Innovation and socio-economic development challenges in South Africa:

An overview of indicators and trends

Alexis Habiyaremye, Nicola King and Fiona Tregenna

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DSI/NRF SOUTH AFRICAN RESEARCH CHAIR IN INDUSTRIAL DEVELOPMENT

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Abstract

This working paper is based on a report undertaken for the Department of Science and Innovation. We begin by discussing the potential role of innovation in addressing the multiple pressing socio-economic challenges facing South Africa, and briefly reviewing selected international and national strategic initiatives for science, technology and innovation (STI) and development in South Africa. Developmental progress has been uneven across all dimensions of the socio-economic landscape and new ideas are needed to deliver transformative outcomes. Of particular relevance here is the role of innovation in catalysing, accelerating and supporting progress towards the addressing of these challenges. A more central positioning of an innovation-based approach, integrated across policy domains, could be fundamental to a shift away from 'business as usual' and to meaningful progress around South Africa's socio-economic and environmental challenges. The paper provides an overview of the high-level macro-economic social and environmental indicators and trends necessary to enhance an understanding of the role of innovation in creating sustainable and inclusive socio-economic development in the country. Specifically, key data and trends in the following domains in socio-economic development are presented here: economic growth; job creation; poverty alleviation; standards of living; skills development; export growth and competitiveness; climate change mitigation and adaption; renewable energy growth; access to and supply of clean water; high-quality healthcare services; and affordable food. In each domain, we also reflect on the possibilities of innovation for improved outcomes. Finally, the paper identifies some key directions for future research regarding the role of innovation in socio-economic development in South Africa.

Keywords: Innovation, sustainable development, South Africa

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About the Authors

Alexis Habiyaremye, DSI/NRF South African Research Chair in Industrial Development, College of Business and Economics, University of Johannesburg. Email: alexish@uj.ac.za.

Nicola King, DSI/NRF South African Research Chair in Industrial Development, College of Business and Economics, University of Johannesburg. Email: nicolak@uj.ac.za.

Fiona Tregenna, DSI/NRF South African Research Chair in Industrial Development, College of Business and Economics, University of Johannesburg. Email: ftregenna@uj.ac.za.

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1. Introduction

The South African economy is unique and its structure continues to be shaped by the country's colonial and apartheid legacy. The stubbornly low rate of economic growth continues to compound the 'triple challenges' of poverty, unemployment and inequality in the country. In 1994, the South African government faced the immense challenges of addressing the high rates of poverty, inequality and unemployment in the country, while transforming the economy and raising the rate of economic growth (Tregenna et al., 2021). To date, developmental progress has been uneven across all dimensions of the socio-economic landscape and new ideas are needed to deliver transformative outcomes. Science, technology and innovation (STI) have a central role to play in addressing the multiple challenges the country faces and in enabling meaningful socio-economic progress.

1.1 Purpose of this synthesis report

The primary purpose of this report is to provide an overview of the high-level macro-economic social and environmental indicators and trends necessary to enhance an understanding of the role of innovation in creating sustainable and inclusive socio-economic development in the country. Specifically, key data and trends in the following domains in socio-economic development are presented here:

- Economic growth
- Job creation
- Poverty alleviation
- Standards of living
- Skills development
- Export growth and competitiveness
- Climate change mitigation and adaption
- Renewable energy growth
- Access to and supply of clean water
- High-quality healthcare services
- Affordable food.

A detailed analysis of the role of innovation in each of these domains is beyond the scope of this report, and could be an important topic for future research, as discussed further in the concluding section of this report. However, this report does point to some broad connections between innovation and developmental outcomes.

2. Innovation and socio-economic development challenges in South Africa

Innovation, or the process of applying new knowledge or knowledge combinations to create new or improved products, new processes or production methods, new ways of doing things or breaking into new markets, is inherent in economic activities and is a critical driver of their dynamism (Fagerberg et al. 2010). Since the pioneering work of Schumpeter (1934), innovation has come to be considered as an indispensable driver of economic dynamism and competitiveness. In Schumpeter's perspective, development is described as a historical process of structural changes that are driven primarily by

innovation (Śledzik 2013). In the relationship between innovation and economic growth, knowledge is treated as the key asset for growth because it is not subject to diminishing returns like physical assets. In Schumpeter's initial description (which is closely followed by the Oslo Manual's definition), innovation can be defined by each of the following five aspects:

1. Launch of a new product or a new species of an already known product;
2. Application of new methods of production or sales of a product (new to the industry);
3. Opening of new markets;
4. Acquiring new sources of supply of raw material or semi-finished goods;
5. New industry structure, such as the creation or destruction of a monopoly position.

In all these aspects, the connecting thread is the application of new knowledge by profit-seeking entrepreneurs to create new sources of competitive advantage and business profits.

As background to the overview of data and trends in various domains, which forms the main focus of this report, this section introduces the links between innovation and development outcomes in the South African context.

2.1 Background and overview

Despite the existence of islands of innovation excellence in the South African economy, innovation takes place in a context of economic stagnation that has characterised the country for several decades (Kruss 2020). Based on its extensive period of low and erratic growth rates, the South African economy has been described by various observers as being stuck in middle-income stagnation with limited dynamics of transition to high-income status (Doner and Schneider 2016; Albuquerque 2019; Kruss 2020). This stagnation can be linked to structural constraints that impede the growth performance of the economy. Among the main structural characteristics impeding transformative innovation is the existing economic policy, which is based on a non-developmental 'welfarism' to address inequalities using fiscal policy, accommodating the mineral-energy complex and promoting financialisation rather than secondary industrialisation (Swilling et al. 2015). According to Kruss (2020), South Africa has been classified in the middle-income category for more than 71 years (starting as a lower-middle-income economy in 1950), with an average growth rate of 1.17 percent, while benchmark calculations indicate that a growth rate of more than 2.3 percent per year is necessary for a country to transition to high-income status. The five-year average growth rate before the COVID pandemic was below two percent per annum, and the economic disruption caused by the pandemic has made the performance only worse. South Africa's per capita income levels as a percentage of those of the USA have been declining steadily – from about 37 percent in 1980 to 23.3 percent in 1995 – before remaining stuck around this level for more than 20 years, with a recorded ratio of 23.6 percent in 2015 (Kruss 2020).

For innovation to drive development, the role of the state in defining the mission and providing the necessary impetus is crucial (Mazzucato 2018). For South Africa as a developing country whose economy has been stagnating for several years (Kruss 2020), the ability to harness innovation to change its growth trajectory is a strategic choice that ought to be given due attention. Despite the critical role that developmental states are expected to play in steering innovation and industrialisation, the most recent business innovation survey report, published in 2020 (covering innovation activities over the period 2014 to 2016), indicates that only a third of South African businesses that engaged in innovation activities (33.6 percent) were aware of government financial support for innovation. This proportion is even lower for businesses that do not engage in innovation,

of which only one in ten reported to be aware of government support for innovation. More than 75 percent of businesses engaging in innovation fund their innovation activities by relying mainly on their own financial resources, and only less than two percent of businesses engaged in innovation reported to have used government support as a source of innovation financing. Only one in five innovative firms use procurement contracts with the public sector, but just less than a third of these public procurement contracts involved innovation (South Africa Business Innovation Survey 2020).

2.2 Innovation as a driver of socio-economic development

Through its capacity to disrupt markets by rendering old technologies obsolete and continuously creating new ones, innovation is at the heart of the industrial mutation that defines long-term growth trajectories. While the role of innovation in the dynamics of economic growth seems firmly established, much less attention has been paid to its role in economic development (Fagerberg et al. 2010). In contrast to growth, which focuses on the expansion of production irrespective of who benefits from it, development is concerned more with its effects on human freedoms and the removal of constraints and deprivations that prevent people from leading the dignified lives that they have reason to live (Sen 1999). For developing countries to benefit from the advantage of innovation and new technological knowledge, it is commonly understood that they have to develop appropriate 'capabilities' that enable them to overcome their technological disadvantage (Fagerberg and Srholec 2009). Those capabilities have been presented under different concepts, such as 'technological capability' (Kim 1980), 'technological mastery' (Dahlman and Westphal 1982), 'absorptive capacity' (Cohen and Levinthal 1990), or 'social capabilities' (Abramovitz 1986), as fundamental to the process of development and technological catch-up (Fagerberg and Srholec 2009, p.2). According to Khan (2004), the nexus between capability-based innovation and development runs through 'positive feedback loops' that lead to a virtuous circle by which innovations lead to higher productivity, which leads to growth and prosperity, which in turn form the basis for more innovations

What people can achieve with their capabilities is influenced by "economic opportunities, political liberties, social powers, and the enabling condition of good health, basic education, and the encouragement and cultivation of initiatives" (Sen 1999, p.5). In South Africa, the National Development Plan (NDP30) presents aspirational development goals that reflect the capabilities expected to be achieved by the South African society by the year 2030 (National Planning Commission, 2012). Those capabilities are categorised according to nine core domains that underpin the decent standards of living targeted for 2030:

1. Nutrition
2. Housing, water, sanitation and electricity supply
3. Transport
4. Education and skills
5. Safety and security
6. Health care
7. Employment
8. Recreation and leisure, and
9. Clean environment.

According to the National Planning Commission, education and skills training, as well as access to good employment opportunities, are the capability areas in which South Africa needs to make the most progress. These two domains are key to achieving the development objectives, as they are directly connected to innovation strategy through the nexus between the quality of training needed to produce advanced human skills and the labour productivity generated by the deployment of these skills in the workplace. Progress is achieved by the effect of skills on more efficient production, but also through the accumulation of skills and capabilities through learning by doing and labour-augmenting technical change (Ziesemer 2021). The building up of human skills in all domains is one of the key drivers of innovation, because skilled and trained brains are better prepared to produce new ideas and try them out for the creation of new processes, new production methods, new products and new services (Ziesemer 1991). Technological progress is also a driver of social change as the introduction of new products, new production processes and new markets change the consumption patterns and create new possibilities for social interactions and new technical change.

In the context of South Africa, the accumulation of human capabilities projected by the NDP forms a key input for the reinforcement of the innovation system, which in turn catalyses innovation as a key enabler of development through its effects on creative destruction (Schumpeter 1934; Aghion and Howitt 1992). Because of the key role that the National Development Plan assigns to STI in reaching its 2030 vision, the 2019 White Paper on Science, Technology and Innovation, as approved by the government, provides a strategic policy framework for building the necessary capabilities and using policy instruments to harness the power of innovation for tackling socio-economic challenges. Such policy instruments include the use of public procurement as a vehicle to strengthen the South African innovation environment and increased support for the private business sector, with closer collaboration to foster a culture of innovation and improve the related outcomes.

The commitment of the government to increase the funding of the innovation ecosystem and reach the gross expenditure of research and development (GERD) target of 1.5 of the country's GDP is a further indication of the government's determination to harness the power of innovation in order to expand the state's capacity to meet the nation's socio-economic challenges. Innovation policy in itself, however, is not a substitute for the broader economic development strategy, which encompasses several domains of planning and organising, as well as resource mobilisation. For the achievement of the innovation policy objectives, the National Development Plan (NDP30) also identified water, power, marine, space and software engineering as domains of special consideration because of the perceived comparative and competitive advantages that South Africa is endowed with in these domains.

South Africa can rely on the strengths of its academic and public research excellence as well as the conducive innovation ecosystem of its largest metropolitan areas (in particular Cape Town and Johannesburg) to support innovation in the private sector and reap the corresponding benefits. However, questions remain about the nature of this research excellence, and its relevance to South Africa's developmental challenges. It is important that STI is responsive to the specificities of South Africa and to South Africa's own socio-economic development needs, as discussed further in this report.

Furthermore, South Africa's tax incentive system, tends to favour innovations at the technology frontier, involving mostly large firms active in the export sector (World Bank 2017). This may become a limiting factor on the benefits of an innovation support strategy, because the target beneficiaries of

these incentives are in the skills intensive activities and have only limited employment potential (in a country grappling with chronically high unemployment rates).

Box 1: Frontier technological innovations as solutions to developmental challenges

Technological innovations have the potential to help confront modern developmental challenges, including the Sustainable Development Goals (SDG). Advances in the computer sciences and information technology, such as Big Data analysis and the Internet of Things, present new opportunities to generate the most efficient solutions to developmental challenges through improved decision-making by providing rapid and reliable information streams. By enabling connectivity between objects and machines, the Internet of Things allows for the efficient management and monitoring of productive activities, thereby providing new possibilities to create new technological solutions and improving production efficiency in domains as diverse as transport, health care, energy supply and agriculture.

Likewise, the possibilities offered by Artificial Intelligence in domains requiring logical reasoning, complex problem-solving and image recognition can be harnessed to spur new economic activities and accelerate development by contributing to the transformation of production processes in domains such as robotics, computer-aided design and manufacturing. Biotechnology and Nanotechnology are other frontier technologies with potential to help confront developmental challenges. The ability of countries to benefit from these technologies depends critically on strategies that governments put in place to harness their potential.

Source: UNCTAD (2018)

2.3 Policy and strategy initiatives for innovation in South Africa

The role of STI in achieving the sustainable development goals (SDGs) and driving inclusive growth has gained traction over the last few years and is now prioritised in many policy, legislative and strategic reports both internationally, regionally and nationally. Table 1 outlines the core objectives for some of the international and regional strategies related to the adoption and implementation of STI for sustainable development outcomes. This section does not aim to provide an exhaustive list of all strategies and initiatives but rather to highlight some of the relevant initiatives.

Table 1: Selected international and regional strategic initiatives for STI and development in South Africa

STI Strategies	Policy objectives	STI outcomes
International initiatives		
UNCTAD Commission on Science and Technology for Development (UNCTAD, 2021)	*Preparing for a period of deep and rapid technological change, *Science, technology and innovation for sustainable development, *Ensuring equitable and inclusive globalisation.	*Strengthening and aligning Science, Technology and Innovation systems and industrial policies, *Building digital skills among students and the workforce, and *Closing digital divides.
Regional initiatives		
SADC Regional Indicative Strategic Development Plan (RISDP): Environment and Sustainable	Science and technology and Environment and Sustainable Development are highlighted as priority intervention areas for SADC	Regional call for targeted and strategic investment into science and technology and water-related environmental challenges.

STI Strategies	Policy objectives	STI outcomes
development, Science and Technology (SADC, 2001)		
Science, Technology and Innovation Strategy for Africa 2024: sustainable management of natural resources and environments to secure the interest of future generations (AUC, 2020)	*Priority 1 - Eradicate hunger and achieve food security. *Priority 4 - Protect our space. *Priority 5: Live together - build the society. *Priority 6 - Wealth creation.	STI interventions to address: *Low commodity yields, climate change and variability, water and land management, agricultural production, *Earth observation and monitoring of Africa's abundant natural resources, including minerals, biodiversity and associated indigenous knowledge through Earth Observation, Navigation and Positioning, Satellite Communication, Space Science and Astronomy, *Build necessary infrastructure, train people, leverage STI for sustainable socio-economic development, *Innovation-led, knowledge-based Economy, co-creation and commercialisation of new technological frontiers such nanotechnology.
AUDA-NEPAD Science, technology and innovation (STISA-2024) (AUDA-NEPAD, 2014)	*Supporting African countries to invest in socio-economic developmental change through STI	*Development and implementation of robust STI indicators for Africa.

Source: International and regional reports as referenced above.

Some of the key national strategies and initiatives which involve STI and its role in developmental outcomes, across the eleven core domains discussed in this report, are outlined in Table 2 below. This table covers some of the latest strategies related to innovation and socio-economic development, it is not intended to be exhaustive nor include every policy across each domain but rather aims to highlight some of the strategies around innovation and socio-economic development.

Table 2: Selected national strategic initiatives for STI and development in South Africa

Domain	National initiatives	Policy objectives	STI outcomes
National development	National development plan (NDP) (NPC, 2012)	*Eliminating poverty and reducing inequality by 2030	*Ensuring a dynamic, inclusive and prosperous knowledge economy is underpinned by ICT and drives innovative solutions for socio-economic development.
Science, technology and innovation	White Paper on Science, Technology and Innovation (STI) (DST, 2019)	*Maximising the considerable potential of STI to help South Africa thrive	*Enhancing the innovation culture in society and government, *Developing a more enabling environment for innovation, *Developing local innovation systems, *Supporting social and grassroots innovation, *Expanding the innovation research system, *Developing high-level human capital, *Endorsing a pan-African STI agenda, *Increasing the investment in STI.

Domain	National initiatives	Policy objectives	STI outcomes
Economic growth	Economic transformation, inclusive growth, and competitiveness: Towards an Economic Strategy for South Africa (National Treasury, 2019)	*Modernising network industries, *Lowering barriers to entry,	*Supporting high growth firms that drive innovation and employment, *Establish incentives for innovation that drive growth, *Investing in R&D and skills development to maintain innovation comparative advantages for example in the mining sector, *The creation of a small business and innovation fund focussing on the ideation and start-up phases of a business where the market failure in small business finance is binding, *Strengthening innovation systems and technology absorption.
	Industrial Policy Action Plan (2018/19-2020/21) (DTI, 2018)	*Creating and strengthening new entities to serve as innovation, technology transfer and commercialisation support structures	*The development of the Decadal Plan which will replace the Ten-Year Innovation Plan (2008 – 2018), *Improve the coordination and governance of STI programmes across government and the NSI, *Restoring, transforming and building the human pipeline in research and development (R&D), *Adapting to and leveraging opportunities related to 4IR, *Intsimbi Future Production Technologies Initiative (FIPT)
	National Industrial Policy Framework (DTI, 2007)	*Facilitating diversification beyond the current reliance on traditional commodities and non-tradable services, *Moving towards a knowledge economy	*Shifting from learning to use existing technologies to increasing innovation and development of domestic technologies,
Job creation	Economic transformation, inclusive growth, and competitiveness: Towards an Economic Strategy for South Africa (National Treasury, 2019)	*Prioritising labour-intensive growth	*Creating jobs through science, technology and innovation interventions, focussing on agriculture and services, including tourism.
	National Industrial Policy Framework (DTI, 2007)	*Adopting a labour-absorbing industrialisation path with a particular emphasis on tradable labour absorbing goods and services and economic linkages that	*Diversifying the economy beyond its reliance on traditional tradables and consumption-led services, *Investing in activities that are under-provided by the market such as industrial upgrading, industrial infrastructure and innovation and technology.

Domain	National initiatives	Policy objectives	STI outcomes
		catalyse employment creation	
Poverty alleviation	Innovation for poverty alleviation programme (DST, 2010)	*Using science and technology to reduce poverty through job creation, the development of small and medium enterprises, economic growth and improved quality of life	*Creating jobs through science, technology and innovation interventions, *Establishing sustainable livelihoods through small-scale science and technology-based agro-processing and aquaculture industries, *Enhancing human settlements through appropriate technologies for access to clean water, information and communication technologies and renewable energy.
	National Industrial Policy Framework (DTI, 2007)	*Adopting inclusive growth for historically disadvantaged people and marginalised regions into the mainstream of the industrial economy	*Increasing support measures for process and product innovation, and commercialisation of technologies that support poverty alleviation.
Standards of living	White Paper on Science, Technology and Innovation (STI); Promoting innovation for inclusive rural transformation in South Africa (Policy Brief) (DST, 2019)	*Reducing income inequality which is stifling economic growth, health and education outcomes, *Harnessing innovation for equitable rural social change	*Enhancing innovation and technology for social inclusion and economic growth while maintaining traditional jobs, *Strengthening of rural innovation systems and value chains across primary, secondary and tertiary sectors, *Establishing linkages to ensure innovation adoption, diffusion and adaption.
Skills development	National Skills Development Strategy III (DHET, 2019)	*Expanding access, improved quality and increased diversity of provision of skills, *Integrating the skills landscape with PSET institutions, *Ensuring skills development for the future.	*The establishment of a “catalytic” fund (20% of the skills levy to fund research and innovation across sectors, *Promoting strategic partnerships and innovation including linkages in the skills system, youth programmes, small businesses and co-operatives and rural development.
	National Digital and Future Skills Strategy (DCDT, 2020)	*Ensuring that education sectors including SETAs build a strong focus and invest in digital skills and in the development of digital innovation	*Establishing a national system of innovation (NSI), *Strengthening the research and innovation capacities at institutions of higher learning, in digital incubators, within research entities, and across the private and governmental sectors, *Preparing learners for the future digital world of work and innovation, * Expanding innovation funding, including the South African Research

Domain	National initiatives	Policy objectives	STI outcomes
			Chairs (SARChI) and the many other innovation funding mechanisms, *Establishing partnerships to grow local digital innovation.
Export growth and competitiveness	Economic transformation, inclusive growth, and competitiveness: Towards an Economic Strategy for South Africa (National Treasury, 2019)	*Promoting export competitiveness and harnessing regional growth opportunities	*Growth in innovation and productivity through reducing consumer price mark-up costs, reducing anti-competitiveness, for example, through multiple broadband suppliers in the Telecoms sector, *Ensuring export orientation and sophistication through innovation.
	National Exporter Development Programme (NEDP) (DTIC, 2020)	*Increasing exports, for those products and services that add value and contribute to employment and the green economy	*Developing a pool of export-ready companies, *Through innovation ensure that exports grow, and new markets and export products are developed.
Climate change mitigation and adaption	The National Climate Change Response Policy (NCCRP) (DEA, 2013)	*Responding to climate change, including provisions for adaptation and mitigation	*Developing technologies with potential for contribution to emissions reductions, *Driving innovation, research, and skills for future value capture.
	South Africa's low emission development strategy 2025 (SA-LEDS) (DEA, 2020)	*Ensuring a low carbon growth trajectory and a just transition in building resilience to climate change	*Investing in resource-efficient and cleaner production technologies, *Ensuring skills development in innovation around cleaner production.
Renewable energy	DME Energy Efficiency Strategy of the Republic of South Africa (DME, 2005)	*Contributing towards affordable energy for all, *Minimising the negative effects of energy usage upon human health and the environment	*Deferring the need to build new power plants through the adoption of STI for renewable energy, *Adopting renewable technology in industrial, commercial and domestic buildings to ensure energy efficiency, *Exploring energy efficiency measures in the fuel mix in road freight and transport through bio-fuels.
	DTI Auto green paper on the advancement of new energy vehicles in South Africa (DTIC, 2021)	*Raising South Africa's competitiveness in the transition from the internal combustion engine era into electro-mobility solutions and technologies	* Transitioning South Africa towards cleaner fuel technologies, *development and investment in new energy vehicle component technology and expansion of the fledgling electric supply chain, *Adopting new and sustainable manufacturing processes to significantly reduce greenhouse gas emissions and improve environmental wealth.
Access to supply of clean water	The National Water Research, Development and Innovation (RDI) Roadmap (WRC et al., 2015)	*Improved economic, health, social and environmental benefits related to the water resources management of South	STI interventions to achieve: *At least one breakthrough technology every five years, *Increasing the number of small and medium sized enterprises operating in the water sector,

Domain	National initiatives	Policy objectives	STI outcomes
		Africa through the use of STI	*Increasing access to water for rural communities, including provision of sanitation for all in a sustainable manner.
High-quality healthcare services	National digital health strategy for South Africa (2019-2024) (DoH, 2019)	*Strengthen health systems, *Transforming the way health services are provided, *Ensure better health for all South Africans	*Developing leadership capacity for digital health innovation and adaptive management, *Establishing a robust physical and network infrastructure and broadband connectivity for priority digital health applications and services, * Develop enhanced digital health technical capacity.
Affordable food	National development plan (NDP): Chapter 6 (NPC, 2012)	*Reduce food insecurity and malnutrition	*Supporting innovation to close the urban/rural food price gap, *Innovative technologies to ensure effective nutrition education, *Innovative agriculture and agri-processing to produce fruit and vegetables.
	Zero hunger programme for South Africa (DAFF, 2012)	*Ensuring equal access to food security	*Establishment of a food insecurity information system, *Innovative food distribution networks through agro-industrial development, *Research, technology and innovation to manage food security risks.

Source: National reports as referenced above.

Conceived of as "the introduction of new-to-the world and new-to-the-firm goods, services, business practices, and organisational methods", innovation has the potential to drive sustainable socio-economic change in South Africa (World Bank, 2017, p. 26). Innovation is embedded across the legislative, policy and strategic frameworks for South Africa's economic and social development domains (Table 1 and Table 2) however its ability to translate into significant changes to the country's economic and social priorities remains relatively slow. The adoption of innovation strategies remains debated in both developing and developed economies as it poses the perceived threat of automation and the resultant loss of unskilled or lower-skilled employment (World Bank, 2017; National Treasury, 2019). Some of the potential impacts that innovation has for socio-economic development and the domains identified above, are outlined below:

- Job creation: Innovation in any sector potentially creates jobs and raises the consumption of the poorest by 40 percent of households at the aggregate level (World Bank, 2017, p. 27),
- Skills development: The South African government has put in place a sophisticated system to support entrepreneurship, technology absorption, and innovation in the private sector including measures across the education sector to drive training and skills development for the future,
- Export growth and competitiveness: Disruptive technologies can strengthen competition, for example the e-hailing platform Uber's success despite regulatory constraints the traditional taxi industry's vested interests. Further reducing mark-ups realized in dominant market positions by 50 percent could realise 300,000 additional jobs and lift 600,000 people out of poverty (World Bank, 2017, p. 27). The South African Department of Trade, Industry and

Competition (DTIC) National Exporter Development Programme (NEDP) also focuses on increasing exports, particularly of those products and services that add value and contribute to employment and the green economy,

- Access to healthcare: Vula (a mobile app for healthcare) was founded by an ophthalmologist who volunteered in rural areas in South Africa realising that many people did not have access to specialists or the ability to travel to seek care. The app "enables primary health care workers to fill in a standard questionnaire, take photos, do a basic medical test, and send it to the on-call specialist. The response time is fifteen minutes and the doctor can see other patients while waiting for the advice of the specialist". This innovation has resulted in both cost savings and the support of rural healthcare workers (World Bank, 2017, p. 29),
- Poverty reduction: Poorer households are observed to gain the most from innovations in public transportation, electricity, food, footwear, beverages, and agriculture. Due to the number of unskilled and semi-skilled people employed in the mining sector and dependent on social housing, innovations in these sectors are also expected to have a poverty alleviation impact (World Bank, 2017),
- Innovation and the 4IR: The Presidential Commission on the Fourth Industrial Revolution will co-ordinate South Africa's response to 4IR including policies, strategies, and plans that will position South Africa as a leader in this area, supporting socio-economic development and innovation (DTPS, 2019).

The adoption and implementation of effective innovations relies on increased investment into research and development (R&D), both public and private sector investment. Ultimately, the assimilation of externally generated innovations and those produced within South Africa could drive greater inclusive and equitable socio-economic development.

2.4 Conclusion

As a continuous application of new knowledge or combinations of ideas to generate new solutions to existing production and consumption constraints, innovation has the potential to contribute to solving developmental challenges. For most developing countries, the ability to exploit the opportunities offered by technological innovations and to benefit from their potential to accelerate development depends on establishing critical capabilities that enable local firms and institution to adopt, master and apply externally developed technological knowledge. It is through the accumulation of scientific, technological and social capabilities (supported by development-driven institutions and a mission-oriented incentive system) that modern scientific and engineering discoveries can be transformed into large-scale industrial production systems capable of lifting living standards and enhancing freedoms. Strategic planning, resource mobilisation and intensive human capital investment are essential preconditions for building these capabilities, as exemplified by the experience of countries that managed to achieve rapid growth and development and close the technology gap, such as Japan, Korea, Taiwan and, more recently, China, which succeeded in lifting more than 850 million people out of poverty in just 40 years (World Bank 2019). With strengths in science, innovation and technology in certain domains, which Kruss (2020) refers to as islands of excellence, South Africa has the potential to expand its innovation capabilities and harness them to unlock the low-growth cycle that has characterised the county's economy for several decades. Integration between innovation strategy, industrial policy and bargaining strategies to upgrade coalitions will be critical to the potential success of leveraging innovation and technological knowledge for development in South Africa.

3. Sub-sectoral indicators of and trends in socio-economic and environmental change in South Africa

This section presents an overview of indicators of and trends in the key socio-economic and environmental challenges facing South Africa. Within the national and global constraints, creative solutions need to be devised by using all available tools of modern science and technology in order to strengthen the common foundation of an inclusive and cohesive society. Innovation offers opportunities to harness the power of new knowledge and find solutions to old and new challenges. The examples provided in the boxes present concrete examples, including from the rest of the world, of how the power of innovation, guided by strategic planning, can be deployed to overcome substantive socio-economic and environmental problems. Eleven sub-sectoral challenges have been identified and are set out below. Key indicators and data trends for these challenges are selected and discussed.

3.1 Economic growth

South Africa's economy has been growing at a slow and erratic pace for much of the period following the 2007–2009 global financial crisis. Over the five years preceding the outbreak of the COVID-19 pandemic, real GDP growth rate averaged 0.84 percent per annum, which is lower than the population growth rate (Schröder and Storm 2020). This implies that per capita GDP growth has been negative, a trend that started in 2014. As a result, when adjusted for inflation, the current size of the South African economy is no higher than it was in 2012 at 2010 constant prices (Statistics South Africa [Stats SA] 2021). It is estimated that, due to the effects of the pandemic restrictions, output contracted by seven percent in 2020 (Stats SA 2021).

The key growth performance indicators presented here include, in addition to the real growth rate of gross domestic product (GDP), the ratio of gross domestic fixed capital formation (GDFCF). Fixed capital formation is important for growth to the extent that it determines the pace at which knowledge-embodying production factors, such as machinery and industrial equipment, are being accumulated. Embodied technology is indeed a predictor of future productivity (Barba Navaretti and Soloaga 2001).

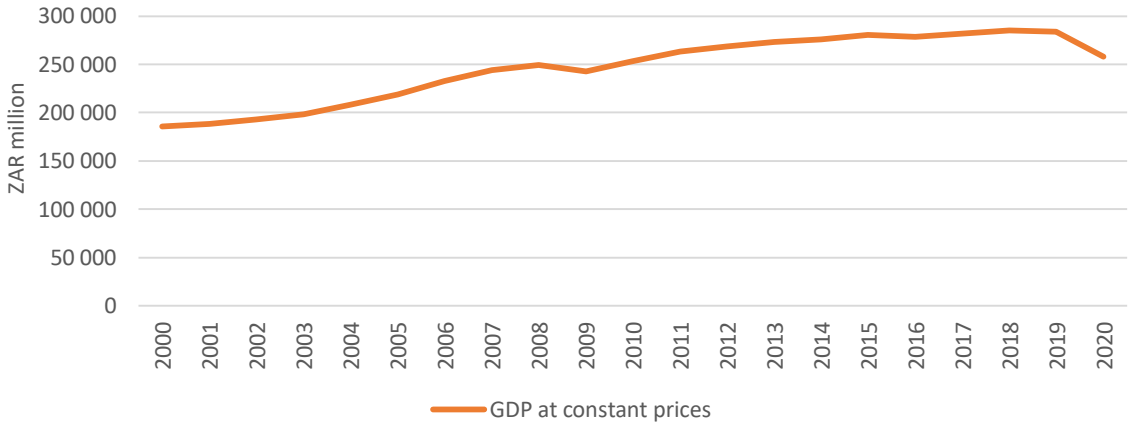
Table 3: Critical indicators of economic growth performance

Indicator	Data source
Annual GDP value at constant 2010 prices	*Statistics South Africa*
Real GDP growth rate	*Statistics South Africa*
Per capita GDP growth rate	*Statistics South Africa*
Gross fixed capital formation	*Statistics South Africa*

3.1.1 GDP

As can be seen in Figure 1, real GDP at constant 2010 prices has been increasing at a modest pace, but was affected adversely by the 2007–2009 global financial crisis. The graph also indicates a flattening of the output since 2014 as a result of the disappointing growth rate, which could hardly compensate for inflation. Output contracted in 2020 due to the effects of COVID-19 and the associated containment measures.

Figure 1: Market value of GDP, 2000–2020, (constant 2010 ZAR millions)



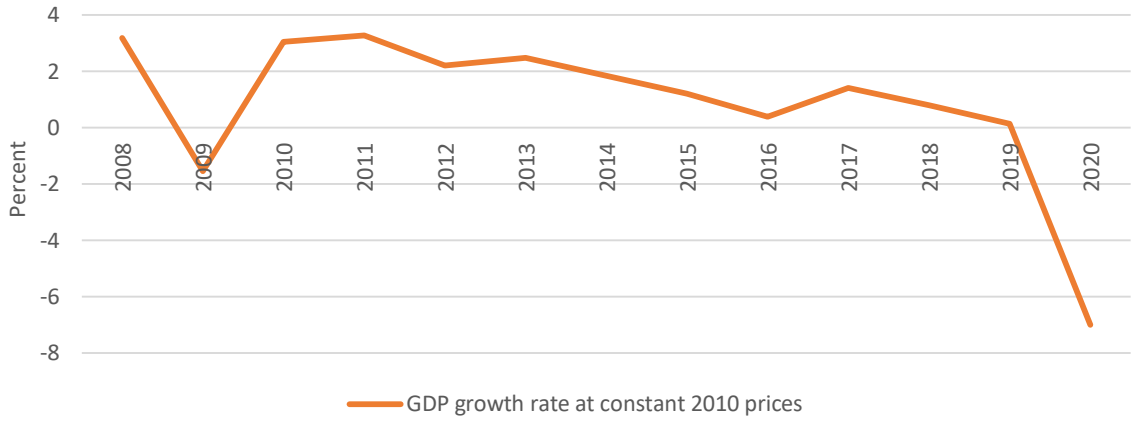
Source: Statistics South Africa (2021)

3.1.2 GDP growth trends

South Africa's economic performance has been poor over an extended period of time, with a clear downward trend since 2011 (Figure 2). Even though the seven percent decline in output caused by the COVID-19 pandemic was a massive hit on the growth rate, it came at a moment when the economy was hardly emerging from a short recession period. Even before the COVID-19 pandemic struck in the first quarter of 2020, the projections for economic growth were relatively modest, with hardly any sign of take-off. The economic rebound and employment recovery in the last two quarters of 2020 signal expectations of a positive growth rate for the current year and a modest recovery, but it will take longer for the economy to recover fully from this shock.

For 2021, the growth rate can be expected to reach 3.3 percent, mainly because the previous decline lowered the base from which growth is computed. This rate can be expected to slow down to 2.2 percent in 2022 and settle back to 1.6 percent in the year thereafter (National Treasury of the Republic of South Africa 2021). These expectations are assumed to materialise in a global recovery climate, with a global output growth of 5.5 percent expected for 2021 and 4.2 percent for 2022. A potential obstacle to keeping the growth momentum in the future is the growing government debt burden, which has been exacerbated by the costs of responding to the pandemic and is expected to rise from 80.3 percent of GDP in 2020/21 to 87.3 percent of GDP by 2023/24. This will imply debt-service costs reaching R338.6 billion per year, which will constrain government's ability to use fiscal instruments to stimulate growth in the future.

Figure 2: GDP annual growth rate, 2008–2020 (percentage)



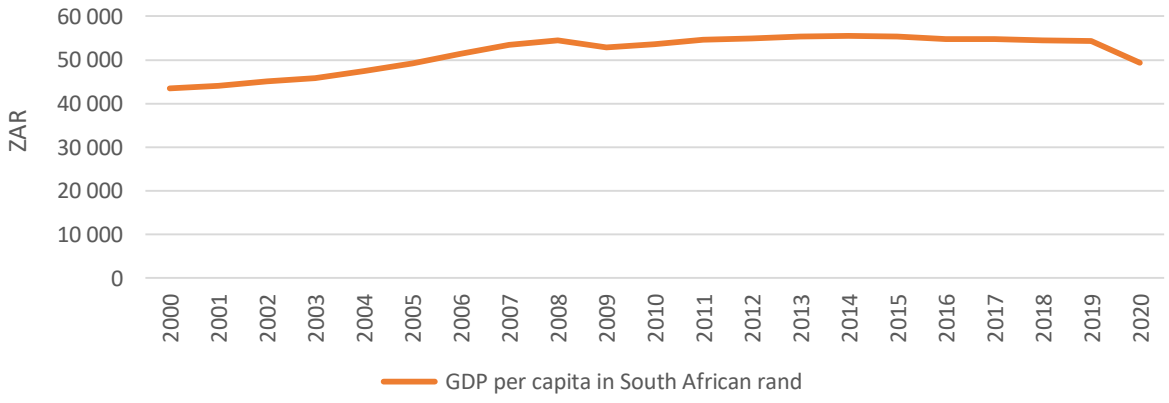
Source: Statistics South Africa (2021)

3.1.3 Per capita GDP growth rate

As a result of the persistently weak output performance, per capita GDP stagnated after the global financial crisis and reached a peak in 2014. Since then, the weak economic performance led to negative per capita GDP growth rates, as it fell short of the population growth rate and failed to regain enough strength to prevail over the latter (Figure 3). The devastation caused by COVID-19 since the second quarter of 2020 have made it even more difficult to reverse this trend, to the extent that the real per GDP capita (at 2010 constant prices) reverted to the 2005 level (Stats SA 2021). In comparison, the Republic of Mauritius, which had a per capita GDP fairly comparable to South Africa's in 2005, doubled its per capita GDP level by 2018.

South Africa's poor growth performance shows up more starkly when assessed on a per capita basis, as shown in Figure 3.

Figure 3. Per capita GDP at 2010 constant prices, 2000-2020 (ZAR)

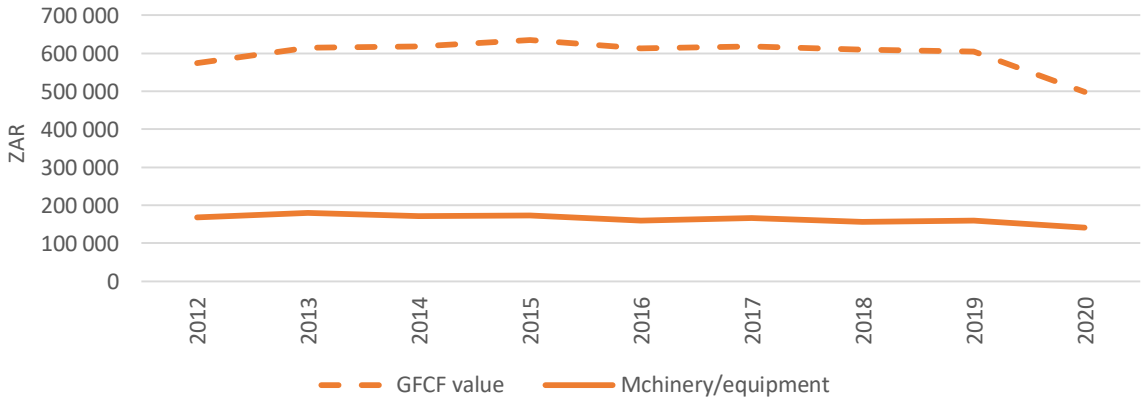


Source: Statistics South Africa (2021)

3.1.4 Gross fixed capital formation (GFCF)

Gross domestic fixed capital formation (GFCF) is an important lead indicator of future growth performance, as it is associated with the pace at which productive capital and embodied technological knowledge are accumulated. Productive capital and its technological content, in turn, determine the future activity level. The amount and quality of capital and equipment available to each worker for the production process also affect labour productivity (with decreasing marginal returns), and therefore influence the growth rate of output. Because capital equipment and machinery are also the vehicles through which embodied technological knowledge is deployed in the production process, the rate of GFCF has the potential to affect the rate of technical change to the extent that it relates to capital equipment-embodying technology. A close look at the composition of capital formation assets reveals that machinery and equipment form the largest share in asset value with respect to the total, but their share remains below 30 percent over the period considered. Figure 4 presents the total values of fixed capital formation (at constant 2010 prices), as well as the corresponding investment in machinery and equipment added to the capital stock over the period 2012 to 2020. While the annual real value of capital investments remained relatively stable over that period, fixed capital formation dropped significantly in 2020 in reaction to the COVID-19 crisis. The declining trend had set in two years earlier, but was exacerbated by a sharp decline in capital investment across all industries as the economy entered lockdown restrictions.

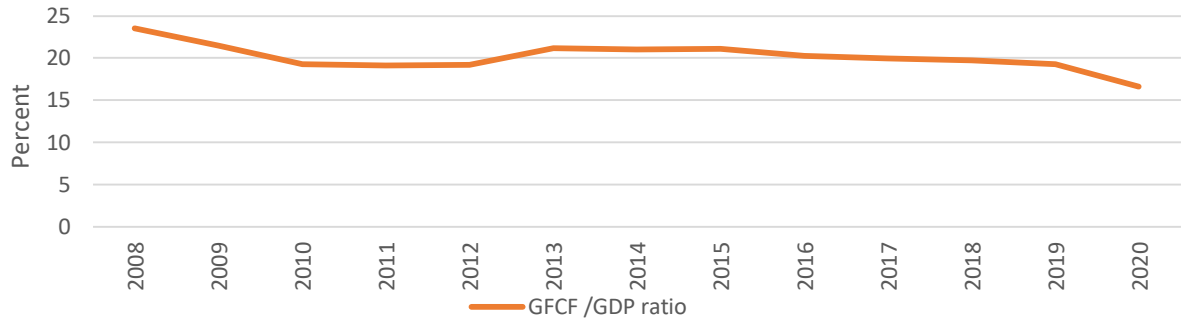
Figure 4: South Africa's investment in machinery and equipment and total gross fixed capital formation at constant 2010 prices, 2012-2020 (ZAR)



Source: South African Reserve Bank (2021)

Relative to its GDP, South Africa's ratio of capital accumulation has been at around the 20 percent level over the last decade, but started to drop below this level over the last four years (see Figure 5). This ratio of 20 percent of GDP is the global average for GFCF, while the average for upper-middle-income countries was about 28 percent in 2016 (Pettinger 2016). Countries with recent experiences of high growth rates, such as China and Vietnam, have been devoting relatively high shares of their GDP to capital formation. While a higher share of capital investments reduces the share of current consumption, it benefits future growth by facilitating technological change and pushing the production possibility frontier outward. The resulting output expansion may equally lead to virtuous growth circles through learning-by-doing and economy-of-scale effects.

Figure 5: Gross domestic fixed capital formation ratio, 2008-2020 (percentage of GDP)



Source: South African Reserve Bank [SARB] (2021)

For manufacturing activities with a learning curve, the learning-by-doing effects are another important source of labour productivity growth, as more experienced workers improve their work routines and become more efficient at performing their tasks and less prone to errors and mistakes. Innovation and technological change also contribute to increasing labour productivity through their effect on increasing the capital–labour ratio and shifting the production function outward, respectively. In innovation-driven economies, technological changes due to the absorption of foreign technologies or the development of home-grown innovations through local research and development efforts can be the primary mechanism underlying labour productivity growth and the corresponding output growth performance. The experience of Korea's innovation-based growth strategy illustrates the importance of using technological change as an engine of growth and development (see Box 2).

Box 2: Industrialisation, innovation and economic growth in Korea

Innovation and technological change contribute to increasing labour productivity through their effects on increasing the capital-labour ratio and shifting the production function outward. In innovation-driven economies, technological changes due to the absorption of foreign technologies or the development of home-grown innovations through local research and development efforts can be the primary mechanism underlying labour productivity growth and the corresponding output growth performance. Among newly industrialised economies, Korea remains one of the most remarkable examples of innovation-based development. After its remarkable transformation from an impoverished agrarian economy to a high-tech industrial powerhouse in less than 40 years, Korea has now become a global innovation leader, with a consistent top ranking in Bloomberg's innovation index of the world's 60 most innovative economies (Jamrisko et al. 2021). The country was able to achieve this prowess through sustained efforts in human capital accumulation and massive R&D investments since the 1970s, which transformed it into one of the world's most innovation-intensive economies. With 4.5 percent of its GDP spent on R&D investment in 2020, it also has one of highest ratio of R&D spending to GDP, second only to Israel (Dayton 2020). With its innovation-based development strategy, which emphasised domestic competence building for industrial technology acquisition, Korea succeeded in building a unique innovation system that supports sustainable economic growth generated by industrial production (Chung 2011). The strength of this innovation system was built thanks to the government's commitment to a strategy that prioritised technology acquisition and national innovation competence for "technology-based national development" during the period 1961 to 1991 (Chung 2011). The payoffs of this strategy have been impressive, leading to innovation leadership in target domains such as the production of technology-intensive products (semiconductors, cellular phones, liquid crystal displays, automobiles, etc.). Korean firms attained technological capability through informal channels for technology transfer, then evolved from imitation and reverse engineering to innovation in the 1970s by relying on highly competent human resources, as well as on the government's incentives to support intensive R&D investment in the domains that were critical to its growth strategy. The contribution of R&D stocks to economic growth has been increasing, along with economic development. By 2008, it was estimated that the stock of R&D accounted for 22.7 percent of economic growth in Korea in the period 1971 to 1990, and reached 30 percent over the period 1991 to 2006.

Source: Chung (2011)

3.1.5 Conclusion

South Africa's economic performance has been sluggish over the last decade. This poor performance has been attributed to several factors, including its structural constraints that favoured extractive industries and financialisation instead of innovation-driven industrialisation (Mohamed 2019). Without comprehensive reforms and a strategic reorientation, the economy is unlikely to break out of its low growth inertia and reach a sustainable growth path. Whereas the contribution of innovation to industrial competitiveness is generally accepted as a stylised fact in the neo-Schumpeterian tradition, quantifying this contribution remains a daunting challenge, owing to the methodological complexities. One way of approaching this issue is to estimate how total factor productivity growth in an economy can be related to the change in the stocks of R&D, as suggested by Griliches and Lichtenberg (1984). The calculated elasticities vary from one economy to another, but can be used as generic indicators of the growth benefits that can be attributed to the economic advantage of technology and innovation. As shown by the example of Korea, innovation can be an engine of economic growth if the policy choice of government strategy provides for sufficient quality of human resources and offers the required incentives for the industry to succeed. Of primary importance in the success of an innovation-driven growth strategy is market co-creation, whereby the public sector defines the development mission to be achieved and builds coalitions with the private sector in coordinating the innovation competencies and efforts required to achieve the mission, as suggested by Mazzucato (2018).

3.2 Job creation

After shedding more than two million jobs in 2020 as a result of the lockdown and other containment measures associated with COVID-19, the South African economy has been operating below its production capacity, despite the strong job recovery reported by the third survey wave of the National Income Dynamics Study (Spaull et al. 2021). But even before the pandemic struck, the economy had been suffering from productivity stagnation, mainly due to the underutilisation of existing production capacity, according to Schröder and Storm (2020). Since the advent of democracy in 1994, the reduction of high unemployment rates became one of the priorities of government policy. With the help of a relatively robust economic growth performance, unemployment rates dropped steadily, from a high of 33.4 percent in 2002 to 22.7 percent in 2008, before the global financial crisis hit and led to job shedding (Ngandu et al. 2010). In the aftermath of that crisis, the economy struggled to recover the job losses, and unemployment has been on the rise, reaching a peak of 32.5 percent amidst the COVID-19 crisis. To relaunch employment recovery in the wake of the massive job shedding caused by the COVID-19 lockdown, the Presidential Employment Stimulus Programme was deployed for the creation or protection of 600 000 job opportunities, with plans for approximately 74 000 more to be created (Habiyaremye 2021; Presidency of the Republic of South Africa 2021). We shed light on job creation with the help of the following indicators, as presented in Table 4.

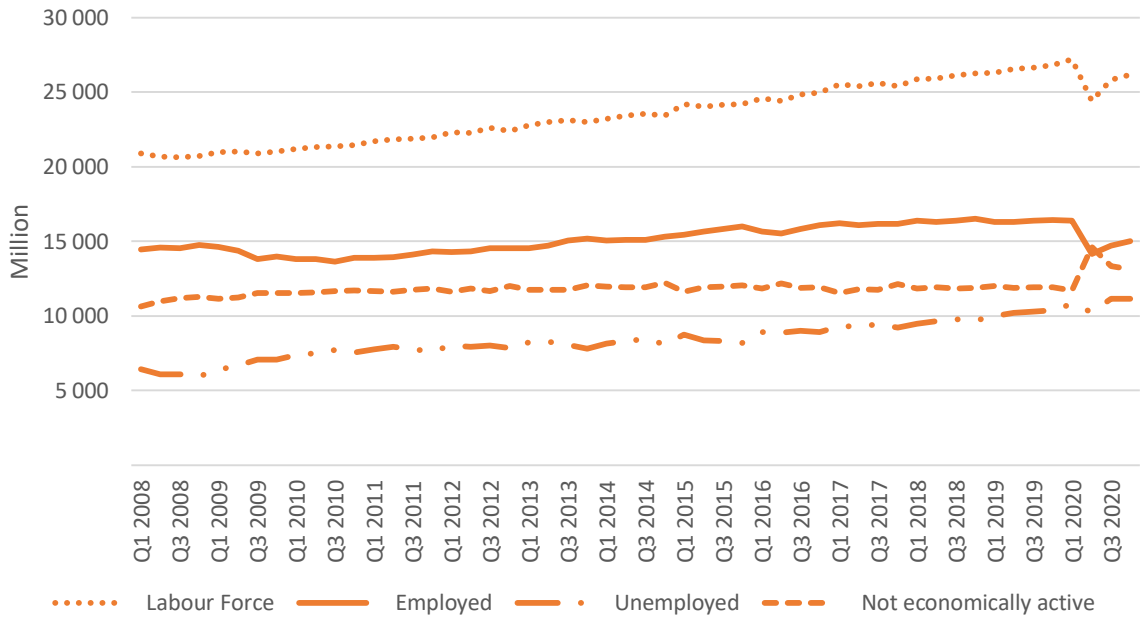
Table 4: Critical indicators of job creation in South Africa

Indicator	**Data source**
Labour force participation rate	*Statistics South Africa*
Absorption rate	*Statistics South Africa*
Unemployment rates	*Statistics South Africa*
Youth unemployment rates	*Statistics South Africa*

3.2.1 A steadily growing labour force

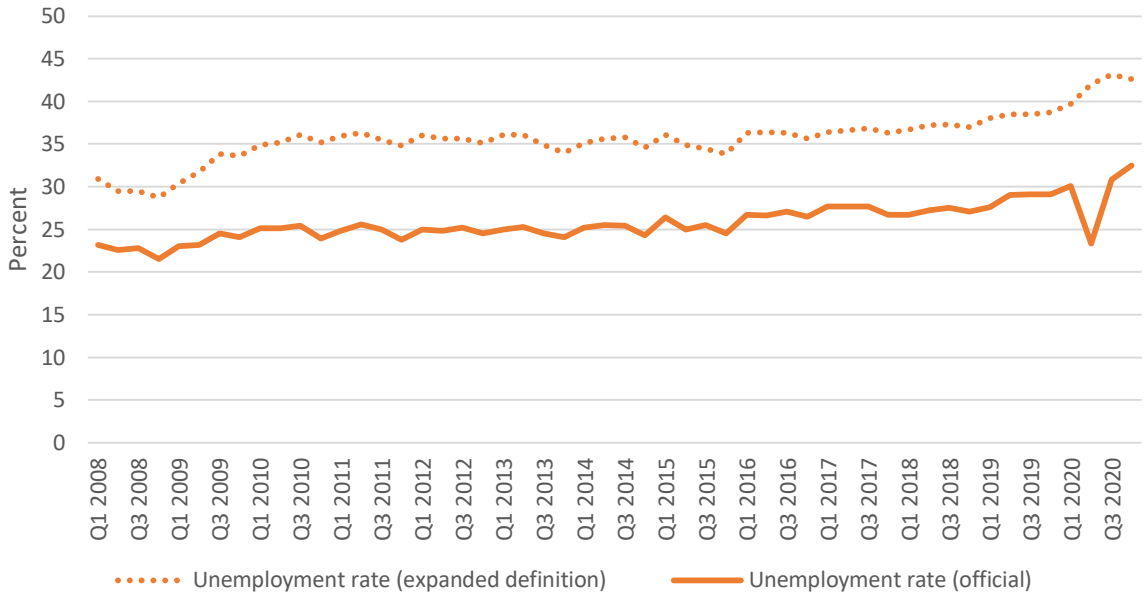
When apartheid-era restrictions on employment were lifted, the number of people joining the labour market increased considerably in the first years of democratic South Africa. Increased access to quality education for previously excluded black Africans also implied changes in supply in the labour market. In the fourth quarter of 2020, there were 39.3 million people of working age in South Africa (age 15 to 64 years). Of the working-age population, 17.1 million were not economically active, which corresponds to a labour force of 22.3 million people. The country's labour force participation rate reached 54.20 percent in September 2020. With the partial employment recovery in the second half of 2020, the number of employed reached 15 million by December 2020, while 7.2 million remained unemployed, resulting in an official unemployment rate of 32.5 percent. With 2.9 million discouraged workers, the unemployment rate according to the expanded definition is therefore higher at 42.6 percent.

Figure 6: South African labour force by nature of employment, 2008–2020 (millions)



Source: Quarterly Labour Force Survey (2020)

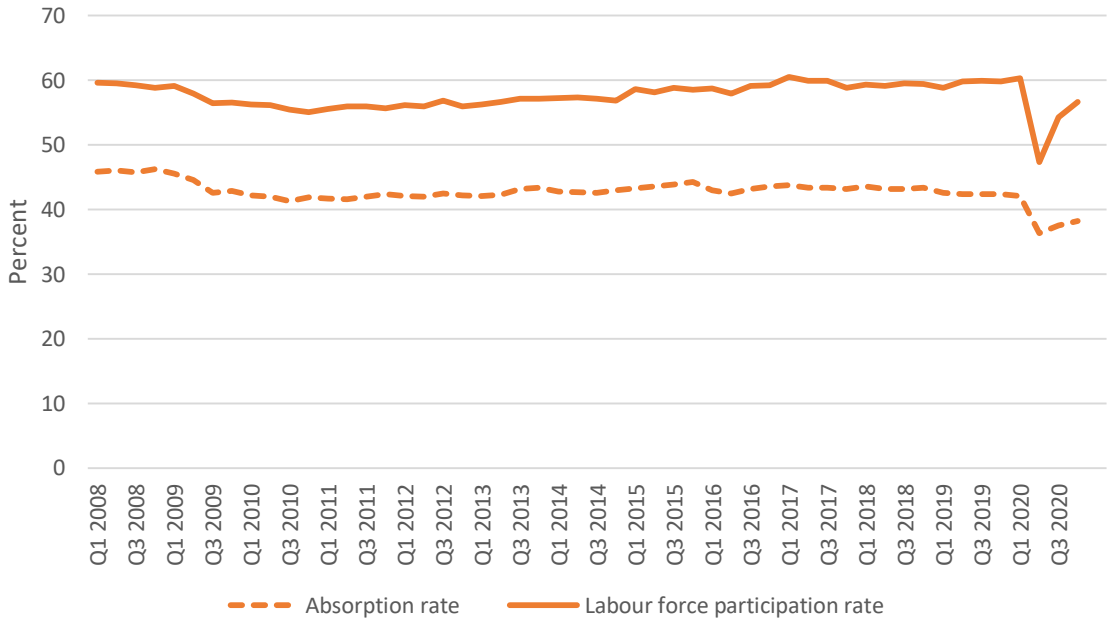
Figure 7: South African unemployment rate, 2008–2020 (percentage)



Source: Stats SA, Quarterly Labour Force Survey (2020)

Labour market data indicates that the rate of employment to total population has declined from 43.29 percent in 2008 to 39.53 percent in 2019. With such a low level of employment absorption, a substantial share of the potential labour input necessary to stabilise and increase the per capita GDP is excluded from participation in the production process.

Figure 8: Labour force absorption and participation rates, 2008–2020 (percentage)



Source: Quarterly Labour Force Survey (2020)

The biggest driver of job creation in the aftermath of the global financial crisis has been the public sector, which has added more than half a million jobs with an increasingly high level of skills between 2008 and 2016. The services sector has been the other engine of job creation, with 2.7 million jobs created between 2001 and 2012 (UNU-WIDER 2016).

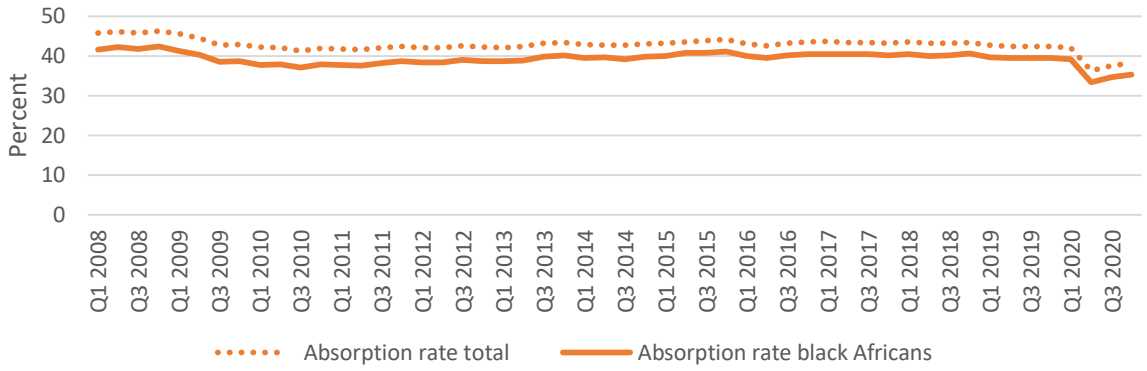
3.2.2 Trends in job creation

Job creation in South Africa has been slow in comparison to the shifts in the labour force. For the third quarter of 2020, there were significant movements from the non-economically active categories to the active labour force, of which the number of employed persons increased by 543 000 in comparison the previous quarter. At the same time, total unemployment increased by 2.2 million, whereas the number of discouraged workers who no longer sought work also increased by 225 000 (Quarterly Labour Force Survey 2020).

Job creation, however, is a costly operation, while public finances have only limited capacity to expand employment through fiscal spending if the efforts are not coordinated with the industry in a broader industrial policy strategy. In South Africa, the job multiplier of fiscal stimulus spending has been estimated at six to seven jobs created for each R1 million spent by the government on job creation (Schröder and Storm 2020). The R100 billion budget of the presidential employment stimulus for 600 000 jobs is one of the high-profile policy initiatives to stimulate employment (Presidency of the Republic of South Africa 2021), whereas the proposed R2.3 trillion infrastructure stimulus in partnership with the private sector represents a considerable opportunity to expand employment over the next 10 years (Habiyaremye et al. 2021).

The latest job-creation report based on the quarterly labour force survey of the last quarter of 2020 indicates that employment increases between the third and the fourth quarter were observed across several industrial sectors, with the community and social services generating the highest number (170 000 jobs added), followed by construction (86 000), private households (76 000), transport (65 000), and trade (55 000). The absorption rates remain relatively low, especially for young people aged 15 to 24, with only 7.6 percent (unemployment rate of 63.2 percent), those aged 55 to 64, with an absorption rate of 37.4 percent, and those aged 25 to 34, with an absorption rate of 41.8 percent. The only age categories to have an absorption rate above 50 percent are those aged 35 to 44, with 56 percent, and 59.1 percent for those aged 45 to 54. The employment absorption rate for black Africans is noticeably lower than that of other population groups, and their unemployment rate also remains higher.

Figure 9: South African employment absorption rates, 2008–2020 (percentage)



Source: Quarterly Labour Force Survey (2020)

3.2.3 Youth unemployment

Youth unemployment is of particular concern. Especially among the age group 15 to 24 years, the unemployment rate (expanded definition) has been hovering above 60 percent for the last decade, reaching an extremely high rate of 73.8 percent in the last quarter of 2020 (Statistics South Africa, 2021b). This rate remains high, despite the fact that a large portion of the youth in this age category is economically inactive, with a labour force participation rate fluctuating between 38.9 percent in the first quarter of 2008 and 37.1 percent before the onset of COVID-19 pandemic in March 2020. A closer look at the structure of youth unemployment reveals that African youth are disproportionately affected by unemployment and poverty, especially young people in rural areas, where industries and economic opportunities are very scarce.

In its diagnostic overview of 2011, the National Planning Commission (NPC) had already identified the high rate of unemployment, especially among the youth, as one of the central contributors to widespread poverty in the country. The NPC traces the roots of this historically high rate of unemployment back to the century-long denial of access to quality education, as well as the special restrictions that kept Africans from living in areas that facilitated access to skills accumulation. For most of the apartheid period, institutional and special isolation contributed to impeding their ability to accumulate the skills and qualifications necessary to be ready for the modern labour market. The geographical isolation of settlements where most black youth live remains a challenge to this day.

3.2.4 Conclusion

The strength of any economy depends on its capacity to deploy its human resources in productive activities. In this regard, the functioning of the labour market in South Africa is also one of the main determinants of the socio-economic outcome measures for the population. In a society already characterised by high income and wealth inequality, a stable job is one of the safest means for workers to be shielded from vulnerability to poverty, while the loss of employment significantly increases the likelihood of falling into poverty.

Innovation is understood in government policy discourage to have a considerable potential for job creation and for driving social change in South Africa. Both the National Development Plan (NPD30) and the DST's 2019 White Paper on Science, Technology and Innovation highlight the role of Science,

Technology and Innovation in addressing the country's socioeconomic challenges. Despite optimistic expectations about the power of innovation in creating jobs, both theory and empirical evidence from the innovation literature provide enough reasons for caution. Theoretical arguments suggest two main channels through which innovation affects employment: product innovations tend to favour employment growth due to their positive effects on demand, while process innovations and technical change, by reducing production costs, tend to have a displacement effect and reduce demand for labour (Pianta, 2000; Peters 2008; Vivarelli 2014, etc.).[1] In aggregate, however, several compensation mechanisms exist through which process innovation and technical change can still lead to increase in demand for labour if their multiplier effects outweigh the displacement effect:

1. Compensation via capital goods production: displaced labour can be used in the capital goods sector to produce new machines in demand for the diffusion of technological change (if technical progress is brought about by embodied technological knowledge) (Vivarelli 2014);[2]
2. Compensation via lower prices, by which cost reduction passed on to consumers in competitive markets increases market demand, which may lead to volume expansion (depending on price elasticity) and thus increased labour demand (Vivarelli 1995);
3. Compensation through new investments: innovation and technical progress lead to cost reduction which enable entrepreneurs to accumulate profits before competition forces price reduction: when these accumulated profits are invested in new production, new employment is created (Stoneman 1983);
4. Compensation by decrease in wages: labour-saving process innovations could lead to a downwards wage adjustment (instead of layoffs), which leads to higher demand for labour (Venables 1985).
5. Compensation through increased incomes: if unionised workers take a share in the larder profits due to production cost reduction, technical progress leads to higher workers incomes which increase market demand and induces higher demand for labour (Boyer 1988).

In practice, there are several obstacles to the working of the compensation mechanism. Employment outcomes of innovation can therefore vary widely from positive to negative across industrial sectors (Pianta 2000; Peters 2008; Vivarelli 2014). Inefficient regulations, intellectual property regimes and lack of competition are some of factors impeding compensation mechanisms through price reduction (Vivarelli 2014). Empirical evidence of employment growth induced by innovation is also ambiguous, with some studies like Greenan and Guellec (2000) reporting positive effects of technological innovation on firm-level employment growth in France, while Blechinger et al. (1998) report evidence of negative effect of technological change on employment growth in Germany, with stronger effects in larger firms. Simonetti, Taylor and Vivarelli (2000) also found process innovation to be mostly labour saving, with compensation mechanism restoring employment through price reduction and income growth. They also found product innovation to lead to a significant increase in labour intensity only in the technological leader. In contrast, Cirera and Sabetti (2016) found new sales associated with

[1] The overall effect of product innovation on employment is positive if demand for newly created products outweighs the loss of production due to substitution (those that become obsolete as a result of the entry of new ones).

[2] In skills-intensive sectors, skills-biased innovation may lead to constraints in employment because of the high level of skills required, which may displace unskilled labour, while the scarcity of skilled human resources limit the employment potential of the new production (Amendola and Gaffard 1988; Berman et al. 1994, Machin 1996).

product innovations to be produced with higher or equal levels of labour intensity in developing countries. For Spain, Alonso-Borrego and Collado (2002) found evidence that innovative firms tend to create more jobs and to destroy less employment than non-innovative firms, especially with innovation measures based on process innovations. Jobs created through innovation-induced technological change are commonly skills intensive and may lead to greater income dispersion in developing countries (Vivarelli 2012). Some innovations, such as those created by frontier technology applications, may even threaten employment creation by contributing to job displacement as advance artificial intelligence, robotics and the internet of things may considerably reduce the numbers of human input needed to perform some operations (UNCTAD 2021). Because of the high skills requirements associated with certain jobs created as a result of innovation, technological change may result in more income polarisation since the benefits are skewed towards skilled workers. For imitation-based innovations, positive employment effects are more limited, even though imitation plays an important role in technology diffusion and may generate more employment benefits in the long run (Peters 2008).

In South Africa, evidence from the Business Innovation Survey data suggests that, while product innovation has a positive effect on employment growth in manufacturing firms (and not in service firms), process innovations have a negative effect on employment growth, for both the manufacturing and service sectors (Sithole and Buchana, 2021). In a study conducted by the World Bank (2017) using computable general equilibrium (CGE) modelling, innovation was estimated to generate employment in multiple sectors of South African economy, with positive effects on the consumption level of the bottom 40 percent of the income distribution[3]. The International Labour Organization (ILO) also estimates that South Africa can create 462 thousand additional jobs by investing in clean energy generation, improvement in energy efficiency, pollution control, and sustainable natural resource management (World Economic Forum 2017).

Since the massive job losses of the last global financial crisis, the public sector has been one of the main drivers of employment creation in South Africa, but the rate of absorption has not improved (slightly falling instead) because of the strong growth of the labour force. The slow pace of private investment expansion and the skills mismatches that characterise the South African labour market have resulted in a low employment growth rate, accompanied by a mounting unemployment. Government programmes intended to stimulate job creation have resulted in the creation and protection of employment opportunities in the wake of the massive job losses due to the COVID-19 lockdown (Spaull et al. 2011), but have not been enough to reverse the growing trend of unemployment. The existing estimates of fiscal job multiplier and employment elasticities output for the South African economy signal important limitations in the capacity of government to use fiscal stimulus measures to expand employment, since the costly job creation would put additional pressure on government finances that are already drained by the costs of fighting the effect of the pandemic. Purpose-driven partnerships between state and private sector to mobilise private investment

[3] Noteworthy in this estimation are the effects of innovation in gold mining and social housing on both employment creation and increase in consumption of the 40 percent poorest households, as well as the effect of innovation in transportation system on consumption increase, potentially through easing the constraints of special planning on the mobility of low-income households.

expansion in are one of the available options to create new dynamics for economic growth as an engine of reliable employment growth (Doner and Schneider, 2016).

With a view to harness the innovation and technological change as a strategy to capture the potential benefits of innovation on employment creation, the South African government has put in place policies and systems to support entrepreneurship, technology absorption, and innovation in the private sector. Instruments deployed to encourage innovation and entrepreneurship include incubators, grant schemes employee training and tax incentives (World Bank, 2017). Additional financial resources and non-financial incentives are also deployed to promote technology adoption and facilitate collaboration between industry and public research institutions. No less than four government department are involved in that effort: the Department of Science and Innovation (DSI), the Department of Trade, Industry and Competition (DTIC), the Department of Small Business Development (DSBD) and the Department of Public Enterprises (DPE). Local governments and the Industrial Development Corporation (IDC) are also actively involved in the implementation of this strategy (World Bank, 2017). These efforts can benefit from the strength of the South African innovation system in the form of research excellence with relevance, innovation incentives and a conducive institutional setting.

3.3 Poverty alleviation

3.3.1 Characterisation of poverty in South Africa

While poverty among the economically excluded has long been a feature of South African society under apartheid, substantial progress has been made in reducing the intensity and influence of poverty since the democratic transition in 1994, mainly as a result of the implementation of a redistributive transfers programme in the form of government grants (Leibbrandt et al. 2010). More limited has been the pace of reduction of the incidence of poverty, which implies that poverty rates have remained significantly high for a middle-income country. As of 2018, according to the World Bank (2018) assessment report, nearly half of the population of South Africa was still considered chronically poor at the upper-bound national poverty line, of R992 per person per month (2015 prices). For the chronically poor, poverty is persistent, with few prospect of getting out of it.

In addition to the chronically poor, poverty or the risk thereof affects the ‘transient poor’ segment of the population, which is comprised of people who run an above-average risk of falling into poverty in the case of any external shocks. The segment of non-poor but vulnerable to poverty consists of people who temporarily have their basic needs covered, but face an average risk of slipping into poverty. When these two groups are added to the chronically poor, it appears that, for almost 76 percent of the population, poverty is an ever-present threat (World Bank 2018). Poverty measures in South Africa are based on welfare indicators collected in Income and Expenditure Surveys (IES) and Living Conditions Surveys (LCS), which are periodically administered by Stats SA. For this report, we use the poverty indicators as reported in Table 5.

Table 5: Critical indicators of poverty alleviation

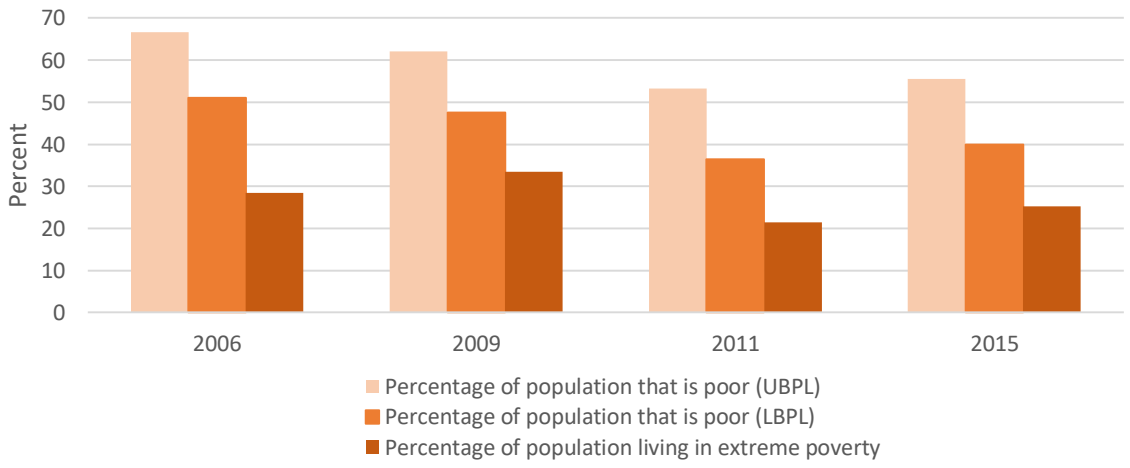
Indicator	Data source
Headcount poverty ratios (different poverty lines)	*Statistics South Africa*
Food insecurity and food poverty	*Statistics South Africa, National Income Dynamics Study*
Poverty intensity	*Statistics South Africa, World Bank*
SA multidimensional poverty index	*Statistics South Africa, World Bank*

3.3.2 Poverty headcount ratios (at various poverty lines)

Headcount poverty ratios declined over the period 2006 to 2011, but poverty reduction has been slower since then (Figure 10). As a result, more than half of South African households were still living in poverty in 2017 at the national upper-bound poverty line, while a quarter of the households were below the food poverty line (Zizzamia et al. 2019). Using the lower-bound poverty line, the headcount poverty ratio declined from 51 percent in 2006 to 36.4 percent in 2011, but rebounded to 40 percent in 2015. In contrast, the corresponding ratios of people living in extreme poverty have been slower in their decline: these have fluctuated between 28.4 percent in 2006 and 25.2 percent in 2015, with the only period of decrease coming between 2009 and 2011.

These ratios represent several millions of South Africans having to deal with hardships in meeting their basic needs. More than 30 million people were still living in poverty at the upper-bound poverty line in 2015, while 13.8 million people were trapped in extreme poverty. A closer analysis of the NIDS poverty data has brought to light more insight into the dynamics of poverty, suggesting that eight out of ten South Africans found themselves in a situation of poverty at least once over the six-year period between 2008 and 2014/2015 (Schotte et al. 2018; Zizzamia et al. 2019). In terms of spatial distribution, rural households have a higher proportion of people living under the upper-bound poverty line (UBPL).

Figure 10: Headcount poverty ratio, at the upper-bound poverty line, 2006-2015 (percentage)

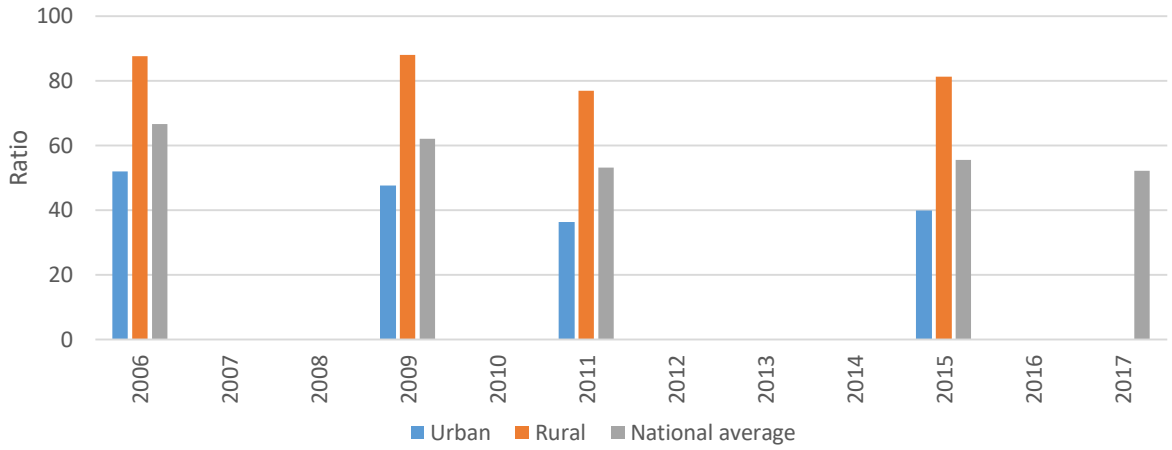


Source: Statistics South Africa (2017a)
Note: Data available for intermittent years.

In South Africa, poverty is also characterised by strong spatial concentration, reflecting the lasting damages of the spatial planning of apartheid, combined with economic exclusion. While there are large differences in poverty ratios between rural and urban areas (with poverty concentrated in the former 'bantustans'), stark concentrations of poverty can also be found in informal settlement

neighbourhoods in urban areas and in areas that were reserved for the economically excluded under apartheid (World Bank 2018). Statistics South Africa survey data indicate that, in 2006, 87.6 percent of rural residents were poor at the upper-bound poverty line, while only 52 percent of the urban population was poor in the same survey (Figure 11). By 2015, the poverty ratio at the upper-bound poverty line was still a high 81.3 percent of rural households, while the rate for urban households had dropped to 40 percent.

Figure 11: Headcount poverty ratio at the upper-bound poverty line, 2008–2017 (ratio)



Source: Statistics South Africa (2017); World Bank (2018)
Note: Data available for intermittent years.

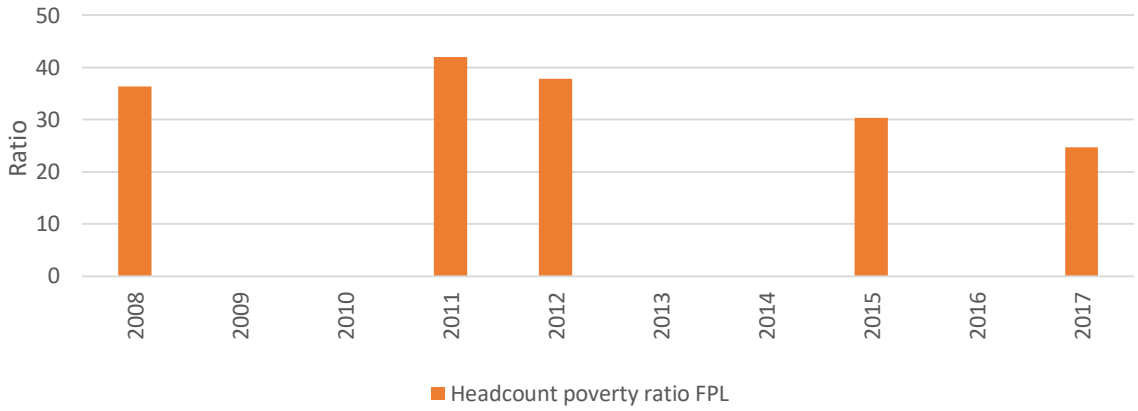
Half of those found to experience poverty over that period remained persistently below the poverty line over the entire period (Schotte et al. 2018). People who experience poverty on a transient basis are those who have a better level of education and derive most of their income from employment, as opposed to the chronically poor, who have unstable sources of income. Race remains a significant factor in the determination of the incidence of poverty in South Africa, as black Africans remain more likely to be poor than their white and Indian compatriots. In comparison, whites are 26.6 percent less likely to fall into poverty and 42.6 percent less likely to remain poor, even after controlling for differences in education (Zizzamia et al. 2019).

Insecurity associated with vulnerability to poverty often leads to low-income traps, as risk-averse people minimise the risk of falling into poverty by avoiding economic activities that may yield higher returns, but bring with them a higher risk of failure. As a result, about 50 percent of the South African population was found to be trapped in chronic poverty from which they remain highly unlikely to escape (Schotte et al. 2018). Poverty trends suggest that, despite government intervention to limit the effect of poverty on households through social grants, the incidences of poverty have not declined significantly. Data from the World Bank indicate that the income share of the bottom 10 percent of earners has been below one percent since 2005, while the share held by the lowest 20 percent also remained below 2.6 percent. Given the growing income and wealth concentration observed in the last decade, this tends to imply that, far from improving, the income share of the poorest quintile of the population has slowly been shrinking, signalling the constraint to upward social mobility for most people in the bottom income group.

3.3.3 Food insecurity and food poverty line ratios

One of the characteristics of poverty in South Africa is the surprisingly high proportion of households exposed to food insecurity. As can be seen in Figure 12, almost one in four South Africans still has trouble getting enough resources to meet basic food needs. This ratio is high in comparison to other upper-middle-income countries, and is even higher than the corresponding rate in many countries with a lower income level than South Africa (World Bank 2018). With data from the NIDS, Van der Berg et al. (2021) point out that, at the beginning of the COVID-19 lockdown in April 2020, 47 percent of households reported running out of money to buy food. At the end of 2020, 41 percent of South African households were still running out of their food budget, while 18 percent experienced household hunger and 16 percent of households reported facing child hunger. Child hunger is especially problematic, as it may lead to cases of growth stunting, for which South Africa has higher rates in comparison to countries with a similar level of per capita income (Van der Berg et al. 2021).

Figure 12: Poverty ratios using the food poverty line (headcount poverty ratio, FPL) (ratio)



Source: Statistics South Africa, National Income Dynamics Study (2020)
Note: Data available for intermittent years.

Government and NGOs have been providing targeted support to reduce the adverse effect of food insecurity. The restrictions imposed by COVID-19 containment measures brought additional complications to the food insecurity issue by limiting the role the National Schools Nutrition Programme (NSNP) had been playing in providing relief of child hunger through the provision of school meals. The extent of the food insecurity problem, however, is such that the support provided is only effective in limiting the effect without addressing the causes of the problem. While some of the households receiving food support may be shielded from hunger temporarily, they may remain vulnerable to it if their main protection from hunger is precisely this food grant. A longer-term solution to the food insecurity problem requires more integrated policies involving equitable reforms in the structures of food production and distribution chains, as well as general poverty-eradication measures aimed at increasing the permanent income of impoverished households and giving them access to public services and financial options that will enable them to engage in rewarding economic activities.

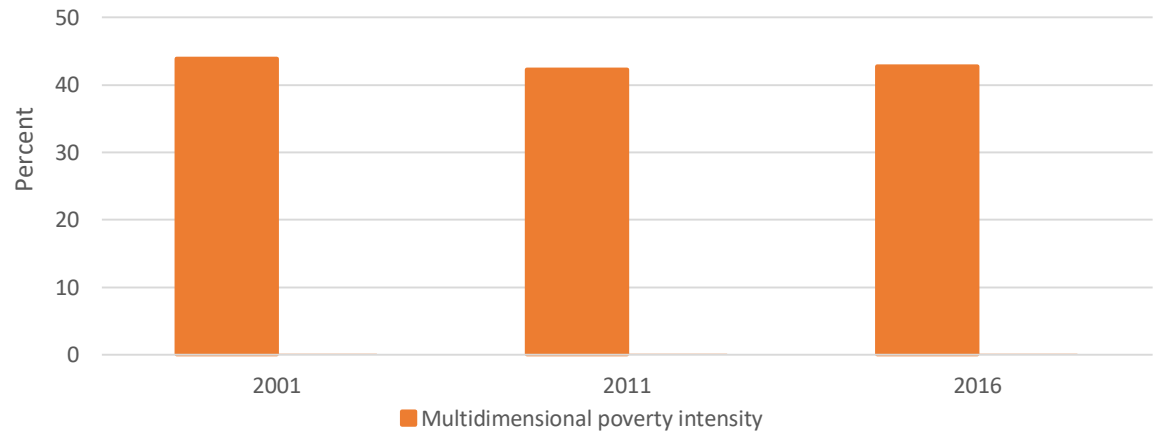
3.3.4 Poverty intensity and the South African multidimensional poverty index

Although headcount ratios provide useful information about the incidence of poverty, they are insufficient to fully capture the effect of poverty on the levels of deprivation experienced by those

who live in poverty. In addition to the aspect of deprivation measured by insufficient income to cover basic needs, the multidimensional poverty index captures the severe deprivation experienced by households in terms of lack of access to health, education and decent living standards. These dimensions of deprivation affect people's ability to live dignified lives and limit their capacity to develop to their full potential. In the context of South Africa, Stats SA adapted the global multidimensional poverty index (based on the Alkire Foster method) to the social implications of consistently high unemployment rates and developed the South African Multidimensional Poverty Index (SAMPI). On the basis of this indicator, the reduction in the severity in which poverty affects people in South Africa has been slower than the reduction in the headcount ratios (see Figure 12).

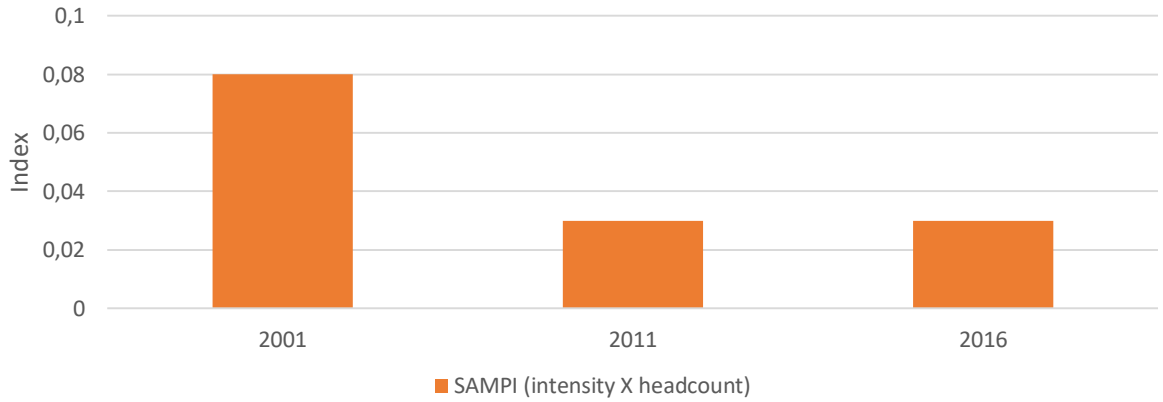
Poverty intensity decreased only marginally, from 43.9 percent in 2001 to 42.8 percent in 2016, which implies that the lived experiences of deprivation among people living below the poverty line hardly improved. The growing unemployment levels have made it difficult to bring down the intensity of deprivation. The calculated SAMPI (= intensity X headcount) decreased marginally, from 0.08 in 2011 to 0.03 in 2016 (Figure 13).

Figure 13: Poverty intensity and multidimensional poverty index in SA, 2001–2011 (percentage)



Source: World Bank (2018)
Note: Data available for intermittent years.

Figure 14: South African multidimensional poverty index, 2011–2016 (index)



Source: World Bank (2018)
Note: Data available for intermittent years.

Box 3 below highlights the role of infrastructure investments, territorial collaboration and technological innovation in achieving poverty reduction.

Box 3: Infrastructure investments, territorial collaboration and technological innovation in China's poverty reduction strategy

The experience of China in poverty reduction, which saw 850 million people lifted out of poverty in 40 years, is unique in human history. In the last eight years alone (2012 to 2020), 98.99 million people have been lifted out of poverty, at which time extreme poverty was entirely eradicated. China's State Council has made poverty alleviation a priority area of its socio-economic policy, with President Xi Jinping directing the battle in person. A multiplicity of strategy and target measures were used to win this herculean task. Because of the development strategy adopted at the beginning of the opening up, which favoured the coastal areas to develop first, residual poverty has predominantly been concentrated geographically in the rural areas of the interior. Strategies to tackle it include prioritising independent development of the impoverished areas through massive investment in infrastructure and public services, territorial collaboration between prosperous coastal regions and less prosperous areas of the hinterland, comprehensive social security coverage, and also the deployment of science and technology in an approach to fuel local productivity and economic take-off. Investment in infrastructure made it possible to loosen many structural constraints that trapped some areas in poverty by facilitating personnel mobility, logistics, as well as knowledge and information flow between these areas and the outside world.

Collaboration on poverty alleviation between coastal and interior regions has facilitated the transfer of food processing; clothing manufacturing and other labour-intensive industries to the rural areas end boosted employment and income. Between 2012 and 2020, a total of 1 290 innovative platforms and business start-ups were established in impoverished counties, whereby 77 000 people were paired up with professionals from prosperous regions to receive guidance on new technology to be applied in their impoverished regions. With an army of technicians and substantial funding, the government launched 37 600 high-tech programmes in the battle for poverty alleviation, which contributed to transforming those areas into new production centres. In regions that were too inhospitable to implement infrastructure and investment programmes, a relocation policy was used to move the population into areas where access to services and development projects would be easier. A comprehensive monitoring programme was deployed to ensure that people who emerged from poverty did not relapse. A grace period is offered, during which people emerging from poverty continue to benefit from poverty-alleviation measures until their status is secure.

Source: State Council Information Office of the People's Republic of China (2021)

3.3.5 Conclusion

Post-apartheid South Africa has put in place a wide-ranging system of social grants to limit the adverse effect of poverty on households and children. Various government programmes, including the provision of school meals, have contributed to reducing the degree of deprivation faced by poor households. Poverty-alleviation policies in South Africa have been effective in limiting the adverse effect of multiple deprivations on households, but have been slow in reducing the number and proportion of households exposed to these deprivations. The ratio of children who are exposed to food insecurity with the risk of growth stunting is still high, certainly in comparison to countries with similar levels of per capita income. The rate of poverty reduction as a result of improvements in growth performance has shown low elasticities in South Africa, partly because of the skewed income distribution, whereby the already better-off capture the highest share of the additional income (World

Bank 2018). In order for economic growth to bring about poverty reduction, it therefore is necessary to design policies that combine growth stimulation and inequality reduction.

While innovation and technological change can be expected to have beneficial effects on growth performance in the long run, their effects on poverty reduction are less straightforward if their rents accrue mostly to high-skilled and high-income entrepreneurs, which would heighten the potential to exacerbate income polarisation. Given South Africa's economic stagnation, with the corresponding budgetary constraints on state finances, the desirable changes in the poverty-reduction strategy will ultimately be linked to more comprehensive economic reforms, which will be required to disentangle the country's economy from its decades-long stagnation.

3.4 Standards of living

The extreme levels of income and asset inequality are reflected in the disparities in the living conditions of South African households. While a sizable fraction of households enjoy all the amenities of modern living conditions, the legacy of spatial segregation continues to perpetuate the exclusion of some of the formerly disadvantaged groups from access to public services. Access to a decent disposable income to cover living expenses is one of the major determinants of the living conditions of households. Ownership of household appliances serves as an indicator of the level of comfort available to households to foster their wellbeing in daily life. For this report, we focus on the following indicators of living standards

Table 6: Critical indicators of standards of living

Indicator	Data source
Average monthly household expenditure	*Statistics South Africa*
Percentage of households residing in formal dwellings	*Statistics South Africa*
Percentage of households using electricity for lighting and cooking	*Statistics South Africa*
Percentage of households with access to piped water	*Statistics South Africa*
Percentage of households with access to improved sanitation	*Statistics South Africa*
Ownership of household appliances and equipment	*Statistics South Africa*

The most recent data used here as indicators of living conditions come from the General Household Survey (GHS) 2019, released by Statistics South Africa (Stats SA) in December 2020; this is the source of all data cited in this section.

3.4.1 Household expenditures

For the year 2019, only 18 percent of the sample households reported having a monthly expenditure of R10 000 or more. There are stark racial disparities in disposable income: while only 10 percent of black African households report monthly expenditure of more than R10 000, the corresponding proportion among white households is 69.5 percent.

3.4.2 Percentage of households living in formal dwellings

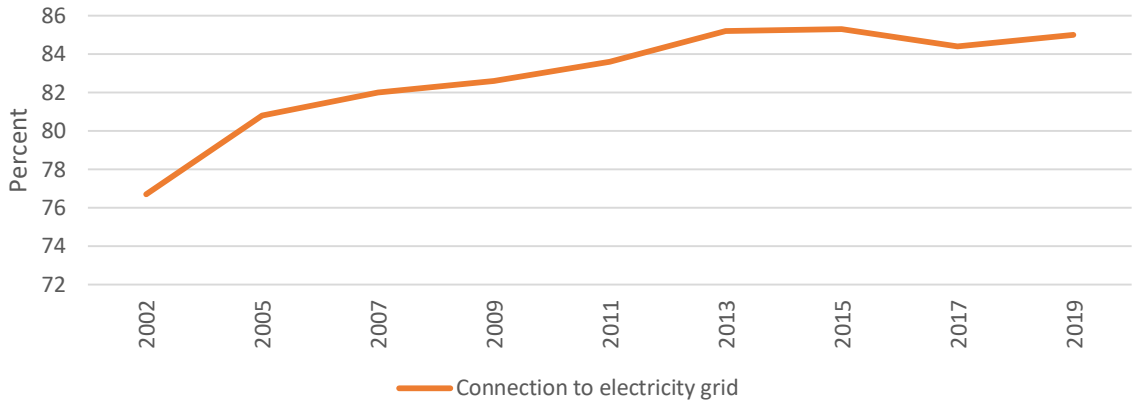
Data from the GHS 2019 show that almost 82 percent of South Africa households lived in formal dwellings, while 12.7 percent were housed in informal dwellings and 5.1 percent in traditional dwellings. In metropolitan areas, while the proportion of households residing in formal dwellings remains at the South Africa average of 81.9 percent, informal dwellings house 16.8 percent of households, which is above the national average. With almost 20 percent of its residents in informal

housing, Cape Town has the largest proportion of informal housing, far above the South African average.

3.4.3 Access to electricity grid

Access to electricity as a source of energy for lighting, for running electrical appliances and as the main fuel for cooking occupies an important role in the living standards of households. As a result of continuous efforts by public services to expand access, the percentage of South African households connected to the electricity grid increased from 76.7 percent in 2002 to 85.0 percent in 2019 (see Figure 15).

Figure 15: Percentage of households connected to the electricity grid, 2002–2019 (percentage)



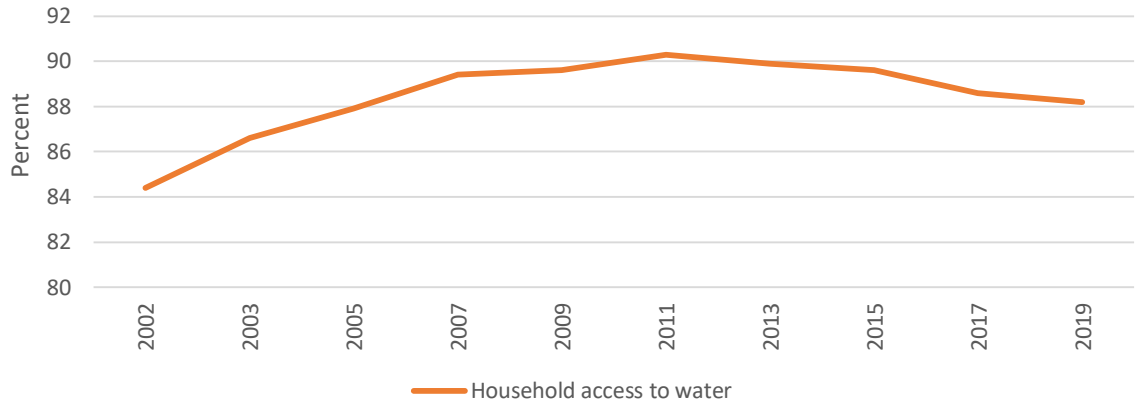
Source: General Household Survey 2019 (Statistics South Africa 2020)
Note: Data available for intermittent years.

In terms of energy supply for cooking, the percentage of households using electricity for cooking increased from 57.5 percent in 2002 to 79.9 percent in 2014, before declining to 75.1 percent in 2019.

3.4.4 Access to piped water

Over the period 2002 to 2019, the percentage of households with access to piped water in their dwellings went up from 84.4 percent to 88.2 percent (see Figure 16).

Figure 16: South African households with access to piped water, 2002–2019 (percentage)



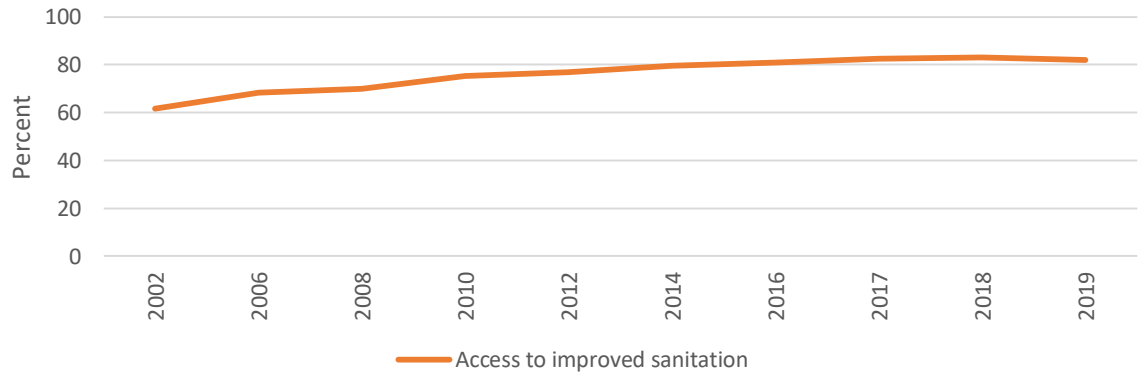
Source: General Household Survey 2019 (Statistics South Africa 2020)
Note: Data available for intermittent years.

According to Statistics South Africa, the apparent decline in the percentage of households with access to running water observed after 2011 is due to the steady growth in the number of households, at a rate of 2.4 percent per year. This means that even though the number of households with access to water increased in absolute terms, the proportion has declined, as the increase in access could not keep up with the stronger growth in the number of households over that period. In absolute terms, the number of households with access to piped water went from 9.3 million households in 2006 to 13.6 million households in 2019.

3.4.5 Access to improved sanitation facilities

Improved sanitation facilities consist of flush toilets connected to a public sewerage system or a septic tank, or pit toilets with a ventilation pipe. The average percentage of South African households with access to improved sanitation increased from 61.7 percent in 2002 to 82.1 percent in 2019.

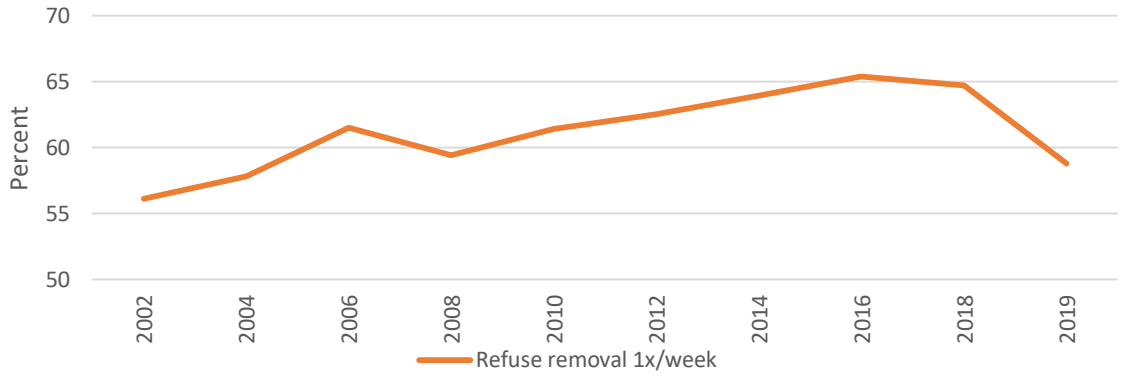
Figure 17: South African households with access to improved sanitation facilities, 2002-2019 (percentage)



Source: General Household Survey 2019 (Statistics South Africa 2020)
Note: Data available for intermittent years.

Directly related to access to sanitation is the removal of refuse. The proportion of households that reported having access to municipal services for refuse removal at least once a week also increased between 2002 and 2019, as can be seen in Figure 18. The proportion of households with refuse removal services at least once per week increased from 56.1 percent in 2002 to 65.7 percent in 2016, before declining to 58.8 percent in 2019. The apparent decline after 2016 may again be due to a rapid growth in the number of households.

Figure 18: South African households with access to refuse removal services, 2002–2019 (percentage)



Source: General Household Survey 2019 (Statistics South Africa 2020)
Note: Data available for intermittent years.

3.4.6 Ownership of household appliances

As a final indicator of living standards, ownership of household equipment and appliances is as follows: 31.2 percent of households own one or more vehicles in a functioning condition, 89.8 percent of households have electric stoves, while 81.7 percent of them have one or more television sets. Finally, 39.4 percent of households own a washing machine, while 22.7 percent own one or more computers.

3.4.7 Conclusion

Living standards in South Africa display disparities that reflect the extreme levels of income and wealth inequality stemming from long periods of enforced exclusion of large segments of the population from economic opportunities. Since the advent of democracy, the government has embarked on a programme of service delivery aimed at improving the living conditions of previously disadvantaged South Africans, and the indicators covered here show that significant improvements have been achieved over the last two decades. One of the lasting legacies of apartheid-era spatial planning is the persistently high share of households living in informal settlements in metropolitan areas, with limited access to public infrastructure and with long distances to cover to reach their workplace.

Innovation and technological progress in service delivery can considerably improve the living standard of communities, especially if they consist of novel developments or improvements that reduce costs and make those services more affordable. For example, the adoption of solar or other renewable energy-production systems may provide viable alternatives to connection to the traditional grid in remote areas that are difficult to access. Likewise, grassroot frugal innovations, such as solar ovens or clay refrigerators that do not use power, may produce affordable appliances that improve the living comfort of low-income communities without putting them in financial distress.

Frugal innovations, however, are not a substitute for the long-term development target of provide a lasting solution to the problem of poor living conditions. To truly bring meaningful change to the living conditions in informal settlements, for example, it may be necessary to overhaul the spatial planning structures that produced this problem in the first place, while planning for modern rapid mass transfer infrastructure with a view to significantly reducing the cost of access to work for the residents of these settlements.

3.5 Skills development

Skills shortage has been often identified as one of the main constraints on employment growth in South Africa. To address the skills gap problem, the government passed the Skills Development Act of 1998 and launched the National Skills Development Strategy to coordinate skills development in the education and training institutions as well as across industries. In 2000, Sector Education and Training Authorities (SETA) were created to help reduce the skills gaps and the resulting lack of employment opportunities, which often leads to chronic unemployment and poverty. The public Further Education and Training (FET) college system was assigned a central role in the government's programmes intended to develop skills among the youth and adults of South Africa. The skills development strategy has entered a new phase with the promulgation of the National Skills Development Plan 2030 in March 2019. This plan forms the main framework through which the government's skills development policy of is implemented.

We use the indicators presented in Table 7 to provide a picture of the current state of skills development in South Africa.

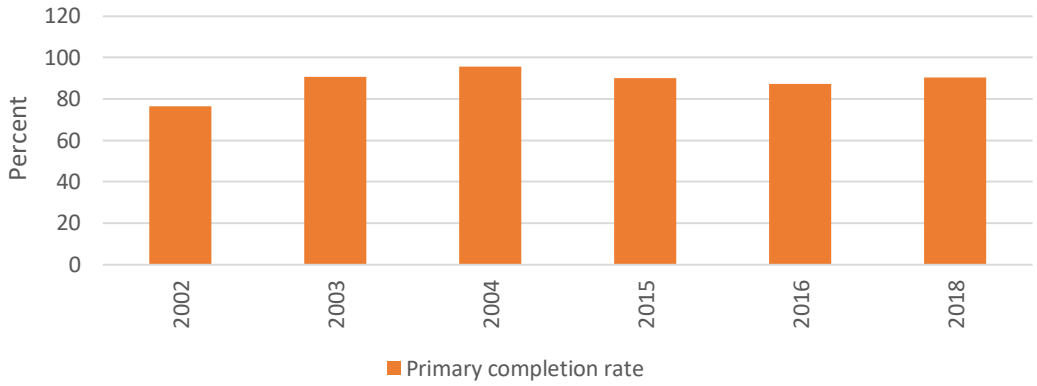
Table 7: Critical indicators of skills development

Indicator	Data source
Primary completion rate	*Statistics South Africa*
Proportion of adult population with post-secondary education	*Statistics South Africa*
Educational attainment	*Statistics South Africa*

3.5.1 Primary completion rate

The state of skills development in South Africa is complex because of unusual variances between its indicators. For example, the country has one of the highest levels of primary school enrolment in all of Africa with 98 percent of children being enrolled, but produces one of the lowest educational outcomes in terms of children literacy and numeracy performance (Spaull, 2013). Despite the high rates of school enrolment, school data analyses have brought to light that of the 100 pupils that start school, only 50 are likely to make it to grade 12, out of which 40 will pass, and only 12 of them would eventually qualify for access to higher education (Amnesty International 2020). The primary completion rate represents the number of children who reach the last grade of primary education divided by the population at the entrance age for the last grade of primary education. This rate has been growing over the period 2002-2018, reaching more than 95 percent in 2004 and stabilising above 90 percent in the years after.

Figure 19: South Africa's primary completion rate, 2002–2018 (percentage)

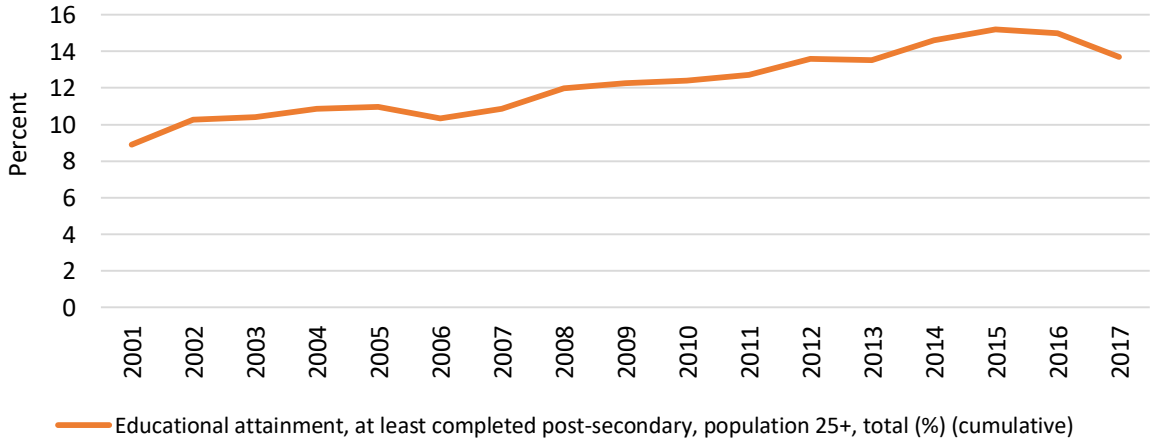


Source: World Bank (2021)
Note: Data available for intermittent years.

3.5.2 Educational achievement: Proportion of adults with post-secondary education

The skills development programmes put in place through the national skills development strategy and other government policies have gradually contributed to skills development over the last 20 years. The percentage of adult population with at least post-secondary qualifications has been growing slowly and reached 15 percent in 2016 (see Figure 20). In contrast, the indicator of educational achievement in terms of the average number of years of schooling has stagnated over the same period, with hardly any visible increase. This implies that most skills accumulation has contributed to increasing the number of individuals with skills levels close to the existing average, but has done less for the expansion in the number of people with tertiary education.

Figure 20: Proportion of adult population aged 25+ with post-secondary education, 2001–2017 (percentage)



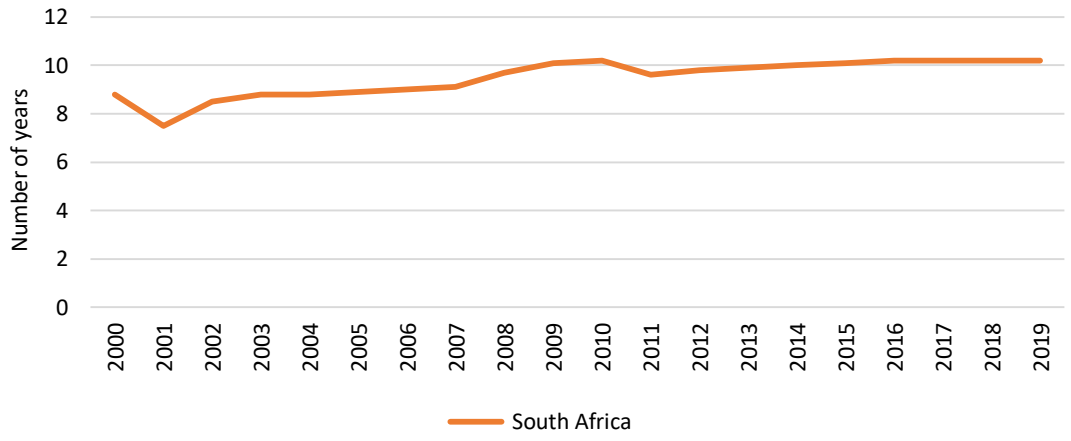
Source: World Bank (2021)

3.5.3 Educational achievement: Average number of years of schooling in adult population

A common indicator of skills development outcomes is provided by the average number of years of schooling in the adult population, which gives a general idea of the level of formal schooling of the

average adult person. The average number of years of schooling has increased gradually since 2001, and has been hovering around the value of 10 years since 2009, according to World Bank data (Figure 21). Measured by this indicator, South African educational attainment compares favourably with countries with similar levels of income, but the low quality of this schooling, which has already been pointed out, is a serious source of bias in such a comparison, because the number of years of schooling does not say much about the quality of that schooling. The next indicator looks at the content knowledge of mathematics teachers, which often reflects in the performance of learners in international mathematics assessments.

Figure 21: Educational attainment in average number of years of schooling, 2000–2019



Source: World Bank (2021)

3.5.4 Mathematics knowledge of grade 6 teachers

By international comparison, South Africa has been performing poorly in comparison with countries in terms of educational achievement, as well as in mathematics and science literacy, where it trails comparative countries with similar levels of per capita income. In terms of performance in the Trends in International Mathematics and Science Study (TIMSS Grade Eight/Nine mathematics and science 1995, 1999, 2002, 2010), South Africa has performed worse than all participating countries, even after improvements were achieved. When it comes to educational outcomes, South Africa has one of the least-performing education systems compared to other middle-income countries that participate in cross-national assessments of educational achievement (Spaull 2013).

The quality of a teacher's knowledge content is important to the expected skills accumulation, especially in basic education. Spaull (2016) reports that most South African grade 6 mathematics teachers do not possess the levels of mathematics content knowledge required for a good-quality mathematics and science education. Compared to several Sub-Saharan African countries or other upper-middle-income countries, South Africa's ratio of grade 6 teachers with the desired level of mathematics content knowledge. Venkat and Spaul (2015) analysed the performance of South African grade 6 mathematics teachers in the Southern and Eastern African Consortium for Monitoring Educational Quality (SACMEQ) III teacher mathematics test and found indications that 79 percent of grade 6 mathematics teachers showed content knowledge levels below the grade 6/7 band. Moreover, those among the minority of teachers who had a high-level content knowledge were unevenly distributed in the education system. Their findings suggests that many of those teachers

with content knowledge at or above the desired level were most likely distributed in the sub-system of better performing schools, which represent only 20 percent of the entire school system. The gaps between the desired qualification of teachers and the actual level of most of them is an issue that has persisted and requires a political solution because it also affects the pace and quality of skills accumulation at higher levels.

3.5.5 Funding for technical vocational education and training (TVET)

In terms of resource mobilisation, the government has been spending a substantial amount of its budget to finance basic and post-school education, which together accounted for 19 percent of the government budget in the 2021 Budget Review (National Treasury of the Republic of South Africa 2021). In the skills development strategy, the TVET college system plays a very important role as a skills accumulation channel, the success of which is crucial for the achievement of the NDP30 objectives. Under the existing arrangement, skills development though the TVET system is a shared responsibility between the state and private sector, with the state committing to funding 80 percent of the costs of the programmes and establishing a bursary programme to support enrolled students' financial needs. According to the Department of Higher Education and Training (2019), technical and vocational training is crucial for the accumulation of skills necessary for industrialisation and the development of the manufacturing sector, which is significantly underdeveloped relative to the country's level of development.

The size of the South African TVET college system is also considered too small for the size of the country's economy by international standards. Because of the skewed funding system in the educational budget, which allocated 84 percent of its funding to schooling, 11 percent to university education and only four percent to TVET colleges, skills development through the TVET college system was seriously underfunded until the adoption of the new funding framework proposed in 2019 (Government Gazette of 22 November 2019). The proposed improvement in the funding system was intended to develop the TVET college system in order to reach the target of 2.5 million enrolment in 2030, as envisioned in the NDP for the achievement of its development objectives. While the old funding system was based on the full-time equivalent number of students enrolling at each college, the new framework proposed a combination of input and output performance measures, whereby 10 percent of the funding each year would be based on the number of graduates who obtained their certification from the college two years earlier (to allow for adequate data collection).

Learnerships and skills development in enterprises are usually funded through a compulsory national levy grant system, whereby employers contribute a fixed percentage of payroll via the South African Revenue Service. The funds generated in this manner are subsequently channelled to skills development and training through the SETAs and to a National Skills Fund to be used for strategic priorities.

3.5.6 Conclusion

South Africa continues to face the constraints of a skills shortage, which limits the ability of its economy to deploy sufficient levels of human capital to strengthen the country's productivity and international competitiveness. Critical levels of human capital are indispensable for an economy to be able to absorb externally developed technological knowledge that would help the local economy to improve its production processes. To meet the challenges of the skills shortage, the government has

adopted a comprehensive strategy involving multiple institutional actors and private enterprises with the aim to provide the necessary funding and infrastructure to facilitate training for those intending to increase their employability in the labour market, but also to sharpen the skills of those who are already employed. Despite substantial financial resources invested to finance skills development, the skills development and educational outcomes have remained problematic in South Africa, as the quality of its educational system continues to trail that of comparative countries in Africa and others with similar income levels. Despite having some of the leading universities on the African continent, the country is still trying to attract foreign professionals with critical skills to help bridge the existing skills gaps. A long-term solution to the disappointing performance of the educational outcomes will require in-depth reform and a quality upgrade of the basic education system and infrastructure to bring them in line with international best practices.

3.6 Export growth and competitiveness

Export competitiveness is an important determinant of a country's economic performance, as it gives indications of the capacity of an economy to earn foreign exchange in international markets. Export competitiveness also signals the quality and sophistication of the corresponding country's production system and its ability to meet high, stringent international requirements. Among the determinants of export competitiveness, the labour productivity and innovation performance of a country's enterprises play a prominent role. They affect the efficiency with which products and services can be brought to the market, but also their market attractiveness with respect to those from other countries. Trade openness and the attractiveness of the incentive systems put in place to promote quality and support export also play a prominent role in strengthening export competitiveness. The export-promotion and incentive schemes available to support exporters and help them mitigate the risks they face in foreign markets is equally important for strengthening the country's export growth. The diversification of a country's exports and the technological content of its exported products provide interesting indications of its resilience to external shocks and the elasticity of their demand respectively. A more diversified export composition is better capable of resisting unexpected changes in prices, since different export industries are usually affected differently by price or demand shocks.

Table 8: Critical indicators of export growth and competitiveness

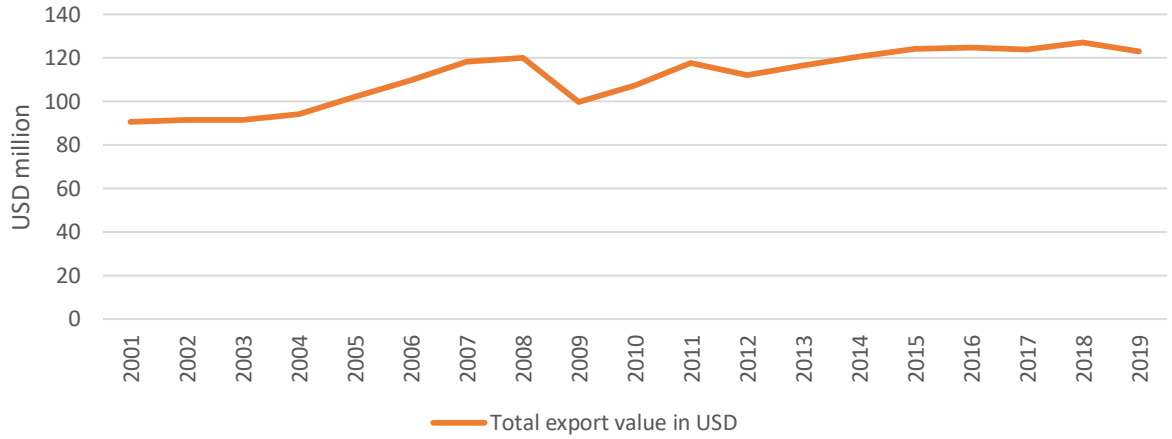
Indicator	**Data source**
Export value	*World Bank*
Export share of GDP	*Statistics South Africa*
Share of ores and minerals in exports	*Statistics South Africa*
Share of manufacturing in total exports	*Statistics South Africa*
Share of high-tech in manufacturing exports	*Statistics South Africa*

3.6.1 South Africa's export value and export growth

Being an open economy, South Africa maintains trade and economic partnership agreements with the main developed markets, such as the European Union, the United Kingdom and the United States. Accounting for 11.4 percent of South Africa export revenues in 2020, China is the largest export market for South African goods and services, followed by the United States, with a share of 8.3 percent. The total export value of goods and services from South Africa has been growing steadily in recent decades, interrupted only by a sharp decline in 2009 during the global financial crisis (Figure 22). Just

before the onset of that crisis, total export value had reached the level of USD 120 billion per year, which it only reached again in 2014 (value measured in constant 2010 prices).

Figure 22: South Africa total export value in, 2001–2019 (constant USD millions)



Source: World Bank (2021)

3.6.2 Export to GDP ratio

The ratio of exports to total GDP has been relatively stable at around 30percent since the end of the global financial crisis (see Figure 23). It has a robust support system for local exporters, including a marketing and investment assistance scheme, an export credit and foreign investment reinsurance programme, export credit incentives and export finance funds. The purpose of these schemes is to support South African exporters to increase their market operations in the countries to which they export or in which they develop new markets by reducing their risk exposure and increasing their access to low-cost finance for their operations.

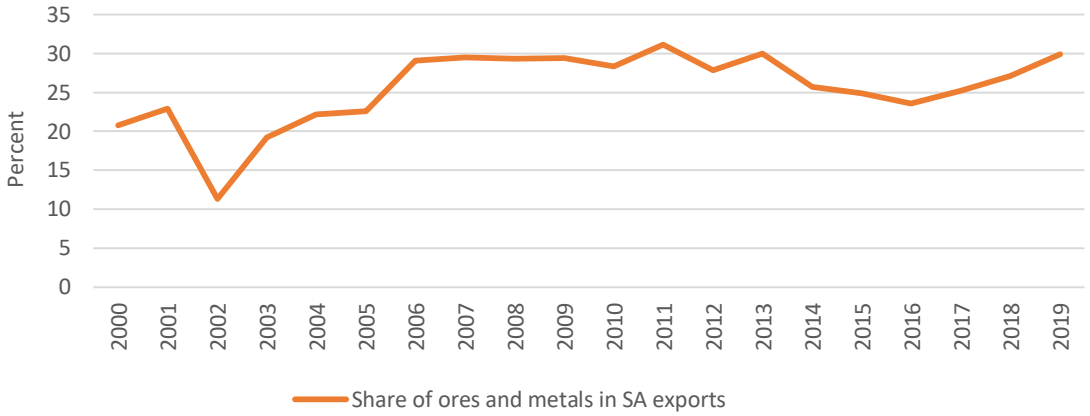
Figure 23: South Africa's share of export goods and services as a percentage of GDP, 2008–2019 (percentage)

Source: Statistics South Africa, 2021a

Despite the country's relatively good ranking in terms of global competitiveness, South Africa's exports remain characterised by a high concentration of commodities. According to World Bank data, the share of ore and metals in total exports was about 30 percent in 2019. In 2020, South Africa's top export products (at ISIC 4 digit level) were: platinum (12.6 percent), gold (7.9 percent), iron ores and

concentrates (7.2 percent), motor cars and other motor vehicles (5.4 percent), coal (4.6 percent), ferro alloys (3.2 percent), and manganese ores and concentrates (2.9 percent). Of the top eight export products, only motor vehicles are manufactures; the others are derived from the country's mineral resource endowment.

Figure 24: Share of ores and metals in South African exports, 2000-2019 (percentage)



Source: Statistics South Africa, 2021a

South Africa's exports have long been dominated by ores and metals, and manufactured exports have seen their share of export stagnate in the last decade, with a slightly declining trend (Figure 25). The export of ores and metals represents the rate of extraction of natural capital endowment, rather than the industriousness of the country's productive forces. For a country relying heavily on mining products to grow its exports, it would have to extract and deplete more of its deposits. In contrast, if exports are dominated by manufactured goods or skills-intensive services, export growth is more likely to reflect improvements in production and successful innovations. Long-term competitiveness is ultimately determined by the productivity growth of each country's human capital, rather than the fortuitous availability of natural resource deposits.

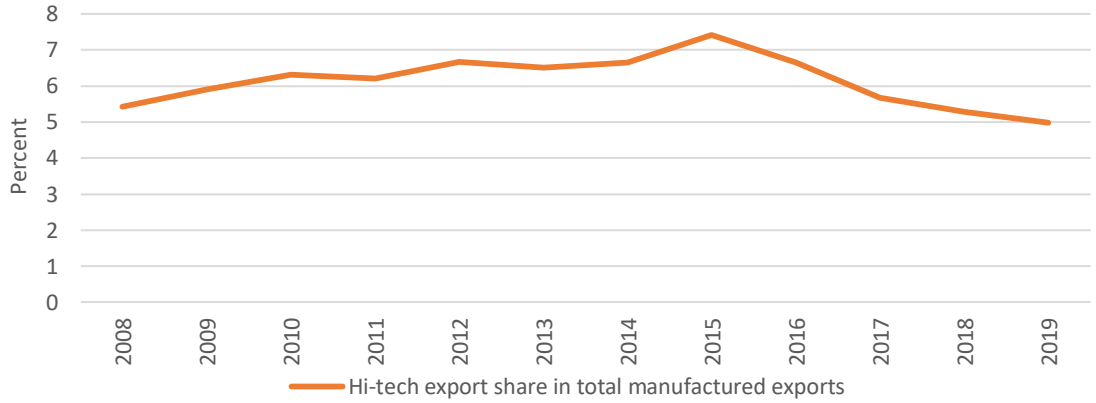
Figure 25: Manufactured exports as a percentage of total exports, 2008–2019 (percentage)

Source: Statistics South Africa, 2021a

3.6.3 Share of hi-tech in manufactured exports

Export growth and competitiveness require sustained investment in innovation in order to keep their products attractive to foreign consumers and competitive in international markets. Intensive investment in research and development (R&D), and the associated innovation, therefore have an important role to play in supporting export growth, and the upgrading of the composition of exports and competitiveness in global markets. For South Africa to grow its export markets and increase the competitiveness of its export products, it may be useful to harness the power of industrial innovation and diversify its export offering. The current concentration on ores and metals in South Africa's export basket limits the export growth potential, which creates space for innovation to harness technological change and generate new sources of export that gradually will reduce the dominance of natural capital extraction.

Figure 26: South Africa's percentage of hi-tech export share in total manufactured exports, 2008-2019 (percentage)



Source: Statistics South Africa, 2021a

3.6.4 Conclusion

South Africa is an open economy, but its export structure remains characterised by the dominance of mining products, which have a limited potential for growth and competitiveness. On the World Economic Forum's Global Competitiveness Index 4.0, which provides a measure of national competitiveness based on institutions, policies and factors that determine the level of productivity, South Africa scores 62.4. This is an improvement on the previous year and ranks in the same category as other middle-income countries, such as Columbia, Azerbaijan, Turkey and Costa Rica. Among middle-income countries in Sub-Saharan Africa, it ranks second only to Mauritius, which has a score of 64.3 (Schwab 2019).

The incentive schemes used to support South African exporters is an important contributor to increasing their performance in export markets. Long-term growth in South African exports requires investment in innovation with the aim to diversify the country's export portfolio and increase the technological content of its export products for stronger competitiveness in world markets. This implies that the economy would need to tap into its vast reserves of low-cost labour to develop industries capable of leveraging their potential for competitive manufacturing production.

3.7 Climate change mitigation and adaption

3.7.1 The challenge of climate change

Climate change presents one of the most complex and greatest threats to socio-economic development. Furthermore, its effects are often felt most severely by the poor and vulnerable groups in society. The effects of climate change are highly variable; while some regions become hotter and drier, others become wetter and colder. South Africa is not immune to these shifting patterns. The country has already experienced higher temperatures, more variable rainfall and extreme weather events. Examples are: devastating and prolonged droughts and water shortages, which affect employment, poverty and food security in both rural and urban areas; floods, which can destroy crops and infrastructure, disrupt power supplies, and lead to loss of life; and heatwaves, which affect human and livestock health and lower crop yields (Blignaut 2009; Arndt et al. 2021). Changes in the climate will continue for decades, and the degree to which climate change will affect different regions in South Africa is likely to vary widely, driving extremes in changes to key climate variables such as precipitation (Arndt et al. 2021). Due to these uncertainties and their interactions with South Africa's growth and development challenges, measuring and understanding the drivers and consequences of climate change are important if the South African government is to protect its most vulnerable citizens.

The mitigation of climate change through climate adaptation strategies provides the opportunity to transform the health of South Africa's economy, enabling the building of long-term resilience (Department of Forestry, Fisheries and Environment [DFFE] 2020). By mitigating climate change, sustainable economic development goals may be achieved, thereby ensuring resilient societies. Various indicators are used to measure the core drivers of climate change, including the central importance of CO_2 emissions, as well as other greenhouse gas emissions such as SO_2 and methane.

Table 9: Critical indicators of the mitigation of climate change in South Africa

Indicator	Data source
Annual CO_2 emissions per capita	*Ritchie and Roser*
Cumulative CO_2 emissions	*Ritchie and Roser*
CO_2 emissions in South Africa	*Ritchie and Roser*
CO_2 emissions by fuel type	*Ritchie and Roser*

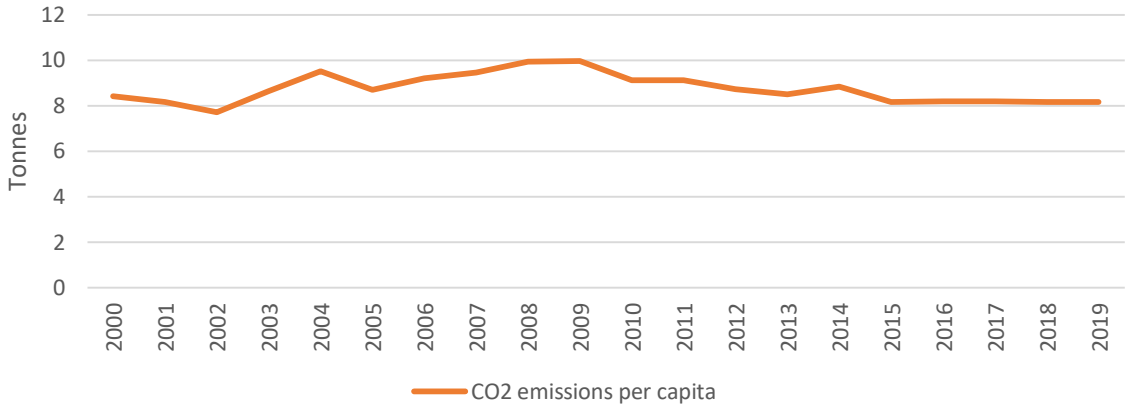
3.7.2 CO_2 emissions

Climate change indicator trends are shown in the graphs below, showing only trends for indicators for which current data are available. Figure 3.7.1 shows CO_2 emissions per capita for South Africa since 2000. Carbon dioxide (CO_2) emissions are shown from the burning of fossil fuels for energy and cement production, excluding land use. CO_2 emissions are measured on a production basis and do not correct for emissions embedded in traded goods (Ritchie and Roser 2020). South Africa remains dependent on coal-fired electricity generation, and the emissions per capita of CO_2 continue to rise; the country recorded levels at 8.17 tonnes per capita in 2019.

South Africa has one of the highest rankings in terms of CO_2 emissions per capita in the world (Buthelezi and Davies 2014). This is driven by the country's historic and current dependence on the burning of fossil fuel for the generation of energy, particularly of electricity. Although efforts have been made to address these high levels of emissions and the overall trend has been declining since

2003, the country's continued dependence on ESKOM for its electricity generation, coupled with the heavy demands from the extractive industry, namely mining, combined with the high dependence on road transport, these emissions are likely to remain high for some time relative to global standards.

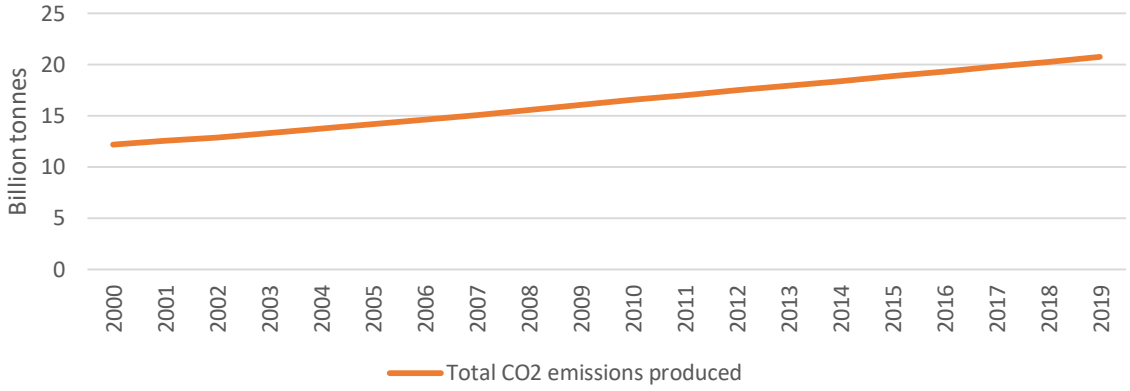
Figure 27: Annual CO_2 emissions per capita, 2000–2019 (tonnes)



Source: Ritchie and Roser (2020)

Figures 28 and 29 show the CO_2 emissions for South Africa to date; in 2019, South Africa produced 20.72 billion tonnes of the world's CO_2 emissions. Despite the marginal observed decline in per capita emissions, absolute emissions continue to rise. This is a reflection of the South Africa's dependence on coal-fired power stations to generate the majority of the country's electricity.

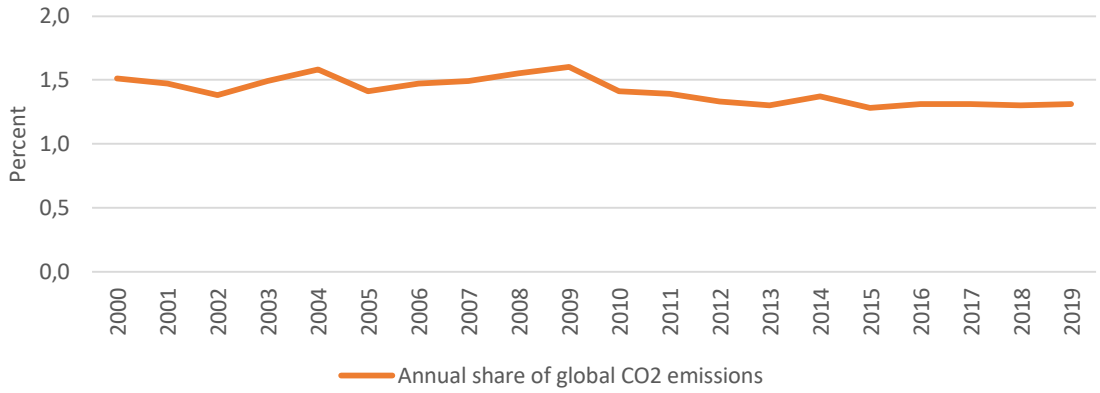
Figure 28: Cumulative CO_2 emissions, 2000–2019 (billion tonnes)



Source: Ritchie and Roser (2020)

In 2019, South Africa produced 1.3 percent of the world's CO_2 emissions.

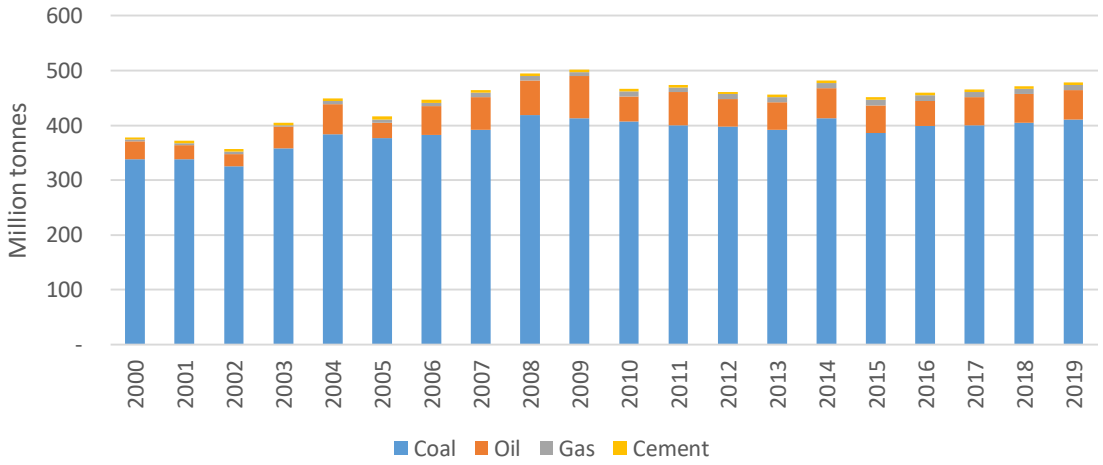
Figure 29: CO_2 emissions in South Africa, 2000–2019 (percentage share of global emissions)



Source: Ritchie and Roser (2020)

South Africa generates CO_2 emissions from various fuel types and sectors. In 2019, coal was the dominant source of emissions (86 percent), followed by oil (11 percent), Gas (2 percent) and cement (1 percent).

Figure 30: CO_2 emissions by fuel type, 2000–2020 (million tonnes)



Source: Ritchie and Roser (2020)

Box 4 below provides examples of innovative solutions used to mitigate or adapt to climate change.

Box 4: Climate adaptation strategies

Climate adaptation strategies vary widely from large-scale solutions to small-scale household level technology options. Some examples include:

i) "Windows of opportunity" exist for scaling-up sustainable land and water management activities that ensure healthy ecosystems and enable the sustainability of improved livelihoods. The Watershed Organisation Trust, based in India, has implemented effective climate adaptation strategies in the Maharashtra province using innovative technologies and solutions to ensure ecosystem based adaptation strategies. These solutions have realised improved water security, greater productivity in agriculture, lower costs for land management and better management of climate change related risks such as droughts (Indurkar et al. 2020; Watershed Organisation Trust [WOTR] 2020)

ii) The Climwarn project in Kenya: Rural farmers are enabled to manage their crops with better care through an early warning system that alerts communities of potential floods or other risks (UNEP 2016);

iii) The 'Trump Forest' project: Makes the use of drones to plant trees with the aim of planting a million trees to curb the impacts of climate change (Malo 2018);

iii) Electric cars and the use of autocatalytic converters in petrol and diesel cars.

3.7.3 Conclusion

The deployment of climate technologies has increased on an unprecedented scale globally in recent years. In particular, renewable technologies are becoming more competitive. If the world is to achieve the objectives of the Paris Climate Change Agreement, innovation needs to play a critical role in scaling up climate adaptation technologies (UNFCCC 2017). Two categories of clean technologies are available, those that address mitigation and those that address adaptation. Mitigation technologies aim to reduce greenhouse gas emissions or to capture them, while adaptive technologies allow users to adjust to and manage the negative effects of climate change (ICC 2015). Innovation for climate mitigation and adaption also reflects diverse dimensions, namely, technology development and technology diffusion. The use of scientific knowledge to obtain solutions is referred to as technology development, technology diffusion refers to the process by which new technologies are transferred, deployed and used (ICC 2015).

The creation of an optimal innovation and technology environment, requires the implementation of policies that "attract innovators from abroad, encourage investment in innovation, and stimulate domestic innovation and collaborative technology partnerships" both within South Africa and beyond. Ultimately enabling companies, consumers, and the economy to move up the innovation value chain (ICC 2015, p. 2). In order to mitigate and adapt to climate change, South Africa's dependency on coal-fired electricity generation needs to be addressed and innovation solutions for climate adaptation strategies need to be adopted. Currently indicators are not used that measure for example: the land area under revegetation, the planting of indigenous trees for carbon dioxide absorption or water use reductions, these strategies, in turn, support economic growth through higher yielding agriculture, securing water supplies and allow for the adaptation to the devastating risks of climate change such as floods and droughts.

3.8 Growth in renewable energy

3.8.1 Developments in renewable energy

Globally, the energy debate has been charged with a complex and dynamic debate. The 'energy trilemma' highlights the challenges in ensuring the security of supply and environmental sustainability, and ensuring access for the poor (World Energy Council 2019). South Africa faces these challenges even more acutely, as the country has one of the highest Gini coefficients in the world and remains heavily dependent on the use of coal for energy generation. Coal is the dominant source of energy generation in South Africa, as it remains a relatively 'cheap' source of energy, and South Africa has abundant reserves of this natural resource. Minerals extraction also contributes to the country's GDP (Stats SA 2016).

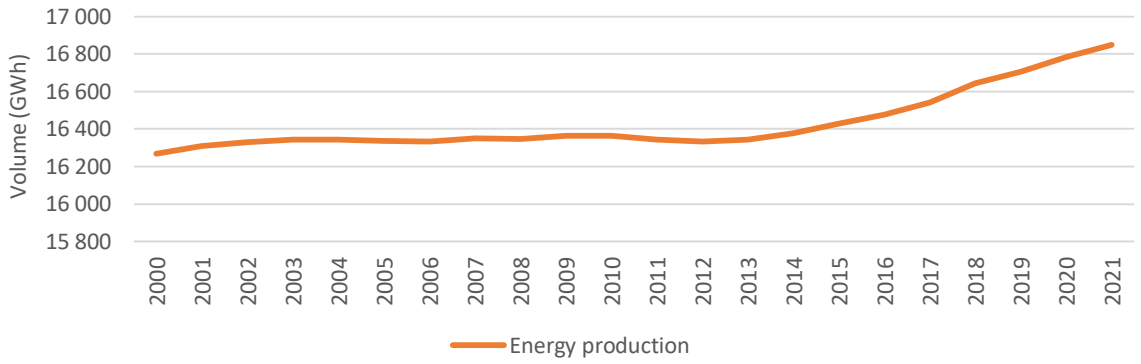
In the 2013 renewable energy statistics, solar energy was absent; however, in 2016, it contributed 2 151 GWh to the South African national grid, or 0.9 percent of the total GWh produced. Wind power was responsible for producing 18 GWh of electricity in 2013, rising to 2 126 GWh in 2016, or 0.87 percent of the total GWh produced in the year. This is related to the construction of various wind farms in the Jeffreys Bay and Cookhouse areas in the Eastern Cape (Department of Energy 2015).

Table 10: Critical indicators of renewable energy growth in South Africa

Indicator	**Data source**
Electricity production	*DME*
Renewable electricity output	*World Bank*
Renewable energy by type	*Statistics South Africa*
Load shedding in South Africa	*Wright and Calitz*

3.8.2 Energy sources

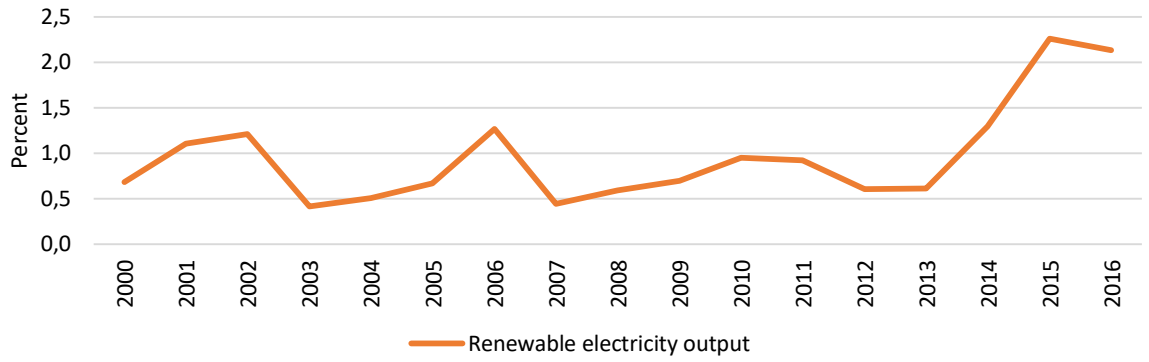
Figure 31: Physical volume of energy produced in South Africa (GWh)



Source: Department of Energy (2021)

South Africa has committed itself to supporting the development, demonstration and implementation of renewable energy sources for both small- and large-scale applications (Department of Energy, 2019). Renewable energy output is increasing in South Africa, but it remains a very small component of the broader energy mix. Due to the rising cost of traditional fossil fuel-based energy, renewable energy is becoming an increasingly viable option. South Africa is presently rated as the twelfth most attractive country for investment in renewable energy in Africa (Department of Energy 2019). To date, the Renewable Energy Independent Power Producers Procurement Programme (REIPPPP) has attracted investment (equity and debt) to the value of R209.7 billion, of which R41.8 billion (20 percent) is foreign investment (Department of Energy 2019). This augurs well for South Africa, as the programme has received international acclaim for fairness, transparency and the certainty of the programme (Department of Energy 2019).

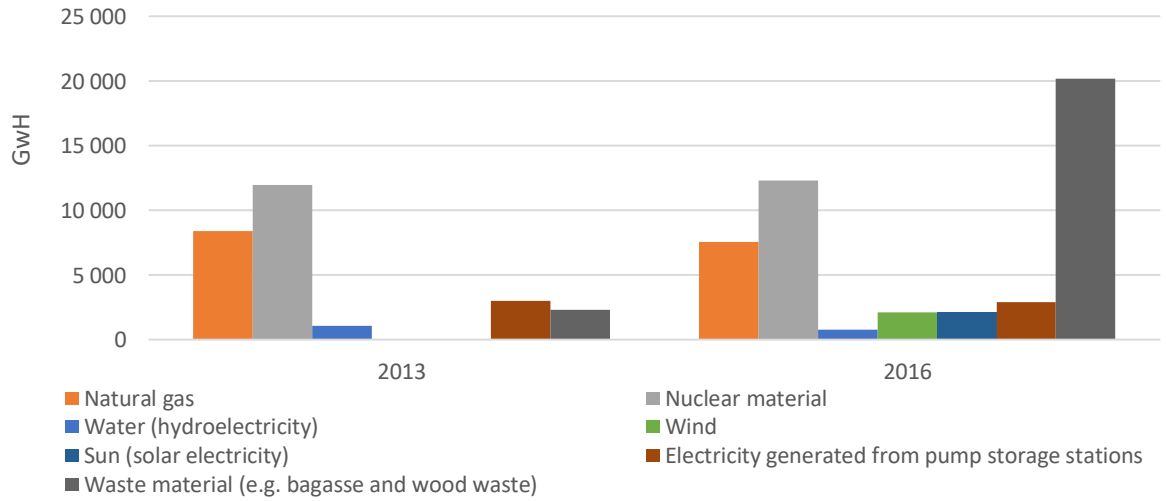
Figure 32: Renewable electricity output, 2000–2015 (percentage of total electricity output)



Source: Statistics South Africa (2016)

South Africa has the fifth largest deposit of recoverable coal reserves in the world, estimated at 66.7 billion tonnes (Department of Energy 2016). Consequently, coal continues to dominate the energy landscape, followed by waste material and nuclear energy. A concern for South Africa is the rising dependence on diesel. Renewable energy produced by wind power has increased from 18 GWh in 2013 to 2 126 GWh in 2016, accounting for 1.8 percent of the energy mix in 2016. Solar power accounted for 0.89 percent of the total energy mix in 2016, generating 2 121 GWh of power.

Figure 33: Renewable energy by type (Gigawatt-hours)

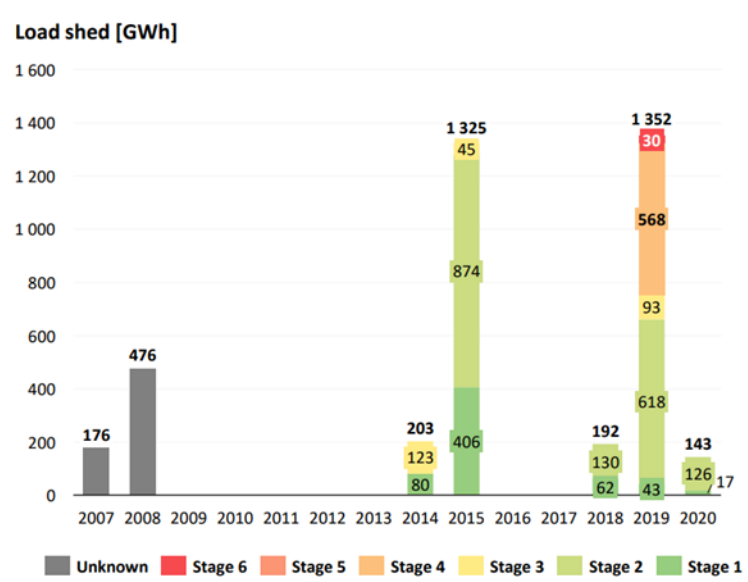


Source: Statistics South Africa (2016)

Given the challenges facing South Africa's economy due to the insecure supply of electricity production, renewable energy alternatives remain critical to reducing the dependency on coal fired power generation and to ensuring stable supply alternatives. South Africa experienced the worst year on record for load shedding in 2019, where blackouts persisted for a total of 1,352 GWh or 530 hours (Wright and Calitz, 2020). During 2019, level 6 load shedding was implemented for the first time as two thirds of Eskom's total capacity was offline (Wright and Calitz, 2020). Figure 3.8.4 below shows the historical trend in rolling blackouts from 2007 to 2020. Wright and Calitz (2020) estimate that the

total economic loss to the South African economy over this period was between R167 billion and R338 billion, while R60 billion to R120 billion of that loss was driven by the blackouts recorded in 2019.

Figure 34: Load shedding between 2007 and 2020 (Gigawatt-hours)



Year	Duration of outages (hours)	Energy shed (GWh)	Est. econ. Impact (ZAR-bln)
2007	-	176	8-15
2008	-	476	21-42
....	....	....	....
2014	121	203	9-18
2015	852	1325	58-116
2016	-	-	-
2017	-	-	-
2018	127	192	8-17
2019	530	1352	59-118
2020 (YTD)	80	143	6-12

Source: Wright and Calitz, 2020

Box 5 below provides examples of how technological innovation for renewable energy can be used to reduce the impact of climate change and drive a cleaner energy mix within a country.

Box 5: Technological innovation for renewable energy

Examples of technological innovation for renewable energy include:

i) Energy generation through footsteps: A project undertaken by Shell in Brazil. Technology is used that converts the weight of a footstep through kinetic tiles to generate electricity. Shell livewire implemented this technology on a soccer field and as the community play soccer, their footsteps generate electricity (Shell, 2014),

ii) eSolar: Innovative solar power plants for China and India based on solar power plants using flat mirrors, or heliostats, to concentrate sunlight onto a centrally located water tank suspended from a tower. Since the mass-manufactured components are designed for rapid construction, uniform modularity and unlimited scalability, the company can offer cheap utility scale power plants, thereby achieving a significant competitive advantage (ICC, 2015),

iii) The Berkley-Darfur stove: Provides a safe, energy-efficient wood-burning cook stove to millions of people in the developing world. It aims to improve health (by reducing smoke inhalation), aid the environment (by reducing the amount of wood needed for fuel) and alleviate poverty (by reducing the amount of time needed to devote to gather wood every day) (Stromburg, 2013),

iv) The window socket: A solar charger that can be stuck to a window or placed on the floor during sunlight hours, it stores about 10 hours' worth of electricity that can be used to charge any device and is shaped like a traditional wall socket for ease of use (Stromburg, 2013).

3.8.3 Conclusion

Innovation is an important factor in the early promotion of energy efficiency in low-income housing, as well as in the investigation of the use of solar cookers and potential local manufacturing to provide clean and sustainable energy solutions for housing in South Africa. Renewable energy is regarded as the stepwise solution to addressing service delivery needs for many South Africans (DME 2015).

Renewable energy in South Africa is sometimes associated with large-scale, grid-connected projects as constructed under the REIPPPP. However, renewable energy can be deployed on a smaller, stand-alone scale, where it can directly benefit households, farmers, communities and businesses. This remains important, as a large portion of South Africa's population is classified as energy poor, with an estimated 40 to 49 percent of households falling into this category (DME 2015). In order to address the challenges related to both energy poverty and climate-change risks, non-electrified and electrified options are being considered. This is also expected to alleviate the burden on ESKOM. Non-grid electricity supply by way of solar PV systems has been identified as the most suitable, temporary alternative to grid electricity (DME 2015).

Renewable energy innovations are rapidly advancing across all sectors, providing simple sustainable solutions at various scales, national, provincial, local and household. South Africa's dependency on coal-fired power generation drives high greenhouse gas emissions counts for the country, fuels climate change and fails to meet the demands of many households. Innovations that drive technological change and adoption provide the opportunity to extend access to electricity or power generation to South Africa's citizens.

3.9 Access to and supply of clean water

South Africa remains a water-scarce country, averaging approximately 500 mm of rainfall per annum, although this rainfall is distributed unevenly across the country. Some regions may experience substantially higher rainfall, while others remain arid. Water availability and access to safe, clean and reliable water supplies are critical for future economic growth and social development outcomes in the country.

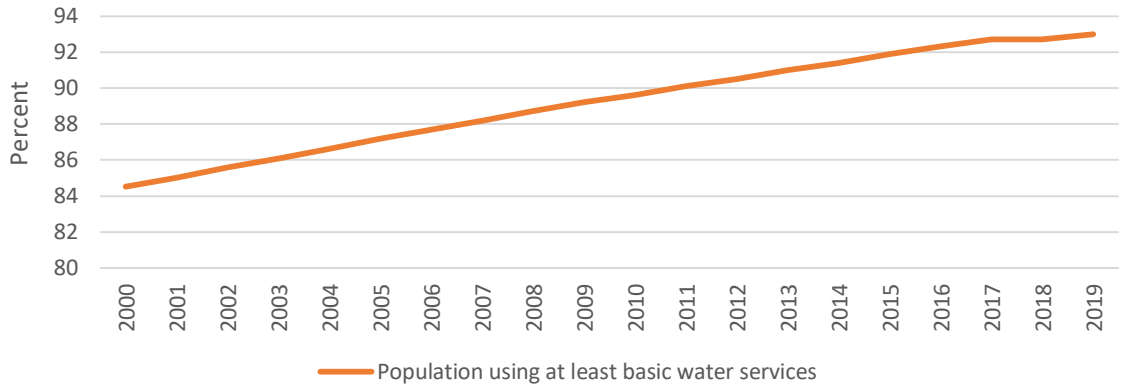
Table 11: Critical indicators of access to and supply of clean water in South Africa

Indicator	Data source
Population using at least basic drinking water services	*FAOSTAT*
Population using at least basic sanitation services	*FAOSTAT*
Population served with water	*DWS*
Population served with sanitation	*DWS*
Backlogs in water service provision	*DWS*
Backlogs in sanitation service provision	*DWS*

3.9.1 Access to water and sanitation

The population accessing a minimum of basic drinking water services increased from 89.6 percent to 92.7 percent between 2010 and 2017. In 2019, the Department of Water and Sanitation (DWS) indicated that 93 percent of South Africans had access to water services (South African Government News Agency 2019).

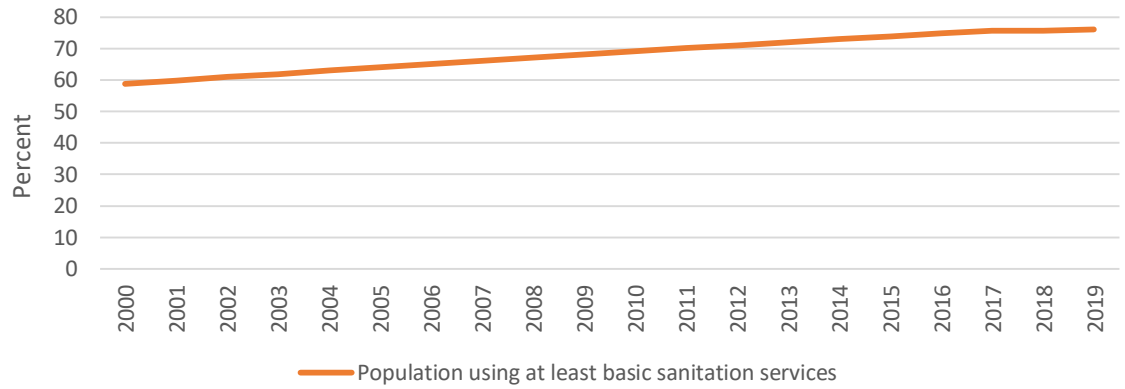
Figure 35: Population using at least basic drinking water services, 2000–2019 (percentage)



Source: DWS (2019); FAOSTAT (2021)

The population accessing basic sanitation services at a minimum increased from 69 percent to 75.7 percent between 2010 and 2017. In 2019, the Department of Water and Sanitation (DWS) indicated that 76 percent of South Africans had access to water services (South African Government News Agency 2019).

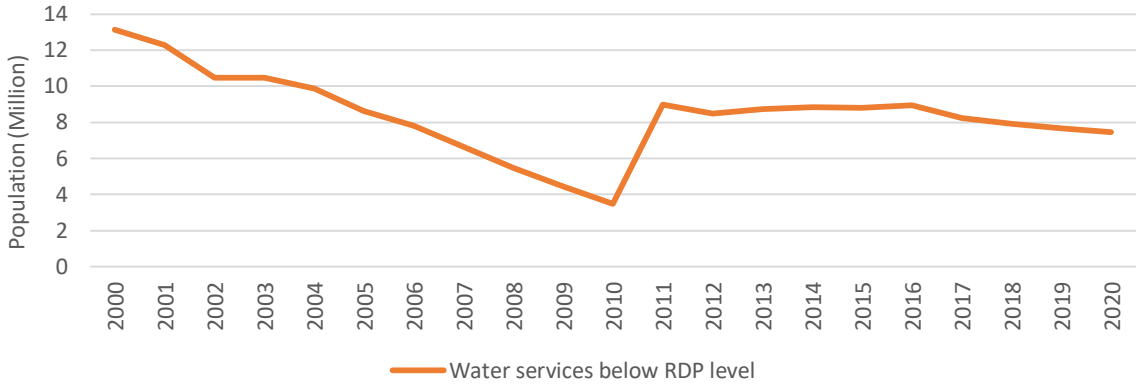
Figure 36: Population using at least basic sanitation services, 2000–2019 (percentage)



Source: DWS (2019); FAOSTAT (2021)

The population accessing water services below the RDP level decreased by 43 percent between 2000 and 2020. In 2020, KwaZulu-Natal received the largest share of service delivery, at 31 percent of the total, followed by the Eastern Cape (27 percent), Limpopo (19 percent), Mpumalanga and the North West province (nine percent each), Gauteng (three percent), and the Free State and the Northern Cape (one percent).

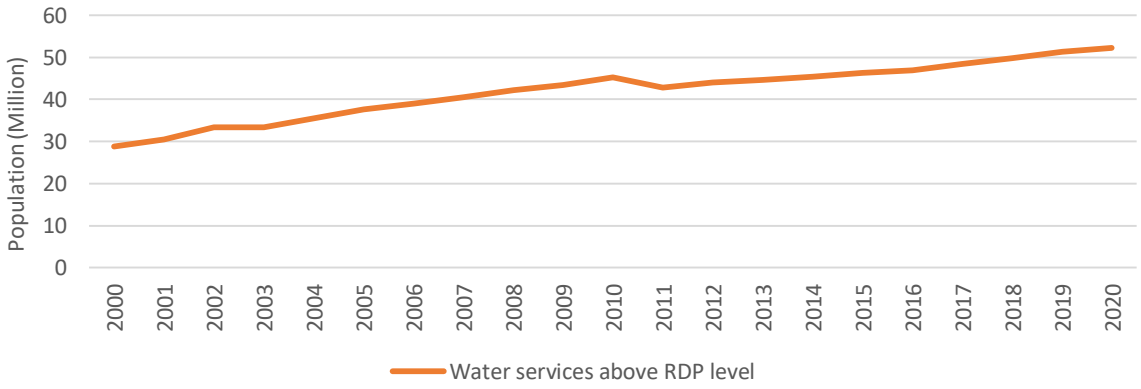
Figure 37: Population served with water services below RDP level, 2000–2020 (millions)



Source: DWS (2021)

The population accessing water services above the RDP level increased by 81 percent between 2000 and 2020. In 2020, Gauteng received the largest share of service delivery, at 30 percent of the total, followed by KwaZulu-Natal (18 percent), the Western Cape (13 percent), the Eastern Cape (nine percent), Mpumalanga and Limpopo (eight percent), North West (seven percent), Free State (six percent), and the Northern Cape (two percent).

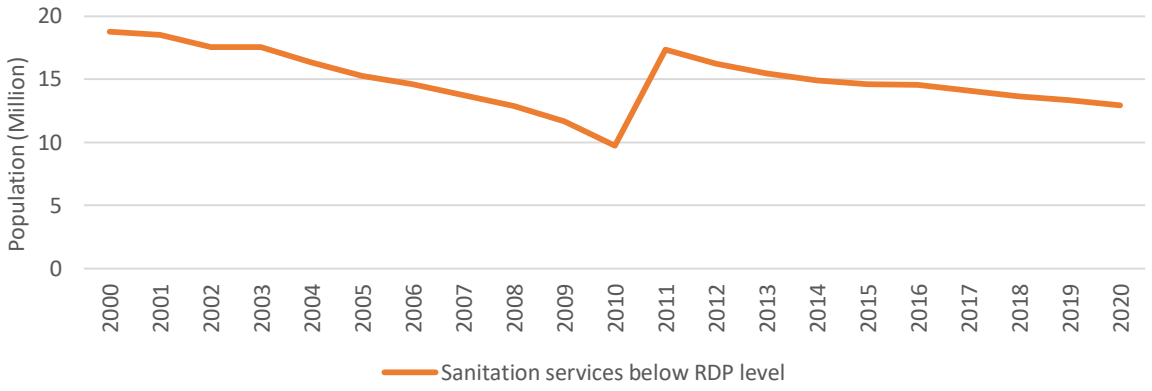
Figure 38: Population served with water services above RDP level, 2000–2020 (millions)



Source: DWS (2021)

The population accessing sanitation services below the RDP level decreased by 31 percent between 2000 and 2020. In 2020, KwaZulu-Natal received the largest share of service delivery, at 30 percent of the total, followed by the Limpopo province (21 percent), Mpumalanga (14 percent), the North West province and Eastern Cape (10 percent each), Gauteng (eight percent), Free State (four percent), the Northern Cape (two percent) and the Western Cape (one percent).

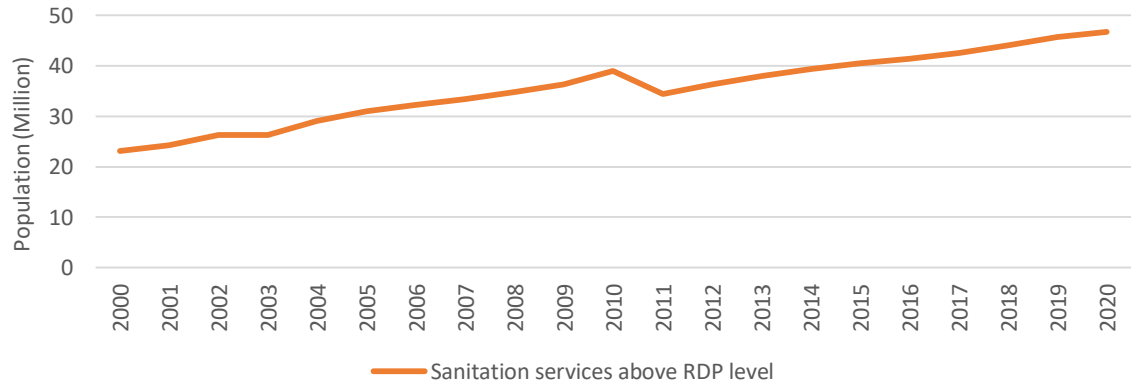
Figure 39: Population served with sanitation services below RDP level, 2000–2020 (millions)



Source: DWS (2021)

The population accessing sanitation services above the RDP level increased by 102 percent between 2000 and 2020. In 2020, Gauteng received the largest share of service delivery, at 31 percent of the total, followed by KwaZulu-Natal (17 percent), the Western Cape (15 percent), the Eastern Cape (11 percent), Limpopo (seven percent), Mpumalanga and North West (six percent each), the Free State (five percent), and the Northern Cape (two percent).

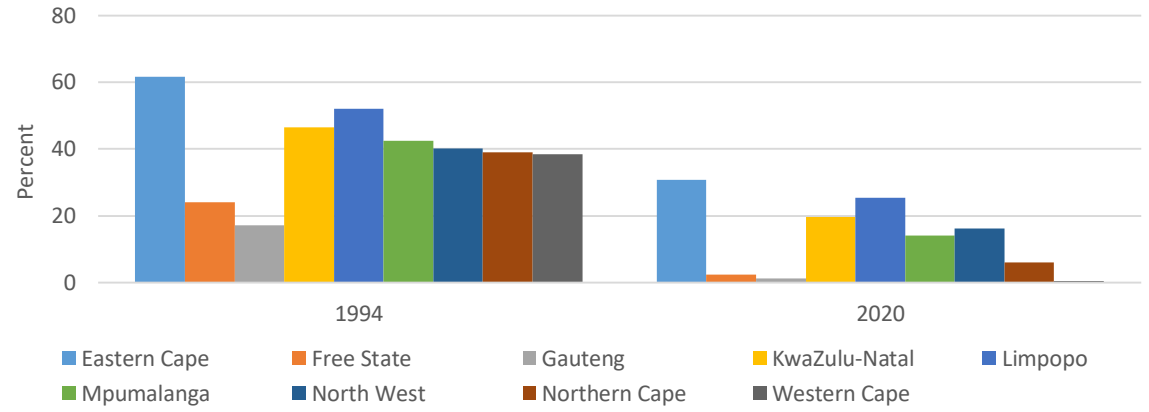
Figure 40: Population served with sanitation services above RDP level, 2000–2020 (millions)



Source: DWS (2021)

The South African government has made concerted efforts since 1994 to address backlogs in service delivery for both water and sanitation services. These backlogs indicate a declining trend across all nine provinces.

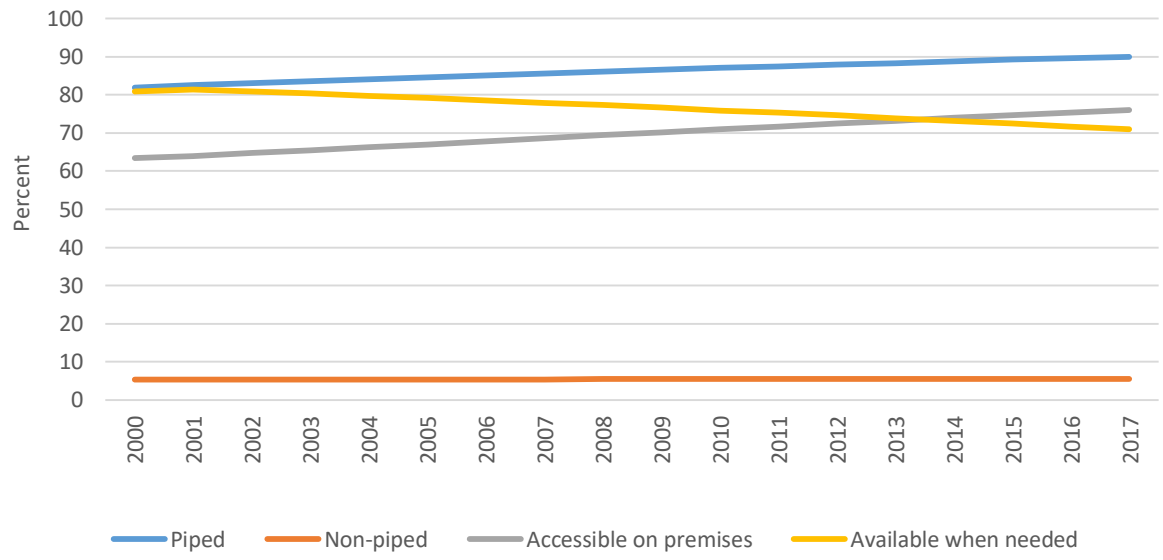
Figure 41: Backlogs in provision of water and sanitation services, 1994–2020 (percentage)



Source: DWS (2021)

Water services in South Africa have improved through the delivery of piped water to households and water being available on premises. Water services delivered by non-piped means remained flat, while water made available when needed decreased between 2000 and 2017.

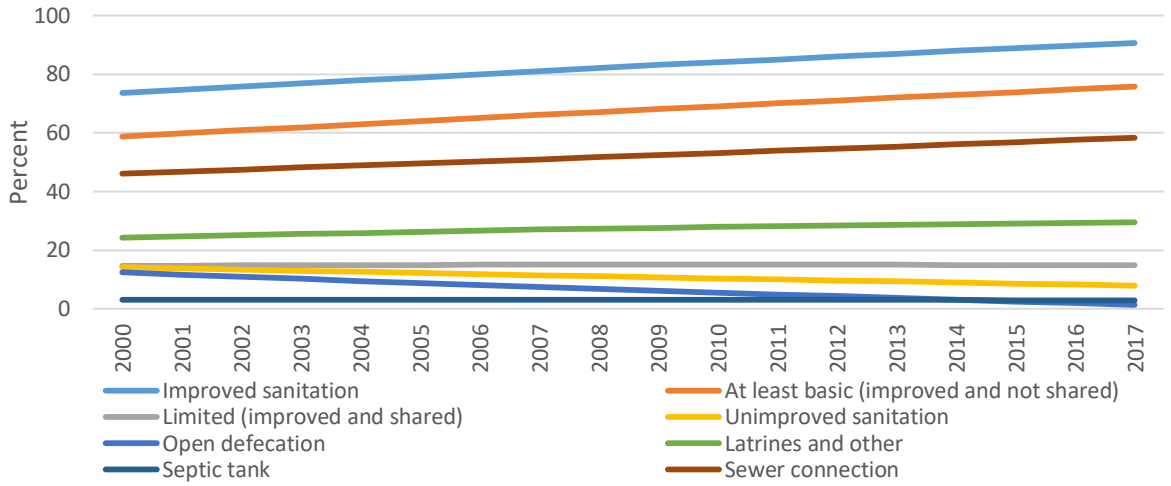
Figure 42: Water services by source, 2000–2017 (percentage)



Source: Statistics South Africa (2021c)

Sanitation service delivery has also shown an improvement in quality over the period 2000 to 2020 as sewer and latrine connections have increased. The use of septic tanks and no access to facilities declined over the same period.

Figure 43: Sanitation services by source, 2000–2017 (percentage)



Source: Statistics South Africa (2021c)

Box 6 below outlines an innovative technological solution being implemented in the Western Cape to monitor and manage water supply, ultimately saving water in times of water stress.

Box 6: The Bridgiot smart water meter

The Bridgiot smart water meter, developed by Stellenbosch University, uses digital innovation to save water by monitoring leaks. Consumers use the system to detect leaks and intervene strategically to cut consumption based on data generated by the system. The university started a company called Bridgiot to provide the systems and a water-monitoring service. The digital smart water system was installed in sixty local schools in the Western Cape in 2017 and, by January 2018, had generated water savings of 15 million litres, or R700 000.00 in financial savings.

Source: Head (2018)

Box 7 below summarises the research, development and innovation (RDI) roadmap for water research in South Africa, which envisages a key role for STI in improving access to clean water.

Box 7: The National Water Research, Development and Innovation (RDI) Roadmap

The National Water (RDI) Roadmap provides a structured framework to focus the contribution of RDI activity to the implementation of national policy, strategy and planning in water resources management in South Africa. The roadmap focuses on delivering i) at least one breakthrough technology every five years, ii) increasing the number of small and medium sized enterprises operating in the water sector, iii) increasing access to water for rural communities, including provision of sanitation for all in a sustainable manner. The aim is to drive significantly improved economic, health, social and environmental benefits for the country. The roadmap consists of seven clusters divided into water supply and water demand side needs and interventions, as follows:

Water supply:
1. Increase ability to make use of more sources of water, including alternatives
2. Improve adequacy and performance of supply infrastructure
3. Improve governance and operational performance

Water demand:
1. Improve governance, planning, and management of demand and use
2. Reduce losses and increase efficiency of productive use
3. Improve performance of pricing, monitoring, billing, metering and collection

Source: Water Research Commission et al. (2015)

3.9.2 Conclusion

The sustainable management of water and sanitation is critical to meet greater efforts to end poverty, advance sustainable development and sustain peace and stability in South Africa. Statistics on access to water and sanitation demonstrate that access at a macro-level has improved, but that district and local averages, particularly in poor areas, remain low. Similarly to the lack of access to health care, the lack of access to water and sanitation has a disproportionate effect on vulnerable groups and the poor. A serious challenge to the management of effective water and sanitation delivery in South Africa remains the collection and storage of water and sanitation data, including the regular monitoring of water and sanitation infrastructure (DWS 2015).

3.10 High-quality healthcare services

The South African healthcare system reflects the unequal legacy left by apartheid and remains polarised today. Poverty still fundamentally determines health outcomes. The poor have limited resources to source alternative healthcare options, and remain dependent on a deeply under-resourced government healthcare system. The 2011 census found that men aged 40 to 59 from the poorest quintile were six times more likely to die within the next year than the corresponding group from the richest decile (Stats SA 2011; Burger and Ngwenya 2021). Public health care in South Africa is legally available to everyone, but has been constrained by financial and investment shortages, resulting in shortages of proper supplies, functioning machinery and high-quality services. The services provided often require patients to wait for extended periods of time, along with the unavailability of skilled doctors and little warning of appointment times. Although the country's level of life expectancy has risen over the past ten years, it remains relatively low, driven by the prevalence of HIV and tuberculosis.

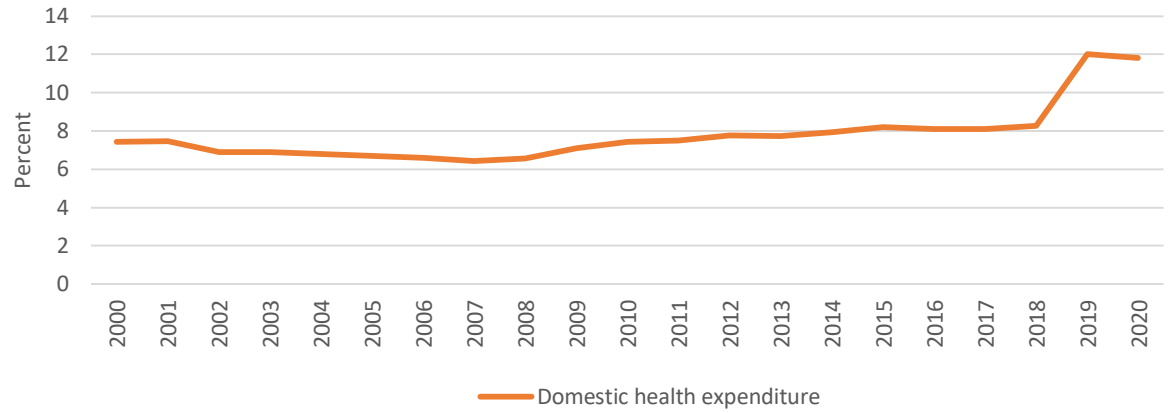
Table 12: Critical indicators of high-quality healthcare services in South Africa

Indicator	Data source
Domestic general government health expenditure	*National Treasury*
Public and private health expenditure	*National Treasury*
Life expectancy at birth	*Statistics South Africa*
Shifts in mortality trends in South Africa	*Statistics South Africa*

3.10.1 Expenditure on healthcare

Domestic government expenditure on health is expected to translate into higher-quality health care in South Africa, as well as better access to health care by vulnerable groups in society. South Africa's contribution to healthcare expenditure has been increasing, from 6.5 percent of GDP in 2008 to 8.2 percent in 2018, and it was significantly higher in 2020, at 11.8 percent. However, this has failed to translate into quality and accessible health care for the majority of the population.

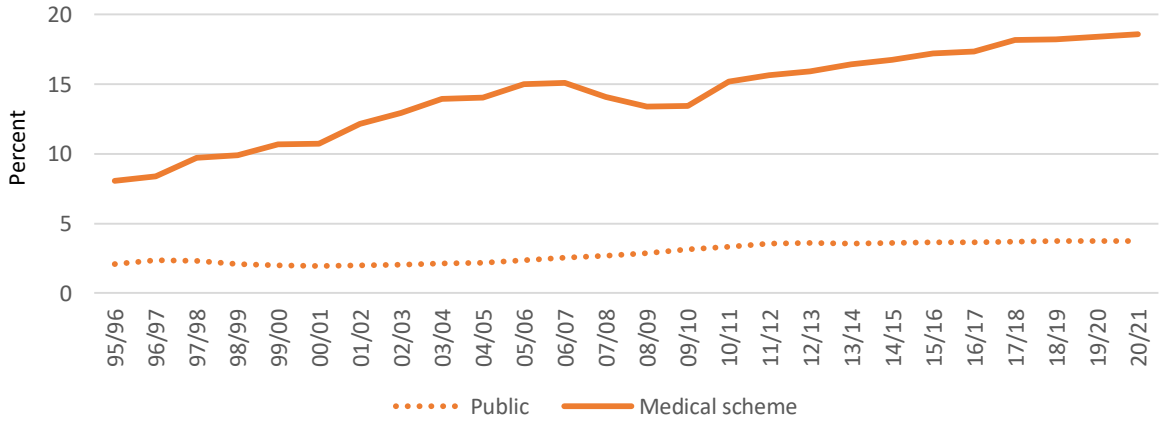
Figure 44: Domestic government expenditure on health, 2010–2019 (percentage of GDP)



Source: National Treasury (2019)

South Africa has two distinct healthcare services; one is private and serves the minority of the population who can afford to pay increasingly steep monthly as well as out-of-pocket fees. The other is public, funded mainly by tax revenues and serving the vast majority of citizens. Although only 17 in 100 people have private medical insurance (Burger and Ngwenya 2021), the private sector healthcare spend is 4.2 percent of GDP, versus 4.4 percent for the public sector (Department of Planning, Monitoring and Evaluation [DPME] 2017). This unequal resourcing leads to unequal health outcomes that mirror the fault lines of race and geography inherited from apartheid. The African Union Abuja Declaration target of spending at least 15 percent of the public budget on health is not being met by the South African government, with the estimated budget spend for 2020/21 at 11.8 percent. Furthermore, real per capita public health expenditure has remained flat since 2012, evidence of a decade of low economic growth, fiscal constraints and rising input costs in the country (Blecher et al. 2017).

Figure 45: Public and private health expenditure as percentage of GDP, 1996-2021 (percentage)



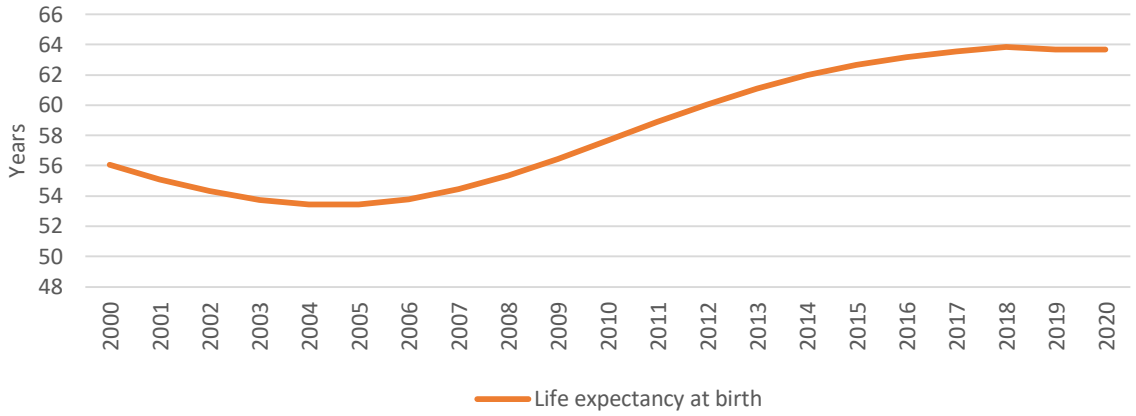
Source: National Treasury of the Republic of South Africa (2021)

3.10.2 Health outcomes

Life expectancy in South Africa remains low, at a mere 63.7 years. The low life expectancy at birth for South Africans is predominantly attributed to the prevalence of HIV and TB in the country. Although

the incidence of HIV has fallen systematically over the past 10 years, it is estimated that seven percent of people between the ages of 15 and 49 years test positive (Stats SA 2020).

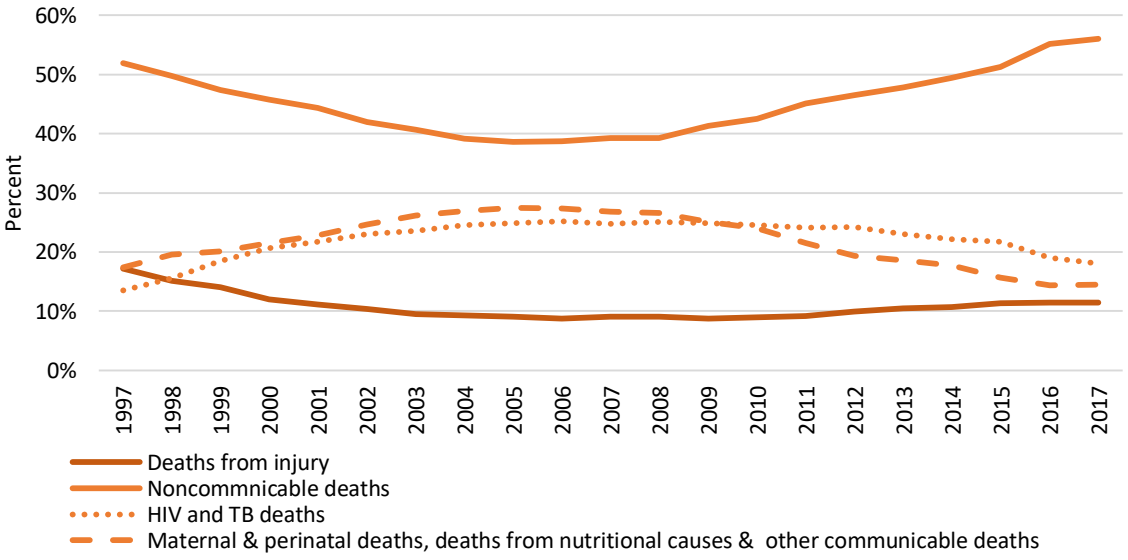
Figure 46: Life expectancy at birth (years)



Source: Statistics South Africa (2021)

Based on the categorisation of the ICD-10 (International Classification of Diseases and Related Health Problems), the five leading causes of disease in South Africa have not changed between 2015 and 2017. Tuberculosis is the leading cause of death in the country, followed by diabetes. Cerebrovascular diseases and other forms of heart disease are in positions three or four respectively. HIV is ranked fifth (Stats SA 2020).

Figure 47: Shifts in mortality trends in South Africa, 1997–2017 (percentage)



Source: Statistics South Africa (2020)

3.10.3 Conclusion

Innovation remains an important tool for delivering high-quality universal health care. Innovations need to range across a diverse set of issues and core drivers. The drivers of high-quality health care include (WHO, OECD and WB 2018):

- Having a well-defined national quality policy and strategy;
- Demonstrating accountability for delivering a safe, high-quality service;
- Ensuring that reforms driven by the goal of universal health coverage build quality into the foundation of their care systems;
- Ensuring that health systems have an infrastructure of information and information technology capable of measuring and reporting the quality of care;
- Closing the gap between actual and achievable performance in quality;
- Strengthening the partnerships between health providers and health users that drive quality in care;
- Establishing and sustaining a health-professional workforce with the capacity and capability to meet the demands and needs of the population for high-quality care;
- Purchasing, funding and commissioning based on the principle of value;
- Financing research on quality improvement.

Access to affordable and high-quality healthcare services in South Africa is critical for the achievement of socio-economic development outcomes. Funding for improved services, good governance of funding streams, and clear and accountable management targets are also necessary to ensure appropriate and effective development outcomes in the sector.

3.11 Affordable food

Whilst South Africa is food secure at the national level, the country remains food insecure at the household level, as not all households have access to adequate affordable food. The findings on food security vary by provincial location, population group and household size (Stats SA 2019). Physical access to food at the national and regional levels in South Africa, supported by the associated infrastructure such as roads and market outlets to buy food, ensure food security at a macroeconomic level (Thomson and Metz 1998). However, economic access to food depends on the purchasing power of households and the level of food prices (Thomson and Metz 1998). Many households' ability to spend on food is limited, and access to affordable food remains a development challenge. In 2017, almost 20 percent of South African households had inadequate or severely inadequate access to food (Statistics South Africa, 2019).

Affordability is a key component of food security (IGD 2013). The failure for people to access safe and nutritious food at affordable price levels, threatens their welfare (IGD 2013). Typically, food affordability improves as incomes improve, but this positive relationship may disintegrate when currency fluctuations make food imports more expensive, economic, fiscal or financial events influence incomes and prices, or food-related inputs become more expensive due to rising demand, for example agri-chemicals or fuel (IGD 2013).

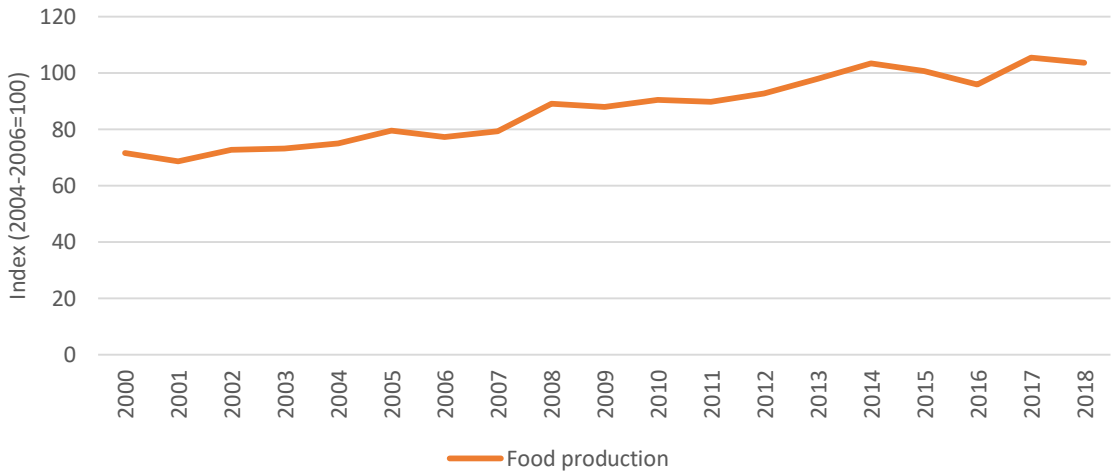
Table 13: Critical indicators of affordable food in South Africa

Indicator	Data source
Food production index	*World Bank; Statistics South Africa*
Crop production index	*World Bank; Statistics South Africa*
All consumer price index	*Statistics South Africa*
Food consumer price index	*Statistics South Africa*
Food consumer price index by province	*Statistics South Africa*
Household debt to income	*South African Reserve Bank*
Number of people undernourished	*FAOSTAT*
Per capita food supply	*FAOSTAT*

3.11.1 Food production

The food production index covers food crops that are considered edible and that contain nutrients; it provides an indication of the state of food production in South Africa and the potential for food security in the country. In 2018, food production started to show a decline, driven to some extent by extreme weather events in the country and relatively cheap imports. The food production index for South Africa rose by 45 percent between 2000 and 2018, and by 14 percent between 2010 and 2018.

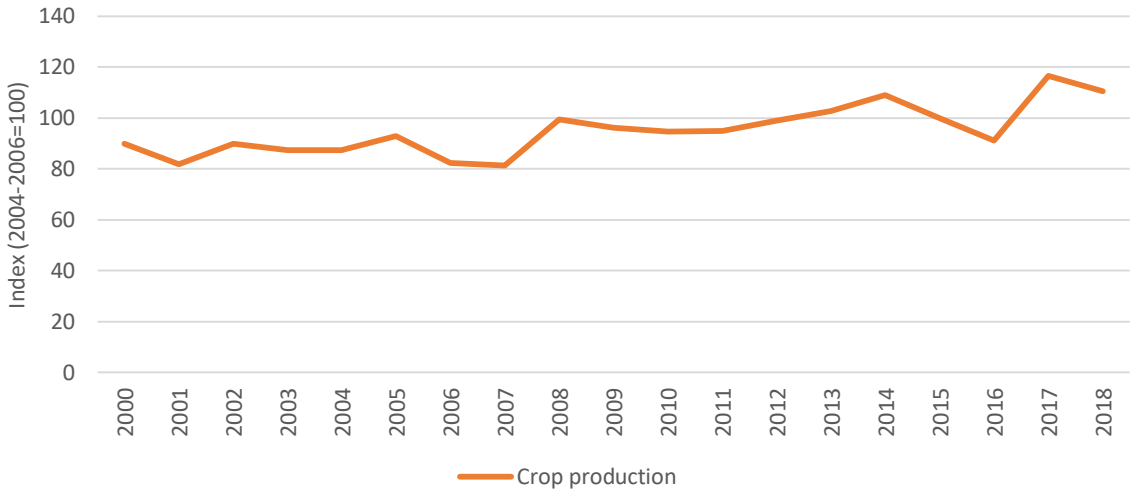
Figure 48: Food production index, 2000–2018 (index)



Source: World Bank (2021)

The crop production index shows agricultural production for each year relative to the base period of 2004 to 2006 (FAOSTAT 2021). Some of this production is exported and the indicator needs to be considered in conjunction with the food production index and the consumer price index to determine both the availability of food supply and any risks related to shortages that will drive the cost of food supply upwards, thereby affecting the affordability of food in the country. The crop production index rose by 23 percent between 2000 and 2018 and by 17 percent between 2010 and 2018.

Figure 49: Crop production index, 2000–2018 (index)

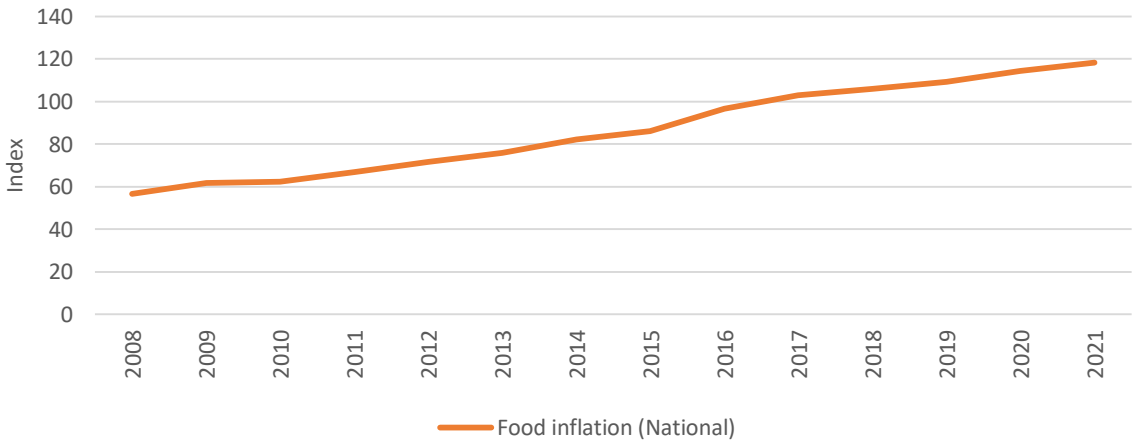


Source: World Bank (2021)

3.11.2 Food affordability

Despite overall inflation in South Africa recording its lowest level in 16 years and the second lowest level in 59 years in December 2020, food inflation has continued to rise in the country (Stats SA 2020). The food consumer price index (FCPI) measures changes in the prices paid by consumers for a basket of food. The FCPI reflected the highest level in 13 years for the first quarter of 2021 (Statistics South Africa, 2021). This indicator shows the affordability of food in South Africa and raises concerns as income inequality and unemployment rise in the country, exacerbating food affordability for many South Africans.

Figure 50: Food inflation in South Africa, 2008–2021 (index)



Source: Statistics South Africa (2021)

Food inflation has different regional effects. Two of the poorest provinces in South Africa have reflected the highest food inflation over the past 14 years; these are the Eastern Cape, with the highest food inflation of 114 percent, and the Northern Cape, at 113 percent. These are followed by the Western Cape at 112 percent, the Free State at 111 percent, Gauteng at 108 percent, Mpumalanga at

107 percent, both KwaZulu-Natal and the Limpopo provinces reflected food inflation of 105 percent, while the North West province had the lowest food inflation, of 97 percent.

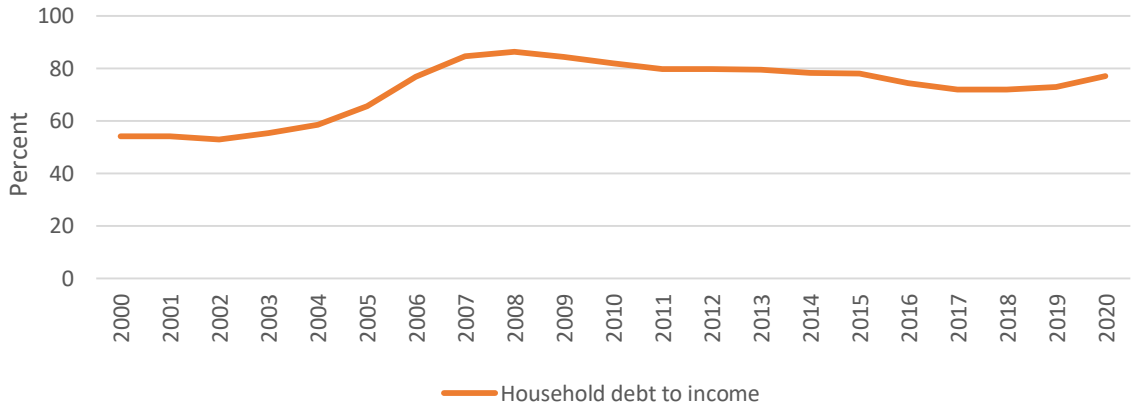
Table 14: Food inflation by province, 2008–2021 (index 100=2006)

Province	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Western Cape	57	63	64	69	74	78	83	88	97	104	108	110	113	120
Eastern Cape	55	60	61	66	70	74	79	84	96	102	104	109	111	117
Northern Cape	55	59	61	66	73	76	82	86	96	103	106	109	111	116
Free State	56	61	62	67	71	75	80	85	96	103	107	110	113	119
KwaZulu-Natal	57	62	62	66	71	76	82	85	96	102	104	108	110	116
North West	58	63	63	67	71	75	82	86	96	102	104	107	109	115
Gauteng	58	63	63	68	73	78	84	88	97	104	107	111	113	120
Mpumalanga	57	62	62	66	71	76	82	86	96	103	105	108	111	118
Limpopo	55	59	59	64	68	72	80	84	97	102	102	106	108	114

Source: Statistics South Africa (2021)

Affordable food is also dependent on household income. Since 2002, South Africa's debt-to-income ratio for households has risen by 43 percent, reflecting a level of 77 percent in 2020 (SARB 2021). Rising debt and the inability of households to meet these debt obligations limits the available income for buying nutritious food.

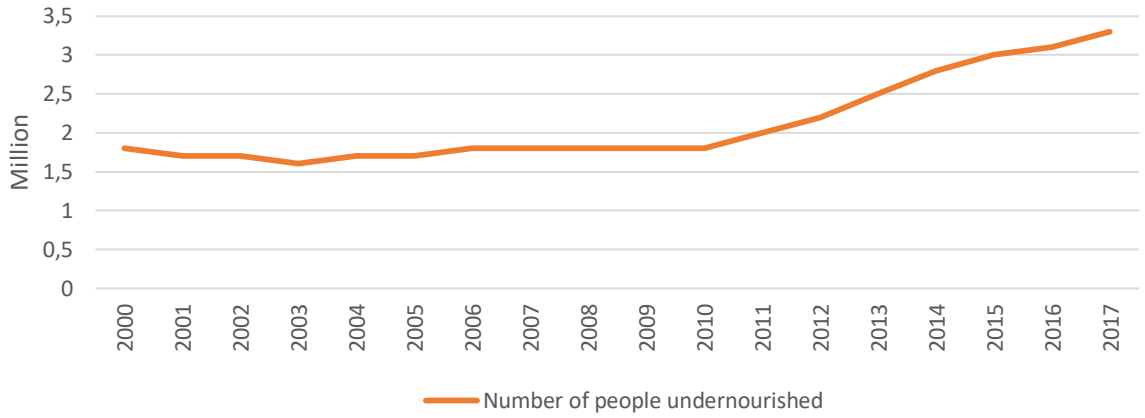
Figure 51: Household debt to income, 2000–2020 (percentage)



Source: South African Reserve Bank [SARB] (2021)

The number of people undernourished provides an indicator of the number of people who are not accessing an appropriate and sustainable food supply in order to remain healthy. It may also be used as an indication of the number of people who cannot afford food daily. The number of people living in an undernourished state in South Africa has risen over the past 10 years, from 1.8 million to 3.3 million (FAOSTAT 2021).

Figure 52: Number of people undernourished (three-year average) (millions)



Source: FAOSTAT (2021)

3.11.3 Food supply

Food supply variability provides an indication of the calorie intake people are able to consume and remain healthy. Access to affordable food influences the variability of per capita food supply, indicating the kilocalories a person consumes per day. In South Africa, this indicator fell by 72 percent between 2009 and 2017. Almost one quarter of the South African population now live below the national food poverty line, and 27 percent of children under five years of age experience stunted growth (May 2021).

Figure 53: Per capita food supply, 2010–2017 (kcal/capita/day)

Source: FAOSTAT (2021)

3.11.4 Conclusion

The role of innovation in food affordability is complex and multifaceted. Innovations range from developing higher yields with lower water use and lower pesticide use at the point of agricultural production. The food value chains in South Africa are also limited to a few large supermarkets, and opportunities exist to create more inclusive value chains that integrate small-scale agriculture and farmers. Innovations around access and distribution are also necessary. Overall, innovations for food

affordability are required across the whole food value chain to ensure not only access to physical food, but also access to adequate levels of nutrition.

Food affordability and the ability to access the appropriate nutrition on a daily basis are critical for socio-economic development. Food affordability without the necessary nutrition value undermines people's ability to work, study and function in society. Both food affordability and nutritional values remain important to meet the developmental goals of South Africa. Although South Africa is considered to be food secure at the national level, it faces a "double burden of malnutrition comprising under-nutrition and micro-nutrient deficiencies, and over-weight/obesity" (May 2021, p. 1). Consequently, South Africa bears a disproportionate burden of food insecurity in Sub-Saharan Africa, given the country's relative wealth.

4. Conclusion and recommendations

South Africa continues to face profound economic and development challenges. The need to address the 'triple challenges' of poverty, unemployment and inequality in South Africa, while transforming the economy and raising the rate of economic growth remains acutely stark.

To date, developmental progress has been uneven across all dimensions of the socio-economic landscape, with gains in one area not necessarily translating into gains in another area. New ideas are needed to deliver transformative outcomes. A combined and complex systems approach needs to be undertaken that incorporates the impacts and effects that changes in one developmental area will have on another developmental area.

Further, South Africa arguably does not have an institutionalised system for measuring policy impacts at present. While this is more complex than measuring outputs and outcomes, it is crucial for designing, implementing, monitoring and adapting policies. Relatedly, the country lacks an indicator architecture for the tracking of policies and plans and their impact.

Well-researched and practically implementable solutions are needed, if sustainable and inclusive socio-economic development is to be realised. This report outlines some of the critical indicators that will need to be measured on a regular basis to ensure that implementation of innovative solutions is driving positive socio-economic development outcomes for the country.

Innovation can serve as an important engine of economic growth, that allows for the expansion of capabilities and infrastructure to shift the growth trajectory away from stagnation towards sustainable inclusive growth is needed. Ultimately, innovative approaches that allow for long term sustainable outcomes in socio-economic development may provide the step-wise change required for effective socio-economic development in the country.

4.1 Data considerations

This review focussed on contextualising STI and sustainable development in South Africa. The data selection aimed to use predominantly South African data sources. Across to data for certain domains data was readily available and easily accessible, however, for some of the indicators data challenges were evident.

Effective decision-making and implementation strategies are dependent on timeous, relevant data. This is also important for risk management and disaster management. Various data series available

for these indicators are based on historical surveys and recent data is often limited to a few data points that are not always up-to-date. An innovative system for the timeous and current collection of relevant data for measuring socio-economic outcomes is necessary for appropriate planning and for policy design and implementation. Where relevant, such data also needs to be disaggregated from a national, to provincial, to district, to municipal level in South Africa.

Future research options that provide for a systematic and inexpensive way to collect and collate this data, supported by technological innovations whereby data is uniformly available in accessible and user-friendly formats, is needed. For example, data based on the General Household Survey is collected on a five-yearly basis limiting the time series changes available on a monthly or annual basis; this data is important for monitoring poverty and other key issues. Other indicators such as the crop production index or food production index have not been updated recently, and the blue and green data collection mechanisms for water were discontinued limiting the broader availability of data across the water sector.

Where data is available, it would be preferable for this to be availed in formats that are readily accessible and user-friendly. For example, some of the data utilised for this report required each point to be individually entered into a format that allowed for data analysis. Accessibility of relevant data is important for researchers as well as for policymakers.

In relation to this particular report, the broader question remains regarding the collection of data and indicators related specifically to innovation across the eleven domains and whether it may be necessary to identify innovation linked socio-economic indicators and commence collection of data that allows for the measurement of the impact of innovation on socio-economic development.

4.2 Recommendations for future research

Research is needed to analyse the fundamental and proximate causes of the development challenges facing South Africa, to form the basis for feasible short-, medium- and long-term strategies for addressing these. Of particular relevance here is the role of innovation in catalysing, accelerating and supporting progress towards the addressing of these challenges. A more central positioning of an innovation-based approach, integrated across policy domains, could be fundamental to a shift away from ‘business as usual’ and to meaningful progress around South Africa’s socio-economic and environmental challenges. This links with the needs for an indicator architecture and for an institutionalised system for measuring policy impacts.

The key research imperative emerging from this report lies in more in-depth research around the relationships between innovation and outcomes in the various domains discussed here. An overview has been presented here of indicators and trends in eleven domains, with brief reflections around links with innovations and some exploratory indications as to the possible role of innovation, and STI more broadly, in addressing these. A full understanding of the possible role of innovation in each of these domains is beyond the scope of this report, but is crucial for policy – both overall STI policy and the policies of line departments and other stakeholders in each individual domain. A thorough understanding of this requires in-depth research in each domain, as to the role of contributing to developmental outcomes in respective domains.

While there will be some commonalities in the role of innovation across domains, this role is also domain-specific. For instance, the role of STI in contributing to higher rates of aggregate economic

growth, will be very different from the role of STI in promoting renewable energy or in improving access to clean water. Also worth noting in this regard is that types of innovation, and STI more broadly, differ significantly across domains.

This sort of analysis would entail new research by domain as to the actual and potential role of innovation. The analysis could draw on sub-national and national experiences from South Africa, as well as international experiences, particularly around success stories and best practice. It would also be pertinent to consider constraints on innovation by domain, and constraints and obstacles to innovation contributing to superior domain outcomes, as well as shedding light on possible strategies towards overcoming both of these sets of constraints.

This sort of research would need to involve researchers with innovation expertise as well as researchers with domain-specific expertise, working in an integrated manner. Inter-, multi- and trans-disciplinary skills and methods would be required.

Some common methodological approach/es could be of value for the benefit of a consistent and integrated approach, but appropriate methodologies would also vary by domain. Such methodologies could include case study and other qualitative approaches (for instance around successful and even unsuccessful cases of the role of innovation in development outcomes); quantitative modelling (such as Computable General Equilibrium (CGE) or econometric approaches). These could draw on and extend methodological best practice around the role of innovation in development outcomes, including from international literature and praxis.

For such research to be relevant to policy, it would be important to take it forward in an approach that involves relevant government departments and stakeholders in the various domains. Such research would be important in informing both innovation policy and policy specific to each domain, in an integrated manner. The abovementioned sort of research would need to unfold over a period of time in order to achieve sufficient depth and rigour, and would need to be well conceptualised at the outset.

References

Abramovitz, M. 1986. Catching up, forging ahead, and falling behind. Journal of Economic History 46: 386–406.

African Union Commission. 2020. Science, technology and innovation strategy for Africa 2024 (STISA-2024. African Union Commission, Addis Ababa, Ethiopia.

Aghion, P., and Howitt, P. 1992. A model of growth through creative destruction. Econometrica 60: 323–351.

Albuquerque, E. 2019. Brazil and the middle income trap: Its historical roots. Seoul Journal of Economics 32(1): 23-62.

Amendola, M. and Gaffard, J.L. 1988. *The Innovative Choice*. Oxford: Basil Blackwell.

Arndt, C., Gabriel, S., Hartley, F., and Strzepek, K.M. 2021. Climate change and the green transition in South Africa. In Oqubay, A., Tregenna, F., and Valodia, I. (eds.), The Oxford handbook of the South African economy. Oxford: Oxford University Press. (forthcoming).

AUDA-NEPAD. 2014. Towards achieving the Science Technology and Innovation Strategy for Africa (2024). AUDA-NEPAD, Midrand.

Barba Navaretti, G., and Soloaga, I. 2001. Weightless machines and costless knowledge – An empirical analysis of trade and technology diffusion. Policy Research Working Paper Series 2598, The World Bank, Washington DC.

Berman, E., Bound, J., and Griliches, Z. 1994. Changes in the Demand for Skilled Labor within U.S. Manufacturing: Evidence from the Annual Survey of Manufacturers. The Quarterly Journal of Economics 109: 367-397.

Blechinger, D., Kleinknecht, A., Licht, G., and Pfeiffer, F. 1998. The Impact of Innovation on Employment in Europe - An Analysis Using CIS Data. ZEW Dokumentation 98-02, Zentrum fuer Europaeische Wirtschaftsforschung, Mannheim.

Blignaut, J.N., Ueckerman, L. and Aronson, J. 2009. Agriculture production's sensitivity to changes in climate in South Africa. South African Journal of Science No 105, pp: 61-68.

Boyer, R. 1988. New Technologies and Employment in the 1980s: From Science and Technology to Macroeconomic Modelling. In. Kregel, J., Matzner, E and Roncaglia, A. (eds). Barriers to Full Employment. London: Macmillan. pp. 233-268.

Burger, M., and Ngwenya, M. 2021. The economics of health in South Africa. In Oqubay, A., Tregenna, F., and Valodia, I. (eds.), The Oxford handbook of the South African economy. Oxford: Oxford University Press. (forthcoming).

Buthelezi, S.A., and Davies, T.C. 2014. The environmental and health impacts of carbon emission from active and abandoned coal mines, in South Africa: A review of secondary data. Presentation at the Closing Workshop of the IGCP/SIDA Projects 594 and 606, 27 May, Mangosuthu University of Technology, Prague, May 26–27.

Chung, S. 2011. Innovation, competitiveness, and growth: Korean experiences. Annual World Bank Conference on Development Economics 2010. The World Bank, Washington DC.

Cirera, X., and Sabetti, L. 2016. The effects of innovation on employment in developing countries: Evidence from enterprise surveys. Policy Research Working Paper No. 7775. World Bank, Washington DC.

Cohen, W.M., and Levinthal, D.A. 1990. Absorptive capacity: A new perspective on learning and innovation. Administrative Science Quarterly 35: 128–152.

Dahlman C.J., and Westphal, L. 1982. Technological effort in industrial development – An interpretative survey of recent research. In Stewart, F. and James, J. (eds.), The economics of new technology in developing countries. London: Pinter, pp. 105–137.

Dayton, L. 2020. How South Korea made itself a global innovation leader. Nature 581: S54–S56.

Department of Agriculture, Forestry and Fisheries. 2012. Zero Hunger Programme for the Republic of South Africa. Department of Agriculture, Forestry and Fisheries (DAFF), Pretoria.

Department of Communications and Digital Technologies. 2020. National Digital and Future Skills Strategy. Department of Communications and Digital Technologies, Pretoria.

Department of Environmental Affairs (DEA). 2011. National Climate Change Response White Paper. Department of Environmental Affairs, Pretoria.

Department of Energy (DE). 1998. White paper on energy. Department of Energy, Pretoria

Department of Energy (DE). 2015. State of renewable energy in South Africa. Department of energy, Pretoria.

Department of Energy (DE). 2016. South African coal sector report. Department of energy, Pretoria.

Department of Energy (DE). 2016. Draft Post-2015 National Energy Efficiency Strategy. Department of Energy. Pretoria.

Department of Energy (DE). 2019. The South African energy sector report 2019. Department of energy, Pretoria.

Department of Energy (DE). 2020. South Africa's low emission development strategy 2025. Department of energy, Pretoria.

Department of Energy (DE). 2021. Statistical database on energy production. Department of energy, Pretoria.

Department of Environmental Affairs. 2013. The National Climate Change Response Policy. Department of (D), Pretoria.

Department of Environmental Affairs. 2020. South Africa's low emissions strategy. Department of (DEA), Pretoria.

Department of Health (DoH). 2019. National digital health strategy for South Africa (2019-2024). Department of Health, Pretoria.

Department of Minerals and Energy (DME). 2005. Energy efficiency strategy of the Republic of South Africa. Department of Energy, Pretoria.

Department of Forestry, Fisheries and Environment (DFFE). 2020. National climate change adaptation strategy. Pretoria: DFFE.

Department of Higher Education and Training. 2019. Call for public comments on the revised National Norms and Standards for Funding Technical and Vocational Education and Training colleges. Government Gazette No 42849. Pretoria: DHET.

Department of Higher Education and Training. 2019. National skills development strategy III. Department of Higher Education and Training (DHET), Pretoria.

Department of Planning, Monitoring and Evaluation (DPME), 2017. Final impact assessment (Phase 2): White Paper on National Health Insurance. Pretoria: Department of Planning, Monitoring and Evaluation.

Department of Science and Technology. 2019. White paper on Science, Technology and Innovation. Pretoria.

Department of Science and Technology. 2010. Innovation for poverty alleviation programme gets underway. Department of Science and Technology, Pretoria.

Department of Telecommunications and Postal Services. 2019. Terms of reference for the Presidential Commission on the Fourth Industrial Revolution. Department of Telecommunications and Postal Services, Pretoria.

Department of Trade and Industry. 2007. National Industrial Policy Framework (NIPF). Department of Trade and Industry, Pretoria.

Department of Trade and Industry. 2018. Industrial Policy Action Plan 2018/19-2020/21. Department of Trade and Industry, Pretoria.

Department of Trade, Industry and Competition. 2021. Auto green paper on the advancement of new energy vehicles in South Africa. Department of Trade and Industry, Pretoria.

Doner, R. F. and Schneider, B. R. 2016. The Middle-Income Trap. World Politics. 68(4): 608–644.

Fagerberg, J., and Srholec, M. 2009. Innovation, technology and development: Unpacking the relationship(s). In Lundvall, B.-A., Joseph, K.J., Chaminade, C., and Vang, J. (eds), Handbook of innovation systems and developing countries. Building domestic capabilities in a global context. Cheltenham: Edward Elgar.

Fagerberg, J., Srholec, M., and Verspagen, B. 2010. The role of innovation in development. Review of Economics and Institutions 1(2): 1–29.

Greenan, N., and Guellec, D. 2000. Technological Innovation and Employment Reallocation. Labour 14: 547–590.

Griliches, Z., and Lichtenberg, F. 1984. R&D and productivity growth at the industry level: Is there still a relationship? In Z. Griliches (ed.), R&D, patents, and productivity. Chicago: University of Chicago Press.

Habiyaremye, A. 2021. Creating jobs costs money – how can cash-strapped SA shape a post-pandemic turnaround? Fin24, 23 February. https://www.news24.com/fin24/opinion/opinion-creating-jobs-costs-money-how-can-cash-strapped-sa-shape-a-post-pandemic-turnaround-20210223

Habiyaremye, A., Molewa, O., and Lekomanyane, P. 2021. Estimating employment gains of the proposed infrastructure stimulus plan in post-Covid-19 South Africa. The European Journal of Development Research. DOI: 0.1057/s41287-021-00400-5

Hart, T., Jacobs, P., Letty, B., Ramoroka, K., Mangqalaza, H., Mhula, A., and Ngwenya, M. 2014. Promoting innovation for inclusive rural transformation in South Africa: Policy Brief. Human Science Research Council (HSRC), Cape Town.

Head, T. 2018. How have these 60 Western Cape schools managed to save 15 million litres of water? The South African, 17 January. https://www.thesouthafrican.com/news/western-cape-schools-saving-15m-litres-of-water/

Human Sciences Research Council (HSRC). 2020. Business innovation survey: Innovation performance in South African businesses, 2014-2016. Human Science Research Council, Cape Town.

IGD. 2013. Food affordability. https://www.igd.com/articles/article-viewer/t/food-affordability/i/15797

Indurkar, A., Srinidhi, A., D'Souza, M., Kale, E., Stiem-Bhatia, L., and Banerjee, S. 2020. Scaling ecosystem-based adaptation to climate change in Maharashtra, India: An analysis of policies and programmes. Watershed Organisation Trust (WOTR). https://wotr.org/publication/scaling-ecosystem-based-adaptation-to-climate-change-in-maharashtra-india-an-analysis-of-policies-and-programmes/

International Chamber of Commerce (ICC). 2015. Supporting innovation to meet climate change challenges: Policy statement for submission to UNFCCC COP-21. International Chamber of Commerce, Paris.

Jamrisko, M., Lu, W., and Tanzi, A. 2021. South Korea leads world in innovation as U.S. exits top ten. Bloomberg, 3 February. https://www.bloomberg.com/news/articles/2021-02-03/south-korea-leads-world-in-innovation-u-s-drops-out-of-top-10

Khan, H. 2004. Technology and economic development: The case of Taiwan. Journal of Contemporary China 13(40): 507–521.

Kim, L., 1980. Stages of development of industrial technology in a developing country: A model. Research Policy 9: 254–277.

Kruss, G. 2020. Catching up, falling behind: The need to build upgrading coalitions for innovation and inclusive development in South Africa. Nova Economia 30: 1115–1144.

Leibbrandt, M., Woolard, I., Finn, A., and Argent, J. 2010. Trends in South African income distribution and poverty since the fall of apartheid. OECD Working Paper 101, Organisation for Economic Co-operation and Development, Paris.

Machin, S. 1996. Changes in the Relative Demand for Skills. In Booth, A., and Snower, D. (eds) Acquiring Skills: Market Failures, Their Symptoms and Policy Responses. Cambridge: Cambridge University Press, pp. 129-146.

Malo, S. 2018. Trump Forest' hits a million trees in bid to curb climate change. Global Citizen news, Thompson Reuters Foundation. Available at: https://www.globalcitizen.org/en/content/trump-forest-million-trees-curb-climate-change/.

Masindi, V and Dunker, L.C. 2016. State of water and sanitation in South Africa. CSIR built environment: Technical report.

May, J. 2021. Food security, hunger and stunting in South Africa, in Oqubay, A., Tregenna, F., and Valodia, I. (eds.), The Oxford handbook of the South African economy. Oxford: Oxford University Press. (forthcoming).

Mazzucato, M. 2018. Mission-oriented innovation policies: Challenges and opportunities. Industrial and Corporate Change 27(5): 803–815, https://doi.org/10.1093/icc/dty034

Mohamed, S. 2019. The political economy of accumulation in South Africa: Resource extraction, financialization, and capital flight as barriers to investment and employment growth. PhD thesis, University of Massachusetts, Amherst.

National Department of Health. 2015. Twenty-year review: 1994–2014. Background paper: Health. National Department of Health, Pretoria.

National Department of Health. 2017. Saving mothers 2017: Annual report on confidential inquiries into maternal death in South Africa. National Department of Health, Pretoria.

National Planning Commission. 2012. National Development Plan 2030: Our Future-make it work. Pretoria.

National Treasury of the Republic of South Africa. 2021. Budget Review 2021. Pretoria: National Treasury.

National Treasury. 2020. Budget review 2020. National Treasury, Pretoria.

National Treasury. 2019. Economic transformation, inclusive growth, and competitiveness: Towards an Economic Strategy for South Africa. Economic Policy, National Treasury, Pretoria.

Ngandu, S., Altman, M., Cross, C., Jacobs, P., Hart, T., and Matshe, I. 2010. The socio-economic impact of the global downturn on South Africa: Responses and policy implications. Technical report commissioned by Oxfam, Human Sciences Research Council, Cape Town.

Peters, B. 2008. Employment Effects of Innovation Activities. In: Innovation and Firm Performance. ZEW Economic Studies, vol 38. Heidelberg: Physica-Verlag HD, pp 37-107.

Pettinger, T. 2016. Gross fixed capital formation. Economics Help. https://www.economicshelp.org/blog/6536/economics/gross-fixed-capital-formation/

Pianta, M. 2000. The Employment Impact of Product and Process Innovations. In: Vivarelli, M, and Pianta,M. (eds). The Employment Impact of Innovation: Evidence and Policy. London: Routledge, pp. 77-95.

Pouris, A. 2012. Technology Trends: A Review of Technologies and Policies. http://www.thedtic.gov.za/wp-content/uploads/Technology_Trends.pdf

Presidency of the Republic of South Africa. Presidential employment stimulus progress report: February 2021. file:///C:/Users/maris/AppData/Local/Temp/Presidential%20Employment%20Stimulus%20Progress%20Report%20_February%202021.pdf

Ritchie, H., and Roser, M. 2020. CO_2 and greenhouse gas emissions. https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions

Schotte, S., Zizzamia, R., and Leibbrandt, M. 2018. A poverty dynamics approach to social stratification: The South African case. World Development 110: 88–103.

Schröder, E., and Storm, S. 2020. Fiscal policy in South Africa: Closed input-output income and employment multipliers. Institute for Economic Justice, Research Note, No 1, Johannesburg, South Africa.

Schumpeter, J.A. 1934. The theory of economic development. An inquiry into profits, capital, credit, interest, and the business cycle. Cambridge, MA: Harvard University Press. (Reprint 1983: Transaction Publishers (first published in German in 1911)).

Schwab 2019. The Global Competitiveness Report 2019. The World Economic Forum, Geneva.

Sen, A. 1989. Development as capability expansion. Journal of Development Planning 19: 41–58.

Sen, A. 1999. Development as freedom. New York: Oxford University Press.

Shell. 2014. The Power of Innovation: Creating Energy with Footsteps. Shell, London. Available at: https://www.youtube.com/watch?v=EpYRH-njaAI

Sithole, M., and Buchana, Y. 2021. Effects of innovation activities on employment growth in upper-middle-income countries with high unemployment rates. Development Southern Africa 38: 371-390.

Śledzik, K. 2013. Schumpeter's view on innovation and entrepreneurship. SSRN Electronic Journal. DOI:10.2139/ssrn.2257783

Southern African Development Community (SADC). 2001. Regional indicative strategic development plan. Southern African Development Community, Botswana.

South African Government News Agency. 2019. 93 percent of South Africans have access to water services, 22 March. Available at: https://www.sanews.gov.za/south-africa/93-south-africans-have-access-water-services

South African Reserve Bank (SARB). 2021. Household debt to income statistics. Pretoria: South African Reserve Bank.

Spaull, N. 2013. South Africa's education crisis: The quality of education in South Africa 1994–2011. Report commissioned by the Centre for Development & Enterprise (CDE), Johannesburg, South Africa.

Spaull, N., Daniels, R. C et al. 2021. NIDS-CRAM Wave 3 Synthesis Report. National Income Dynamics Study-Corona Rapid Mobile Survey.

State Council Information Office of the People's Republic of China. 2021. Poverty alleviation: China's experience and contribution. http://www.xinhuanet.com/english/2021-04/06/c_139860414.htm#:~:text=China%20has%20raised%20the%20amount,place%2C%20benefiting%2036.89%20million%20people

Statistics South Africa (Stats SA). 2011. Census 2011 10% sample metadata. Pretoria: Statistics South Africa.

Statistics South Africa (Stats SA). 2016. Electricity, gas and water supply industry report. Report No. 41-01-02. Pretoria: Statistics South Africa.

Statistics South Africa (Stats SA). 2017a. General household survey. Pretoria: Statistics South Africa.

Statistics South Africa (Stats SA). 2017b. Gross domestic product report – GDP P0441. Statistics South Africa, annual, quarterly and regional, fourth quarter. Pretoria: Statistics South Africa.

Statistics South Africa (Stats SA). 2017c. Towards measuring the extent of food security in South Africa: An examination of hunger and food inadequacy. Report number 03-00-14. Pretoria: Statistics South Africa.

Statistics South Africa (Stats SA). 2020. Mortality and causes of death in South Africa: Findings from death notification. http://www.statssa.gov.za/publications/P03093/P030932017.pdf

Statistics South Africa (Stats SA). 2020b. General Household Survey 2019. Pretoria.

Statistics South Africa (Stats SA). 2021a. GDP: Quantifying SA's economic performance in 2020. Pretoria: Statistics South Africa.

Statistics South Africa (Stats SA). 2021b: Quarterly Labour Force Survey 2020. Pretoria.

Statistics South Africa (Stats SA). 2021c. Statistical database: Water services by source. Statistics South Africa, Pretoria.

Stoneman, P. 1983. New Technology, Demand and Employment. In: Bosworth, D. (ed). The Employment Consequences of Technological Change. London: Macmillan, pp. 82-96.

Stromburg, J. 2013. Five innovative technologies that bring energy to the developing world. The Smithsonian magazine, May 2. Available at: https://www.smithsonianmag.com/science-nature/five-innovative-technologies-that-bring-energy-to-the-developing-world-49271677/.

Thomson, A., and Metz, M. 1998. Implications of economic policy for food security: A training manual. Rome: Food and Agriculture Organization of the United Nations.

Tregenna, F., Ewinyu, A., Oqubay, A., and Valodia, I. 2021. Challenges and complexities of the South African economy, in Oqubay, A., Tregenna, F., and Valodia, I. (eds.), The Oxford handbook of the South African economy. Oxford: Oxford University Press. (forthcoming).

UNCTAD. 2018. Technology and Innovation Report 2018: Harnessing frontier technologies for sustainable development. Geneva: United Nations Conference on Trade and Development.

UNCTAD. 2021. Technology and Innovation Report 2021: Harnessing frontier technologies for sustainable development. Geneva: United Nations Conference on Trade and Development.

United Nations Environmental Programme (UNEP). 2016. UNEP's CLIMWARN Project in Kenya on Early Warning Systems (EWS). United Nations, Geneva. Available at: https://www.youtube.com/watch?v=waUXps5QV40

United Nations Framework Convention on Climate Change (UNFCCC). 2017. How Technology Innovation Can Boost Climate Action. United Nations, Climate Change. Available at: https://unfccc.int/news/how-technology-innovation-can-boost-climate-action

UNU-WIDER. 2016. Demographic, employment, and wage trends in South Africa. Policy brief 2016-1. Helsinki: World Institute for Development Economics Research.

Van der Berg, S., Patel, L., and Bridgman, G. 2021. Hunger in South Africa during 2020: Results from Wave 3 of NIDS-CRAM. National Income Dynamics Study Report. https://cramsurvey.org/wp-content/uploads/2021/02/10.-Van-der-Berg-S.-Patel-L.-Bridgman-G.-2021-Hunger-in-South-Africa-during-2020-Results-from-Wave-3-of-NIDS-CRAM-1.pdf

Venables, A. 1985. The Economic Implications of a Discrete Technical Change. Oxford Economic Papers 37: 230-248.

Venkat, H., and Spaull, N. 2015. What do we know about primary teachers' mathematical content knowledge in South Africa? An analysis of SACMEQ 2007. International Journal of Educational Development 41: 121–130.

Vivarelli, M. 1995. The Economics of Technology and Employment: Theory and Empirical Evidence. Aldershot, UK: Edward Elgar.

Vivarelli, M. 2014. Innovation, Employment and Skills in Advanced and Developing Countries: A Survey of Economic Literature. *Journal of Economic Issues* 48: 123-154.

Water Research Commission (WRC), Department of Science and Technology (DST), Department of Water and Sanitation (DWS). 2015. South Africa's Water Research, Development, and Innovation (RDI) Roadmap: 2015-2025. WRC Report No. 2305/1/15.

Watershed Organisation Trust (WOTR). 2020. Scaling ecosystem-based adaptation to climate change in Maharashtra, India: An analysis of policies and programmes. Watershed Organisation Trust, India.

WHO, OECD, and WB. 2018. Delivering quality health services: A global imperative for universal health coverage. Geneva: World Health Organization, Organisation for Economic Co-operation and Development, and The World Bank.

World Bank. 2017. South Africa Economic Update: Innovation for productivity and inclusiveness. Washington DC: The World Bank.

World Bank. 2018. Overcoming poverty and inequality in South Africa: An assessment of drivers, constraints and opportunities. Washington DC: The World Bank.

World Bank. 2019. The World Bank in China: Overview. Washington DC: World Bank. https://www.worldbank.org/en/country/china/overview

World Bank. 2021. World Bank Development Indicators. Washington DC: World Bank..

World Economic Forum (WEF). 2017. The Future of Jobs and Skills in Africa: Preparing the Region for the Fourth Industrial Revolution. Geneva: WEF.

Wright, J., and Calitz, J. 2020. Setting up for the 2020s: Addressing South Africa's electricity crisis and getting ready for the next decade. CSIR Energy Centre, Pretoria.

Ziesemer, T. 1991. Human capital, market structure and taxation in a growth model with endogenous technical progress. Journal of Macroeconomics, 13, 47–68.

Ziesemer, T. 2021. Labour-augmenting technical change data for alternative elasticities of substitution, growth, slowdown, and distribution dynamics. UNU-MERIT Working Paper 2021-003. file:///C:/Users/maris/AppData/Local/Temp/wp2021-003.pdf

Zizzamia, R., Schotte, S., and Leibbrandt, M. 2019. Snakes and ladders and loaded dice: Poverty dynamics and inequality in South Africa, 2008–2017. UNU-WIDER Working paper 2019/25, Helsinki.

DSI/NRF South African Research Chair in
Industrial Development (SARChI-ID)
31 Henley Road, Auckland Park,
Johannesburg, South Africa

General enquiries:
Koketso Manyane-Dlangamandla
Email: koketsom@uj.ac.za
Tel: +27 011 559 7454