong performance in terms of Biotechnology science (publications), albeit this too has been in decline in recent years, contrasts with the weak performance in the bioeconomy in technology (patents) and the economic magnitudes (output, employment, and exports) in the bioeconomy.

6.2 Emerging technologies and the South African manufacturing sector

The importance of the fourth industrial revolution (4IR) global megatrend to South Africa was emphasised by the formation of a Presidential Commission on the 4IR some few years back. An outcome of this Commission was a diagnostic report that provided a set of recommendations regarding how the country can benefit from the 4IR. Through this 4IR diagnostic report, there was an expectation that South Africa could derive huge gains on the 4IR from sectors such as automotive, clothing and textiles, metal fabrication, agro-processing, forestry and timber, plastics as well as chemicals. Therefore, a focus of this section on the manufacturing sector partially monitors progress on this aspiration as most of these are the manufacturing subsectors. This section analyses South Africa's capability on select emerging technologies and the emerging technologies PCT patents that are classified as input towards the manufacturing sector. A fractional count is used when referring to the patent numbers.

6.2.1 Emerging technologies capacity

In this sub-section, the analysis of three high-growth technologies internationally is done to understand the performance of the South African innovation system based on publication and patent outputs. The areas to be considered are nanotechnology, biotechnology and digitalisation. These have already been captured as important growth areas in government strategy documents. Additionally, these are key building blocks to the government's push towards the Fourth Industrial Revolution. The areas of nanotechnology and biotechnology are well established and have been reported on in the past reports, but digitalisation has not. Digitalisation is the use of digital technologies to change a business model and is a process of moving to a digital business. Artificial intelligence drives digital transformation, encompassing innovations such as machine learning, 3D printing, IoT, data labelling platforms and predictive analytics. Companies do this in response to growing consumer' demands, to increase efficiencies and lower costs.

Table 6.7 shows patenting trends in the three high-tech sectors. Biotechnology shows a higher level of inventiveness than the other two emerging technology fields. Digitalisation is still at its earliest stage of development, as seen from the lower level of patenting in this field on a yearly basis.

Table 6.7 Patenting Trends in Select Emerging Technologies

	Digitalisation	Nanotechnology	Biotechnology
2011	0	8	14
2012	1	7	8
2013	1	4	15
2014	1	5	20
2015	2	5	13
2016	3	4	14
2017	4	5	11
2018	5	3	12
2019	3	2	15
2020	3	8	10
2021	5	3	13
2022	4	6	13

Source: WIPO Patentscope

Figure 6.1 illustrates the patenting trends in the three fields. The University of Cape Town, with three patents, and Stellenbosch University, with two patents, are responsible for most of the patenting in the digitalisation sector.

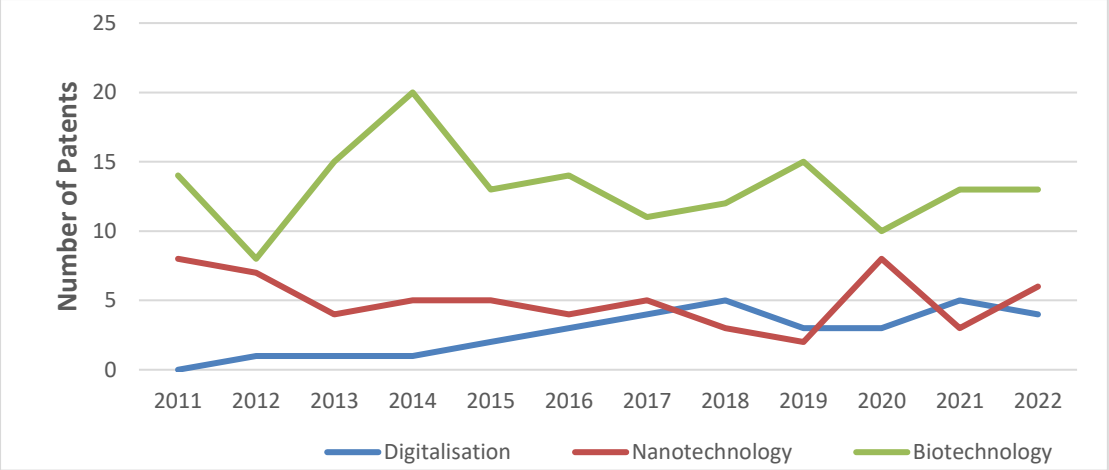


Figure 6.1 Trends in Patenting for the Three Emerging Areas

Source: WIPO Patentscope

The active companies in this area include the security firm, Fidelity ADT, and financial services companies. In the biotechnology sector, a lot of activity occurs in the Western Cape province, with the University of Cape Town (36) having the most patents in this area, followed by Stellenbosch University (29). Stellenbosch University also has the highest number of nanotechnology patents at 11, followed by the University of the Witwatersrand with 10. Some start-up companies such as PST Sensors, Stellenbosch Nanofibres and Rubber Nano Products are also patenting in this sector.

Table 6.8 shows the percentage share of patents by South African-based innovators as a proportion of overall patents granted annually worldwide. Looking at all sectors, South Africa trends at around 0.03% in the ten years under review. The three sectors are in line with this trend, with biotechnology underperforming slightly in most of these years.

Table 6.8 South African Patents in Relevant Emerging Technology as a Share of World Total

	Digitalisation	Nanotechnology	Biotechnology	All sectors
2011	0.03	0.03	0.02	0.03
2012	0.00	0.06	0.02	0.03
2013	0.03	0.06	0.01	0.03
2014	0.02	0.03	0.02	0.02
2015	0.02	0.04	0.03	0.02
2016	0.03	0.04	0.02	0.03
2017	0.03	0.03	0.02	0.03
2018	0.03	0.04	0.02	0.03
2019	0.05	0.02	0.02	0.05
2020	0.02	0.01	0.02	0.02
2021	0.02	0.05	0.01	0.02
2022	0.03	0.02	0.01	0.03

Source: WIPO Patentscope

Table 6.9 shows the growth that has taken place in South Africa in the areas of nanotechnology and digitalisation. For digitalisation, the country's institutions produced a total of 171 publications in 2011, and this grew to 1 518 in 2022, representing a compound annual growth rate of 19%. For nanotechnology, they grew from a low of 279 in 2011 to 2 222 in 2022, a growth rate of 27%. Biotechnology did not show any significant growth during this period.

Table 6.9: Publications in the Emerging Focus Areas

	Digitalisation	Nanotechnology	Biotechnology
2011	171	279	236
2012	192	343	144
2013	253	687	187
2014	247	778	234
2015	428	857	191
2016	470	1 101	219
2017	572	1 190	208
2018	809	1 391	225
2019	921	1 759	300
2020	981	2 091	264
2021	1 269	2 166	279
2022	1 518	2 222	252

Source: Web of Science "Core Collection"

Looking at all sectors, publication share has risen from around 0.5% in 2011 to almost 1% in 2022. Once again, the two fields, nanotechnology and digitalisation, have been growing their share, while biotechnology has shown no growth over the period.

Table 6.10: Percentage Share of Publications for South Africa in the Emerging Technologies

	Digitalisation	Nanotechnology	Biotechnology	All Fields
2011	0.34	0.20	0.85	0.56
2012	0.44	0.23	0.54	0.62
2013	0.52	0.42	0.65	0.62
2014	0.38	0.44	0.76	0.65
2015	0.52	0.45	0.63	0.68
2016	0.51	0.54	0.75	0.73
2017	0.56	0.54	0.74	0.74
2018	0.62	0.56	0.74	0.82
2019	0.60	0.67	0.91	0.84
2020	0.63	0.78	0.76	0.91
2021	0.66	0.77	0.81	0.94
2022	0.69	0.79	0.71	0.84

Source: Web of Science "Core Collection"

Figure 6.2 shows that of the three sectors, nanotechnology and digitalisation seem to be showing the highest growth based on academic publications, with biotechnology essentially stagnant.

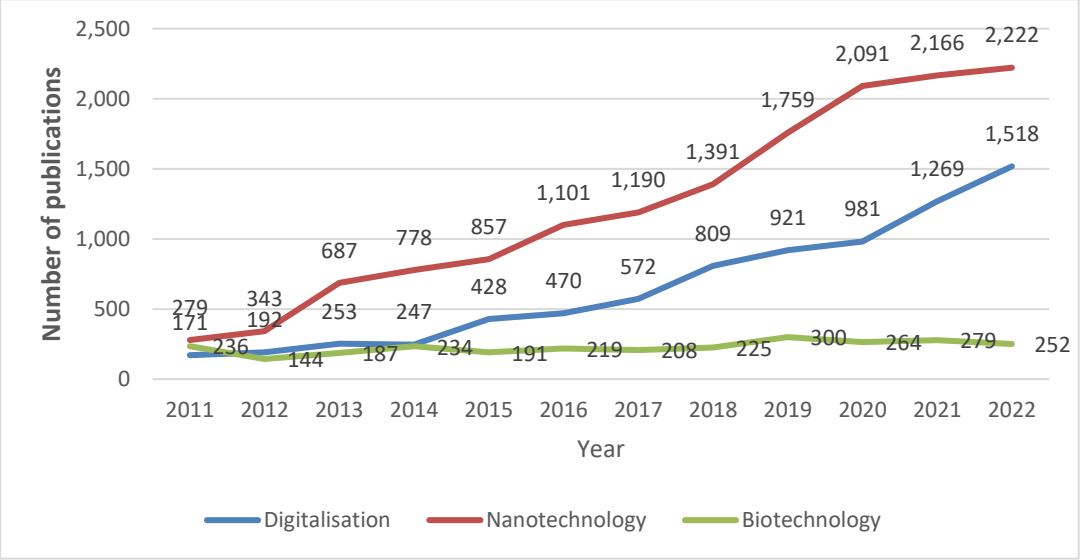


Figure 6.2: Trends in Publications for the Three Emerging Technologies
Source: Web of Science "Core Collection"

6.2.2 Manufacturing-related emerging technologies patents

The country's annual numbers of emerging technologies' patents with potential applications in the manufacturing sector remain low, although their share of all South African PCT patent applications is on the increase (see Figure 6.3). At the peak of the 4IR hype in 2015, South Africa had 17 manufacturing-related emerging technologies' PCT patent applications, representing 5.20% of all PCT patent applications from South Africa in that year.

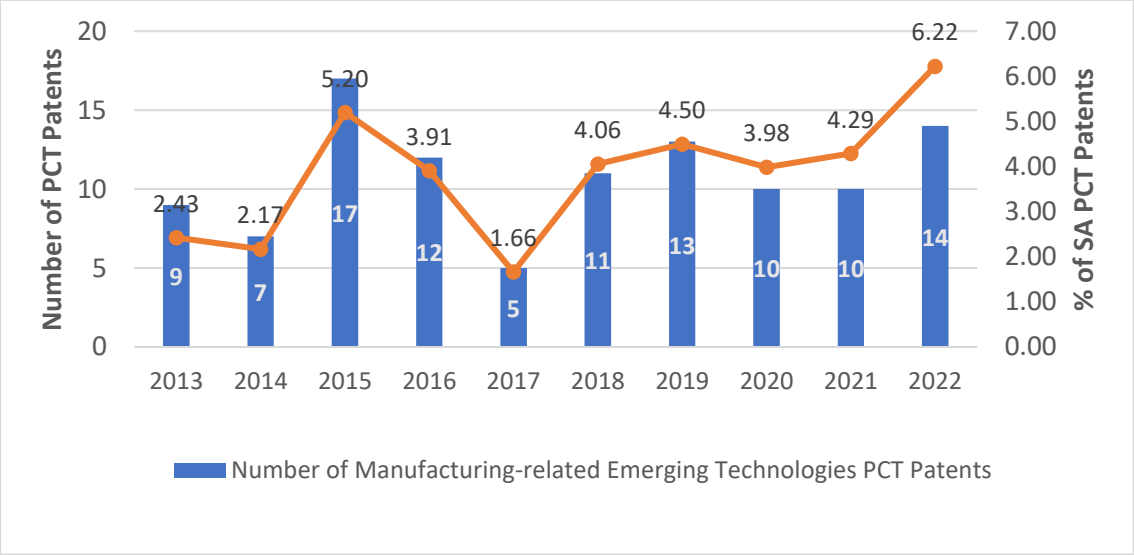


Figure 6.3: Manufacturing-related Emerging Technologies Patents Applications
Source: computed from WIPO "Patentscope"

For some unknown reasons, these patent applications decreased in 2016 and 2017. A plausible speculation is a sudden increase in global demand for 4IR skills, with South Africa losing its inventors to the more developed countries. However, the trend is now looking positive.

A disaggregation of the contribution of various emerging technologies in Table 6.11 shows a more dominant biotechnology (a share of 67.86% in 2022, from 55.56% in 2013), followed by nanotechnology (25.00% in 2022). Although robotics has a longer history in South Africa than the Internet of Things, the latter is on the rise. For the period 2013 – 2022, it had a share of 8.70% of the country's emerging technologies' PCT patent applications.

Table 6.11: Trends of Manufacturing-related Emerging Technologies PCT Patents Contribution by Various Emerging Technologies

	Biotechnology	Nanotechnology	Internet of Things	Robotics	AI and Machine Learning
	%				
2013	55.56	33.33	0.00	11.11	0.00
2014	71.43	28.57	0.00	0.00	0.00
2015	82.35	17.65	0.00	0.00	0.00
2016	70.83	29.17	0.00	0.00	0.00
2017	60.00	40.00	0.00	0.00	0.00
2018	63.64	9.09	9.09	18.18	0.00
2019	53.85	7.69	23.08	7.69	7.69
2020	30.00	40.00	20.00	10.00	0.00
2021	70.00	30.00	0.00	0.00	0.00
2022	67.86	25.00	0.00	0.00	7.14
2013 - 2022	**63.89**	**24.07**	**8.70**	**4.63**	**1.85**

Source: computed from WIPO "Patentscope"

During the same period, robotics only had a share of 4.63%. Artificial intelligence and machine learning areas are also still underdeveloped, although they are high potential areas that are expected to drive the manufacturing sector in the future.

The government's massive investment in emerging technologies is undisputed, as evidenced by a higher share of manufacturing-related emerging technologies' patent applications by the universities (a 54.48% share during 2013 – 2022). The Department of Science and Innovation developed several strategies for emerging technologies, with universities and science councils being the primary beneficiaries of these strategies through assistance on issues such as equipment and human capital development. During 2013 – 2012, the private sector had a share of only 19.75%, which shows a need for the government to de-risk these technologies further.

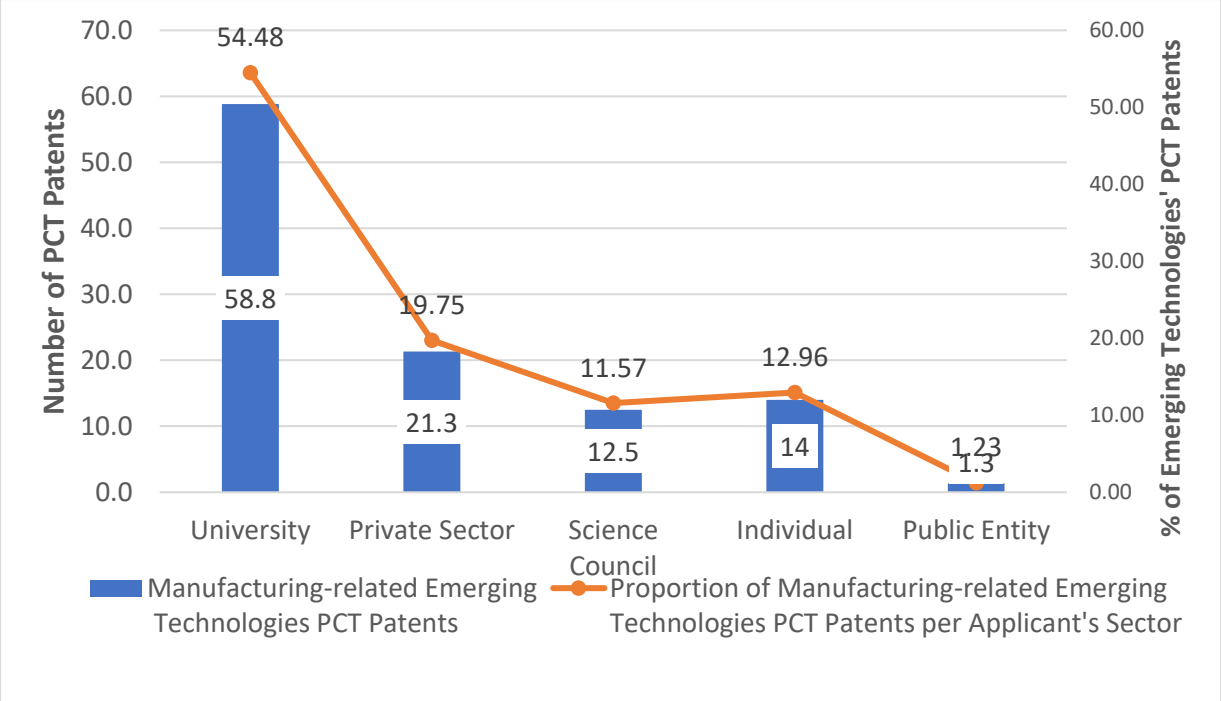


Figure 6.4: Manufacturing-related Emerging Technologies Patents Applications by Applicant's Sector, 2013 - 2022

Source: computed from WIPO "Patentscope"

A further disaggregation of emerging technologies' patent applications by applicant's sector and a specific emerging technology (see **Table 6.12**) shows that both biotechnology and nanotechnologies are developed mainly by the universities, Internet of Things by the individuals and private sector, robotics by the private sector and universities and lastly artificial intelligence and machine learning by the universities and individuals. It is important to note that with the two centres of excellence in nanotechnology located at the CSIR and Mintek science councils are producing a fair share of manufacturing-related nanotechnology patents.

Table 6.12: Manufacturing-related PCT Patents Contribution by Various Emerging Technologies per Applicant's Sector, 2013 - 2022

	Biotechnology	Nanotechnology	Internet of Things	Robotics	AI and Machine Learning
			%		
Universities	61.71	50.96	0.00	40.00	50.00
Private Sector	18.96	12.50	33.33	60.00	0.00
Science Councils	8.33	25.96	0.00	0.00	0.00
Individuals	9.06	10.58	66.67	0.00	50.00
Public Entities	1.93	0.00	0.00	0.00	0.00

Source: computed from WIPO "Patentscope"

A focus on manufacturing subsectors (**Figure 6.5**) shows that most emerging technology patents from South Africa are directed towards medical diagnostic instruments (30.56%). This is mainly the case with biotechnologies and nanotechnologies.

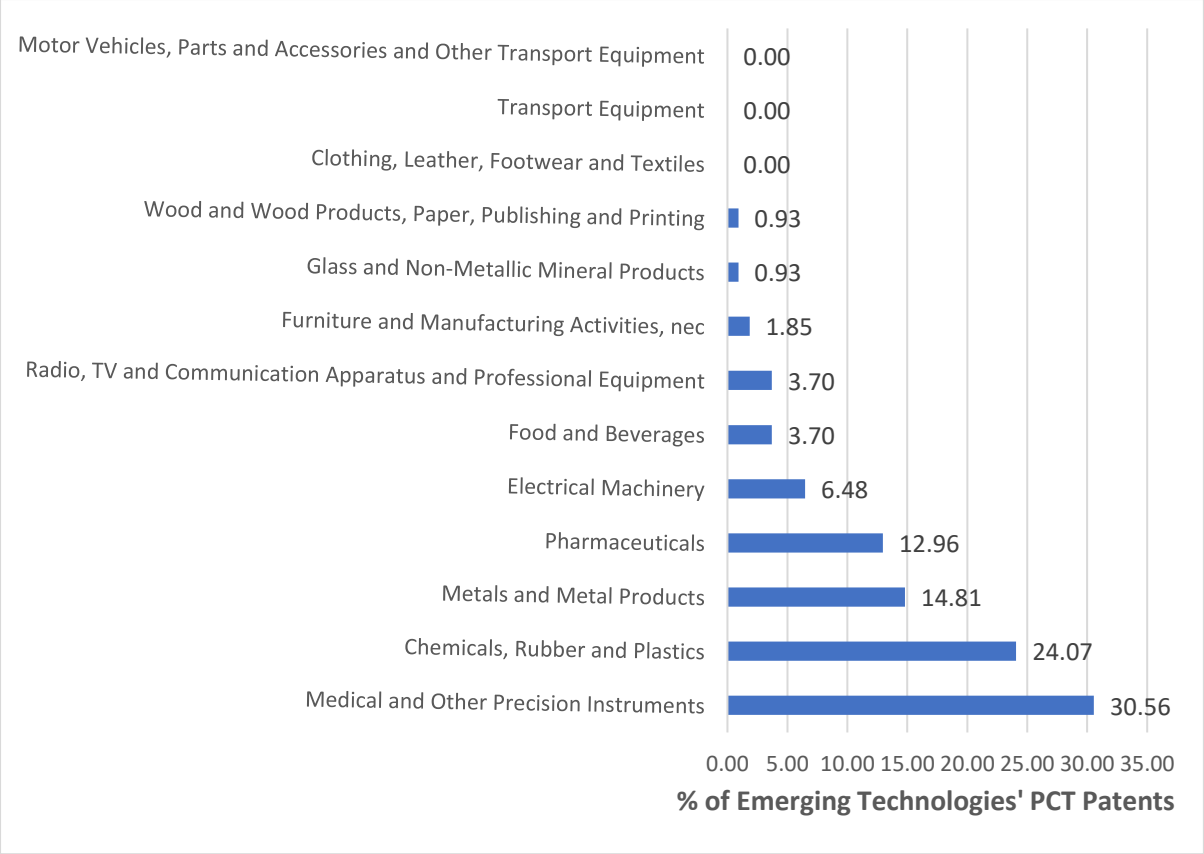


Figure 6.5: Manufacturing-related Emerging Technologies Patents Applications by Subsector, 2013 - 2022

Source: computed from WIPO "Patentscope"

Several applications include improved diagnosis of tuberculosis and other diseases such as cancer and diabetes mellitus. Nanotechnologies are also and invaluable for the improvement of the physical characteristics of chemicals, plastics as well as metal products (see **Table 6.13**). In addition to medical diagnostics, the application of emerging technologies in developing pharmaceuticals also shows potential in South Africa. Although the 4IR diagnostic report had higher hopes for the revitalisation of the clothing and textile as well as the automotive manufacturing subsectors, during the last decade, there were no emerging technology patent applications with potential applications in those subsectors.

The electrical machinery subsector is set to benefit from emerging technologies such as artificial intelligence, machine learning, robotics, and the Internet of Things. Other potential emerging technologies, such as augmented reality and virtual reality, are not yet visible as there were no PCT patent applications of these technologies from South Africa during the 2013 – 2022 review period.

Table 6.13: Manufacturing-related Emerging Technologies PCT Patents Contribution by Various Emerging Technologies per Subsector, 2013 - 2022

	Biotechnology	Nanotechnology	Internet of Things	Robotics	AI & Machine Learning
	%				
Medical and Other Precision Instruments	43,48	11,54	0,00	0,00	0,00
Chemicals, Pubber and Plastics	28,26	25,00	0,00	0,00	0,00
Pharmaceuticals	17,39	7,69	0,00	0,00	0,00
Metals and Metal Products	5,80	34,62	0,00	60,00	0,00
Furniture and Manufacturing Activities	2,17	1,92	0,00	0,00	0,00
Food and Beverages	1,45	11,54	0,00	0,00	0,00
Wood and Wood Products, Paper, Publishing and Printing	1,45	0,00	0,00	0,00	0,00
Electrical machinery	0,00	3,85	33,33	40,00	100,00
Radio, Television and Communication Apparatus and Professional Equipment	0,00	0,00	66,67	0,00	0,00
Clothing, Leather, Footwear and Textiles	0,00	0,00	0,00	0,00	0,00
Glass and Non-Metallic Mineral Products	0,00	3,85	0,00	0,00	0,00
Transport Equipment	0,00	0,00	0,00	0,00	0,00
Motor Vehicles, Parts and Accessories and Other Transport Equipment	0,00	0,00	0,00	0,00	0,00

Source: computed from WIPO "Patentscope"

In terms of the manufacturing value chain stage, most of the claims of the emerging technologies patents are for the components (46 PCT patent applications during 2013 – 2022), followed by subsystems, materials and products. This is not unusual as patents are not necessarily used to protect a complete product but a novel component of a full or incomplete system/ product. However, **Figure 6.6** is still a good indication of a technology readiness level for the application of emerging technologies within the manufacturing sector in South Africa.

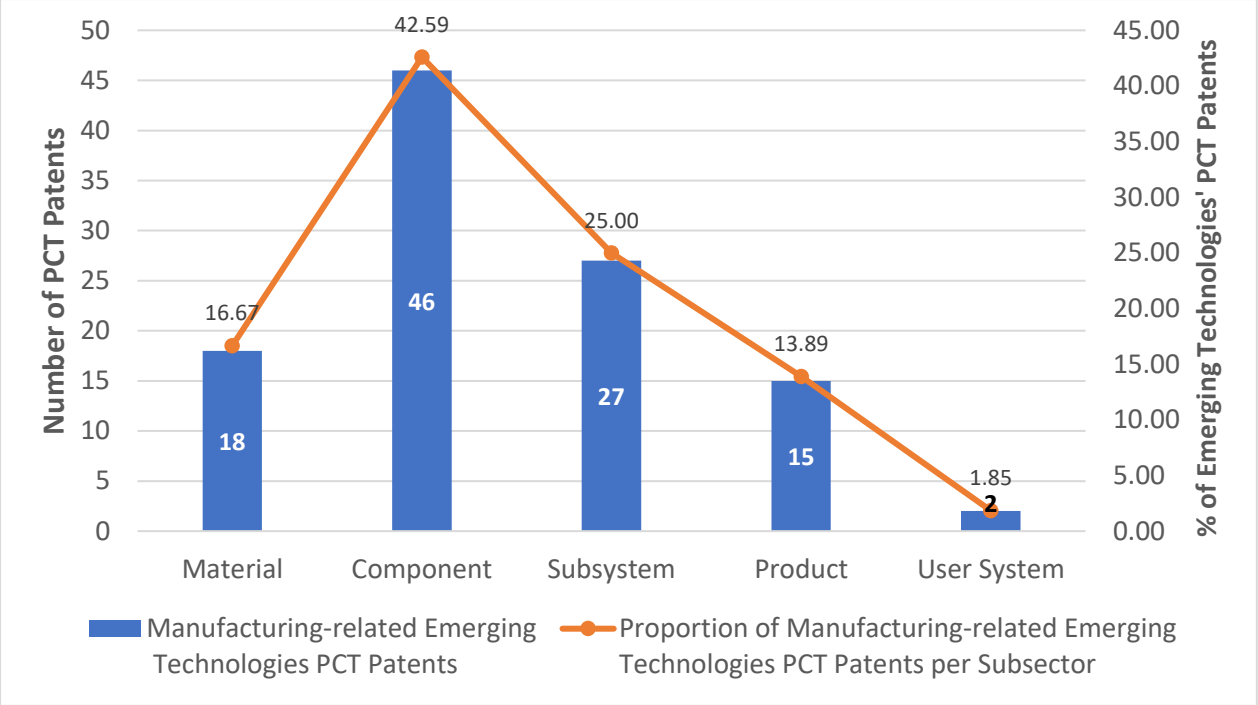


Figure 6.6: Manufacturing-related Emerging Technologies Patents Applications by Value Chain Stage, 2013 - 2022

Source: computed from WIPO "Patentscope"

Table 6.14 shows that emerging technologies are mainly at the component level: biotechnology, the Internet of Things, and robotics. Nanotechnology is mainly at the material level of the manufacturing value chain. Although AI and machine learning have few manufacturing-related patent applications, they have higher potential for inventions at the product and subsystem value chain stages.

Table 6.14: Manufacturing-related Emerging Technologies PCT Patents Contribution by Various Emerging Technologies per Value Chain Stage, 2013 - 2022

	Biotechnology	Nanotechnology	Internet of Things	Robotics	AI and Machine Learning
	%				
Material	7.97	48.08	0.00	0.00	0.00
Component	50.00	25.00	50.00	40.00	0.00
Subsystem	27.54	11.54	33.33	40.00	50.00
Product	13.04	15.38	0.00	20.00	50.00
User System	1.45	0.00	16.67	0.00	0.00

Source: computed from WIPO "Patentscope"

6.3 Provincial systems of innovation

Ready access to accurate and timely provincial-level information is an essential tool for formulating effective science and technology policies at both the provincial and national levels. By studying the performance of their peers, provincial policymakers may be better

able to assess their own involvement in science and technology programmes and performance.

Furthermore, comparing provincial science and technology statistics may alert national policymakers to variations in provincial and regional needs and circumstances. The business sector could also benefit from knowing the expertise available in the regions in which it would like to invest and create facilities.

6.3.1 Provincial economic performance and industrial structure

The economic performance of the nine provinces in South Africa and their contribution to GDP differ considerably. The data presented in Figure 6.7 reveals that Gauteng, the Western Cape, and KwaZulu-Natal are the dominant provinces in terms of economic output, contributing 33%, 16%, and 14%, respectively, to the national GDP in 2022. These three provinces account for about 63% of the national GDP.

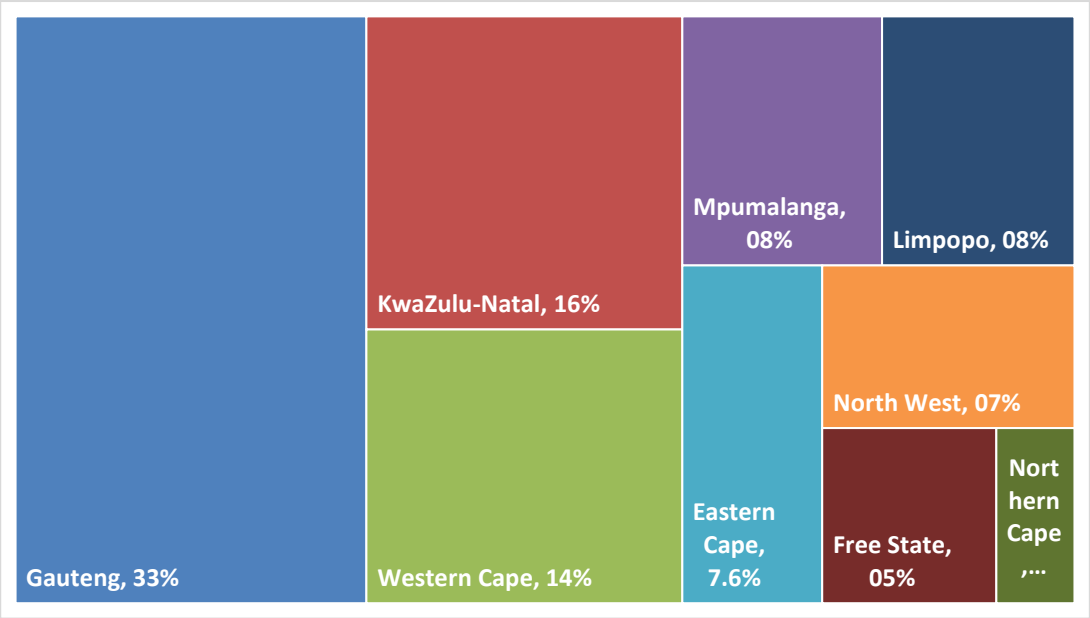


Figure 6.7: Contribution of the Provinces to National GDP
Source: Stats SA, 2022

The Free State and the Northern Cape were the lagging contributors to the country's nominal GDP. The Free State contributed 5%, and the Northern Cape accounted for just over 2% of the national GDP.

As shown in **Figure 6.8**, the structure of the economies also differs significantly. The economies of Gauteng, the Western Cape and the Free State are driven by finance, real estate and business services. The finance sector was the most significant contributor in Gauteng with 31%, followed by the Western Cape with 30% and the Free State with 19%.



Figure 6.8: Provincial Percentage Share of Gross Value Added by Sector

Mining is the largest industry in the Northern Cape, the North West, Mpumalanga and Limpopo provinces. The sector accounts for 30% of GDP in the North West, The industry contributes 25%, 23% and 22% to the provincial value-add of Limpopo, Mpumalanga and the Northern Cape provinces, respectively.

Manufacturing is a key industry in five provinces: the Western Cape, the Eastern Cape, KwaZulu-Natal, Gauteng, and Mpumalanga. It ranks among the top four contributors to their provincial GDPs. Those five provinces also employed 90% of the national manufacturing workforce in 2021.

This disparity in economic contribution and industrial structures affects provincial innovation systems, as the following sections reveal.

6.3.2 Provincial R&D expenditure

Table 6.15 displays great disparity in R&D expenditure among the provinces. The data shows that from 2012/13 to 2021/22, Gauteng had the highest R&D expenditure, followed by the Western Cape and KwaZulu-Natal. These provinces have a high percentage of manufacturing industries, as revealed by their industrial structures. They are also home to leading science councils and research-intensive universities.

Limpopo, Northern Cape, and Northwest are the provinces with the lowest R&D expenditures. The economic structures of these provinces are dominated by mining and personnel services, which are not R&D-intensive industries.

An encouraging trend is that R&D expenditures have gradually recovered across all the provinces since the COVID-19 pandemic.

Table 6.15: Provincial R&D Expenditure Trends

	2012/13	2013/14	2015/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22
	R' million									
Eastern Cape	1 464	1 479	1 734	2 143	2 206	2 301	2 212	2 091	1 999	2 011
Free State	1 714	1 943	1 456	1 778	1 835	2 149	1 977	1 711	1 242	1 733
Gauteng	10 602	11 976	13 687	14 666	16 422	17 320	15 767	14 386	14 718	15 690
KwaZulu-Natal	3 013	2 753	3 187	3 335	3 639	4 173	4 074	3 629	3 279	3 716
Limpopo	619	444	629	627	729	855	807	772	983	1 016
Mpumalanga	612	616	859	791	700	716	854	842	706	1 263
Northern Cape	401	474	576	661	533	577	906	901	867	1 086
North West	890	1 027	1 403	1 209	1 299	1 306	1 682	1 700	1 365	1 499
Western Cape	4 555	4 949	5 814	7 125	8 331	9 328	8 506	8 543	8 382	10 171
South Africa	**23 871**	**25 661**	**29 345**	**32 337**	**35 693**	**38 725**	**36 784**	**34 485**	**33 541**	**38 186**

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

Figure 6.9 displays trends in R&D expenditure. Although Gauteng has the highest expenditure, there has been a decline since 2017/2018. On the other hand, R&D expenditure in the Western Cape has increased gradually during this period.

This unbalanced R&D landscape has implications for innovation performance since R&D intensity is frequently used to determine an economy's innovative capacity.

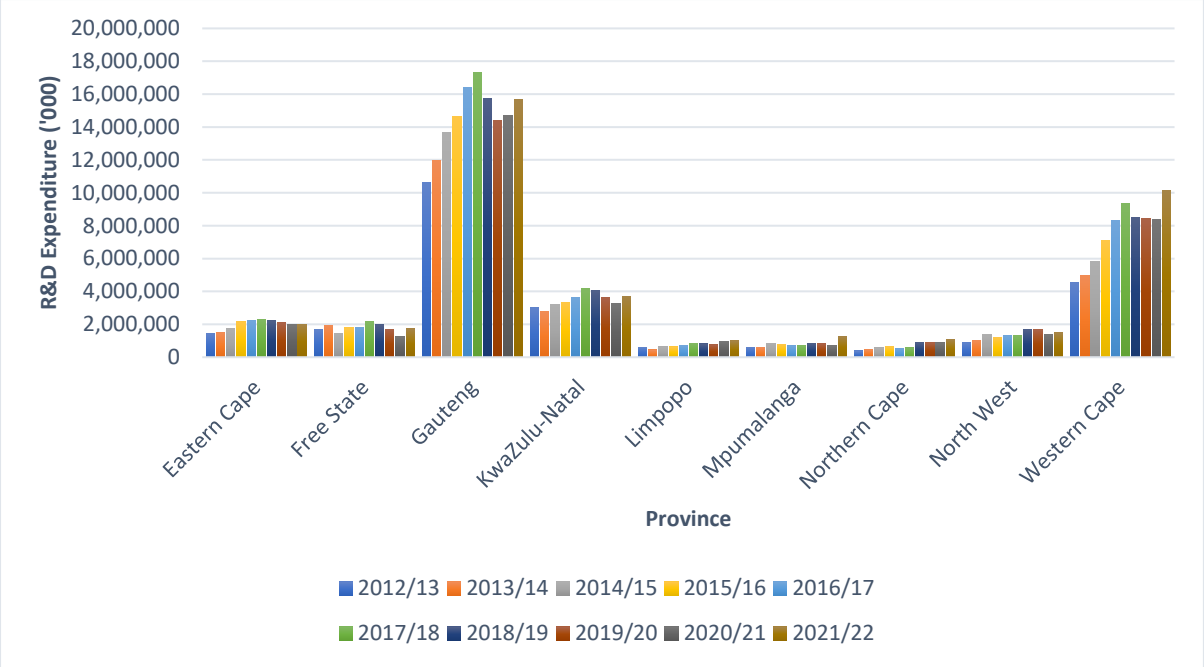


Figure 6.9: Proportion of R&D Expenditure by Province

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

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

Table 6.16 shows business R&D expenditures for each province between 2012/13 and 2021/22. Total business R&D expenditures increased from R10.5bn in 2012/13 to R15.8bn in 2017/18 and thereafter declined to R13.5bn in 2021/22.

Gauteng has continued to have the highest business R&D expenditure (R6.7 bn in 2021/22), followed by the Western Cape (R3.1bn in 2021/22). However, business expenditure in Gauteng has declined from R8.3bn in 2017/18. These two provinces contribute about 73% of total provincial business R&D expenditure.

Table 6.16: Business Sector R&D Expenditure by Province

	2012/13	2013/14	2015/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22
	R' million									
Eastern Cape	468	646	608	652	690	707	675	440	215	241
Free State	1 265	1 375	832	1 124	1 060	1 106	991	694	470	999
Gauteng	5 357	58 136	7 160	7 184	7 876	8 285	7 618	5 447	5 577	6 786
KwaZulu-Natal	1 238	1 434	1 502	1 437	1 553	1 680	1 446	1 194	821	1 061
Limpopo	127	140	161	146	172	223	184	78	200	136
Mpumalanga	223	302	161	340	285	305	393	371	259	581

Northern Cape	380	436	682	452	527	565	602	566	526	581
North West	78	124	226	207	50	60	51	40	29	113
Western Cape	1 434	1 512	1 684	2 275	2 569	2 927	2 489	1 874	1 950	3 172
South Africa	**10 571**	**11 783**	**13 291**	**13 815**	**14 781**	**15 859**	**14 448**	**10 704**	**10 047**	**13 527**

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

Figure 6.10 illustrates the large disparities in provincial business R&D expenditures. Gauteng province had a proportional business expenditure of 50%, which was more than double that of the Western Cape, which was 23.4% in 2021/22. Eastern Cape, Limpopo, and Northern Cape had the lowest expenditures in 2021/22.

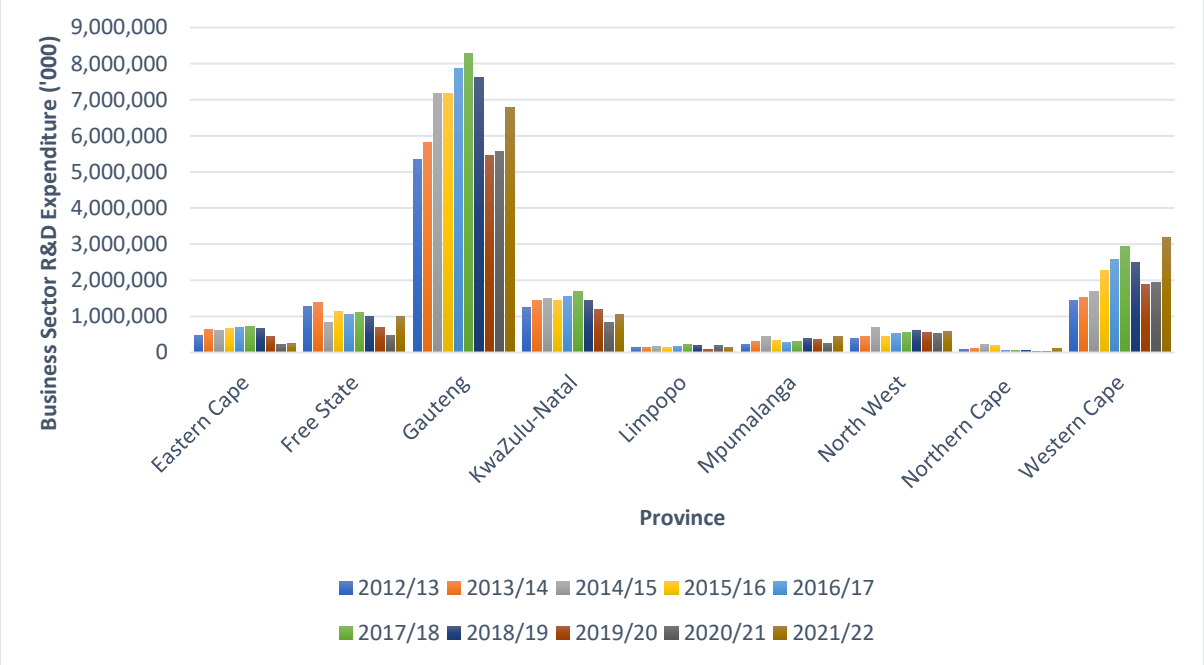


Figure 6.10: Proportional Business Sector R&D Expenditure by Province

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

As **Table 6.17** shows, Gauteng province again has the highest expenditure, followed by the Western Cape and Eastern Cape, which are slightly higher than KZN.

Table 6.17: Government Sector R&D Expenditure by Province

	2012/13	2013/14	2015/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22
	R' million									
Eastern Cape	194	134	227	226	222	281	306	302	384	390
Free State	39	55	61	62	82	82	60	46	52	52
Gauteng	427	690	760	832	885	974	837	582	626	822

KwaZulu-Natal	168	162	178	187	173	207	237	206	285	290
Limpopo	75	96	84	84	77	87	90	81	90	113
Mpumalanga	80	77	94	112	107	104	89	84	74	79
Northern Cape	46	74	57	62	58	61	67	57	61	26
North West	75	62	53	69	66	95	89	525	132	137
Western Cape	334	348	380	379	428	436	451	484	534	564
South Africa	1 438	1 697	1 893	2 013	2 099	2 326	2 223	1 894	2 238	2 472

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

Figure 6.11 shows that the government's proportional expenditure in Gauteng increased from 28% in 2020/21 to 33.2% in 2021/22. During the same period, the proportional government expenditure in the Western Cape declined slightly from 23.9% to 22.8%. As shown, expenditure in the Eastern Cape and KZN also declined slightly.

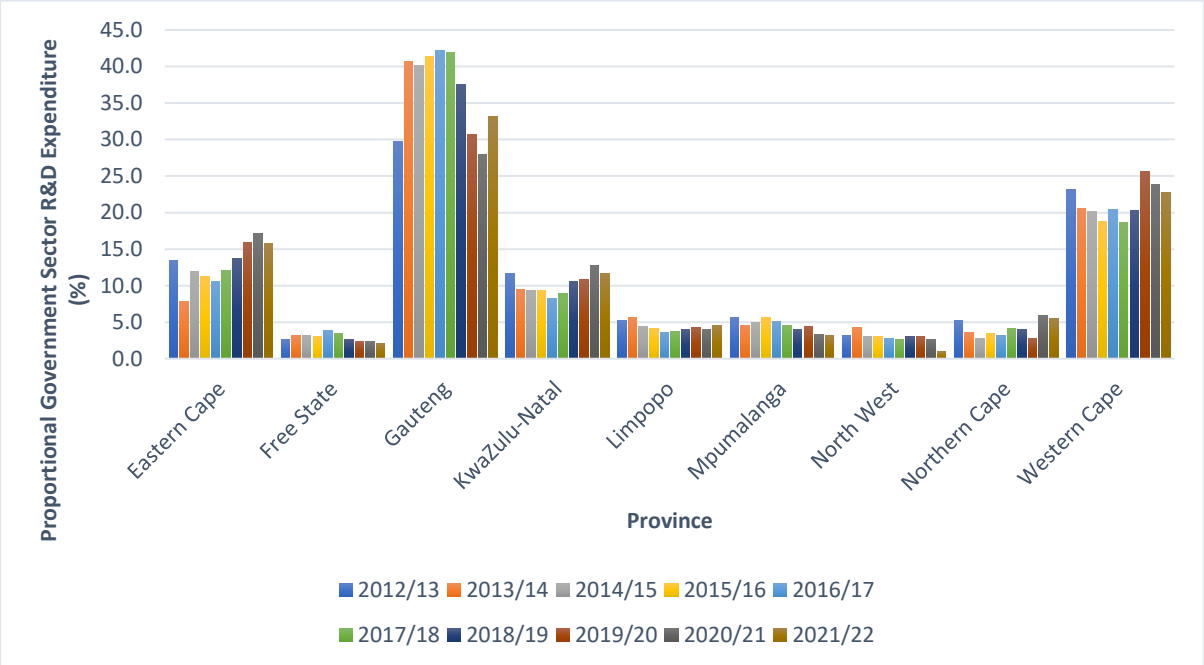


Figure 6.11: Proportional Government Sector R&D Expenditure by Province

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

Table 6.18 displays the level of investment in research and development by the higher education sector in the provinces. The table shows that the province with the highest expenditure in 2021/22 is the Western Cape (R4.9bn), followed by Gauteng (R4.1bn) and KwaZulu-Natal (R1.4bn).

Table 6.18: Higher Education Sector R&D Expenditure by Province

	2012/13	2013/14	2015/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22
	R' million									

Eastern Cape	593	557	612	975	1 003	1 017	1 028	1 124	1 190	1 162
Free State	357	450	491	524	626	894	804	847	625	620
Gauteng	2 119	2 234	2 733	3 306	4 105	4 269	3 730	4 188	4 474	4 113
KwaZulu-Natal	1 137	751	843	904	1 158	1 429	1 647	1 514	1 378	1 472
Limpopo	300	187	216	229	302	359	384	467	541	576
Mpumalanga	182	147	175	191	149	155	171	214	221	585
Northern Cape	311	406	405	444	469	449	834	857	555	642
North West	164	162	147	164	189	181	162	170	52	75
Western Cape	2 170	2 399	2 755	3 140	3 659	4 257	4 424	4 798	4 749	4 987
South Africa	7 333	7 293	8 378	9 877	11 659	13 010	13 183	14 179	13 886	14 232

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

As **Figure 6.12** shows, the Western Cape province surpassed Gauteng with a proportional expenditure of 35% compared to 28.9% in Gauteng. It is worth noting that Gauteng's contribution has declined from 32.5% in 2020/21.

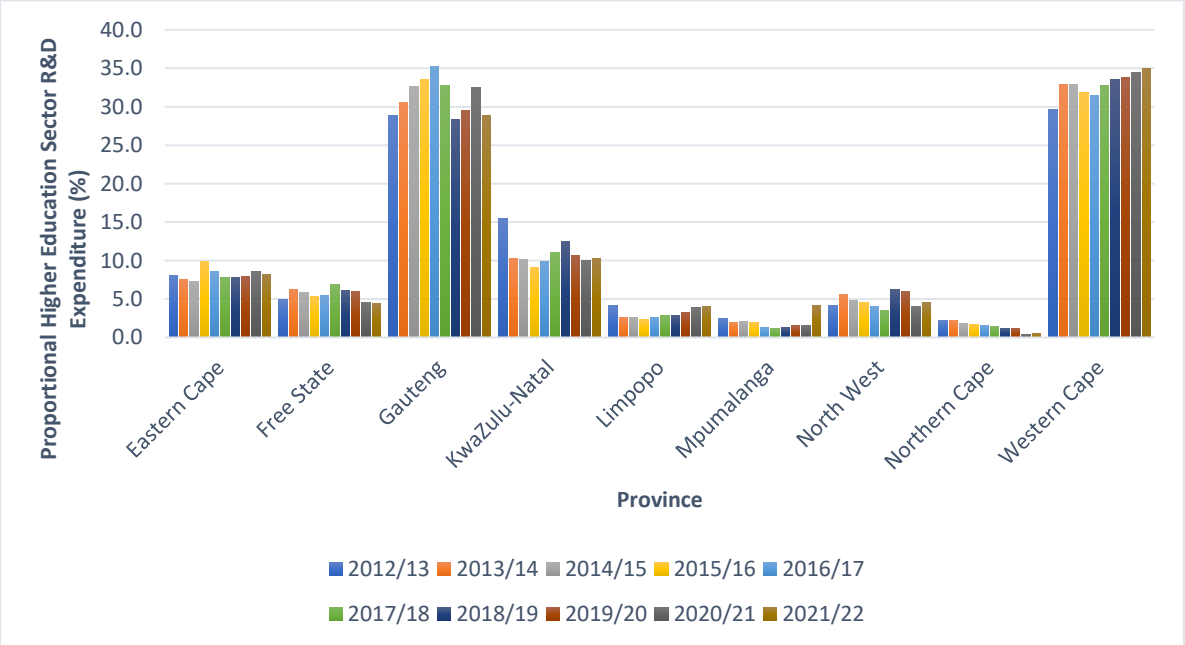


Figure 6.12: Proportional Higher Education Sector R&D Expenditure by Province
Source: HSRC and DSI's National Survey of Research and Experimental Development

6.3.3 Provincial bibliometrics

Comparisons and Discussion

This section provides summary of the information estimated for each province in the country.

Table 6.19 shows the number of publications produced by each province from 2013-2022. Gauteng produces 40% of the country's research. Western Cape and KwaZulu-Natal follow, contributing 25% and 11,5%, respectively. The three provinces together produce 76% of the country's research. Northern Cape and Mpumalanga make the smallest contributions to the country's scientific publications.

Table 6.19: Number of Publications per Province, 2013-2022

Province	Number of Publications	%
Eastern Cape	8 840	3.50
Free State	13 569	5.38
Gauteng	101 327	40.14
KwaZulu Natal	29 302	11.61
Limpopo	578	0.23
Mpumalanga	223	0.09
Northern Cape	107	0.04
North West	14 844	5.88
Western Cape	63 129	25.01
South Africa	252 427	100.00

Source: Estimated by QER from WoS

Table 6.20 shows the publication growth for each province during the ten years. KwaZulu-Natal showed the highest growth (160%) followed by Western Cape (137.58%). The Northern Cape also showed a large growth but from a very small initial position.

Table 6.20: Publication Growth per Province

Province	From (2013) – To (2022)	Growth (%)
Eastern Cape	459 to 1 047	128.10
Free State	688 to 1 393	102.47
Gauteng	5 544 to 10 714	93.25
KwaZulu Natal	1 444 to 3 759	160.32
Limpopo	37 to 68	83.78
Mpumalanga	13 to 24	84.62
Northern Cape	6 to 15	150.00
North West	836 to 1 536	83.73
Western Cape	3 523 to 8 370	137.58
South Africa	15 307 to 24 952	63.01

Source: Estimated by QER from WOS

Table 6.21 shows the scientific disciplines emphasised in each province.

Table 6.21: Areas of Research Emphasis per Province

Province	First Research Area	Second Research Area
Eastern Cape	Environmental Sciences Ecology (1 088)	Chemistry (628)
Free State	Chemistry (1 067)	Engineering (902)
Gauteng	Engineering (10 574)	Science Technology Other Topics (6 357)
KwaZulu Natal	Engineering (2 755)	Chemistry (2 623)
Limpopo	Environmental Sciences Ecology (74)	Agriculture (69)
Mpumalanga	Engineering (59)	Energy Fuels (38)
Northern Cape	Environmental Sciences Ecology (23)	Zoology (18)

North West	Environmental Sciences Ecology (1 351)	Chemistry (1 033)
Western Cape	Environmental Sciences Ecology (4 103)	Engineering (4 051)
South Africa	Engineering (21 763)	Environmental Sciences Ecology (17 841)

Source: Estimated by QER from WOS

It is noted that these are a number of publications as they are allocated to various categories. In South Africa, overall,, engineering and environmental sciences—ecology are the most prolific disciplines, producing 21 763 and 17 841 publications, respectively. These two disciplines appear in all provinces in the first or second position. Chemistry also appears in one of the two top categories in four provinces.

Table 6.22 shows the most prolific organisations producing the scientific research in each Province. It is noted that the identified organisations may be collaborating ones.

Table 6.22: Most Prolific Organisations

Province	Most Prolific Organisation	Second Prolific Organisation
Eastern Cape	Nelson Mandela University (5 295)	Rhodes University (1 479)
Free State	University of the Free State (11 379)	Central University of Technology (1 151)
Gauteng	University of the Witwatersrand (34 308)	University of Pretoria (26 045)
KwaZulu-Natal	University of KwaZulu-Natal (22 107)	Durban University of Technology (3 262)
Limpopo	University of Venda (252)	University of Limpopo (133)
Mpumalanga	Tshwane University of Technology (63)	University of Pretoria (30)
Northern Cape	University of Pretoria (27)	Stellenbosch University (20)
North West	North West University (14 079)	University of Pretoria (598)
Western Cape	University of Cape Town (29 335)	Stellenbosch University (23 840)
South Africa	University of Cape Town (40 623)	University of the Witwatersrand (35 477)

Source: Estimated by QER from WOS

Table 6.23 shows the main countries collaborating with the researchers of each Province. It is apparent that, with the exception of South African organisations that collaborate with each other, the USA is the country's main collaborator.

Table 6.23: Countries Collaborating with the Provincial Organisations

Province	Most Collaborating Country	Second Collaborating Country
Eastern Cape	South Africa (8 840)	USA (1 205)
Free State	South Africa (13 569)	USA (1 535)
Gauteng	South Africa (101 327)	USA (18 212)
KwaZulu-Natal	South Africa (29 302)	USA (6 554)
Limpopo	South Africa (578)	USA (73)
Mpumalanga	South Africa (223)	USA (25)
Northern Cape	South Africa (107)	England (36)
North West	South Africa (14 844)	USA (1 884)
Western Cape	South Africa (63 129)	USA (16 127)
South Africa	South Africa (252 427)	USA (44 810)

Source: Estimated by QER from WOS

Table CD6 shows the main funding organisations. The NRF is the main funding organisation in seven Provinces. The UK appears most of the time as the second funding organisation.

Table 6.24: Funding Organisations

Province	Most Funding Organisation	Second Funding Organisation
Eastern Cape	National Research Foundation (1 895)	UK Research Innovation (397)
Free State	National Research Foundation (2 540)	University of the Free State (515)
Gauteng	National Research Foundation (10 478)	UK Research Innovation (5 241)
KwaZulu-Natal	National Research Foundation (3 646)	UK Research Innovation (2 259)
Limpopo	National Research Foundation (120)	United States Department of Health Human Services (35)
Mpumalanga	National Research Foundation (20)	UK Research Innovation (9)
Northern Cape	European Research Council (20)	University Of Zurich (20)
North West	National Research Foundation (3 020)	UK Research Innovation (811)
Western Cape	UK Research Innovation (6 643)	National Research Foundation (5 845)
South Africa	National Research Foundation (44 569)	UK Research Innovation (13 794)

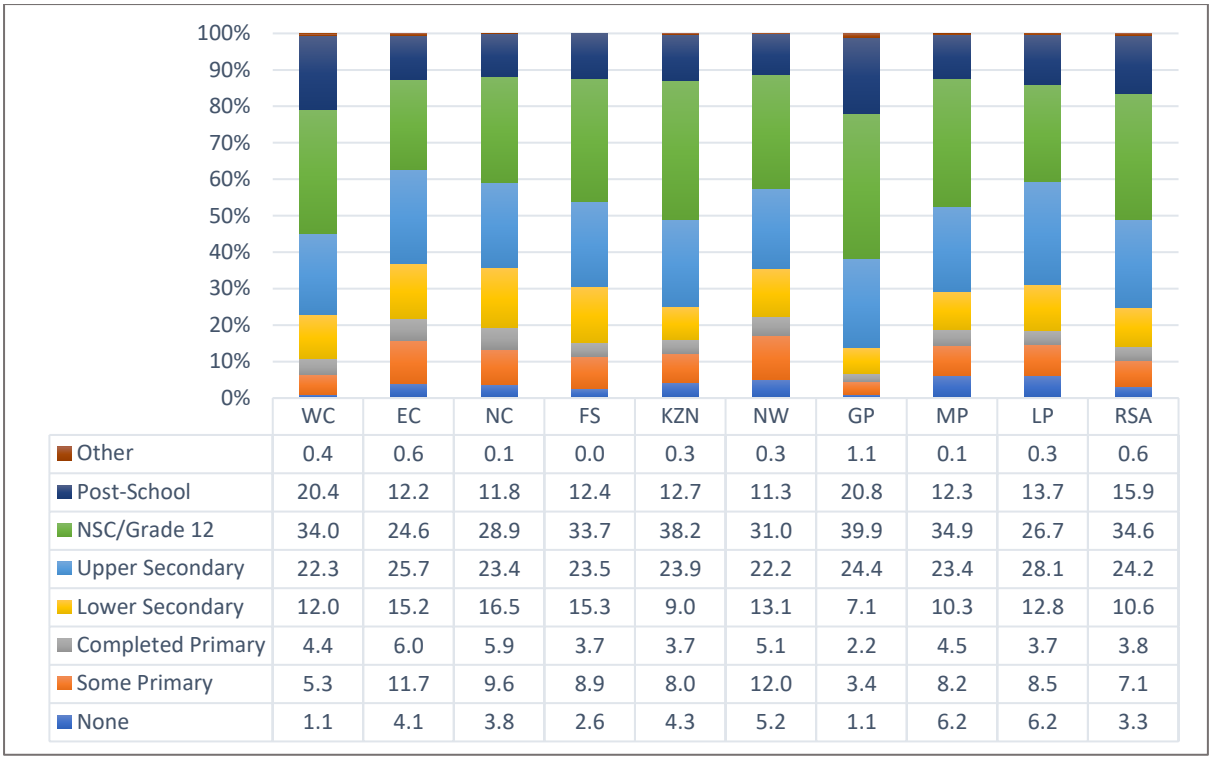
Source: Estimated by QER from WOS

It is apparent that universities are affecting the knowledge base of the various provinces. Similarly, knowledge production in the country is concentrated in three provinces. It may be important for the whole national innovation system to consider the enlargement and/or establishment of universities in the weak provinces.

6.3.4 Educational attainment

Educational attainment of the population is important in the knowledge economy. Countries and regions with high levels of human capital are measured by high educational attainment.

Figure 6.13 shows the percentage distribution of educational attainment for individuals aged 20 years and older by province. NSC/Grade 12 attainment remains below 50% in all the provinces.



	WC	EC	NC	FS	KZN	NW	GP	MP	LP	RSA
Other	0.4	0.6	0.1	0.0	0.3	0.3	1.1	0.1	0.3	0.6
Post-School	20.4	12.2	11.8	12.4	12.7	11.3	20.8	12.3	13.7	15.9
NSC/Grade 12	34.0	24.6	28.9	33.7	38.2	31.0	39.9	34.9	26.7	34.6
Upper Secondary	22.3	25.7	23.4	23.5	23.9	22.2	24.4	23.4	28.1	24.2
Lower Secondary	12.0	15.2	16.5	15.3	9.0	13.1	7.1	10.3	12.8	10.6
Completed Primary	4.4	6.0	5.9	3.7	3.7	5.1	2.2	4.5	3.7	3.8
Some Primary	5.3	11.7	9.6	8.9	8.0	12.0	3.4	8.2	8.5	7.1
None	1.1	4.1	3.8	2.6	4.3	5.2	1.1	6.2	6.2	3.3

Figure 6.13: Percentage Distribution of Educational Attainment for Individuals Aged 20 Years and Older by Province

Source: StatsSA "General Household Survey, 2022"

Gauteng province has the highest level of NSC/Grade 12 at 39.9%, followed by KZN (38.2%) and Western Cape (34%). The Eastern Cape, Limpopo and Northern Cape are the provinces with the lowest percentages of individuals who have attained NSC/Grade 12 level. Nationally, more than one-third (34.6%) of persons aged 20 years and older have attained Grade 12 as highest level of education while only 15.9% have attained some post-school qualifications. Post-school qualifications were most common in Gauteng (20.8%) and Western Cape (20.4%) and least common in North West (11.3%) and Northern Cape (11.8%).

6.3.5 Performance in Mathematics and Physical Science by province

This section presents the performance of the provinces in Mathematics and Physical sciences in NSC. As shown in **Table 6.25**, in 2023, the percentage of learners who achieved 50 and above remains very low, especially in the Eastern Cape, Mpumalanga and Limpopo. What is of concern is that the situation does not seem to be improving year-on-year. The Western Cape is the best performing province at 47% followed by Gauteng at 33.5%. However, there has been a slight improvement compared to the previous years. The national average of only 27.5% paints a disturbing picture.

Table 6.25: Performance in Mathematics by Province

	Mathematics											
	% achieved at 30% and above				% achieved at 40% and above				% achieved at 50% and above			
	2020	2021	2022	2023	2020	2021	2022	2023	2020	2021	2022	2023
Eastern Cape	39.7	46.6	46.1	57.4	23.6	28.0	28.1	37.1	13.6	16.0	16.0	21.8
Free State	66.3	66.6	64.6	69.9	42.7	42.8	41.1	46.9	25.2	25.0	24.6	29.2
Gauteng	65.4	68.2	62.7	69.1	45.9	48.3	44.4	49.8	30.5	31.7	28.9	33.5
KwaZulu-Natal	51.2	54.2	54.6	64.2	33.4	35.0	35.0	44.2	20.4	20.7	20.7	27.2
Limpopo	49.7	54.5	49.9	60.2	31.5	33.7	30.8	40.1	18.8	19.5	18.0	24.6
Mpumalanga	50.9	54.0	52.8	58.0	33.4	34.7	34.3	39.1	20.6	20.6	20.5	24.3
North West	63.4	71.5	59.9	66.7	42.1	47.7	37.9	44.4	25.7	28.5	22.3	26.8
Northern Cape	55.3	59.2	51.5	57.0	34.9	39.1	32.6	36.4	21.2	23.2	20.0	21.7
Western Cape	71.6	73.4	67.9	75.4	54.4	54.5	51.6	58.9	39.8	39.1	37.8	43.0
National	53.8	57.6	55.0	63.5	35.6	37.6	36.0	43.6	22.3	23.0	22.0	27.5

Source: Department of Basic Education, 2024

Table 6.26 shows trends in performance of learners in Physical Science. The performance in this subject is also very low especially when considering the percentage of learners who achieved 50% and above. The national average is only 31.2% and his improved marginally from 30.4 in 2022. The best performing province is the Western Cape and has improved to 46.6% compared to the previous year (45%) is by far the best performing provinces (45.2%). The Northern Cape, Mpumalanga and the Eastern Cape have the lowest performances.

Table 6.26: Performance in Physical Science by Province

	Physical Science											
	% achieved at 30% and above				% achieved at 40% and above				% achieved at 50% and above			
	2020	2021	2022	2023	2020	2021	2022	2023	2020	2021	2022	2023
Eastern Cape	55.6	62.3	70.5	75	32.3	37.4	43.9	48.2	18.2	21.2	24.8	27.7
Free State	71.2	75.1	80.6	80.2	45.0	48.1	53.7	52.5	26.2	28.9	32.0	31.4
Gauteng	72.6	73.5	76.7	77.9	50.2	51.0	53.3	54.8	33.5	34.1	34.9	36
KwaZulu-Natal	69.7	71.2	77.3	77.8	46.0	47.0	53.1	53.3	28.2	28.3	32.2	32.1
Limpopo	63.0	67.8	73.3	77.1	38.3	41.6	46.1	49.5	22.4	23.8	26.9	28.5
Mpumalanga	60.0	61.5	68.1	68.4	37.9	38.5	45.6	44.7	22.9	22.6	27.7	27.1
North West	68.5	77.5	77.3	76.4	42.2	50.4	49.2	48.2	25.5	29.4	28.6	28.4
Northern Cape	53.4	65.2	69.5	67.2	32.0	42.4	42.2	40.1	20.2	24.1	25.1	23.3
Western Cape	76.2	78.3	81.1	82.2	57.5	59.7	61.4	63.2	42.9	44.5	45.2	46.6
National	65.8	69.0	74.6	76.2	42.4	44.8	49.7	51.1	26.3	27.3	30.4	31.2

Source: Department of Basic Education, 2024

6.3.6 Access to information and communication technology

Access to ICT is important for information sharing, making it easier for people to interact and make workers more productive creates and is widely known to contribute to economic development.

Table 6.27 shows that household access to the Internet is very low across all the provinces. Household access was highest in Western Cape (34.7%) and Gauteng (18.6%) and lowest in Limpopo (3.4%) and Mpumalanga (3.9%). While 21.4% of households in metropolitan areas had access to the Internet at home, it was only 1.6% of rural households. What is of concern is that rural household has access of less than 1% in Eastern Cape (0.5%) and North West (0.5%). A large percentage of households accessed the Internet at work (12.9%), Internet cafés or at educational institutions (10.8%) and at home (13.0%). Households in Western Cape (19.8%) and Gauteng (19.3%) were most likely to access the Internet at work, while only 4.8% of households in Limpopo did so.

As shown in the table, mobile access to the Internet has made it much more accessible to households in rural areas.

Table 6.27: Percentage Distribution of Households with Access to the Internet by Province and type of internet access, 2022

Type of internet access	WC	EC	NC	FS	KZN	NW	GP	MP	LP	RSA
Mobile	68.5	63.6	66.1	68.2	74.6	65.7	71.5	76.2	60.8	69.6
Fixed internet at home	34.7	6.6	8.4	6.2	8.3	3.5	18.6	3.9	3.4	13.0
Internet at work	19.8	9.8	10.9	8.6	11.6	6.2	19.3	5.0	4.8	12.6
Public WIFI	13.4	4.2	9.4	5.1	6.8	6.2	11.5	5.5	1.6	8.0
Internet café	7	2.8	1.2	3.2	1.6	2	12.3	3.7	1.3	5.8
At educational facility	9	4.7	1.6	4.8	4.1	3.0	6.8	1.2	1.4	5.0
At library	4.3	1.0	1.3	2.6	3.1	1.4	4.5	0.5	0.6	2.5
Any kind of access	84.6	66.9	68.5	72.6	75.9	67.8	80.0	78.8	62.2	75.3

Source: StatsSA "General Household Survey, 2022"

Nationally, Internet access using mobile devices (69.6%) was the most common form of access to the Internet.

6.3.7 Government innovation support organisations

To support innovation throughout the country, the government has invested in innovation support organisations in various provinces. These organisations are intermediary organisations that provide innovation infrastructure and support services, especially to small medium and micro enterprises (SMMEs) and previously marginalised communities. As shown in **Table 6.28**, there is a broad range of these organisations, including technology stations, living labs and fabrication labs. The table illustrates the geographic distribution of these instruments.

Table 6.28: Type and Geographic Distribution of Innovation Support Organisations

	Eastern Cape	Free State	Gauteng	KwaZulu Natal	Limpopo	Mpumalanga	Northern Cape	North West	Western Cape	Total
Technology Stations	3	2	5	2	1	0	0	0	3	16
Science Parks	1	1	1		0	0	0		1	4
Fab Labs	2	1	2		1		1	1	1	9
Living Labs	2	1	0	3	0	0	1	2	1	11
Ekasi Labs			10							10
Innovation -Colab				1	1				1	3
University based incubators	2	2	4	1					2	10
MLab				1						1

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

SEDA implements the incubator programme which is the largest innovation support programme with a broad national foot print. According to SEDA annual reports, in total there are 110 incubators but information on their geographic distribution was not made available.

The Gauteng province established the eKasi Labs programme implemented by the Innovation Hub, the provincial science centre. The programme is an extension of The Innovation Hub's service offering. It is a micro innovation hub facility spread across the five economic corridors in Gauteng where we foster and cultivate a culture of innovation and entrepreneurship in townships. The facilities are located in Mohlakeng, Sebokeng, Garankuwa, Soweto, Tembisa, Alexandra, Mamelodi, Kagiso, Kathorus and Mabopane.

During 2019 and early 2020, Innovate Durban established the first township innovation centre, known as The Innovation Co-Lab, in Cato Manor. The Innovation Co-Lab aims to provide access to innovation-related tools, information and resources. It's designed to empower people to become more innovative in problem-solving, create opportunities for new businesses, create jobs, and tackle social issues in their community

South African Universities are establishing a variety of university-based technology support incubators and accelerators. Most notable examples (though not exhaustive) of these are Stellenbosch University's LaunchLab, Wits University's Tshimologong, the Nelson Mandela University's Propella Business Incubator and the University of Pretoria's Tuksnovation. One of the key functions of the UBIs is to promote technological transfer and commercialisation and promote entrepreneurship.

6.3.8 Employment in high-, medium- and low-technology industries

Provincial innovation systems are expected to contribute to socio-economic outcomes such as economic development and job creation. As mentioned earlier, one of the key objectives of the provincial innovation strategies is to improve competitiveness. It is assumed that competitive firms will grow, increase market share and in turn provide employment. This section compares employment in the low-, medium- and high-technology in manufacturing sectors at provincial level. The industrial sectors are classified according the OECD (2011) classification as shown in **Table 6.29**.

For the purpose of this report, the medium low-tech and medium high-tech industries have been combined.

Table 6.29: OECD Classification of Sectors by Technology Intensiveness

High-technology industries	**Medium-high-technology industries**
Aircraft and spacecraft	Electrical machinery and apparatus, n.e.c.
Pharmaceuticals	Motor vehicles, trailers and semi-trailers
Office, accounting and computing machinery	Chemicals excluding pharmaceuticals
Radio, TV and communications equipment	Railroad equipment and transport equipment, n.e.c.
Medical, precision and optical instruments	Machinery and equipment, n.e.c.
Medium-low-technology industries	**Low-technology industries**
Building and repairing of ships and boats	Manufacturing, n.e.c.; Recycling
Rubber and plastics products	Wood, pulp, paper, paper products, printing and publishing
Coke, refined petroleum products and nuclear fuel	Food products, beverages and tobacco
Other non-metallic mineral products	Textiles, textile products, leather and footwear
Basic metals and fabricated metal products	

Source: OECD, 2011

n.e.c – "not elsewhere classified"

Employment in High Tech Manufacturing Industries

The share of employment in high technology manufacturing sectors is an indicator of the manufacturing economy that is based on continual innovation through creative, inventive activity. High-tech sectors and enterprises are key drivers of economic growth and productivity, and generally provide high value-added and well-paid employment.

Figure 6.14 illustrates the trends in employment in high technology industrial sector between 2013 and 2022. The figure shows that employment patterns in high technology sectors have not changed significantly at provincial level including in provinces which have

higher research and development expenditures. Gauteng has the highest levels of employment followed by Western Cape.

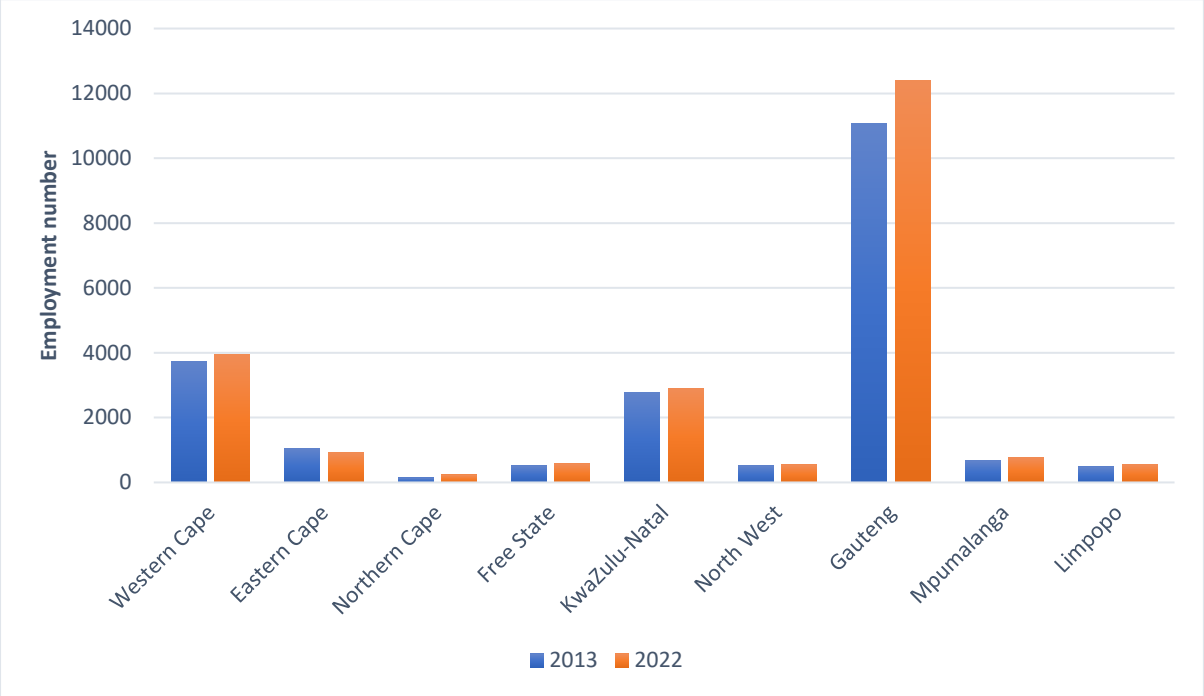


Figure 6.14: Employment in High Tech Manufacturing at Provincial Level

Source Quantec

Employment in Medium-Tech Manufacturing Industries

As shown in **Figure 6.15**, employment in medium technology industries is high compared to the high-tech industries.

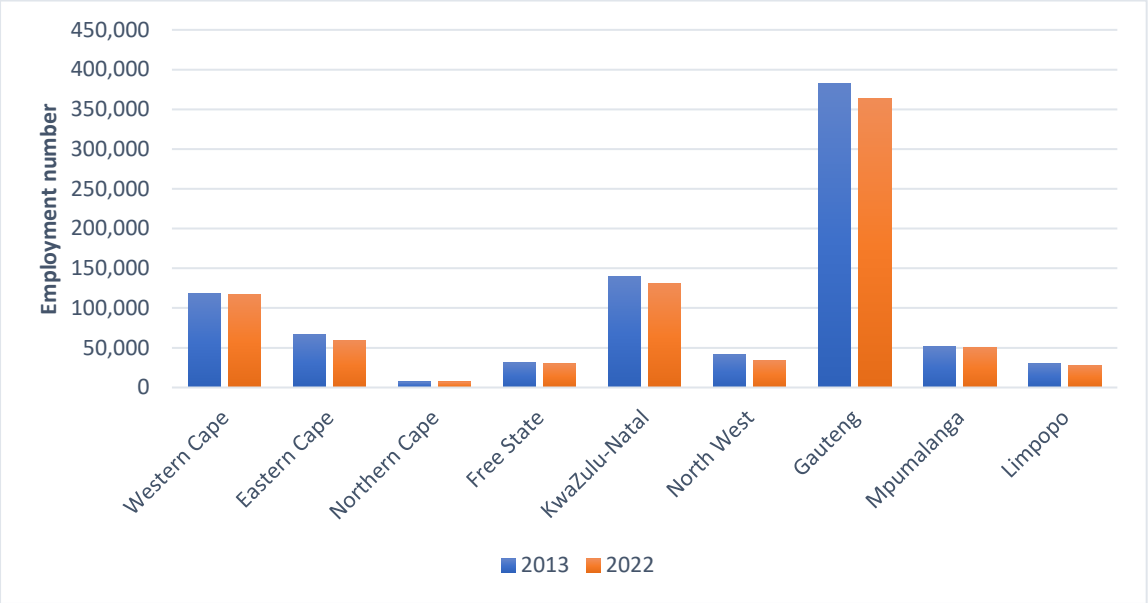


Figure 6.15: Employment in Medium Tech Manufacturing Sectors

Source: Quantec

Gauteng has the highest employment followed by KwaZulu-Natal and Western Cape. What is of concern is the decline in employment in these provinces.

Employment in Low Technology Manufacturing Sectors

As shown in **Figure 6.16**, compared to 2013, employment in low tech industries has either declined or remained the same in all the provinces in 2022. The provinces with the highest employment are Gauteng, KwaZulu-Natal and Western Cape. The provinces which have shown significant declines are KwaZulu-Natal and Western Cape.

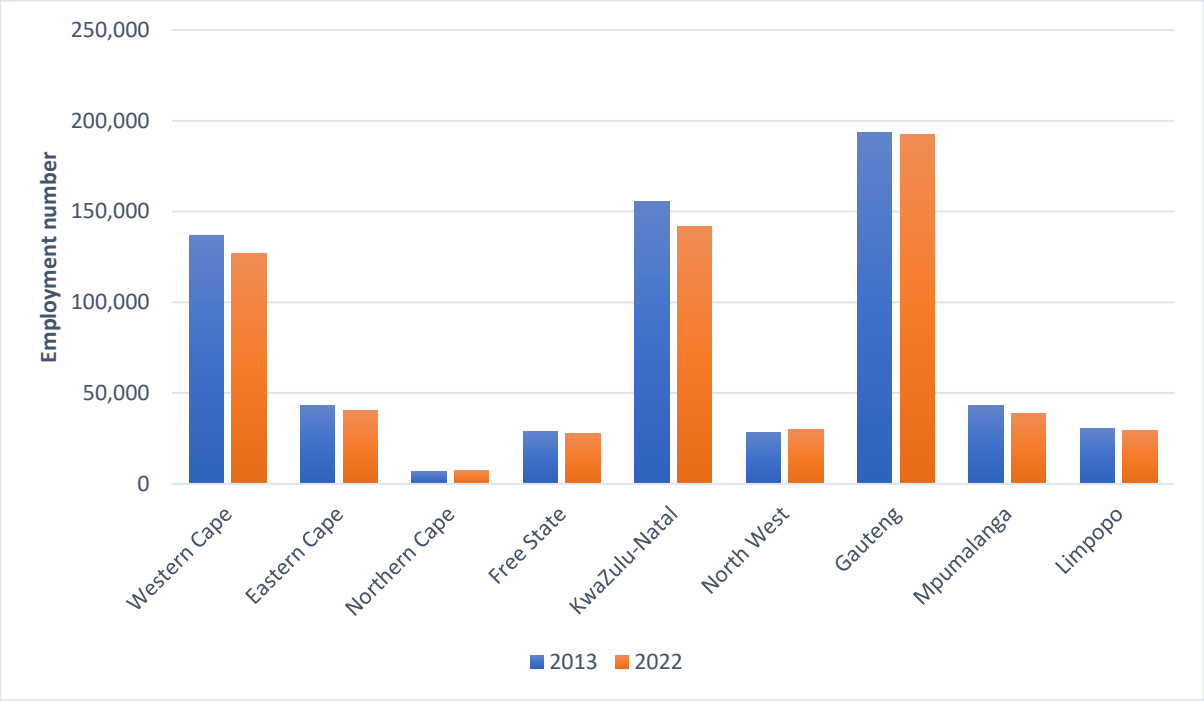


Figure 6.16: Employment in Low Tech Manufacturing Sectors
Source: Quantec

To summarise, employment in high technology manufacturing industries in all the provinces continues to remain very low. Whilst the high tech and low tech are the main employers, between 2013 and 2022 employment is stagnant or is declining.

ANNEXURE A: DISAGGREGATION OF RESEARCH COLLABORATION DATA

A.1. RESEARCH COLLABORATION BY SCIENTIFIC DOMAIN

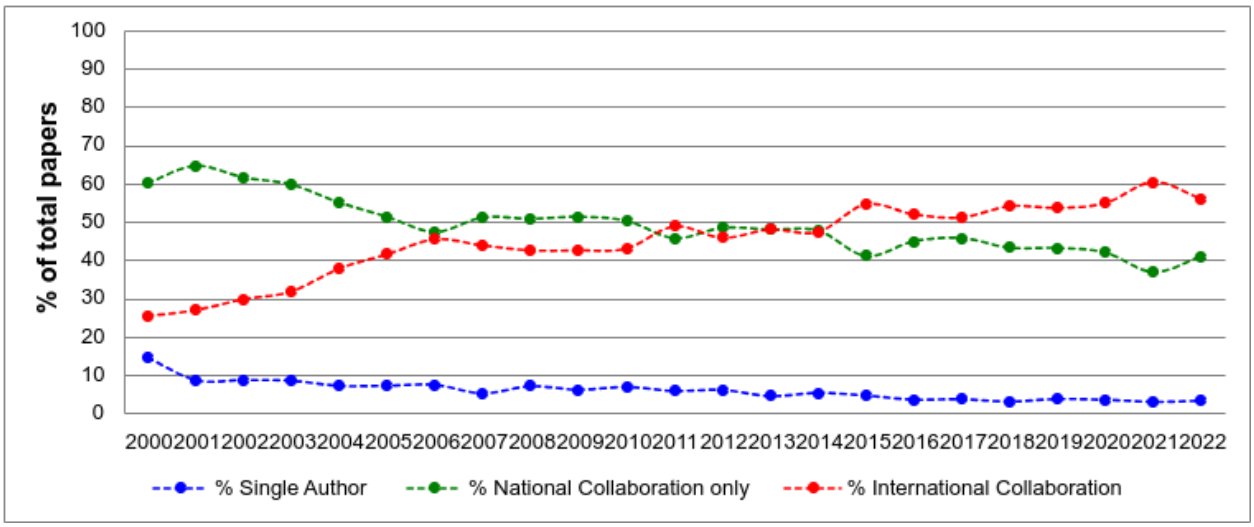


Figure A1: South African Publication Collaboration Profiles in Agricultural Sciences

Source: CREST, Stellenbosch University

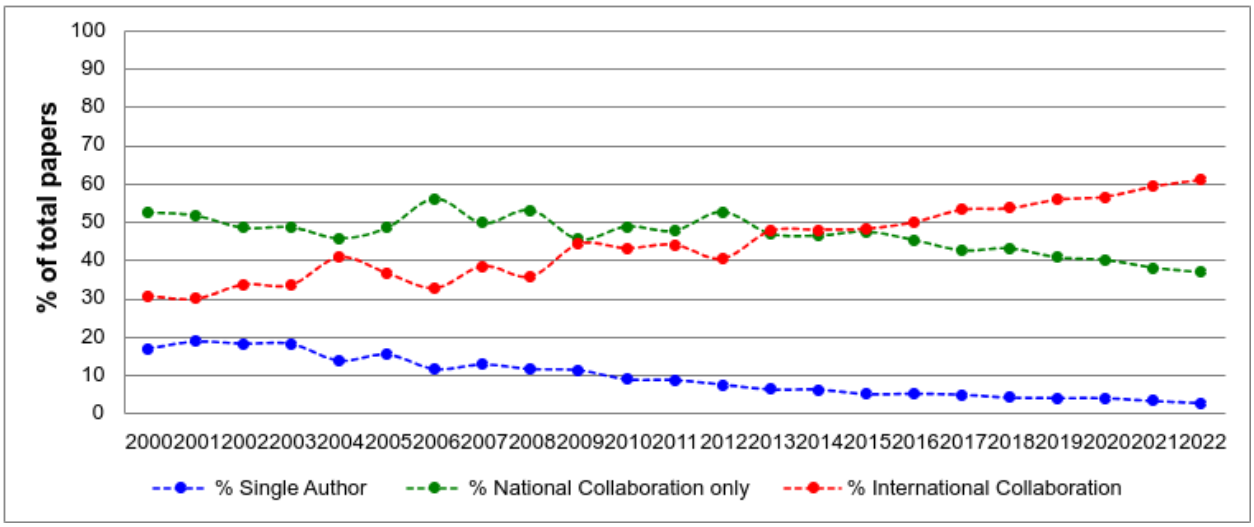


Figure A2: South African Publication Collaboration Profiles in Engineering

Source: CREST, Stellenbosch University.

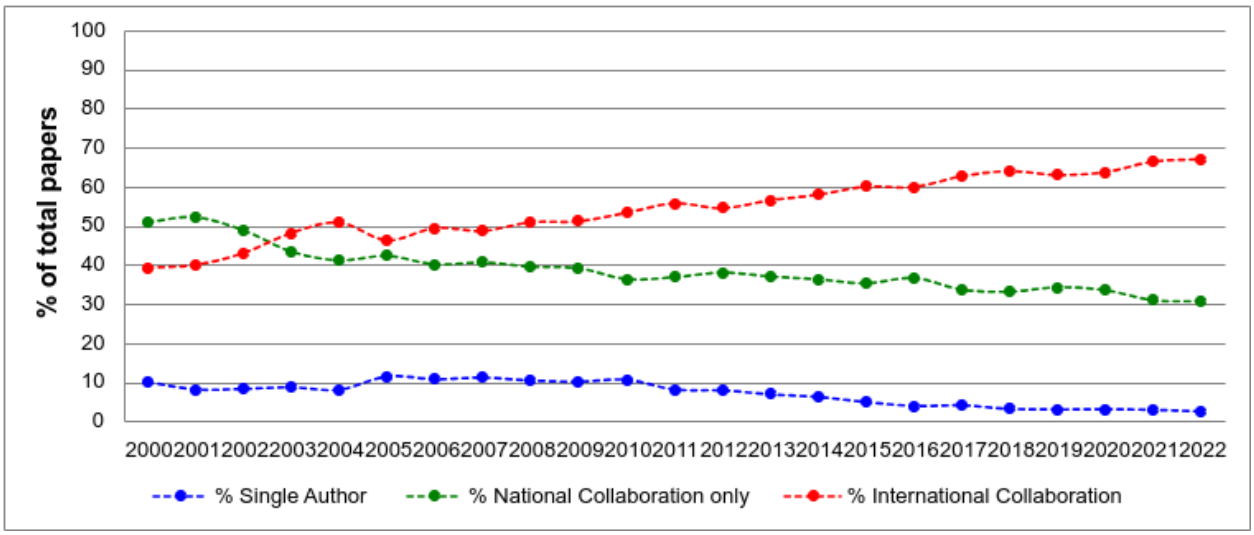


Figure A3: South African Publication Collaboration Profiles in Health Sciences

Source: CREST, Stellenbosch University

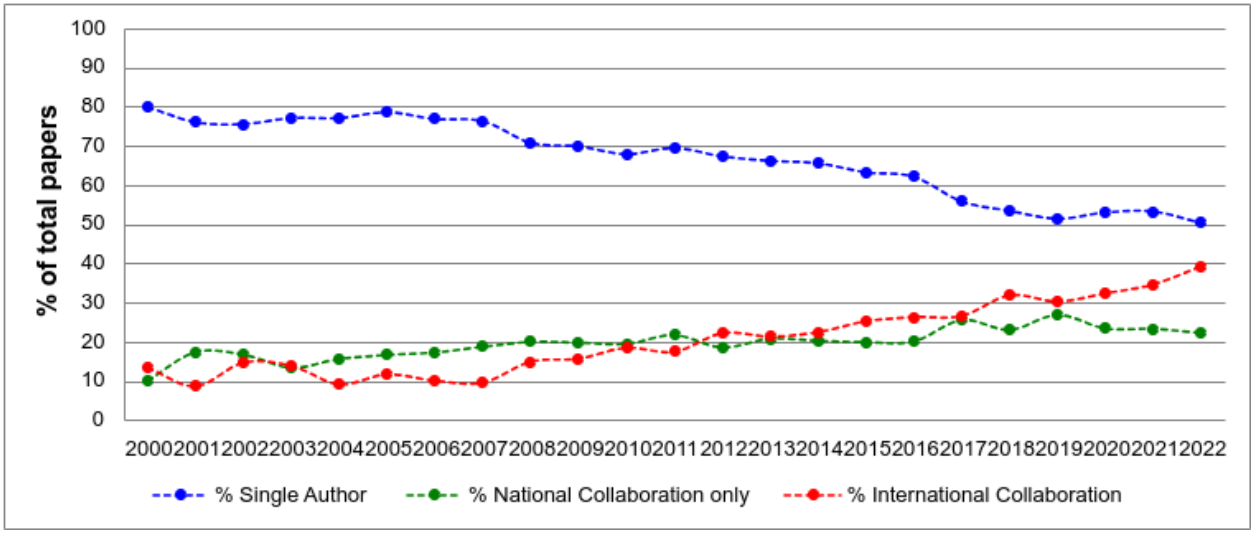


Figure A4: South African Publication Collaboration Profiles in Humanities and Art

Source: CREST, Stellenbosch University

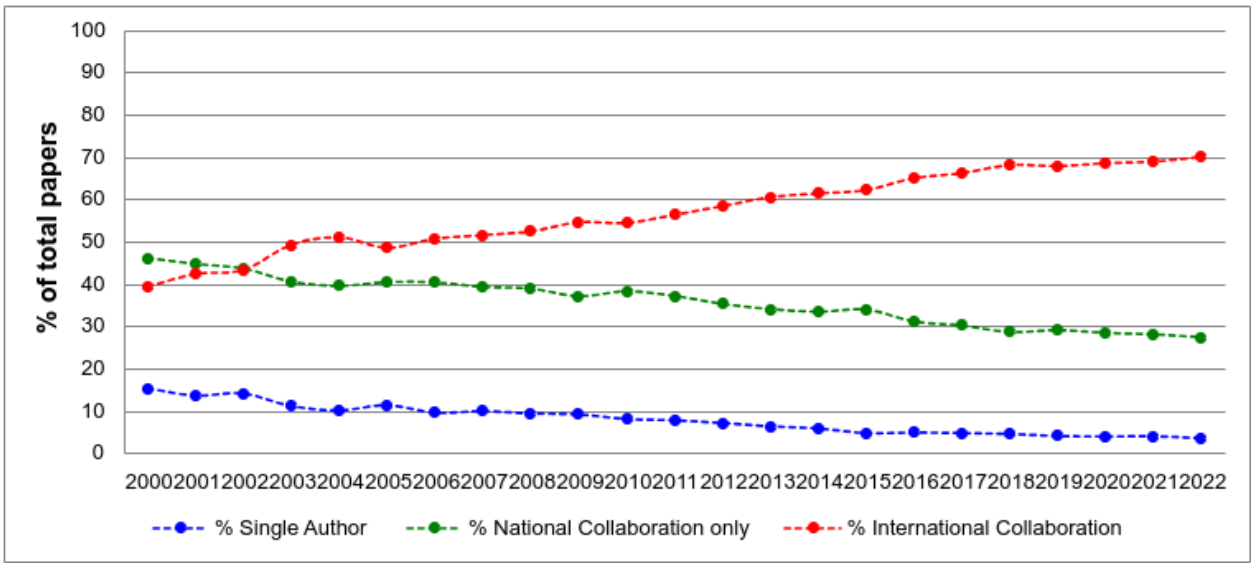


Figure A5: South African Publication Collaboration Profiles in Natural Sciences

Source: CREST, Stellenbosch University

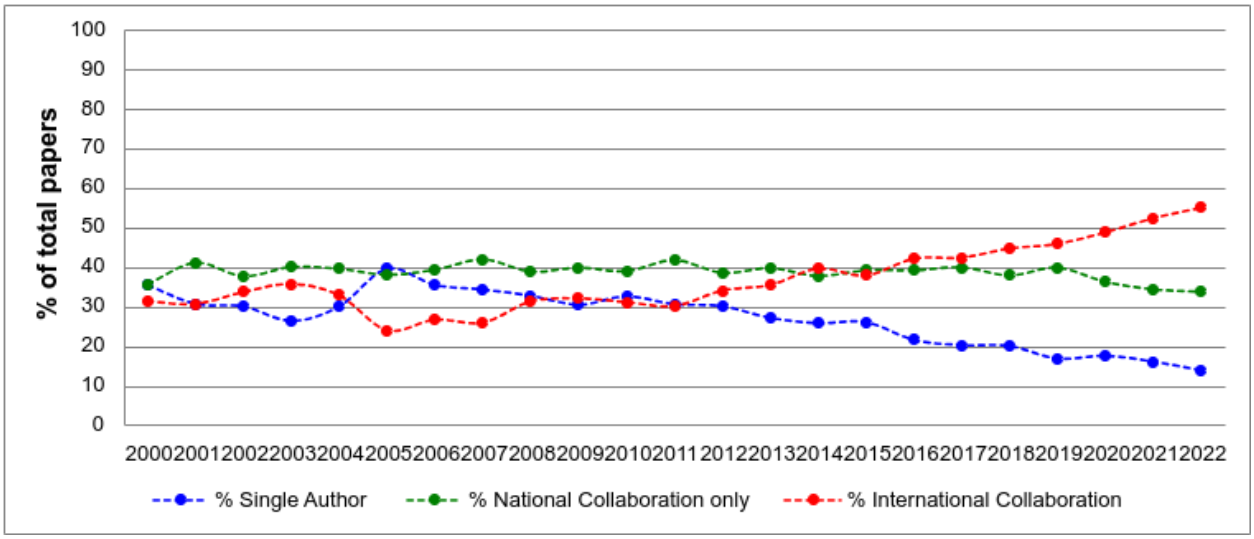


Figure A6: South African Publication Collaboration Profiles in Social Sciences

Source: CREST, Stellenbosch University

A.2. TRENDS IN RESEARCH COLLABORATION BY CITATION IMPACT AND SCIENTIFIC DOMAIN

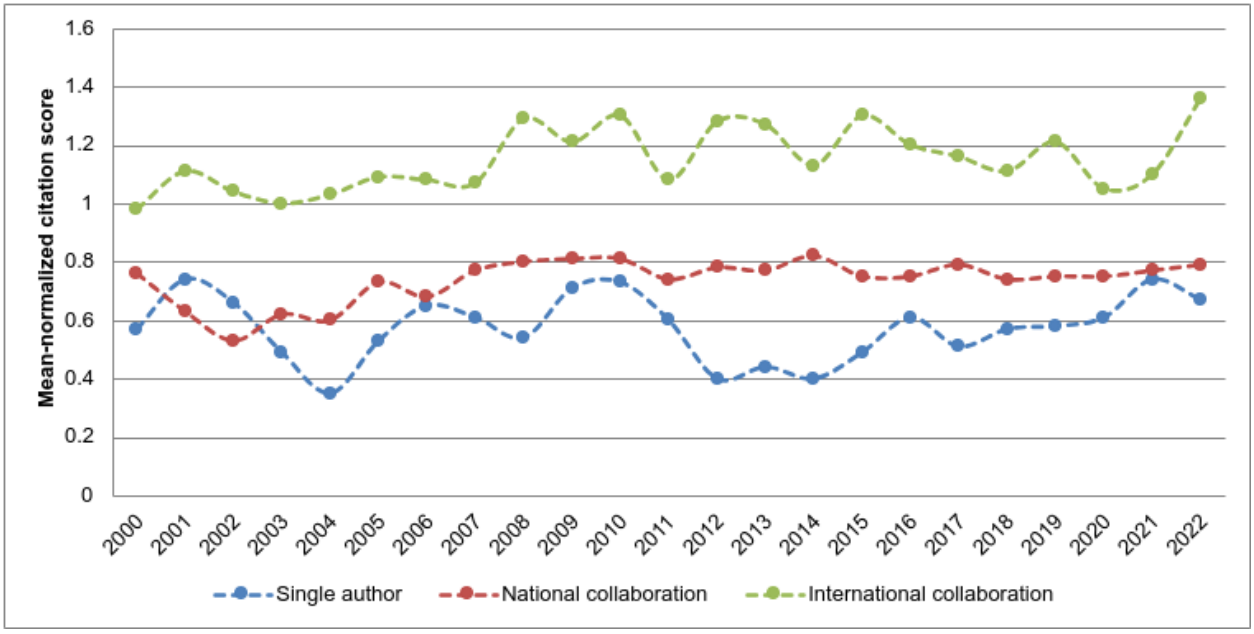


Figure A7: Citation impact by collaboration type in Agricultural Sciences

Source: CREST, Stellenbosch University

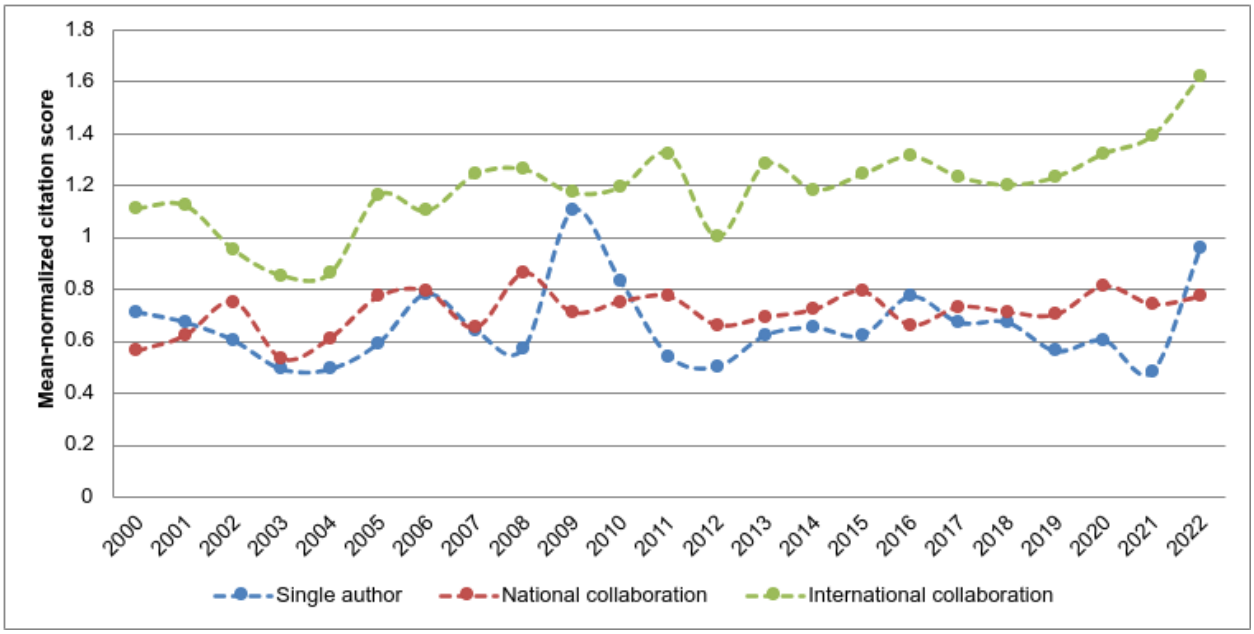


Figure A8: Citation Impact by Collaboration Type in Engineering

Source: CREST, Stellenbosch University

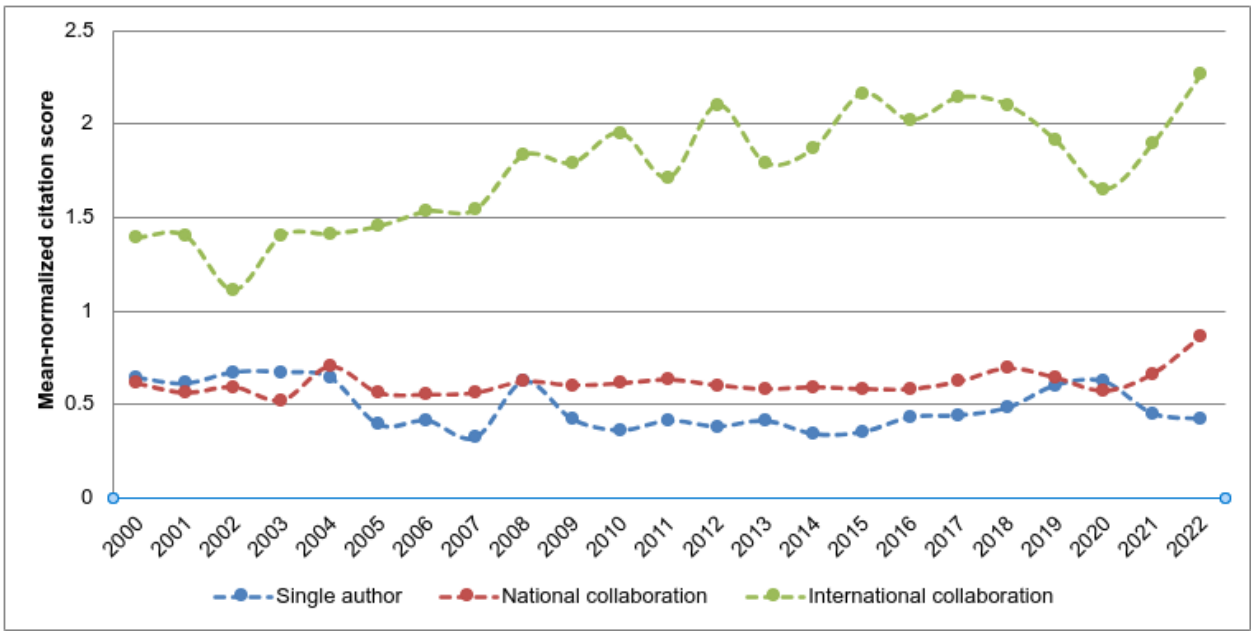


Figure A9: Citation Impact by Collaboration Type in Health Sciences

Source: CREST, Stellenbosch University

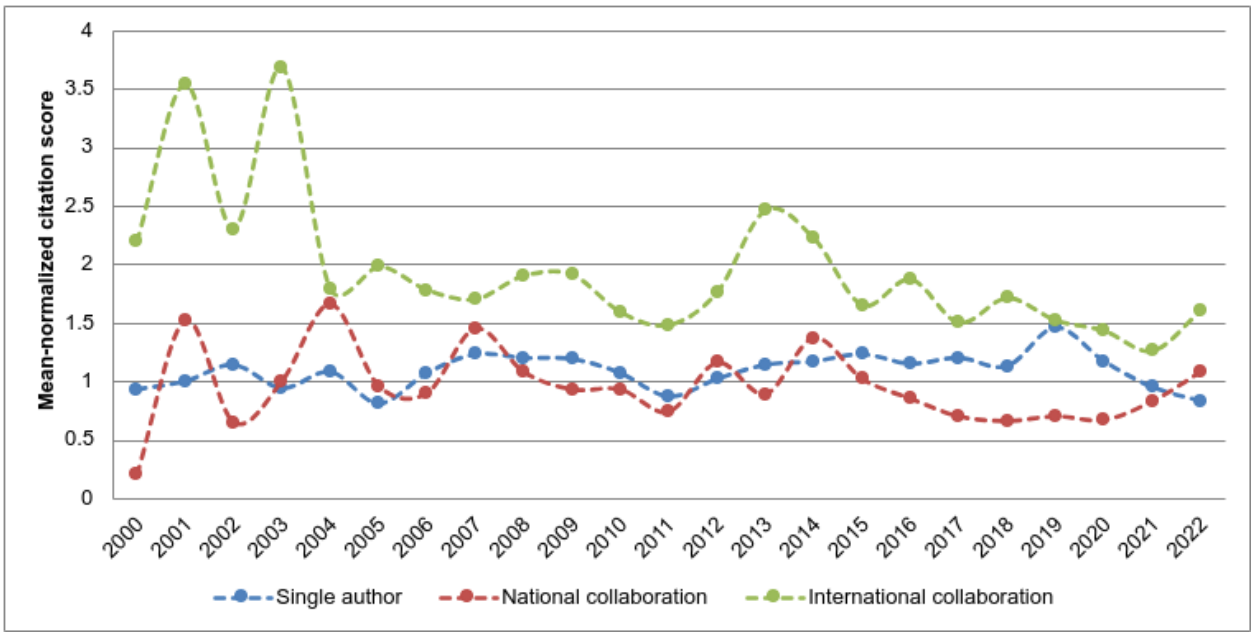


Figure A10: Citation Impact by Collaboration Type in Humanities and Art

Source: CREST, Stellenbosch University

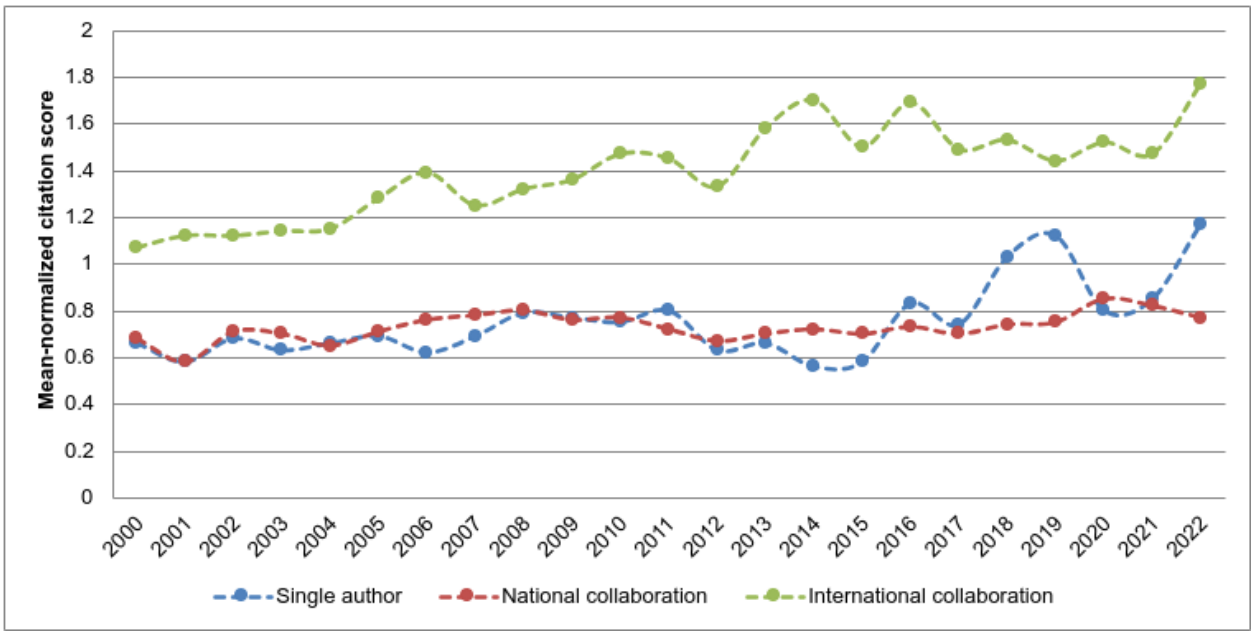


Figure A11: Citation Impact by Collaboration Type in Natural Sciences

Source: CREST, Stellenbosch University

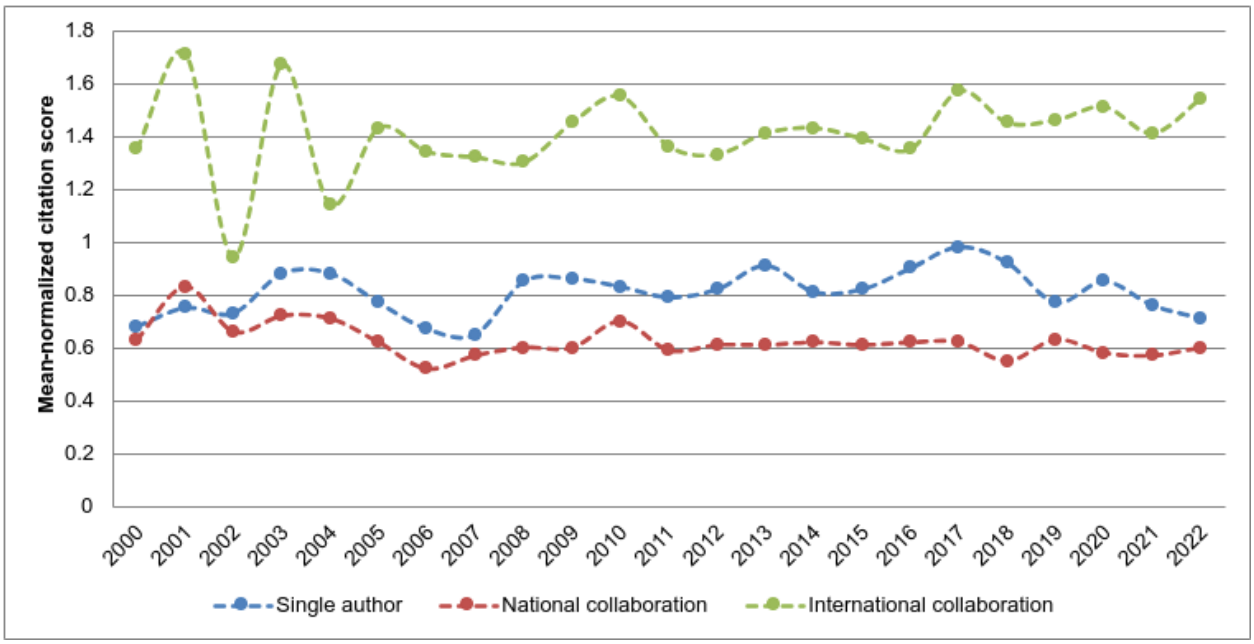


Figure A12: Citation Impact by Collaboration Type in Social Sciences

Source: CREST, Stellenbosch University

ANNEXURE B: TOP CITATION PERCENTILES FOR MAIN SCIENTIFIC FIELDS

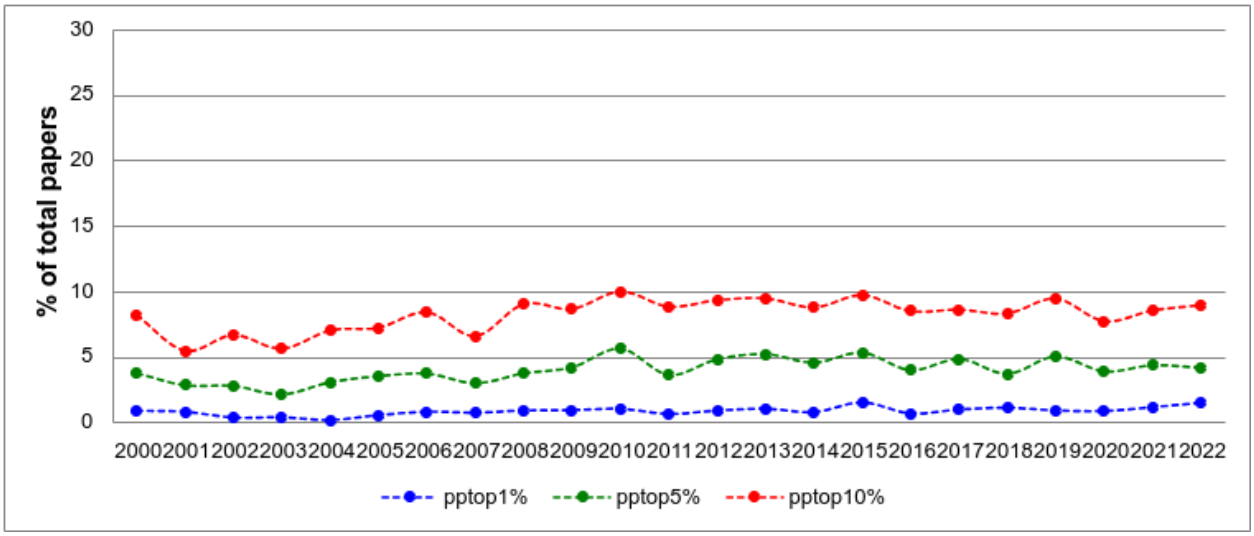


Figure B1: Proportion of South African Publications in the Agricultural Sciences in the Top Citation Percentile Intervals

Source: CREST, Stellenbosch University

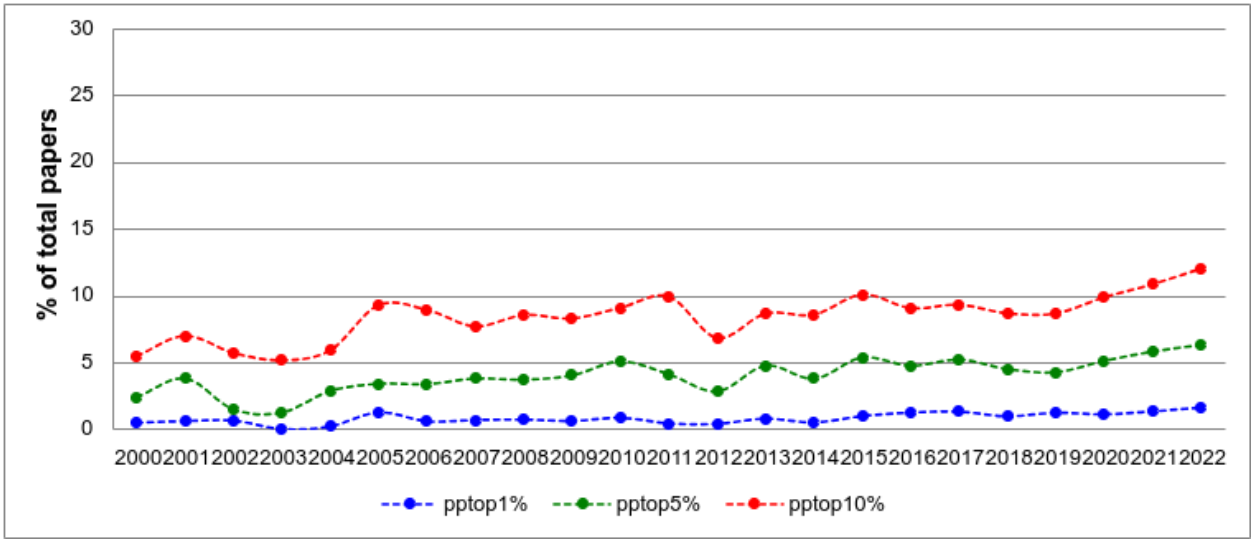


Figure B2: Proportion of South African Publications in the Engineering in the Top Citation Percentile Intervals

Source: CREST, Stellenbosch University

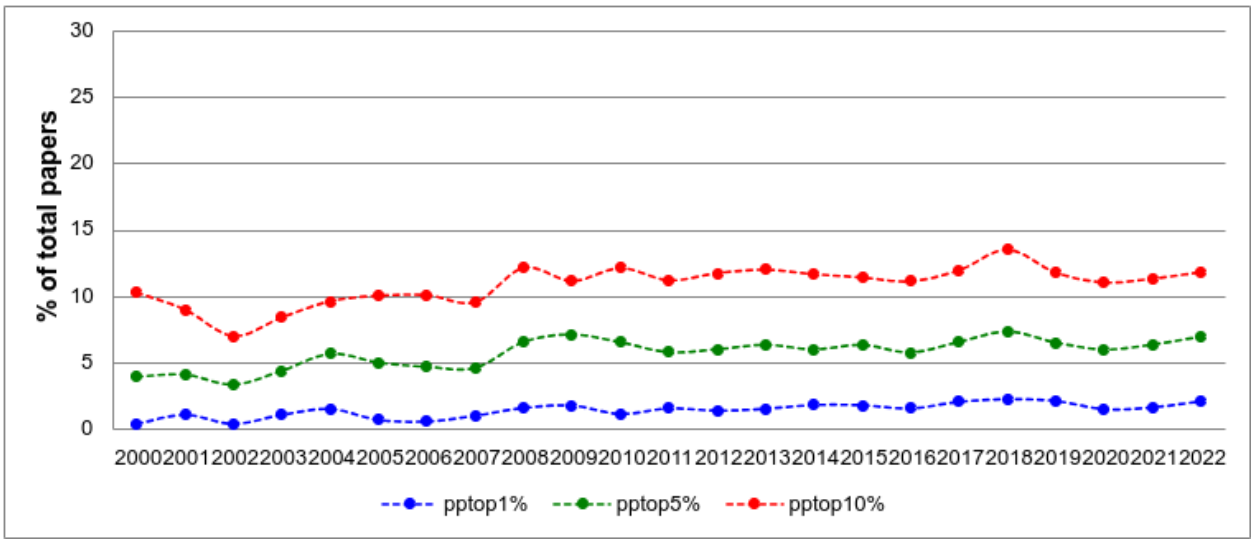


Figure B3: Proportion of South African Publications in the Health Sciences in the Top Citation Percentile Intervals

Source: CREST, Stellenbosch University

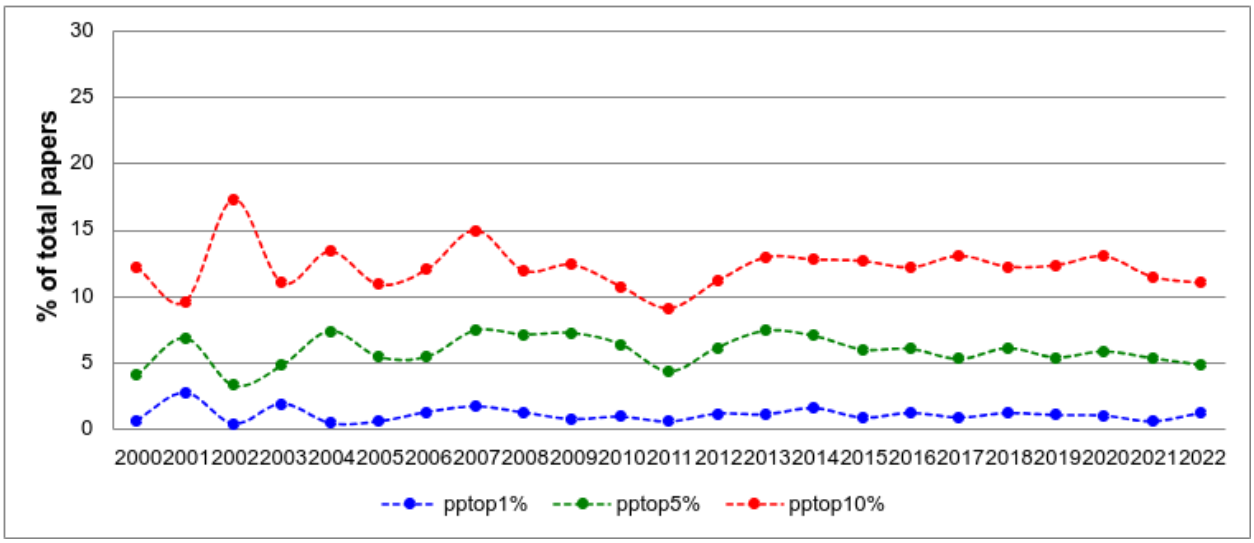


Figure B4: Proportion of South African Publications in the Humanities and Art in the Top Citation Percentile Intervals

Source: CREST, Stellenbosch University

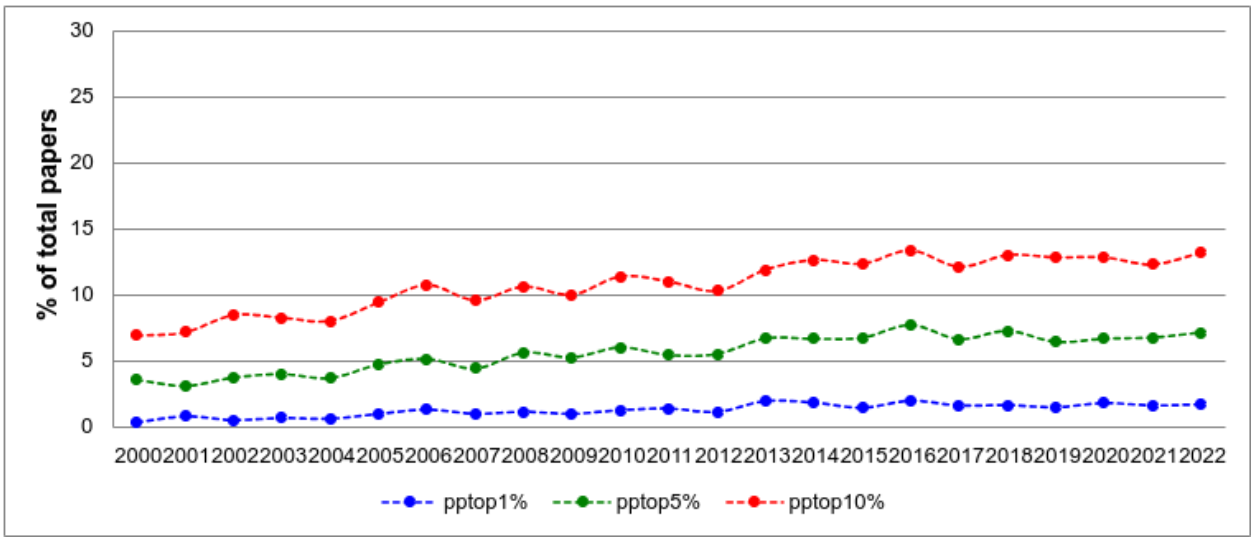


Figure B5: Proportion of South African Publications in the Natural Sciences in the Top Citation Percentile Intervals

Source: CREST, Stellenbosch University

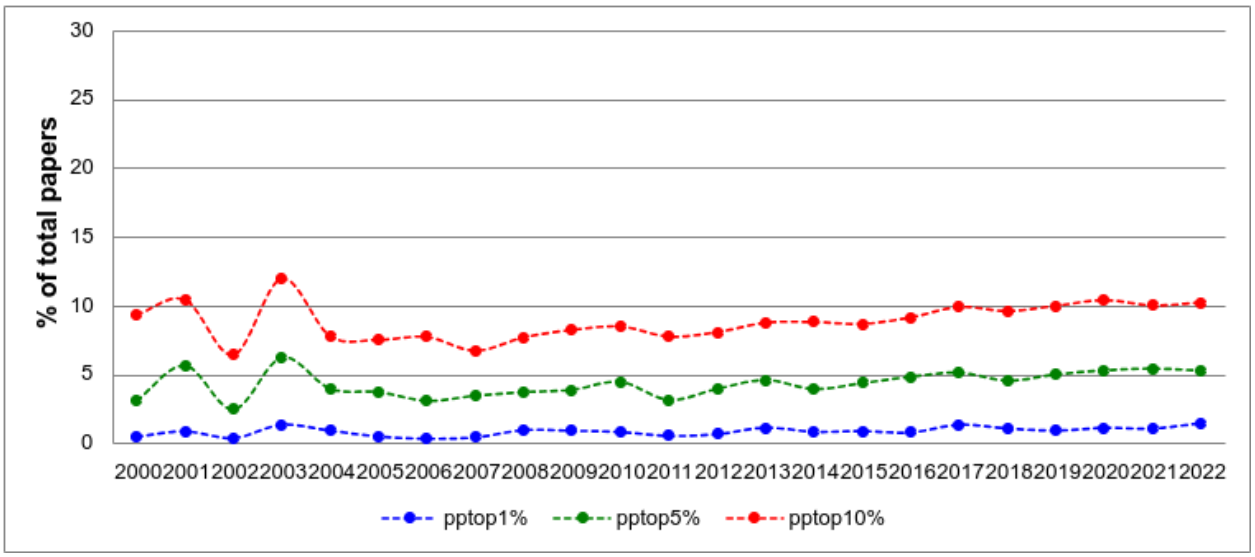


Figure B6: Proportion of South African Publications in the Social Sciences in the Top Citation Percentile Intervals

Source: CREST, Stellenbosch University

ANNEXURE C: DISTRIBUTION OF PUBLICATIONS BY JOURNAL QUARTILES

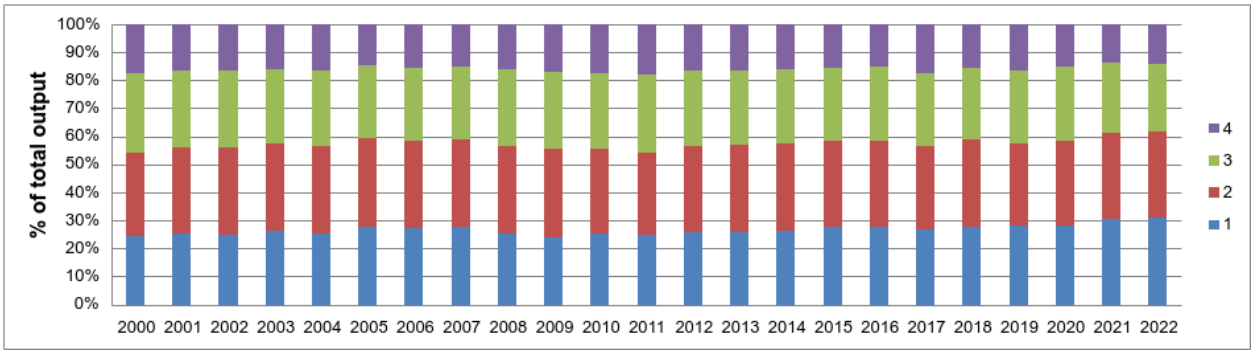


Figure C1: Distribution of South African Publications in Agricultural Sciences by Journal Quartiles

Source: CREST, Stellenbosch University

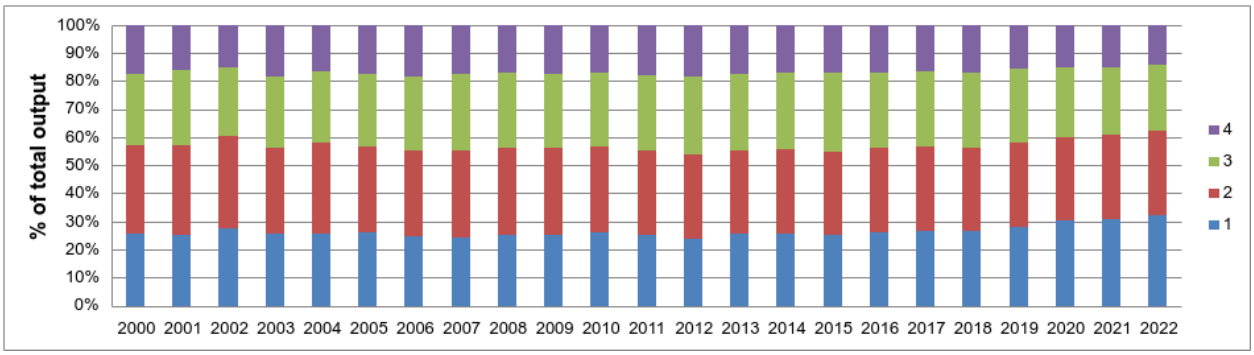


Figure C2: Distribution of South African Publications in Engineering by Journal Quartiles

Source: CREST, Stellenbosch University

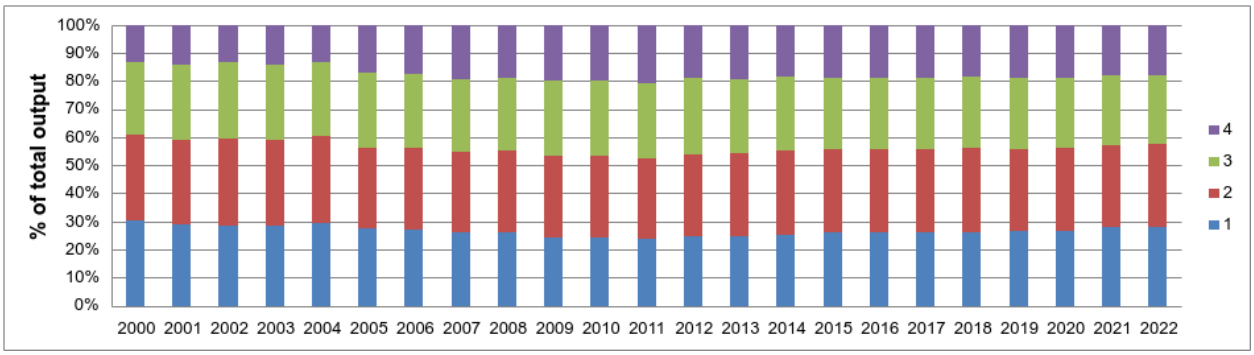


Figure C3: Distribution of South African Publications in Health Sciences by Journal Quartiles

Source: CREST, Stellenbosch University

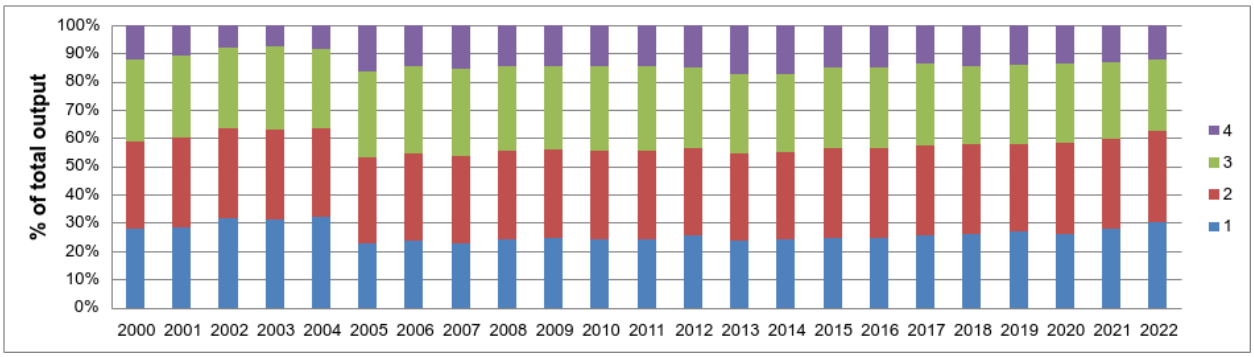


Figure C4: Distribution of South African Publications in humanities and arts by Journal Quartiles

Source: CREST, Stellenbosch University

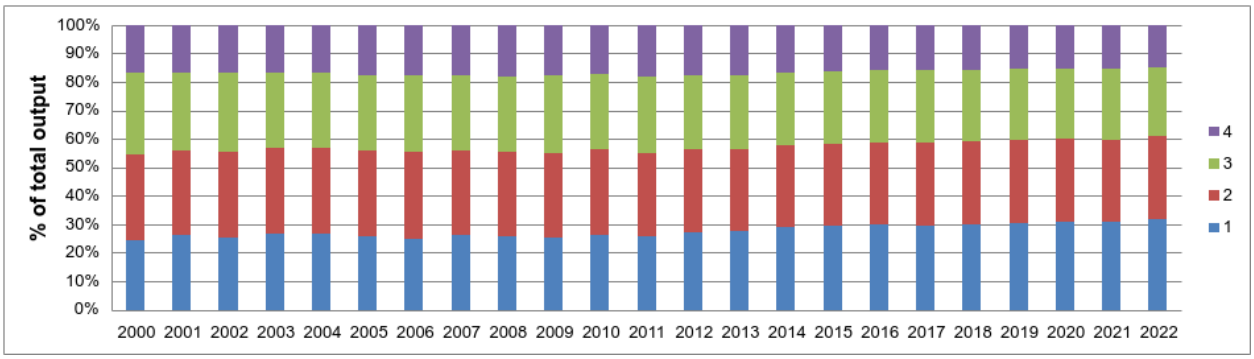


Figure C5: Distribution of South African Publications in Natural Sciences by Journal Quartiles

Source: CREST, Stellenbosch University

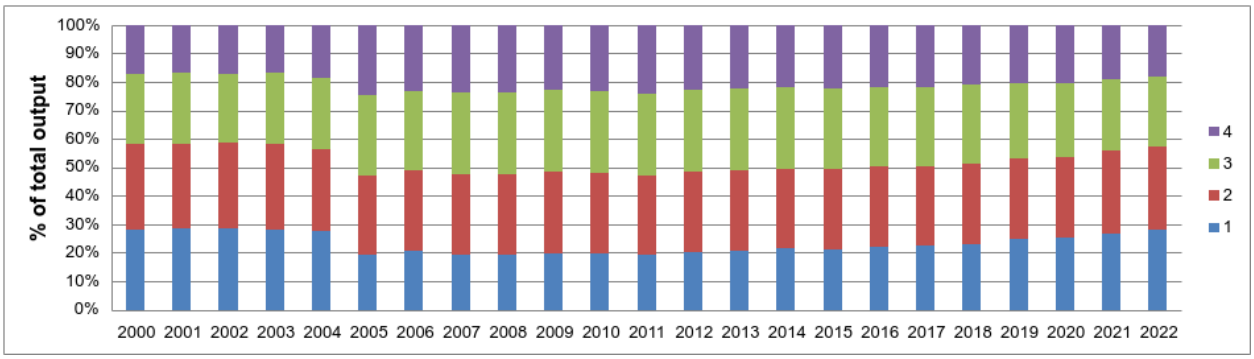


Figure C6: Distribution of South African Publications in Social Sciences by Journal Quartiles

Source: CREST, Stellenbosch University

ANNEXURE D: MEAN NORMALISED CITATION IMPACT BY FIELD

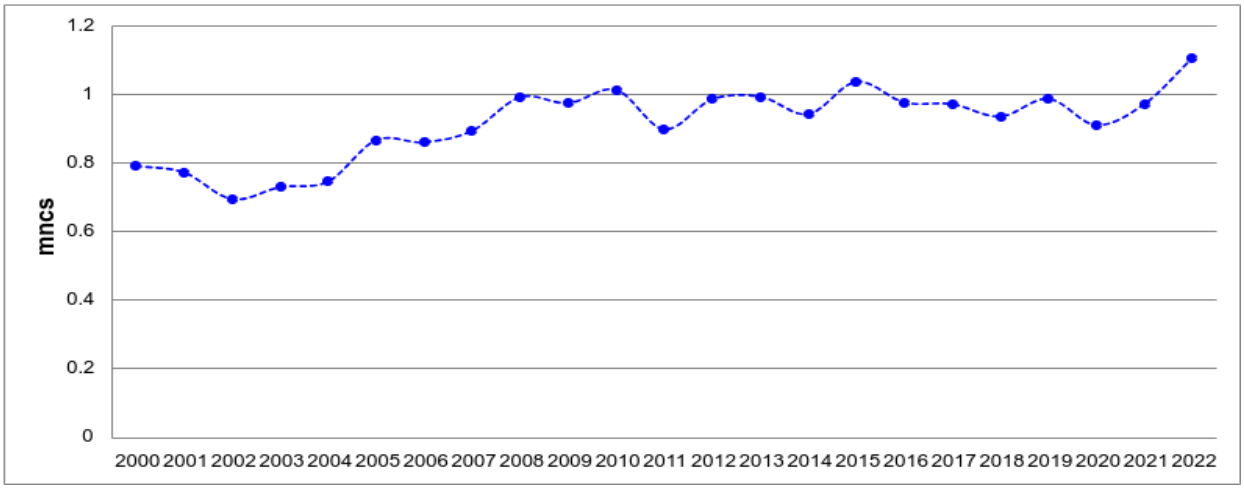


Figure D1: Citation Impact as Measured by MNCS (2-year window) for Agricultural Sciences

Source: CREST, Stellenbosch University

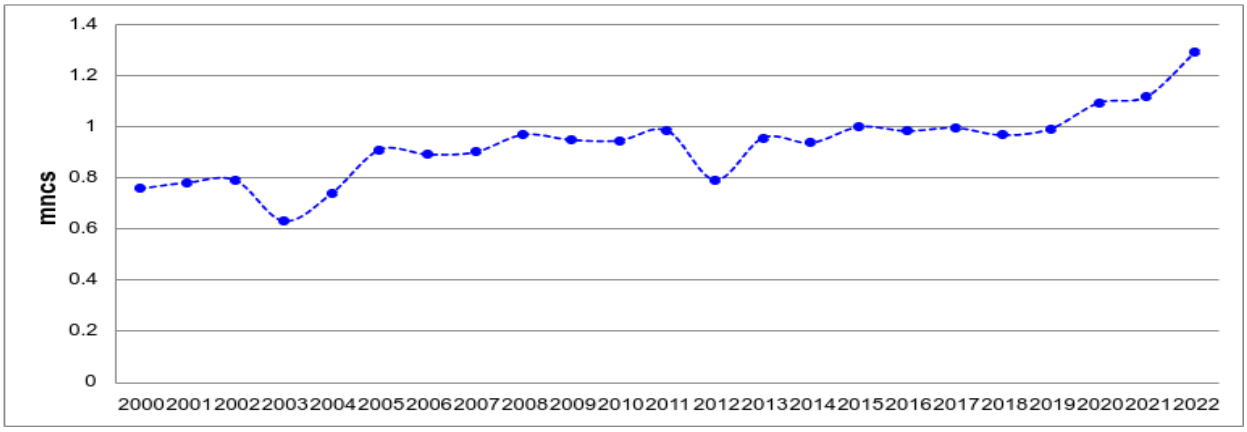


Figure D2: Citation Impact as Measured by MNCS (2-year window) for Engineering

Source: CREST, Stellenbosch University

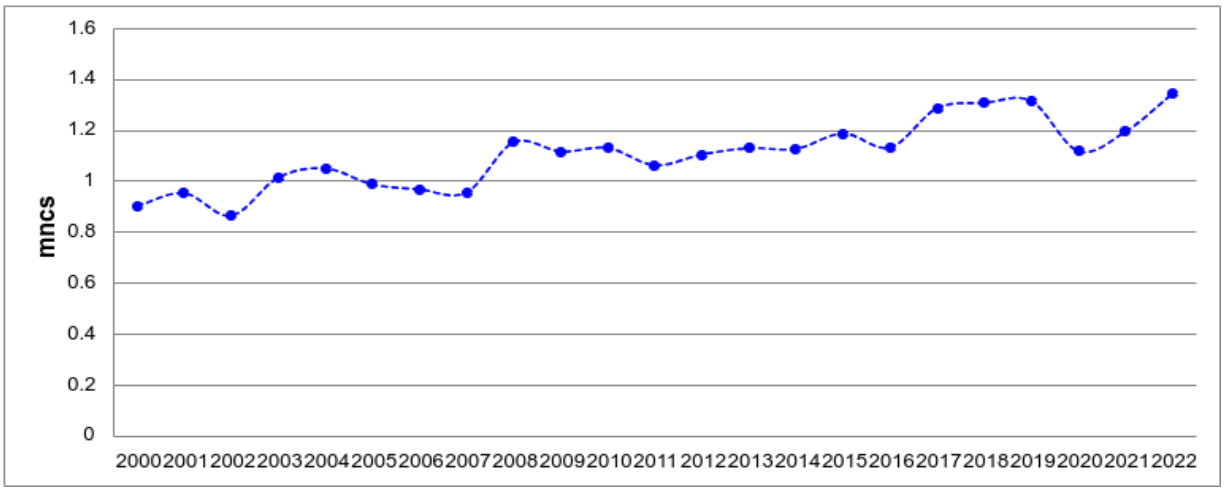


Figure D3: Citation Impact as Measured by MNCS (two-year window) for Health Sciences

Source: CREST, Stellenbosch University

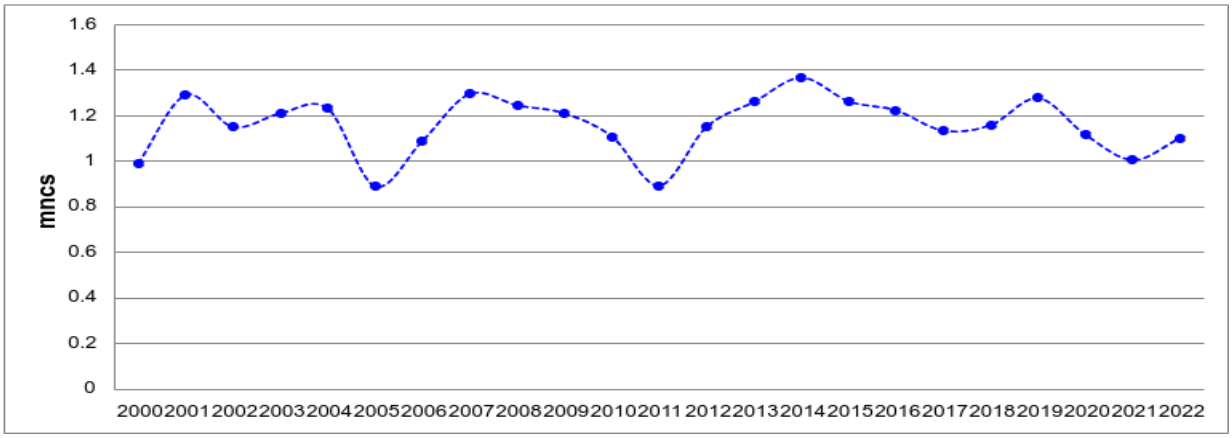


Figure D4: Citation Impact as Measured by MNCS (two-year window) for Humanities and Arts

Source: CREST, Stellenbosch University

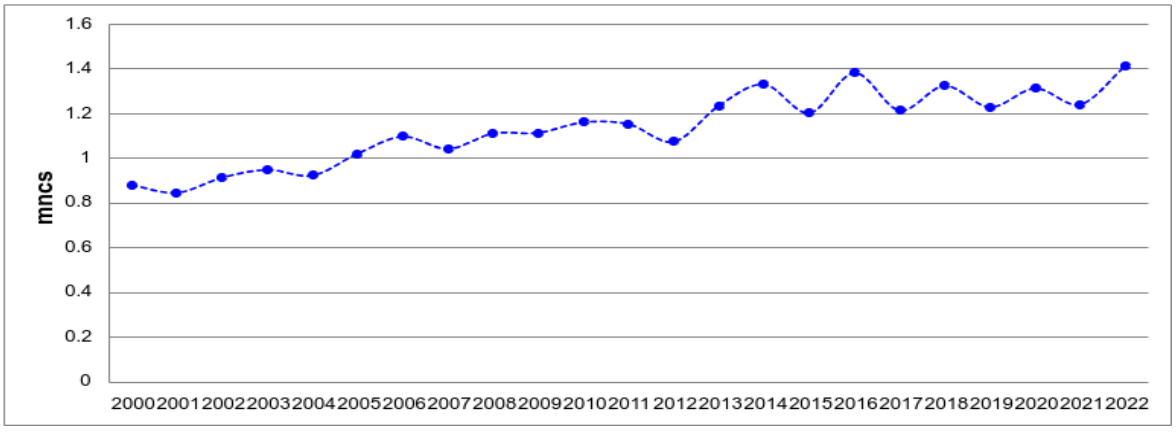


Figure D5: Citation Impact as Measured by MNCS (two-year window) for Natural Sciences

Source: CREST, Stellenbosch University

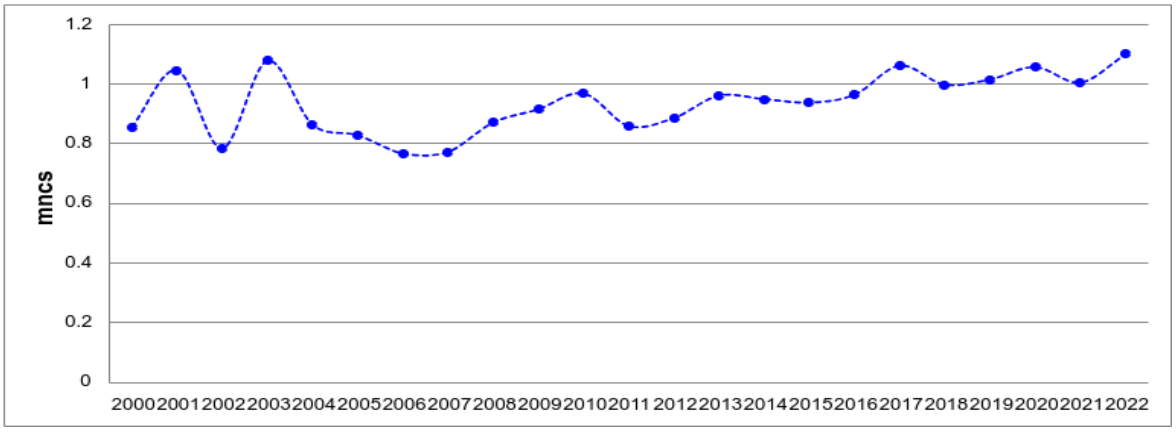


Figure D6: Citation Impact as Measured by MNCS (two-year window) for Social Sciences

Source: CREST, Stellenbosch University

ANNEXURE E: BIBLIOMETRIC ANALYSIS PER PROVINCE

Eastern Cape

Eastern Cape occupies 169 966 Km^2 (13.8% of the country's area). The province has a population of 6 497 100 persons and a population density of 38 people per square kilometre. Main industries in the province are government services (21%), trade, catering and accommodation (18%), finance (16%)[41].

The tables below provide the province's bibliometric profile.

EC1: Publications per Year 2013-2022

Publication Years	Record Count
2022	1 047
2021	1 406
2020	1 271
2019	992
2018	849
2017	604
2016	634
2015	601
2014	491
2013	420
2012	459

Source: Estimated by QER from WOS

[41] https://southafrica-info.com/land/nine-provinces-south-africa/

EC2: Research Areas Emphasised

Research Areas	Record Count	% (Docs from Province)
Environmental Sciences Ecology	1 088	0.123
Chemistry	628	0.071
Marine Freshwater Biology	561	0.063
Science Technology Other Topics	509	0.058
Plant Sciences	500	0.057
Engineering	494	0.056
Materials Science	412	0.047
Education Educational Research	411	0.046
Zoology	367	0.042
Computer Science	346	0.039

Source: Estimated by QER from WOS

EC3: Prolific Organisations

Prolific Organisations	Record Count	% (Docs from Province)
Nelson Mandela University	5 295	59.9
Rhodes University	1 479	16.7
Walter Sisulu University	1 091	12.3
University of Fort Hare	834	9.4
University of Cape Town	780	8.8
National Research Foundation South Africa	681	7.7
University of the Witwatersrand	549	6.2
University of Pretoria	528	6.0
University of KwaZulu-Natal	525	5.9
Stellenbosch University	512	5.8

Source: Estimated by QER from WOS

EC4: Prolific Authors

Authors	Corporate Address	Record Count
Smith GF	NMU	290
Hosten EC	NMU	259
Betz R	NMU	204
Figueiredo E	NMU	167
Adams JB	NMU	131
Nyokong T	RU	127
Truter I	NMU	127
Hofmeyr GJ	WSU	119
Perissinotto R	NMU	112
Cowling RM	NMU	100

Source: Estimated by QER from WOS

EC5: Countries Collaborating with the Province

Countries	Record Count
South Africa	8 840
USA	1 205
England	972
Australia	668
Germany	527
France	427
Nigeria	388
Canada	342
Portugal	302
Netherlands	289

Source: Estimated by QER from WOS

EC6: Funding Organisations

Funding Agencies	Record Count
National Research Foundation	1 895
UK Research Innovation (UKRI)	397
South African Medical Research Council	379
Medical Research Council UK (MRC)	209
National Science Foundation (NSF)	191
Department of Science Technology, India	174
Rhodes University	162
United States Department of Health Human Services	160
Nelson Mandela University	152
National Institutes of Health (NIH), USA	145

Source: Estimated by QER from WOS

Free State

Free State occupies 129 825 Km^2 (10.6 % of the country's area). The province has a population of 2 889 900 persons and a population density of 22 people per square kilometre. Main industries are government services (15%), finance (14%), trade, catering and accommodation (13%)[42].

The tables below provide the province's bibliometric profile.

FS1: Publications per Year

Publication Years	Record Count
2022	1 393
2021	1 951
2020	1 895
2019	1 590
2018	1 493
2017	1 089
2016	1 054
2015	861
2014	809
2013	688
2012	664

Source: Estimated by QER from WOS

FS2: Research Areas Emphasised

Research Areas	Record Count	% (Docs from Province)
Chemistry	1 067	7.9
Engineering	902	6.6
Environmental Sciences Ecology	852	6.3
Physics	788	5.8
Science Technology Other Topics	752	5.5
Materials Science	733	5.4
Agriculture	732	5.4
Education Educational Research	715	5.3
Religion	627	4.6
Mathematics	517	3.8

Source: Estimated by QER from WOS

[42] https://southafrica-info.com/land/nine-provinces-south-africa/

FS3: Prolific Organisations

Affiliations	Record Count	% (Docs from Province)
University of the Free State	11 379	83.9
Central University of Technology	1 151	8.5
University of Pretoria	739	5.4
University of KwaZulu-Natal	618	4.6
University of the Witwatersrand	564	4.2
University of Cape Town	510	3.8
Stellenbosch University	492	3.6
North West University	408	3.0
Agricultural Research Council	299	2.2
KU Leuven	281	2.1

Source: Estimated by QER from WOS

FS4: Prolific Authors

Authors	Corporate Address	Record Count
Swart HC	UFS	655
Atangana A	UFS	343
Conradie J	UFS	290
Ntwaeaborwa OM	WITS	213
Kumar V	UFS	187
Finkelstein M	UFS	156
Dejene FB	WSU	148
Roodt A	UFS	144
Marusik YM	UFS	142
Kroon RE	UFS	137

Source: Estimated by QER from WOS

FS5: Countries Collaborating with the Province

Countries	Record Count
South Africa	13 569
USA	1 535
England	942
Germany	827
Australia	701
India	676
Netherlands	577
Nigeria	568
Belgium	538
France	461

Source: Estimated by QER from WOS

FS6: Funding organisations

Funding Agencies	Record Count
National Research Foundation	2 540
University of the Free State	515
UK Research Innovation (UKRI)	320
South African Research Chairs Initiative of the Department of Science and Technology	256
Department of Science Technology, India	176
German Research Foundation (DFG)	158
United States Department of Health Human Services	151
National Institutes of Health (NIH), USA	137
South African Medical Research Council	135
European Union (EU)	125

Source: Estimated by QER from WOS

Gauteng

Gauteng occupies 18 178 Km^2 (1.5 % of the country's area). The province has a population of 14 273 800 persons and a population density of 785 people per square kilometre. Main industries are government services (19%), finance (23%) and manufacturing (14%)[43].

The tables below provide the province's bibliometric profile.

GU1: Publications per Year

Publication Years	Record Count
2022	10 714
2021	13 150
2020	12 568
2019	12 296
2018	11 044
2017	8 917
2016	8 160
2015	7 079
2014	6 215
2013	5 544
2012	5 128

Source: Estimated by QER from WOS

GU2: Research Areas Emphasised

Research Areas	Record Count
Engineering	10 574
Science Technology Other Topics	6 357
Environmental Sciences Ecology	6 153
Business Economics	5 271
Physics	5 187
Chemistry	4 597
Public Environmental Occupational Health	4 462
Computer Science	4 453
Materials Science	4 236
Infectious Diseases	4 195

Source: Estimated by QER from WOS

GU3: Prolific Organisations

Affiliations	Record Count	% (Docs from Province)
University of the Witwatersrand	34 308	33.9
University of Pretoria	26 045	25.7
University of Johannesburg	19 225	19.0
University of South Africa	10 690	10.6
University of Cape Town	6 260	6.2
Tshwane University of Technology	5 506	5.4
CSIR	4 580	4.5
University of KwaZulu-Natal	4 335	4.3
University of London	4 171	4.1
Stellenbosch University	3 343	3.3

[43] https://southafrica-info.com/land/nine-provinces-south-africa/

Source: Estimated by QER from WOS

GU4: Prolific Authors

Authors	Corporate Address	Record Count
Gupta R	UJ	1 427
Zhang X	UP	1 349
Zhu J	UP	1 334
Zhang Z	UP	1 286
Meyer JP	UP	1 265
Wang H	WITS	1 239
Zhu Y	UP	1 233
Zhu H	UP	1 232
Li X	UP	1 212
Wu Y	UP	1 135

Source: Estimated by QER from WOS

GU5: Countries Collaborating with the Province

Countries	Record Count
South Africa	101 327
USA	18 212
England	12 022
Australia	6 896
Germany	6 635
China	5 564
France	5 420
Netherlands	5 105
Canada	4 889
India	4 416

Source: Estimated by QER from WOS

GU6: Funding Organisations

Funding Agencies	Record Count	% (Docs from Province)
National Research Foundation	10 478	10.3
UK Research Innovation (UKRI)	5 241	5.2
United States Department of Health Human Services	3 378	3.3
National Institutes of Health (NIH), USA	2 807	2.8
Medical Research Council UK (MRC)	2 637	2.6
National Natural Science Foundation of China (NSFC)	2 364	2.3
National Science Foundation (NSF)	2 211	2.2
European Union (EU)	2 082	2.1
Spanish Government	1 871	1.8
German Research Foundation (DFG)	1 609	1.6

Source: Estimated by QER from WOS

KwaZulu–Natal

KwaZulu-Natal occupies 94 361 Km^2 (7.7 % of the country's area). The province has a population of 11 067 500 persons and a population density of 117 people per square kilometre. Main industries are manufacturing (16%), finance (15%) and government services (15%)[44].

[44] https://southafrica-info.com/land/nine-provinces-south-africa/

The tables below provide the province's bibliometric profile.

KZN1: Publications per Year

Publication Years	Record Count
2022	3 759
2021	3 963
2020	3 779
2019	3 315
2018	2 560
2017	2 387
2016	2 287
2015	2 060
2014	2 047
2013	1 701
2012	1 444

Source: Estimated by QER from WOS

KZN2: Research Areas Emphasised

Research Areas	Record Count
Engineering	2 755
Chemistry	2 623
Infectious Diseases	1 929
Science Technology Other Topics	1 795
Public Environmental Occupational Health	1 780
Physics	1 770
Environmental Sciences Ecology	1 723
General Internal Medicine	1 639
Immunology	1 347
Pharmacology Pharmacy	1 086

Source: Estimated by QER from WOS

KZN3: Prolific Organisations

Affiliations	Record Count	% (Docs from Province)
University of KwaZulu-Natal	22 107	75.4
Durban University of Technology	3 262	11.1
University of the Witwatersrand	2 556	8.7
University of Cape Town	2 521	8.6
University of London	2 024	6.9
Harvard University	1 675	5.7
University of California System	1 406	4.8
University College London	1 304	4.5
Stellenbosch University	1 280	4.4
University of Oxford	1 207	4.1

Source: Estimated by QER from WOS

KZN4: Prolific Authors

Authors	Corporate Address	Record Count
Mohammadi AH	CPUT	435
Liu Y	CPUT	305
Hill JC	CPUT	303
Albericio F	UKZN	300
Wang J	UKZN	294
Chen X	UKZN	290
Lewis A	UKZN	289
Li S	UKZN	287

Sliwa K	UCT	287
Kim SH	UKZN	286

Source: Estimated by QER from WOS

KZN5: Countries Collaborating with the Province

Countries	Record Count
South Africa	29 302
USA	6 554
England	4 767
India	2 508
Australia	2 282
Canada	2 086
Germany	2 017
France	1 877
Spain	1 612
China	1 488

Source: Estimated by QER from WOS

KZN6: Funding Organisations

Funding Agencies	Record Count	% (Docs from Province)
National Research Foundation	3 646	12.4
UK Research Innovation (UKRI)	2 259	7.7
United States Department of Health Human Services	2 116	7.2
National Institutes of Health (NIH), USA	1 964	6.7
Medical Research Council UK (MRC)	1 310	4.5
National Science Foundation (NSF)	864	2.9
Wellcome Trust	839	2.9
University Of KwaZulu-Natal	833	2.8
South African Medical Research Council	780	2.7
Spanish Government	755	2.6

Source: Estimated by QER from WOS

Limpopo

Limpopo occupies 125 755 Km^2 (10.3 % of the country's area). The province has a population of 5 774 600 persons and a population density of 46 people per square kilometre. Main industries are mining (25%), government services (18%) and trade, catering and accommodation (13%)[45].

The tables below provide the province's bibliometric profile.

LP1: Publications per Year

Publication Years	Record Count
2022	68
2021	80
2020	88
2019	50
2018	59
2017	44

[45] https://southafrica-info.com/land/nine-provinces-south-africa/

2016	33
2015	40
2014	50
2013	37
2012	25

Source: Estimated by QER from WOS

LP2: Research Areas Emphasised

Research Areas	Record Count
Environmental Sciences Ecology	74
Agriculture	69
Science Technology Other Topics	58
Plant Sciences	45
Public Environmental Occupational Health	39
Infectious Diseases	34
General Internal Medicine	30
Zoology	28
Geology	27
Engineering	25

Source: Estimated by QER from WOS

LP3: Prolific Organisations

Affiliations	Record Count	% (Docs from
University of Venda	252	43.6
University of Limpopo	133	23.0
University of KwaZulu-Natal	59	10.2
University of Pretoria	53	9.2
University of the Witwatersrand	36	6.2
University of South Africa	35	6.1
University of Cape Town	29	5.0
Anova Hlth. Inst.	27	4.7
University of Virginia	25	4.3
Limpopo Dept. Agr. Rural Dev.	22	3.8

Source: Estimated by QER from WOS

LP4: Prolific Authors

Authors	Corporate Address	Record Count
Mashilo J	UKZN	32
Peters RPH	UCT	27
Samie A	UNIIVEN	25
Shimelis H	UKZN	25
Mcintyre JA	UCT	18
Jideani AIO	UNIIVEN	16
Bessong PO	UNIIVEN	14
Struthers HE	UCT	13
Anyasi TA	UNIIVEN	11
Baiyegunhi C	UFH	11

Source: Estimated by QER from WOS

LP5: Countries Collaborating with the Province

Countries	Record Count
South Africa	578
USA	73
England	41
Netherlands	38

Australia	18
Brazil	17
Germany	16
Canada	15
India	14
Kenya	14

Source: Estimated by QER from WOS

LP6: Funding Organisations

Funding Agencies	Record Count	% (Docs from
National Research Foundation	120	20.8
United States Department of Health Human Services	35	6.1
United States Agency for International Development (USAID)	24	4.2
University of Venda	22	3.8
National Institutes of Health (NIH), USA	19	3.3
Centers For Disease Control Prevention, USA	17	2.9
Department of Science Technology India	16	2.8
CGIAR	11	1.9
South African Medical Research Council	11	1.9
University Of KwaZulu-Natal	11	1.9

Source: Estimated by QER from WOS

Mpumalanga

Mpumalanga occupies 76 495 Km^2 (6.3 % of the country's area). The province has a population of 4 442 500 persons and a population density of 58 people per square kilometre. Main industries are mining (20%), trade, catering and accommodation (13%) and manufacturing (13%)[46].

The tables below provide the province's bibliometric profile.

MP1: Publications per Year

Publication Years	Record Count
2022	24
2021	33
2020	42
2019	39
2018	13
2017	16
2016	10
2015	12
2014	12
2013	13
2012	10

Source: Estimated by QER from WOS

MP2: Research Areas Emphasised

Research Areas	Record Count
Engineering	59

[46] https://southafrica-info.com/land/nine-provinces-south-africa/

Energy Fuels	38
Environmental Sciences Ecology	19
Plant Sciences	19
Computer Science	15
Zoology	15
Forestry	12
Parasitology	12
Veterinary Sciences	12
Science Technology Other Topics	11

Source: Estimated by QER from WOS

MP3: Prolific Organisations

Affiliations	Record Count	% (Docs from Province)
Tshwane University of Technology	63	28.3
University of Pretoria	30	13.5
University of Mpumalanga	29	13.0
University of the Witwatersrand	22	9.9
North West University	21	9.4
Stellenbosch University	17	7.6
University of Cape Town	14	6.3
South African National Park	10	4.5
University of Limpopo	9	4.0
MINTEK	7	3.1

Source: Estimated by QER from WOS

MP4: Prolific Authors

Authors	Corporate	Record Count
Jordaan JA	TUT	32
Nnachi AF	TUT	30
Moloi K	UNISA	16
Thango BA	UJ	15
Akumu AO	TUT	13
Aremu AO	NWU	12
Otang-Mbeng W	NWU	10
Abe BT	TUT	9
Hamam Y	TUT	8
Mitchell RG	UP	8

Source: Estimated by QER from WOS

MP5: Countries Collaborating with the Province

Countries	Record Count
South Africa	223
USA	25
England	19
Netherlands	6
Belgium	4
Australia	3
Kenya	3
Luxemburg	3
Mozambique	3
Nigeria	3

Source: Estimated by QER from WOS

MP6: Funding Organisations

Funding Agencies	Record Count	% (Docs from Province)
National Research Foundation	20	9.0

UK Research Innovation (UKRI)	9	4.0
Wellcome Trust	7	3.1
Medical Research Council UK (MRC)	5	2.2
North West University	5	2.2
University of The Witwatersrand	4	1.8
Morris Animal Foundation	3	1.3
Ajubatus	2	0.9
Citrus Research International	2	0.9
Economic Social Research Council (ESRC)	2	0.9

Source: Estimated by QER from WOS

Northern Cape

Northern Cape occupies 372 889 Km^2 (30.5 % of the country's area). The province has a population of 1 213 500 persons and a population density of 3 people per square kilometre Main industries are mining (19%), government services (15%) and finance (12%)[47].

The tables below provide the province's bibliometric profile.

NC1: Publications per Year

Publication Years	Record Count
2022	15
2021	11
2020	18
2019	13
2018	13
2017	15
2016	5
2015	4
2014	5
2013	2
2012	6

Source: Estimated by QER from WOS

NC2: Research Areas Emphasised

Research Areas	Record Count
Environmental Sciences Ecology	23
Zoology	18
Science Technology and Other Topics	13
Behavioral Sciences	9
Geology	9
Life Sciences Biomedicine and Other Topics	9
General Internal Medicine	6
Infectious Diseases	5
Respiratory System	5
Biochemistry Molecular Biology	4

Source: Estimated by QER from WOS

[47] https://southafrica-info.com/land/nine-provinces-south-africa/

NC3: Prolific Organisations

Affiliations	Record Count	% (Docs from Province)
University of Pretoria	27	25.2
Stellenbosch University	20	18.7
University of Cape Town	20	18.7
University of Zurich	20	18.7
University of Cambridge	19	17.8
Kuruman River Reserve	15	14.0
Sol Plaatje University	11	10.3
Council of Geoscience	7	6.5
Kalahari Meerkat Project	7	6.5
University of London	7	6.5

Source: Estimated by QER from WOS

NC4: Prolific Authors

Authors	Corporate Address	Record Count
Manser MB	UP	13
Clutton-brock T	UP	7
Dheda K	UCT	6
Esmail A	UCT	5
Leclaire S	UCT	5
Harmse CJ	SU	4
Manser M	UCT	4
Mastrapa B	UP	4
Mbuli N	UNISA	4
Mendu B	Eskom Holdings SoC Ltd	4

Source: Estimated by QER from WOS

NC5: Countries Collaborating with the Province

Countries	Record Count
South Africa	107
England	36
Switzerland	23
USA	23
France	10
Germany	10
Sweden	7
Scotland	6
Botswana	4
Netherlands	4

Source: Estimated by QER from WOS

NC6: Funding Organisations

Funding Agencies	Record Count	% (Docs from
CNRS	20	18.7
University of Zurich	20	18.7
UK Research Innovation (UKRI)	14	13.1
University of Cambridge	12	11.2
Mava Foundation	9	8.4
Medical Research Council UK (MRC)	8	7.5
National Research Foundation	7	6.5
Human Frontier Science Program	6	5.6
Biotechnology and Biological Sciences Research Council (BBSRC)	5	4.7
National Science Foundation (NSF)	5	4.7

Source: Estimated by QER from WOS

North West Province

Northern West occupies 104 882 Km^2 (8.6 % of the country's area). The province has a population of 3 854 400 persons and a population density of 37 people per square kilometre. Main industries are mining (30%), government services (12%), finance (12%)[48].

The tables below provide the province's bibliometric profile.

NW1: Publications per Year

Publication Years	Record Count
2022	1 536
2021	2 005
2020	1 873
2019	1 790
2018	1 587
2017	1 207
2016	1 165
2015	1 058
2014	897
2013	836
2012	793

Source: Estimated by QER from WOS

NW2: Research Areas Emphasised

Research Areas	Record Count
Environmental Sciences Ecology	1 351
Chemistry	1 033
Engineering	850
Science Technology Other Topics	752
Psychology	726
Religion	715
Astronomy Astrophysics	661
Physics	635
Business Economics	634
Education Educational Research	620

Source: Estimated by QER from WOS

NW3: Prolific Organisations

Affiliations	Record Count	% (Docs from
North West University	14 079	94.8
University of Pretoria	598	4.0
University of the Witwatersrand	596	4.0
University of KwaZulu-Natal	506	3.4
University of Johannesburg	449	3.0
University of Cape Town	426	2.9
Stellenbosch University	399	2.7
University of the Free State	374	2.5
Centre National de la Recherche Scientifique (CNRS)	344	2.3
University of South Africa	328	2.2

Source: Estimated by QER from WOS

[48] https://southafrica-info.com/land/nine-provinces-south-africa/

NW4: Prolific Authors

Authors	Corporate Address	Record Count
Ebenso EE	UNISA	345
Schutte AE	NWU	322
Babalola OO	NWU	262
Khalique CM	NWU	215
Ma WX	NWU	202
Böttcher M	NWU	192
Howatson G	NWU	169
Onwudiwe DC	NWU	169
Malan L	NWU	165
Smit NJ	NWU	159

Source: Estimated by QER from WOS

NW5: Countries Collaborating with the Province

Countries	Record Count
South Africa	14 844
USA	1 884
England	1 274
Australia	1 024
Germany	1 004
Netherlands	853
China	737
Nigeria	719
India	580
France	571

Source: Estimated by QER from WOS

NW6: Funding Organisations

Funding Agencies	Record Count	% (Docs from
National Research Foundation	3020	20.3
UK Research Innovation (UKRI)	811	5.5
Medical Research Council UK (MRC)	752	5.1
North West University	577	3.9
South African Medical Research Council	378	2.5
National Science Foundation (NSF)	334	2.3
National Natural Science Foundation of China (NSFC)	299	2.0
Ministry Of Education Culture Sports Science and Technology Japan (MEXT)	248	1.7
German Research Foundation (DFG)	212	1.4
Japan Society for the Promotion of Science	212	1.4

Source: Estimated by QER from WOS

Western Cape

Western Cape occupies 129 462 Km^2 (10.6 % of the country's area). The province has a population of 6 508 700 persons and a population density of 50 people per square kilometre. Main industries are finance (23%), trade, catering and accommodation (15%) and manufacturing (14%)[49].

The tables below provide the province's bibliometric profile.

[49] https://southafrica-info.com/land/nine-provinces-south-africa/

WC1: Publications per Year

Publication Years	Record Count
2022	6 621
2021	8 370
2020	7 985
2019	7 516
2018	6 700
2017	5 309
2016	5 040
2015	4 401
2014	4 145
2013	3 523
2012	3 301

Source: Estimated by QER from WOS

WC2: Research Areas Emphasised

Research Areas	Record Count
Environmental Sciences Ecology	4 103
Engineering	4 051
General Internal Medicine	3 700
Infectious Diseases	3 681
Public Environmental Occupational Health	3 598
Science Technology Other Topics	3 461
Immunology	2 981
Physics	2 829
Astronomy Astrophysics	2 541
Chemistry	1 791

Source: Estimated by QER from WOS

WC3: Prolific Organisations

Affiliations	Record Count	% (Docs from Province)
University of Cape Town	29 335	46.5
Stellenbosch University	23 840	37.8
University of the Western Cape	5 113	8.1
University of the Witwatersrand	4 957	7.9
University of London	4 744	7.5
University of the California System	3 885	6.2
National Research Foundation	3 698	5.9
Harvard University	3 244	5.1
South African Medical Research Council	3 075	4.9
University of Oxford	2 896	4.6

Source: Estimated by QER from WOS

WC4: Prolific Authors

Authors	Corporate Address	Record Count
Zhu J	UP	1 357
Zhang X	UP	1 345
Wang H	WITS	1 259
Sliwa K	UCT	1 257
Zhang Z	UP	1 223
Zhu H	UP	1 213
Zhu Y	UP	1 180
Li X	UP	1 139
Li S	UP	1 106
Wu Y	UP	1 082

Source: Estimated by QER from WOS

WC5: Countries Collaborating with the Province

Countries	Record Count
South Africa	63 129
USA	16 127
England	12 322
Germany	6 636
Australia	6 356
Netherlands	5 813
Canada	5 481
France	5 197
Switzerland	4 757
Italy	4 547

Source: Estimated by QER from WOS

WC6: Funding Organisations

Funding Agencies	Record Count	% (Docs from Province)
UK Research Innovation (UKRI)	6 643	10.5
National Research Foundation	5 845	9.3
United States Department of Health Human Services	4 272	6.8
National Institutes of Health (NIH), USA	3 972	6.3
Medical Research Council UK (MRC)	3 474	5.5
National Science Foundation (NSF)	2 351	3.7
European Union (EU)	2 314	3.7
South African Medical Research Council	2 285	3.6
Science Technology Facilities Council (STFC)	2 162	3.4
Spanish Government	1 941	3.1

Source: Estimated by QER from WOS

South Africa

South Africa occupies 1 220 813 Km^2 (100 % of the country's area)[50].

The tables below provide the country's bibliometric profile.

SA1: Publications per Year

Publication Years	Record Count
2022	24 952
2021	32 013
2020	30 910
2019	29 394
2018	26 724
2017	21 556
2016	20 415
2015	18 160
2014	16 859
2013	15 307
2012	14 707

Source: Estimated by QER from WOS

SA2: Research Areas Emphasised

[50] https://southafrica-info.com/land/nine-provinces-south-africa/

Research Areas	Record Count
Engineering	21 763
Environmental Sciences Ecology	17 841
Science Technology and Other Topics	14 287
Chemistry	13 701
Physics	11 736
Public Environmental Occupational Health	10 415
Business Economics	9 808
Infectious Diseases	9 193
Computer Science	8 888
Education Educational Research	8 883

Source: Estimated by QER from WOS

SA3: Prolific Organisations

Affiliations	Record Count	% (Docs from Province)
University of Cape Town	40 623	16.1
University of the Witwatersrand	35 477	14.1
Stellenbosch University	29 464	11.7
University of KwaZulu-Natal	29 096	11.5
University of Pretoria	29 087	11.5
University of Johannesburg	23 373	9.3
North West University	15 536	6.2
University of South Africa	12 262	4.9
University of the Free State	11 446	4.5
University of London	9 355	3.7

Source: Estimated by QER from WOS

SA4: Prolific Authors

Authors	Corporate	Record Count
Gupta R	UJ	1 674
Zhang X	UP	1 458
Zhu J	UP	1 428
Wang H	WITS	1 386
Sliwa K	UCT	1 338
Zhang Z	UP	1 305
Meyer JP	UP	1 299
Zhu H	UP	1 289
Zhu Y	UP	1 246
Li X	UP	1 241

Source: Estimated by QER from WOS

SA5: Countries Collaborating with South Africa

Countries	Record Count
South Africa	252 427
USA	44 810
England	30 660
Germany	17 310
Australia	17 018
France	13 007
Netherlands	12 526
Canada	12 357
China	11 355
India	11 300

Source: Estimated by QER from WOS

SA6: Funding Organisations

Funding Agencies	Record Count	%
National Research Foundation	44 569	17.7
UK Research Innovation (UKRI)	13 794	5.5
United States Department of Health Human Services	9 123	3.6
National Institutes of Health (NIH), USA	8 324	3.3
South African Medical Research Council	15 736	6.2
European Union (EU)	4 655	1.8
National Natural Science Foundation of China (NSFC)	4 100	1.6
Spanish Government	3 775	1.5
Wellcome Trust	3 590	1.4
Science Technology Facilities Council (STFC)	3 228	1.3

Source: Estimated by QER from WOS

ANNEXURE F: BUSINESS R&D EXPENDITURE INCREASE IN 2021/22

Table 1: Type of Business R&D Expenditure

	Basic Research (R'000)	Increase (%)	Applied Research (R'000)	Increase (%)	Experimental Development (R'000)	Increase (%)
2018/19	948 319		9 819 344		3 680 170	
2019/20	758 971	-20.0	6 218 563	-36.7	3 726 947	1.3
2020/21	788 740	3.9	6 014 078	-3.3	3 244 526	-12.9
2021/22	1 567 352	98.7	7 834 505	30.3	4 125 325	27.1

Table 2: Proportion of Business R&D Expenditure by Research Field

	2018/19	2019/20	2020/21	2021/22
	%			
Division 1: Natural sciences, technology and engineering	81.1	98.6	94.9	95.2
Mathematical sciences	1.4	1.7	1.8	1.4
Physical sciences	0.6	1.0	1.2	0.6
Chemical sciences	7.6	7.5	6.3	5.3
Earth sciences	1.1	2.7	2.0	1.6
Information, computer and communication technologies	15.9	19.4	21.1	25.4
Applied sciences and technologies	6.5	5.7	5.4	5.7
Engineering sciences	19.3	21.8	22.2	17.3
Biological sciences	1.1	1.6	2.4	1.8
Agricultural sciences	7.0	10.0	6.6	5.5
Medical and health sciences	19.8	22.4	22.8	23.9
Environmental sciences	0.5	1.2	1.0	2.2
Material sciences	0.4	3.6	2.1	4.4
Marine sciences	0.0	0.0	0.0	0.0
Division 2: Social sciences and humanities	**18.9**	**1.4**	**5.1**	**4.8**
Social sciences	18.9	1.4	5.1	4.8
Humanities	0.0	0.0	0.0	0.0
Total	**100.0**	**100.0**	**100.0**	**100.0**

Table 3: Proportion of Business Sector R&D Expenditure by Industry

Standard Industrial Classification	2018/19	2019/20	2020/21	2021/22
	%			
Agriculture, hunting, forestry and fishing	6.6	6.6	4.5	3.4
Mining and quarrying	6.4	6.4	9.2	6.6
Manufacturing	32.3	32.3	28.8	29.9
Electricity, gas and water supply	7.1	7.1	7.1	3.0
Construction	0.0	0.0	0.0	0.1
Wholesale and retail	0.8	0.8	0.6	0.2
Transport, storage & communication	4.7	4.7	2.7	6.0
Financial intermediation, real estate and business services	37.7	37.7	42.3	45.7
Community, social and personal services	4.3	4.3	4.7	5.2
Total	**100.0**	**100.0**	**100.0**	**100.0**

Table 4: Proportion of Business Sector R&D Expenditure by Province

Province	2018/19	2019/20	2020/21	2021/22
	%			
Eastern Cape	4.7	4.1	2.1	1.8
Free State	6.9	6.5	4.7	7.4
Gauteng	52.7	50.9	55.5	50.2
KwaZulu-Natal	10.0	11.2	8.2	7.8
Limpopo	1.3	0.7	2.0	1.0
Mpumalanga	2.7	3.5	2.6	3.2
Northwest	4.2	5.3	5.2	4.3
Northern Cape	0.3	0.4	0.3	0.8
Western Cape	17.2	17.5	19.4	23.4



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