Key Opportunities and Challenges for 4IR in South Africa

Rachel Alexander

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DSI/NRF SOUTH AFRICAN RESEARCH CHAIR IN INDUSTRIAL DEVELOPMENT

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Abstract

The Fourth Industrial Revolution (4IR) can involve changes that range from minor adjustments to the features of products, to the creation of new sectors and technologies that transform how the economy operates and how people's daily lives are structured. 4IR is spreading around the world at different paces. This fourth and concluding paper in SARChI Industrial Development Working Paper Series WP 2021-8 provides insight into two key questions. The first is, 'What are the barriers and opportunities for South African firms related to 4IR?' To answer this question, the paper presents a set of key drivers, opportunities and challenges. To guide action on identified opportunities and challenges, relevant recommendations that have been developed through a variety of recent publications are included. To answer the second question, 'What are the risks and opportunities for South Africa as 4IR spreads?', this paper considers the effects of the spread of 4IR systems on South Africa's economy, environment, and employment and presents a variety of perspectives that have been shared by key stakeholders.

Keywords: 4IR, Industrial development, South Africa

JEL codes: O25, O14, O31, O33, L22, L52, L62, L64, L91, L96

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1. Introduction

This is the last paper in a working paper series that has identified a number of dynamics that are connected to innovation and the conditions through which South African businesses can and are adopting practices associated with the Fourth Industrial Revolution (4IR). Across the papers, 4IR is seen as "an era where people are using smart, connected and converged cyber, physical and biological systems and smart business models to define and reshape the social, economic and political spheres (Presidential Commission on the Fourth Industrial Revolution [PC4IR], 2020)". The papers have been developed based on reviewing available published material and a set of 51 interviews conducted with South African businesses and other key stakeholders (see Annexure A).

The first paper, 'The Fourth Industrial Revolution and National Innovation Systems: Key Concepts and Snapshot of South Africa' (Alexander, 2021a), provides background information. Specifically, it discusses key concepts, including 4IR, innovation, innovation systems and industrial development. It also provides a snapshot of the current situation in South Africa related to 4IR and key areas of economic development. The second paper, 'Assessing the Ability of the National Innovation System of South Africa to Facilitate the Fourth Industrial Revolution' (Alexander, 2021b), assesses key features of South Africa's national innovation system related to their ability to support 4IR expansion. The third paper, 'The Fourth Industrial Revolution in South African Manufacturing and Connectivity: Case Studies of Automotive and Mining Equipment Manufacturing along with Logistics and ICT Infrastructure and Services' (Alexander, 2021c), shares the experiences of South African businesses related to the spread of 4IR in connectivity services and manufacturing.

This fourth and concluding paper provides insight into two key questions explored in this series. The first is, 'What are the barriers and opportunities for South African firms related to 4IR?'. The second is, 'What are the risks and opportunities for South Africa as 4IR spreads?'. The findings presented in this paper are based on the concepts discussed in the first paper, and the empirical material considered in the second and third papers.

Section 2 of this paper addresses the first question. It presents a set of key drivers, opportunities and challenges related to how 4IR can spread in South Africa. To guide action on identified opportunities and challenges, relevant recommendations that have been developed through a variety of recent publications are included.

The second question is addressed by considering the effects of the spread of 4IR systems on South Africa's economy, environment, and employment, which are explored in sections 3, 4 and 5. Another concern is that perceptions of 4IR can shape how stakeholders react to the changes that are taking place. Annexure B provides a range of perspectives that have been shared by South African stakeholders related to the future of 4IR. These opinions cover the areas of the

speed and inevitability of change, businesses of the future, jobs of the future, and expectations for the government.

2. Paths to Expanding 4IR in South Africa

This section considers how features of the national innovation system are shaping businesses' experiences, and discusses challenges and opportunities that can be identified related to facilitating the expansion of innovation and the use of 4IR systems and technologies. Many factors in the innovation system broadly shape the experiences of firms working in South Africa. However, all businesses do not experience the same challenges and opportunities. This section also identifies some differences between the situations of firms working in connectivity services (specifically considering communication and transportation) and manufacturing (specifically considering automotive and mining equipment).

2.1 Changing Contextual Factors

As described in the first and second papers in this series (Alexander, 2021a, 2021b), contextual factors play a large role in shaping the experiences of South African firms. The working paper series identifies a number of barriers and opportunities related to the nature of contextual factors that can help or hinder the development of 4IR.

2.1.1 Regulation and Competitive Environment

In some cases, regulation has been found to inhibit innovation. In a national survey, businesses in industry (mining, manufacturing, and utilities) were more likely to report legislation, regulations, standards, and taxation to be barriers to innovation, at 16%, compared to those in services (trade, logistics, finance, and engineering and tech), where 8% reported this challenge (Centre for Science, Technology and Innovation Indicators [CeSTII], 2020). In interviews, firms described not being able to use promising technological solutions that violated existing rules. Modifying regulations to adapt to the emerging needs of 4IR systems will be important to allow 4IR to expand in South Africa. However, it is important to consider that certain regulations are necessary to ensure the equitable provision of services, fair competition, safety, and other factors.

The competitive environment in which South African firms operate creates a variety of opportunities and challenges. Notably, competition is felt differently in different sectors. In the same survey mentioned above, only 13% of firms in industry (mining, manufacturing, and utilities) described the market as being dominated by established enterprises as being a barrier to innovation. This can be compared to 18% in services (trade, logistics, finance, and engineering and tech) (CeSTII, 2020). Firms in industry were also less likely to report too much competition in their market as being a barrier to innovation, with 17% reporting this challenge, versus 22% in services.

One issue is that, in some product and services markets, South African firms compete with global firms that are becoming more efficient and offering better services through 4IR. This increased level of competitive pressure can be a driver for firms to adopt 4IR systems. In interviews, firms described being able to include increasingly modularised technology into their offerings in order to keep up with global competition.

A challenge that exists in the competitive environment is the lack of competitive dynamics in some sectors. The existence of monopolies and oligopolies in certain sectors creates barriers to innovation. Another issue is individual firms dominating multiple sectors through vertical integration (Bell et al., 2018).

Bell et al. (2018) outline multiple benefits that could be achieved by increasing competition. One is that increased competition can promote innovation. A second is that opening markets would increase the ability of new businesses to enter, which would be helpful for black entrepreneurs. A third is that such a change could reverse the current situation where actors with strong market power can reinforce inequality by facilitating transfer from the poor to the wealthy through earning high profits from non-competitive products. A number of recommendations have been put forward related to opening up the economy to more competition (see Box 1).

Box 1: Recommendations for Opening the Economy for More Competition

- Improve the competitiveness of strategic state-owned enterprises (SOEs), and further expose South Africa's large conglomerates to foreign competition
- Give regulators more independence from line ministries in energy, transport and telecommunications to address the fact that regulatory restrictions, particularly in network industries, stifle competition and cause high levels of concentration
- Accelerate the adoption of the Single Transport Economic Regulation Bill (which consolidates the economic regulation of transport within a single framework and policy, and establishes the Transport Economic Regulator and the Transport Economic Council)
- Create a broader competition policy as part of industrial policy to facilitate the entry and growth of new businesses, particularly black entrepreneurs
- Align this new broader competition policy with development finance that supports capability building and learning
- Encourage risk-tolerant 'patient capital' to allow new firms to grow and have the chance to compete with incumbents
- Local government can open up opportunities, such as through determining how retail space is configured
- Create a 'supermarket code' that commits retailers to having shelf space for smaller businesses and to carrying out supplier development initiatives

Source: Bell et al., 2018; World Bank, 2018b; Organisation for Economic Cooperation and Development (OECD), 2020

2.1.2 Infrastructure

A key challenge in South Africa is insufficient infrastructure. This challenge is felt differently by businesses in connectivity services to those in manufacturing. From 2014 to 2016, this was particularly a challenge for service sector businesses, with 11% of businesses in services (trade, logistics, finance, and engineering and tech) reporting a lack of infrastructure as a barrier to innovation, compared to only 3% in industry (mining, manufacturing, and utilities) (CeSTII, 2020). However, the growth of 4IR systems will make connectivity infrastructure more important for all businesses. Notably, information communication technology (ICT) infrastructure, dependent on both electricity and internet connections, can facilitate increased data sharing, a key element of many 4IR systems. Deficiencies in current infrastructure systems, furthermore, also provide a key opportunity for developing 4IR systems.

Notably, even when advanced infrastructure is not available, businesses can adopt 4IR systems. As the South African context faces its own specific challenges, customised solutions can be developed. Innovative systems can be constructed to accommodate different levels of infrastructure. One respondent spoke about the potential use of local networks for facilitating road communication, which can be developed when nation-wide systems are insufficient.

> *What it will be at the end is communications between vehicles and between vehicles and infrastructure, not necessarily. And I don't think it's necessarily required. I don't think it's necessarily required to have all of this going over the internet and 5g and 4g and what have you, because it's, in a sense, sufficient to have local communication around the vehicle, with the infrastructure around it. Not saying there isn't the use case for [internet communication] but that's the essence of what you require.*
>
> *South Africa specifically, I think, in general, in these kinds of things, we lag, what's happening internationally quite a bit. So, if we talk of Internet of Things in general, and not only necessarily vehicles. For us, [a] big concern is we don't have coverage. In many places outside of major metros, broadband speed's not great. There are a bunch of things on the horizon that seemed to be capable of breaking that. So, if you look at satellite broadband, that kind of thing, which is starting to gear up now, that'll considerably change the picture in South Africa. (F21-I37)*

When infrastructure is of a poor quality, there are multiple opportunities for expanding the use of 4IR. On the one hand, 4IR-enabled systems can be incorporated into new infrastructure as it is built. On the other hand, new services can be developed that are based on 4IR technologies. Considering logistics services in South Africa, Gain Group (2020) identified a number of opportunities that could involve 4IR and have commercial opportunities (see Box 2).

Box 2: Opportunities for Expanding Logistics Services that can Incorporate 4IR

- Enhancing customs operations
- Smart port operations
- Managing congestion
- Improving supply chain agility, time and costs

Source: Gain Group, 2020

However, sometimes deficiencies in infrastructure provision create barriers for businesses to develop and expand 4IR systems. In some cases, poor quality or low-tech existing infrastructure can inhibit the development of new systems that would need to be integrated. Multiple respondents spoke about working with poor quality and outdated technology, sometimes describing how new projects have to be designed to fit with existing systems. To address the problems of inadequate infrastructure, a number of recommendations related to improving infrastructure as a support service are listed in Box 3.

Box 3: Recommendations for Improving Infrastructure as a Support Service

- Increase public investment in transport infrastructure while improving cost containment, planning and implementation
- Build 4IR infrastructure
- Facilitate increased use of data to enable innovation
- Use central planning for organising infrastructure provision, which is a need that becomes more important with the expansion of 4IR technologies, such as the Internet of Things (IoT)

Source: United Nations Conference on Trade and Development (UNCTAD), 2018; OECD, 2020; PC4IR, 2020

2.1.3 Availability of Inputs

The availability and characteristics of inputs are also important contextual factors. One key opportunity is that South African firms have access to a wide variety of global technologies. Firms are often easily able to import equipment and knowledge. As discussed in the earlier papers in this series (Alexander, 2021a, 2021b, 2021c), people are increasingly learning about global technologies through a variety of mechanisms, including foreign direct investment (FDI), flows of staff and existing staff connecting to online communities. The connections are often able to facilitate the sharing of tacit knowledge, which is often crucial for successfully implementing new technologies.

Emerging technologies and ideas that have been developed around the world have the potential to bring numerous benefits to South Africa. Manufacturing processes, and the products produced, have numerous opportunities related to 4IR. Disruptive digital technologies, such as predictive analytics, additive manufacturing, machine learning and artificial intelligence (AI), and

the Industrial Internet of Things, can improve South Africa's efficiency, productivity and competitiveness (PC4IR, 2020).

PC4IR (2020) has identified specific opportunities for technologies to benefit South African manufacturing value chains (see Box 4). For the mining industry, these technologies can save money, reduce environmental impact, and improve employment experiences, particularly by improving safety. Mining equipment manufacturers can expand their involvement in 4IR in numerous ways (see Box 5). Harnessing these technologies can be driven through the work of public research institutions (PRIs) and funding opportunities/incentives for the private sector.

A second factor related to inputs is the employment situation in the country. Two key barriers to the spread of 4IR can be identified. One barrier is the high unemployment rate and corresponding desire to preserve existing jobs. Some companies spoke about choosing not to automate because it would result in job losses. This can be a barrier to developing 4IR production processes. The high unemployment rate and the need to employ more people can create pressure against the adoption of 4IR practices, which could give rise to reducing employment. However, the loss of jobs through 4IR is debated, as some argue that 4IR adoption will create new types of jobs.

Box 4: Opportunities for 4IR to Support Manufacturing Value Chains

- Workforce upskilling, reduced training time and improved productivity can be supported through digital advances using technologies like remote assistance, machine learning, wearables and augmented reality
- Advanced analytics can use data from sensors, and from smart and connected devices
- Digital supply chain monitoring can provide visibility to all stakeholders, eliminates bottlenecks, increases production throughput, better manages demand, and reduces inventory, warranty and delivery costs
- 3D printing can reduce unplanned downtime, and printing parts on site can lower lead time from a few days to a few hours
- An integrated platform for collaboration and the exchange of data within and across multiple value chain stakeholders can reduce transaction costs and time, and reduce the cost of operations
- Digital sales can use machine learning, artificial intelligence and chatbots to automate customer interaction, and analytics to target and customise offerings
- Digitally enabled manufacturing can drive production cost optimisation, faster time to market, and mass production of individually configured products
- Smart factories can involve technologies, such as robotics, sensors and autonomous machines, which can transform conventional manufacturing processes through automating repetitive tasks
- Automation can reduce production time and wasted inputs

Source: PC4IR, 2020

Box 5: Opportunities for 4IR in the Mining Sector

- Remote sensors can help to find deposits
- Robots can work in perilous situations
- AI can identify how to best remove a deposit
- Computerised rock-face mapping can be incorporated into cutting apparatus, alongside material characterisation and fracture investigation
- Using spatial data visualisation through 3D modelling, virtual reality (VR) and augmented reality (AR) can help gain insights with lower costs and less environmental impact
- Geographic information systems (GIS) can help with exploration, report generation, facility and tailings management, sustainability and regulatory compliance, and educating mine managers and representatives

Source: PC4IR, 2020

The second barrier is the low availability of appropriately skilled workers. South Africa's skills deficit includes a lack of necessary skills for people in low-skill, medium-skill and high-skills jobs. A large proportion of the population has low levels of formal education and high levels of unemployment. As those with higher levels of education have lower unemployment rates, companies struggle to find people with high skill levels.

Skills to meet the increasing demands of 4IR norms in the automotive industry are becoming necessary for suppliers to compete (Lamprecht, 2020). With rapidly changing needs related to 4IR, training must evolve to stay up to date and meet the needs of the future. Science, technology, engineering and mathematics (STEM), as well as arts and humanities and social sciences, will be very important (PC4IR, 2020). A number of education-related recommendations have been identified (see Box 6). Some involve relatively minor changes, while others involve rethinking the entire education system. In a 4IR system, qualifications may become less important than competency and skills (e.g. creativity, critical thinking, problem-solving) (PC4IR, 2020). In addition, another way of dealing with this challenge could be easing barriers to hiring foreign workers.

A further issue related to the potential workforce is that there are knowledge bases that are not being harnessed. South Africa has many people, who tend to be concentrated in certain groups (i.e. the black population, people with lower levels of formal education, and younger people), who are unemployed or not participating in the workforce. The perspectives of these people could bring new opportunities for innovation if they are incorporated into existing or new businesses.

Box 6: Recommendations for Improving the Education System

- Improve the quality and quantity of digital skills through training to improve digital

entrepreneurship

- Increase skilled immigration in order to improve the quality and quantity of digital skills and support digital entrepreneurship[1]
- Promote industry collaboration in training:
  - Make use of the Korean model, with large firms playing active roles in partnering with the government to provide skills development programmes, which can be helpful because students from poorer backgrounds often choose vocational training
  - Strengthen cooperation between employers, technical vocational education and training (TVET) institutions and other training providers to expand work-study opportunities
- Provide national-level support and funding for sector approaches, which can reach relevant stakeholders and identify relevant 4IR technologies
- Support lifelong learning:
  - Develop a micro-credentialed skills system that supports lifelong learning to meet the needs of the 4IR economy
  - Increase options for adult education and training to include vocational programmes to adapt to the changing skill needs of employers
- Increase numbers of people receiving education:
  - Train large numbers of South Africa's youth in digital skills so that the country can become a net exporter of such skills
  - Increase the number of students attending TVETs to provide more workers with the needed intermediate-level technical skills, including mechatronic and programming skills
  - Increase the numbers of high-level graduates and improve their diversity
- Provide free higher education, which can help to address poverty
- Improve the quality of basic education delivered to students from poor backgrounds
- Structurally change the education system to reflect the architecture of 4IR over time, which can include flexibility, agility, speed of accreditation, integrating learning systems, mobility of learners, remote content delivery, cognitive flexibility and the use of technology
- Develop mass skills development programmes using public-private partnerships with short-term skill-building courses that are stackable
- Promote social dialogue to encourage national discussion on 4IR and its implications
- Reconsider social protection systems and processes in the light of the changing world of work
- Identify policies and legislation that need to be updated to support creating a skill ecosystem, the changing world of work, and sectors that are high-growth job creators in the 4IR system
- Create policy to help increase the capacity of TVET institutions to build problem-solving skills, with

[1] In a model developed by the World Bank (2018c), developing programmes to entice an increased inflow of skilled immigrants could improve the gross domestic product by 2%, as each new skilled migrant would create 0.5 unskilled or semi-skilled jobs. However, the report notes that greater competition for skilled jobs could lower wages.

options including increased opportunities for work-study offered through agreements with employers
- Create new curricula for universities that meet emerging 4IR skill gaps, including data engineering for machine learning applications and advanced programming for automatic manufacturing control processes
- Provide children with the thinking skills they will need in a technologically advanced world
- Expand involvement of PRIs in training postgraduate students
- Increase investment in skills and education with considerations of cost containment, planning and implementation

Source: Ministerial Review Panel on Science, Technology and Innovation Institutional Landscape (MRP-STIIL), 2017; World Bank, 2018a, 2018b, 2018c; Department of Science and Technology (DST), 2019; Lorenz et al., 2019; PC4IR, 2020; Department of Science and Innovation (DSI), 2020; OECD, 2020

2.1.4 Demand

The level and types of demand that firms have is another key factor shaping their propensity to adopt 4IR systems. Notably, demand challenges are felt differently between businesses in industry (mining, manufacturing, and utilities) and those in services (trade, logistics, finance, and engineering and tech) (CeSTII, 2020). Businesses in industry have similar levels of reporting uncertain demand for innovative goods and services (9%) and a lack of demand from customers (12%) as barriers to innovation. In contrast, 26% of service businesses report uncertain demand as a barrier and only 7% report lack of demand.

One key issue related to demand is the growing desire for products with 4IR features. This is particularly strong from international markets. For example, as South Africa's vehicle exports are focused on markets with growing demand for electric vehicles, manufacturers are going to need to start producing a growing number of them. Also, sales of hybrid and electric cars have been growing in South Africa.

South Africa has the potential to upgrade in the automotive sector. As electric and hybrid car production expands, new opportunities are developing.

> *We got raw materials, right? Maybe we could be the next hybrid battery maker for the world. But we haven't set up the proper technology, raw materials available. That's easy. We can do it if we can convert. I mean, if you look at copper, we used to mine or we still mine it but we sold the mine to the Chinese. We used to mine the copper, make the wire harnesses and export it. And used it locally. Now we mine the raw materials, send it off, and we import the wire. It's going the wrong way.*
>
> *We should be converting those resources into manufacturing. Because we cannot grow a country without a proper manufacturing base. You need industrialisation; you need the manufacturing to grow the country. You can't just be a server. (F22-I39)*

Also notable is that, in CeSTII's (2020) innovation survey, the biggest reason companies that were non active in innovation gave for not engaging in innovation was related to a perceived lack of markets. This can be an issue for 4IR, because in some cases a market needs to be created for a product or service. It is possible that the firms in this survey that were not active in innovation may not have strong dynamic capabilities, that could help them build new markets (Teece, 2010).

A second demand-related issue is the nature of the local market. With high levels of inequality, the country can be seen to house a diverse potential customer base. A challenge that South African firms can face is that the domestic market for some products is small. The market size can be limiting for innovation in sectors that require large-scale production, such as in the automotive sector (Department of Trade and Industry [DTI], 2018). This is particularly an issue for firms related to the production of high-value items. However, firms can have strategies that involve selling within South Africa and abroad. In contrast, South Africa can be seen to have a high level of opportunity related to the bottom of the pyramid (BoP) market (Prahalad, 2012). This group, which includes people living on very low incomes, can be served through a variety of 4IR-enabled products and services, which can increasingly be reached with mobile technology.

A number of local procurement policies are already in place, which is a positive step. However, they are often not achieving their objectives. Refinements are needed in the way local procurement policies are designed and implemented.

2.1.5 Additional Contextual Factors

Crime can also be an issue that shapes innovation prospects. South Africa faces some innovation barriers related to crime. In some cases, the development of 4IR systems has been inhibited by crime and the threat of crime. However, some 4IR businesses have developed through demand that is created because of the risk of crime, such as the creation of businesses that provide security services.

Another contextual factor in the innovation system that plays a big role in South African firms is the status of legacy systems. One issue is that the lack of legacy systems can create opportunities. As 4IR innovations have not yet penetrated all areas of South African society, possibilities exist for South Africa to invest in expanding the use of home-grown technology. For example, one of the respondents said,

> *Specifically in South Africa we need to invest more in global innovation. Cyril Ramaphosa's conversation about Huawei bringing 5G to South Africa, I a hundred percent support that but we also should have our own 5G technology. We should have our own 5G companies. We should have our own infrastructure companies that focus on other opportunities. Because we're buying technology from the Chinese doesn't mean we shouldn't be selling them other technologies that they don't have. We should be focusing on jumping the gap, investing where we can. Making a mark that is proudly*

> *South African. So, if someone says you need that technology, you need that product, you need that thing, the only place you can get it is South Africa. (F16-I31)*

In addition, a lack of infrastructure in some regions can be an opportunity for developing 4IR-type green infrastructure. A number of opportunities exist for incorporating 4IR-related innovations that can bypass legacy systems (see Box 7).

Box 7: Opportunities for 4IR that Bypass a Need for Legacy Systems

- Developing new smart cities
- Green development
- Providing new electrification systems for previously under-served communities

Source: PC4IR, 2020

On the other hand, existing legacy systems can cause impediments to developing new systems. These systems may not be designed in ways that are the most efficient. In addition, they can be incompatible with newly emerging 4IR technologies. In some cases, legacy systems are entrenched and may need radical overhauls in order for more efficient 4IR systems to be developed. This can be a challenge particularly for transportation systems and other connectivity services.

Another key contextual factor is that many current jobs have problematic outcomes, such as health and safety risks. This can be seen as an opportunity for the expansion of 4IR. These risks can encourage the adoption of new systems. 4IR technologies and systems are well suited for enabling the creation of new systems that remove or minimise existing risks.

Finally, South Africa's natural environment provides a context that can create opportunities based on the existence of natural resources, which can be used as a part of 4IR technology. Opportunities exist for developing products that use platinum-group metals, which are mined in South Africa. South Africa produces a high level of platinum-group metals, which are currently used in catalytic converters, a product that will be in less demand as the world moves away from fossil fuel cars (DTI, 2018). However, these materials have potential to be inputs in new types of products.

A key opportunity is the creation of mineral-based energy solutions, such as fuel cells. DTI has been providing incentives to develop new applications and markets for fuel cells in South Africa (DTI, 2018). The government, the Industrial Development Corporation of South Africa and industry are involved in ongoing projects including developing buses, forklifts and mining equipment prototypes, stationary combined heat and power applications, and rural electrification projects (DTI, 2018). Opportunities for South African mining output to enter into battery supply chains also extends to additional products, such as vanadium, manganese and nickel (DTI, 2018).

South Africa mines a variety of metals and minerals that are used in the creation of many products associated with 4IR, such as drones, batteries, wind turbines, smartphones, solar panels and electric vehicles (PC4IR, 2020). PC4IR (2020) describes this situation as creating "extensive value chain opportunities" for these products to transform the economy. It describes the growth of renewable energy, robots and electric vehicles as being able to incorporate high volumes of copper, lithium, cobalt, platinum, chrome and manganese. Accordingly, interview respondents highlighted opportunities for creating domestic industries for producing intermediary components for new manufactured products.

However, while these natural resources can be an opportunity, developing completely new domestic industries to produce related products may be difficult. Hausmann et al. (2008) identify key challenges in such an approach. Domestic processing of natural resources requires specific skills, which may be lacking in South Africa. Consequently, more easily accessible opportunities may be generated by focusing on expanding existing industries and developing new industries that can draw on existing skills sets.

2.2 Shaping the Roles Played by the Innovation System's Key Actors

The nature and behaviour of key actors in the innovation system are pivotal for shaping the dynamics of the innovation system. This section considers the features of the South African business community, financial ecosystem, research ecosystem, support service providers and overarching policy actors. Key barriers to and opportunities for the expansion of 4IR are identified.

2.2.1 Firms

Businesses are a pivotal actor in the national innovation system. Some of the representatives of firms interviewed for this working paper series expressed a strong internal drive to develop 4IR systems. Representatives expressed internal motivations, such as seeing digitalisation as a way to save money or believing changes are necessary to stay competitive in the future. Existing firms also have different levels of openness to change. Notably, in a survey of innovation in South Africa, firms that were innovation-active had a number of different characteristics to firms that were not innovation-active (CeSTII, 2020). This survey also found differences in the structure of businesses in industry (mining, manufacturing and utilities) compared to services (trade, logistics, finance, and engineering and tech), with 29% in industry reporting being part of a larger group and only 15% of those in services.

While the interviews for this working paper series focused on established businesses, many changes to the national economy related to 4IR may be related to the emergence of new businesses. Several of the firms that were interviewed provide 4IR-related services that are relevant to both connectivity services providers and manufacturers. With the potential for

manufactured products to increasingly be provided as services, the differences between these industries may decrease. For example, if the idea of cars as a service that people pay to use when they need to travel expands, then the cars themselves could be thought of as part of the transportation infrastructure of a city.

A key barrier in South Africa is that many firms have traditional business models. This is particularly prominent in manufacturing and physical infrastructure development. It may be more difficult for existing firms to change in ways that incorporate 4IR. One consulting firm pointed out that companies typically need time to learn and develop 4IR systems.

> *Some clients have already tried some applications that maybe didn't work because they probably got in at a wrong level of this technology . . . instead of building properly, they went right up to the top. it didn't work so a number of clients will have to go through that phase for them to then start properly with a proper roadmap in place and proper prioritisation. (F07-I07)*

Another barrier to the spread of 4IR is that South Africa's business ecosystem consists of larger-than-average businesses. Large businesses can be less agile and experience more difficulty when changing systems. However, these businesses typically have more resources, which can be helpful for increasing capacity to absorb new knowledge.

In addition to considering the characteristics of existing firms, it is also important to consider the potential for new start-ups to be developed that are created using 4IR business models and use 4IR technologies. Some of the firms interviewed for this working paper series were explicitly founded to offer 4IR-related services. These new entrants have the potential to disrupt existing industries, as they offer products and services that have new and appealing features or fund their businesses in more efficient models than incumbents.

2.2.2 Financial Services

Financial organisations play a key role in shaping national innovation systems. Funding sources for innovation-active business in industry (mining, manufacturing and utilities) differ from those in services (trade, logistics, finance, and engineering and tech) (see Figure 1). In line with the fact that more industry businesses were found to be part of larger businesses, these businesses were more likely to get funding from a related company. Businesses in these sectors also experienced different challenges related to accessing funds (see Figure 2).

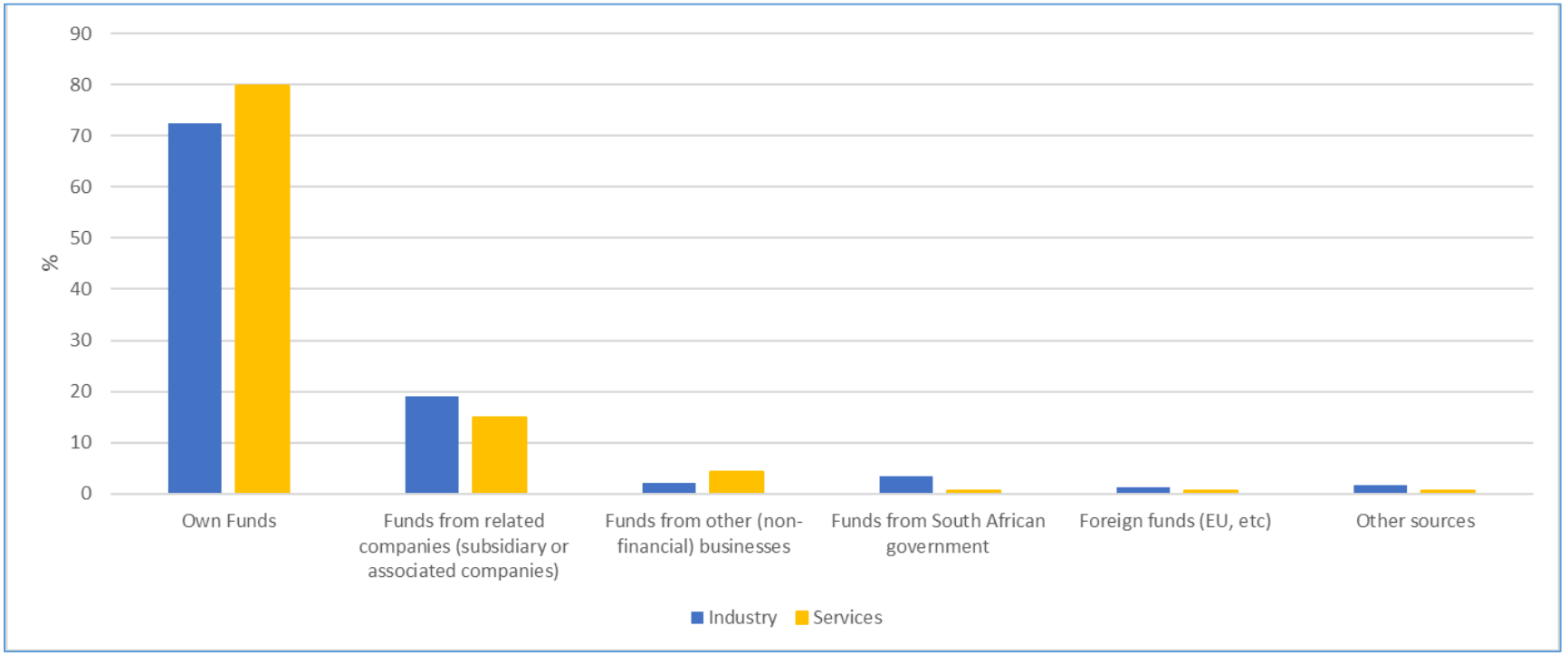
A key challenge related to financing is that many businesses reported a lack of access to funding as a barrier to innovating. In CeSTII's (2020) business innovation survey, this was the most common challenge expressed by innovation-active firms. Also, research in South Africa has shown that larger firms are more likely to have access to loans (Newman et al., 2019). Adding to

this challenge are low levels of available venture capital, which can be a particularly important source of financing to facilitate innovation.

To address this challenge, firms need access to expanded sources of financing. The government has developed multiple funding programmes that are targeted at small businesses and black-owned businesses, which can help this situation. Furthermore, the World Bank (2018c) recommends that access to funding by digital entrepreneurs should be expanded through giving incentives for angel investors to invest in early-stage start-ups, developing angel networks, de-risking investment through blended finance, developing results-based funding to improve service quality, and expanding regional and pan-African programmes to support later-stage digital entrepreneurs.

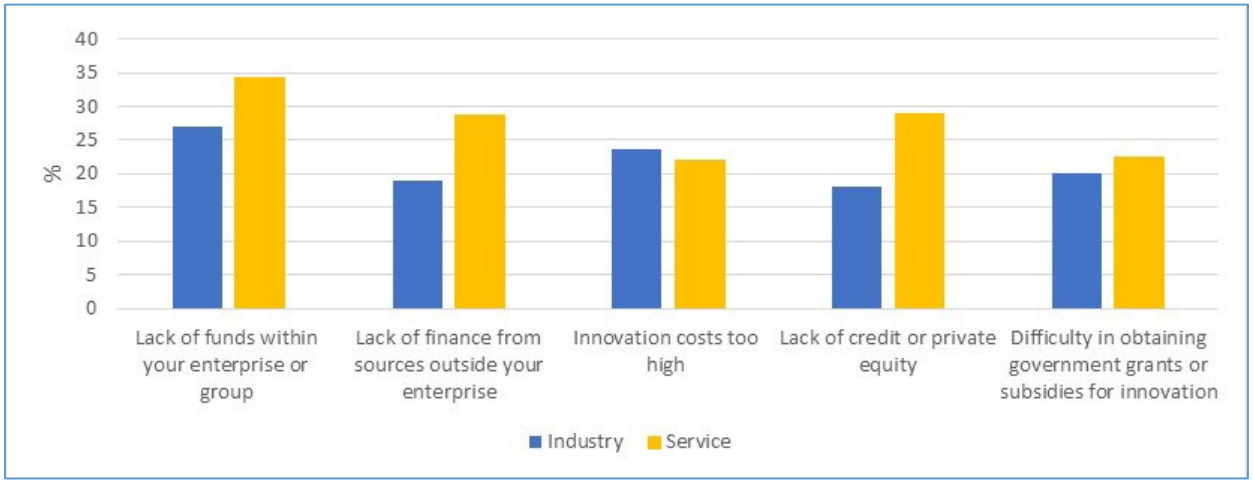
Another key issue with the funding ecosystem is a lack of coordination. This leaves some organisations and activities facing higher levels of difficulty in accessing funding. MRP-STIIL (2017) recommends creating a seamless grant-making regime that covers early pre-commercialisation up to full-scale industrialisation and commercialisation, which can be facilitated through central coordination.

Figure 1: Financial Support for Innovation Activities



Source: CeSTII, 2020

Figure 2: Cost-Related Barrier to Innovation



Source: CeSTII, 2020

South Africa has strong research institutions. However, there is a gap in how they connect with industry. This can be seen in the fact that few businesses look to universities, PRIs and private research institutions as important sources of information (see Section 9.1.3). New initiatives can strengthen these connections.

2.2.3 Research Services

The national research ecosystem is also a key factor in the innovation system. While South Africa has some strong research institutions, weaknesses exist in their ability to provide a full range of services. A number of recommendations have been identified related to strengthening the influence of the public research system on industry needs (see Box 8).

Box 8: Recommendations for Strengthening PRIs

- Develop an overarching policy framework for PRIs that describes the purpose, functions and governance related to national development
- Consider stakeholder roles within this framework, particularly that of the private sector; the research and development (R&D) mandates of DST and other government departments; and the current capacities of PRIs
- Revisit PRIs' mandates during the creation of the framework, taking into consideration their ability to provide short- and long-term support to:
  - the new policy framework
  - line ministries' goals
  - research, innovation and human capital development
  - diversity of knowledge outputs
  - incorporate interdisciplinary R&D
  - develop a geographically balanced portfolio of R&D, institutional presence, investment and impact
  - target social innovation, particularly educational innovation
- Regularly review and revise mandates and develop an evaluation framework that can assess and compare efficiency levels
- Establish new PRIs based on strategic needs and opportunities, and the provisions of and gaps in existing programmes, taking into consideration the financial implications of different models (e.g. centralised or devolved, physical or virtual)
- Develop an enabling legislative framework related to intellectual property rights from publicly funded R&D
- Increase the uptake of locally developed technologies through government procurement
- Establish an AI institute
- Establish a platform for advanced manufacturing and new materials
- Build international research partnerships
- Develop a centralised strategy to support the international recruitment of researchers

Source: MRP-STIIL, 2017; DST, 2019; PC4IR, 2020

2.2.4 General Support Services

Organisations providing a diverse range of other support services can also be an important factor in the national innovation system. While many public support services are available in South Africa, businesses are often not aware of them and can have trouble accessing them. Cunningham (2018) recommends that additional efforts are needed to encourage businesses to seek support from existing programmes. He suggests that these programmes need to reduce barriers to businesses accessing their services, advertise their services more effectively, explain their offerings in accessible terminology, and proactively reach out to industry. In addition, some deficits have been found in their quality. A number of recommendations have been identified relating to improving the provision of support services (see Box 9).

An ecosystem of private firms offering support services is also developing. A number of consulting companies and other firms interviewed for this working paper series were offering products and services that explicitly seek to help connectivity service and manufacturing firms to adopt 4IR technology and systems. These businesses experience a high demand from companies to adopt such changes. An opportunity exists for new businesses to develop that can provide 4IR-related support services and products to existing firms in South Africa.

Box 9: Recommendations for Improving Support Service Provision

- Create an accessible and detailed database of programmes
- Provide incentives for programmes to disseminate technology, and be more demand-sensitive or proactive in efforts to strengthen technological capability
- Add measurements of sectoral influence instead of just measuring the effect on individual businesses, which could encourage support service providers to target networks or collaborative arrangements to encourage the upgrading of sectors, technological domains and industries
- Strengthen the relationships between support service providers, the private sector and policymakers, to allow for problems and opportunities to be identified and addressed more quickly
- Increasing technical support service providers' ability to identify technological change, which could involve collaborating with DSI, DST, industry associations, technical institutions and educational institutions, which could help with developing appropriate reskilling programmes
- Increase focus on learning by doing, technology demonstration and problem solving
- Industry associations and firms can aid support service providers by encouraging technology transfer, investment in technological capability and public sector collaboration to identify missing public goods and technological infrastructure

Source: Cunningham, 2018

2.2.5 Overarching Policy Actors

Finally, actors creating national policies also play a pivotal role in shaping South Africa's innovation systems and 4IR prospects. A key role of public policy can be tilting the playing field to shape innovation incentives (Mazzucato, 2018). While a lot of the discussion above has considered issue-specific policy recommendations, there are two overarching policy issues that are important to consider in relation to 4IR in South Africa. One is that there is a lack of policy coherence, and the other is corruption and mismanagement, which impede the implementation of policies.

Lack of policy coherence has been identified by multiple studies as a key challenge for South Africa's innovation system. Efforts are under way to address this issue. A number of actions that can improve the governance of South Africa's national innovation system have been identified (see Box 10). In addition, DST (2019) outlines that its medium- to long-term policy direction for the national innovation system will be implemented through a series of decadal plans. The first

decadal plan, on science, technology and innovation (STI) was approved in March 2021. The DSI also has a goal of creating a responsive, coordinated and efficient national system of innovation (DSI, 2020). A number of recommendations have also been proposed to improve the targeting of innovation policies (see Box 11). Many of these recommendations can be considered by government actors at all levels.

Box 10: Recommendations for Improving Governance of the National Innovation System

- Create measures to support partnerships across all levels of the national innovation system
- Develop interventions to improve governance of the national innovation system, and policy coherence and coordination, through:
  - establishing a ministerial STI structure, which will set the STI agenda across the government and commit resources to priority programmes, with guidance provided by annual meetings of government, business, academia and civil society;
  - strengthening the National Advisory Council on Innovation (NACI) to provide advice to the new structure
- Introduce policy approaches to increase coherence in areas including education and skills development, the economy, and social development
- Improve sector coordination by using collaborative sector R&D planning and Sector Innovation Funds for priority sectors
- Strengthen governance of national innovation system institutions, including clarifying mandates of departments related to PRIs, as well as improving coordination across PRIs and funding agencies
- Introduce policy to enhance the monitoring and evaluation (M&E) capacity of the national innovation system, such as conducting regular foresight exercises and developing a new M&E framework

Source: DST, 2019

Box 11: Recommendations for Improving the Targeting and Quality of Innovation Policies

- Build a broad coalition to support reindustrialisation
- Place focus on productive investment and widening economic participation
- Expand public investment in public transport and education for economic activity, alongside long-term private investment and entrepreneurship
- Create a new political settlement for industrialisation that involves black constituencies, including trade unions, through skills upgrading and investment
- Support black entrepreneurship through opening the economy
- Ensure the settlement speaks to people's aspirations, involves a shared and binding commitment, includes agreement on expectations for large firms (e.g. rewarding long-term fixed investment)
- Design and deliver it locally while including it in the national agenda
- Re-shape and coordinate technology, industry, trade, development finance and market regulation, while providing clear leadership in areas such as skills building, energy, minerals and agriculture

- Improve institutional capacity and accountability instead of growing the institutions
- Focus on opportunities in the regional economy and align these with the Southern African Development Community's (SADC's) strategies, which will involve importing and exporting through regional value chains and promoting shared benefits
- Build capabilities through bringing together technology policy, investment and industry incentives
- Consider that initiatives should complement each other at the local level
- Incentive programmes should promote wide benefits and avoid enhancing firm dominance
- Support cluster initiatives on skills development, shared facilities for technological capabilities (e.g. design, testing and prototyping), pooling firm resources and developing supply markets
- Use macroeconomic policy to ensure long-term management of natural resource earnings, appropriate exchange rates, inflation incentives for volatile capital flows, and prioritising longer-term investment
- Create a better coordinated supportive environment based on policy and programme certainty, stakeholder collaboration, renewing state institutions and SOEs, and combating public and private rent-seeking, corruption and collusion in order to create needed structural change and lay a platform for strong private sector investment, job creation and inclusive growth
- Develop instruments to align policies, universities and research institutes and promote the involvement of business and NGOs to support social objectives in the national innovation system
- Clarify the related policy framework, which can involve a policy statement and clear institutional leadership, and develop a central repository to publicise activities to improve digital entrepreneurship
- Conduct regular assessments and improvements with an M&E mechanism involving public-private dialogue
- Make key reforms related to exchange control, intellectual property, R&D tax breaks and labour flexibility
- Incentivise future industries, platforms and the use of 4IR technologies through policies
- Use digital infrastructure to improve information access and promote government transparency
- Build interconnected, empowered communities through government-run digital infrastructure
- Move beyond R&D to a broader conceptualisation of innovation, including supporting a whole-of-society approach (innovation compact) to ensure innovation-related policies are coordinated
- Introduce business support measures focusing on small and medium enterprises (SMEs) and revitalising SOEs' role in innovation
- Develop local innovation ecosystems through actions such as integrating support for local and grassroots innovators into local planning and establishing new incubation facilities and innovation support centres
- Include civil society and support neglected innovators to promote innovation for inclusive development
- Exploit new sources of growth from 4IR, the circular economy and ICTs
- Build an innovation mindset, starting in primary school
- Celebrate entrepreneurs and innovation role models

- Adopt innovation approaches within government operations

Source: MRP-STIIL, 2017; Bell et al., 2018; DTI, 2018; World Bank, 2018c; DST, 2019; PC4IR, 2020

With the idea of smart cities with integrated systems, the need for central planning of infrastructure becomes more important. While the infrastructure fund can be a good way to bring in additional investment in infrastructure, the project needs to be organised and not developed based on which project is most 'bankable'. These strategies are important for plans that have recently been announced to develop three new 'smart cities' at Lanseria, the Durban Aerotropolis, and Mooikloof mega-city (BusinessTech 2021).

Corruption and mismanagement are also key barriers to effective innovation policy in South Africa. These issues can result in some people and organisations benefiting more from government services. In some cases, this results in well-connected businesses benefiting disproportionately from government programmes. Bell et al. (2018) describe that a "narrow coalition of elites, buttressed by higher government salaries and social grants for important constituents has undermined investment and reinforced rather than changed the existing structure of economic power". Efforts are also needed to tackle problems that have been identified with SOEs' implementation of government policies.

Another challenge that came up in this working paper series is that, in some cases, government actors making decisions about infrastructure development can lack the needed capacities. This is particularly a challenge for 4IR, as 4IR systems can be more complex than traditional infrastructure. In addition, infrastructure decisions that are made in the present can have long-lasting implications for how systems can be modified in the future. This issue can be addressed by recruiting more qualified staff and partnering with knowledgeable partners. The PC4IR is building some of these connections.

2.3 Strengthening Networks

The nature of networks plays a pivotal role in shaping flows of knowledge and opportunities for businesses. The basic structure of the supply chains considered in this paper are outlined in Table 1. Firm networks can play a big role in shaping innovation processes, as networks provide sources of information and options for collaboration. As noted earlier in this working paper series (Alexander, 2021a, 2021c), formal R&D is just one form of generating innovation, and much learning and innovation happens in firms' interactions and day-to-day practices. As 4IR blurs the boundaries of individual businesses, it creates more opportunities for innovation happening within partnerships. This section considers barriers and opportunities created by network dynamics in South Africa's innovation system.

Table 1: Case Study Supply Chains

Product or Service	*Producers*	*Key Buyers*
ICT or transportation infrastructure	Private businesses	Public sector
Freight forwarding	SOEs and private businesses	Private businesses (and public sector)
ICT services	Private businesses	Private businesses (and public sector)
Mining equipment	Domestic original equipment manufacturers (OEMS)	Mines
Cars	South African factories for multinational companies (MNCs) and South African component suppliers	Global OEMs

Businesses in South Africa have reported relatively low levels of collaboration (CeSTII, 2020). However, these levels differed between businesses across sectors. Considering businesses active in carrying out product and/or process innovation, only 16% in industry (mining, manufacturing, and utilities) reported collaborating, versus 24% in services (trade, logistics, finance, and engineering and tech). Exploring existing patterns can be useful for understanding how to encourage increased levels of cooperation.

Reasons given for businesses in industry and services to engage in collaboration differed (see Figure 3). In addition, the types of partnerships differed (see Figure 4). The most common types of partnerships for industry were with consultants, commercial labs or private R&D institutes; other enterprises within their enterprise group; and clients or customers. In contrast, the most common types of partnerships for services were with suppliers of equipment, materials, components or software; clients or customers; and competitors or other enterprises in their sector.

Identifying pathways for knowledge flows can present an opportunity for increasing knowledge diffusion and innovation. Knowledge flows can take place domestically and through global connections. CeSTII's (2020) survey provides firms' self-reported important sources of information. In this survey, businesses in industry and services report relying on different sources (see Figure 5). Notably, the biggest source of information for businesses in industry is their clients, whereas for businesses in services, the biggest source is their suppliers.

Understanding these connections and noting areas that could be considered as deficient can be useful for shaping future interventions. South Africa has some strong PRIs, but they often have weak connections to industry. This can be seen by the low levels of reliance on universities and industry's low reliance on government and PRIs. An opportunity therefore exists to create better connections between research generated by public institutions and commercial opportunities.

As many countries have more advanced use of 4IR than South Africa, South Africa can benefit from seeking to increase its global connections. This can involve multiple forms. One path is FDI in production. The automotive industry has a lot of FDI that has brought in global technologies. The learning that takes place can expand as employees move to other South African businesses or start their own businesses. However, when firms rely solely on absorbing global technology, they can lose internal innovation capabilities.

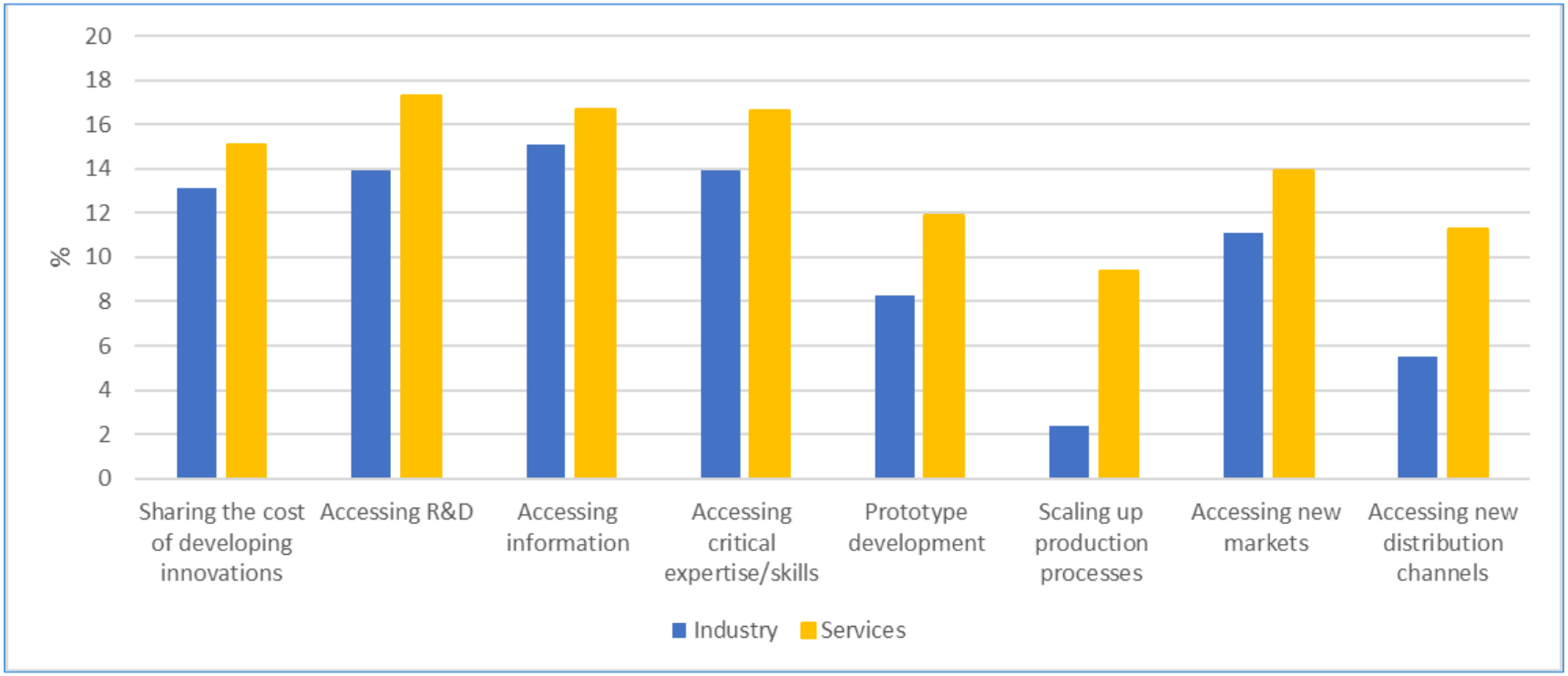
Another learning path related to global networks is firms learning from selling products to global markets. Foreign buyers can have different demands than those within South Africa.

A third learning path is through buyer-supplier relationships. As described in the third paper in this series (Alexander, 2021c), this type of learning can go both ways. Buyers, such as those in the automotive industry, can provide training to their suppliers. In addition, companies developing new 4IR-related offerings can educate their customers about how they can use new types of products and services.

A fourth learning path is individuals personally learning about technology in other countries. This can involve people working abroad, and has also been found to happen when companies sent their employees for training or visits to other countries.

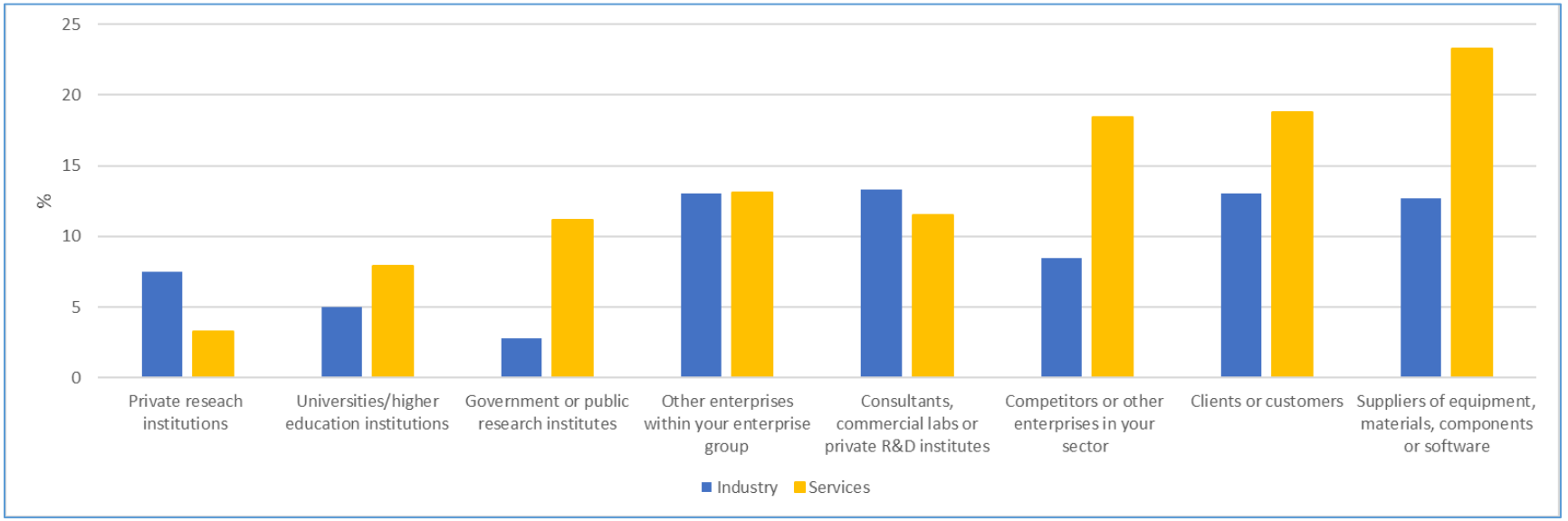
Another key issue related to networks is that South Africa does not have very strong connections with global value chains (GVCs). As there are high levels of economic activity in GVCs, South Africa has an opportunity to change how it is inserted into them. The World Bank (2018a) asserts that increasing integration could lead to increased productivity, competitiveness and job creation. A key concern is how South Africa is connected to these networks. Black (2020) recommends that South Africa should encourage MNCs to move additional parts of their businesses to South Africa, with a particular opportunity for automotive sector R&D.

Figure 3: Reasons for Collaboration



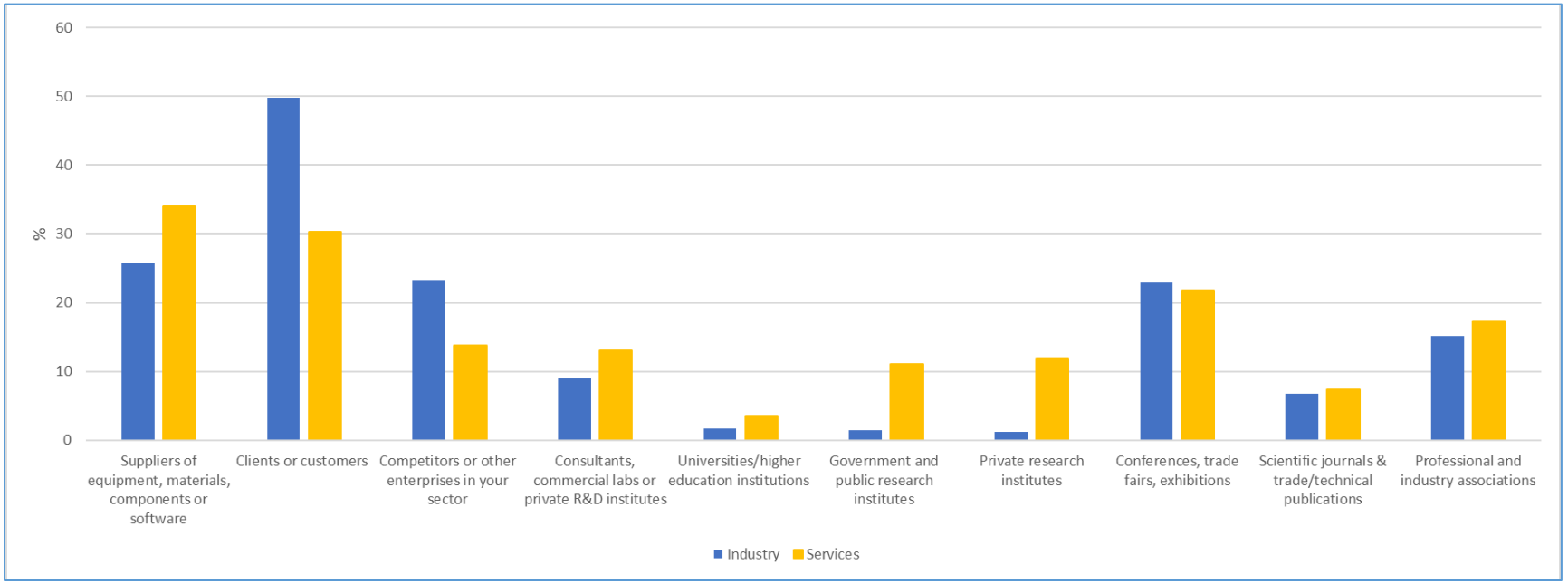
Source: CeSTII, 2020

Figure 4: Collaboration on Innovation Activities



Source: CeSTII, 2020

Figure 5: Highly Important Sources of Information



Source: CeSTII, 2020

Another important factor to consider related to firms' networks is intrasectoral connections. South Africa does have a lot of industry associations, but a gap has been identified related to intrasectoral and cluster-based cooperation related to innovation (Bell et al., 2018). Lorenz et al. (2019) highlight the potential benefits of developing sector-specific initiatives that seek to increase linkages and cooperation between businesses, universities and vocational training.

Finally, the structure of production networks can create barriers when businesses want to engage in innovation. As each of the case study sectors has demonstrated, the ways in which they are able to harness elements of the national innovation system are shaped by their involvement in different types of production networks. A number of sector-specific dynamics can be identified.

2.3.1 Connectivity Infrastructure

For businesses involved in connectivity infrastructure, producers' ability to innovate is shaped by how tenders are framed. The tenders themselves can drive innovation or entrench the status quo. Another key factor related to innovation in these contracts is the status of existing infrastructure. In some cases, suppliers are restrained by having to design systems that are compatible with existing infrastructure, while in other cases they have more leeway to introduce novel aspects. Finally, regulations and public planning play big roles in shaping what types of innovation are possible in infrastructure projects.

2.3.2 Other Connectivity Services

In contrast, connectivity services companies that offer self-designed products for sale have the freedom to be very creative in their offerings. While these businesses can be constrained by existing infrastructure, there are a wide range of opportunities for growth and innovation fuelled by the expansion of 4IR technology.

2.3.3 Automotive Manufacturing

Automotive supply chains are dominated by MNCs that have specific requirements for the components that go into their vehicles. Consequently, businesses in automotive supply chains are, for the most part, limited to process or organisational innovation, as they are required to produce a standard product.

2.3.4 Mining Equipment Manufacturing

Mining equipment producers have a lot of room to experiment. This is enabled by producing short runs and sometimes being able to customise designs for different buyers. The current low levels of adoption of digital technology and 4IR systems in mining create a wide range of opportunities for suppliers to develop new products and services.

3. General Economic Impacts

4IR is creating different impacts across occupational categories and creating different opportunities and challenges across sectors based on factors such as the complexity of the

products or services involved, opportunities for standardisation and customisation, and positions in GVCs (Lorenz et al., 2019). A number of opportunities and challenges can be identified related to the influence of 4IR on the economy.

4IR developments have the potential to make firms more efficient and to offer better products and services to their customers. These changes thus can help businesses to be more successful. As discussed in the first paper in this working paper series (Alexander, 2021a), strengthening manufacturing is important for increasing South Africa's productivity. 4IR is creating wide-ranging opportunities for manufacturing businesses. By harnessing 4IR systems and technologies, South African firms can become more competitive within South Africa, and in global markets.

Accenture (2019) identifies four areas with potential for South Africa's telecoms industry to grow. One is redefining customer engagement, which involves developing products customised to meet consumer needs. The second is called 'beyond the pipe', which involves offering services beyond traditional ones, such as digital services, IoT and VR/AR. The third is developing networks of the future, which can help expand internet penetration. These include alternative connectivity, software-defined networks, zero-touch networks, and cyber resilience. Finally, the fourth is bridging the innovation gap. This can involve adopting new innovation models, such as open innovation, value hacking, incubation and design thinking. Accenture outlines how these actions can lead to substantial value creation in the telecoms industry.

Digital technologies can also help logistics companies to compete on value addition rather than solely on price (Gain Group, 2020). A number of trends can be identified in the logistics industry (see Box 12). These trends can help businesses become more efficient and provide better customer service; facilitate the creation of new business models; become necessary for businesses to stay competitive; and help companies cope with new laws and regulations (e.g. environmental compliance) (Gain Group, 2020). If South African businesses adopt these 4IR technologies, they can better compete against global firms that are currently playing strong roles in South Africa's logistics sector.

Since connectivity services can incorporate 4IR systems, the provision of sufficient connectivity services creates opportunities for expanding 4IR in all sectors. OECD (2020) highlights that increasing South Africa's public infrastructure investment would boost potential growth. As connectivity services involve infrastructure and wider levels of support for 4IR (e.g. integrated smart cities, 4IR logistics service provision), these services can provide wide-ranging support to other industries.

The World Bank (2018a) asserts that the role of ICT as a facilitator for doing business is more important than its status as a sector in its own right. It suggests that interventions that could improve industry services (e.g. a more liberal approach to spectrum management and price competition) should be a priority.

4IR will create new opportunities for small, medium and micro-enterprises (SMMEs) and start-ups. As mentioned by one of the respondents above (F17-I33), in the future more jobs may be created by SMMEs. A variety of options for digital SMME development have been identified (see Box 13). SMMEs can have more options with 4IR, especially as elements of production become fragmented. Opportunities exist for SMMEs to offer services that are currently done in-house by other businesses and to provide new types of services, such as the companies that were reviewed for this working paper series that offer VR-related services. In addition, 3D printing provides opportunities for manufacturing to happen on a smaller scale.

Box 12: Trends in the Logistics Industry

Location and Visibility

- IoT can track goods in real time using sensors and mobile devices, vehicles and other equipment
- Wearable technology can scan barcodes, monitor worker movements to identify potential efficiency enhancements, and determine fatigue
- Blockchain can create, record and store data in a shared network, creating tamper-proof records

Management Information, Planning, Decision-Making

- Big data and predictive analytics can identify patterns and trends to improve demand forecasting and predict future consumer behaviour to optimise order quantities and delivery timing, and reduce the need to keep extra stock

Efficiency Improvements

- AR, through the use of smart glasses or windshield projections, can assist drivers with deliveries
- VR can support training
- Digital supply chain twins, which include all entities' processes and interrelationships, can be used to study systems and improve efficiency
- Digital freight platforms can connect transporters and freight owners directly to match demand with supply

Warehouse Management

- Robots and cobots can use AI to perform tasks such as picking inventory, loading pallets, and moving cargo within a warehouse
- Drones with radio frequency identification (RFID) sensors can scan RFID tags from more than 10 m, allowing faster and more accurate stock counts than with humans, particularly with vertical storage
- Warehouse management systems can involve machine learning for adapting to changing conditions, pay-as-you-go services and cloud software, improvements in user interfaces, integration with IoT, acceptance of last-minute orders, and managing returns to inventory
- Self-driving vehicles may be able to replace long-haul routes with drivers, and the use of platooning technology (linking two or more trucks in convoy) can reduce fuel consumption
- Automatic guided vehicles can be used with warehouse management systems to improve accuracy, speed and cost.

Environmental Impact

- Warehouses can incorporate a number of green technologies, such as cool-roof systems, solar panels, LED lights, thermal glass, and clerestory windows
- Transportation can use alternative fuels, such as liquefied natural gas, electric and hybrid trucks

Source: Gain Group, 2020

Box 13: Digital Options for SMMEs

- Data centres and cloud computing create opportunities for SMMES, and for smaller businesses in collaboration with bigger players
- Digital content, most of which is created abroad, can also be created by South African SMMEs
- Games and apps present many opportunities for SMMEs, particularly related to local issues, which could be promoted through local application stores

Source: PC4IR, 2020

As 4IR technologies can be disruptive, South African firms have opportunities to break into markets that have been closed. This can involve developing new features that make products more competitive than those of incumbents.

Growth of all types of 4IR businesses in South Africa creates opportunities for expanding local supply chains. Supply chain producers can expand their provision of existing types of inputs for 4IR lead firms, and can also incorporate 4IR features and processes into their businesses. Supporting domestic manufacturing can create opportunities for new entrants to markets, increase job creation, and support skills development (Lamprecht, 2020).

As discussed in the first paper of this series (Alexander, 2021a), growth in manufacturing creates a number of spillovers. Growth in the automotive sector, in particular, can have a range of impacts. Notably, automotive sector growth in has been connected to increases in technology absorption, new skills and industrial capabilities (DTI, 2018).

In addition to the potential economic benefits, there are also risks. One type of risk is related to data management. As 4IR systems create a lot of data, developing regulatory systems will be important. Potential problems include (in)accuracy of the data being used to shape decisions that could harm individuals or institutions, and data ownership could provide unfair advantages to individuals or institutions (PC4IR, 2020).

Another risk related to the expansion of 4IR is that, if changes are not managed properly, existing inequalities could be enhanced. In South Africa's current system, productivity gains tend to favour the rich (World Bank, 2018a). This is not inevitable and is an issue that needs to be managed, as 4IR creates changes to economic systems. For example, if production processes become more efficient, consumers should see lower prices, but industries with low levels of competition may prevent this dynamic.

A further risk is that South African businesses will not be able to compete with global competitors who adopt 4IR more quickly. Especially with digital products and services,

competition can be global. South African firms may lose out if they do not innovate to provide competitive offerings.

4. Effects on the Environment

A number of opportunities and risks related to South Africa's environment can be identified. 4IR development has the potential to make infrastructure function more harmoniously with the natural environment. This potential benefit has multiple levels. For example, wireless networks create less destruction than installing fixed systems, and more coordinated transport systems can reduce the levels of shipments.

New products and services that are being developed have the potential to harness the wide variety of technologies and materials that are being developed through 4IR. The potential changes can also result in production processes with significantly less environmental impact. Already, almost a quarter (23%) of businesses that engaged in product or process innovations from 2014 to 2016 reported a reduction in environmental impacts (CeSTII, 2020).

Through 4IR developments, environmentally friendly power sources can become the norm. Power needs can be streamlined by using smart systems that, for example, balance use across different times of the day. 4IR development also can involve creating products such as electric cars, which do not need to have internal combustion engines.

An important opportunity is that 4IR systems can support the creation of a circular economy. This involves systems that reuse resources without creating waste – a key issue for manufacturing businesses. Notably, potential exists to adopt circular economy practices in the mining industry (PC4IR, 2020).

A risk is that 4IR-related changes to production and consumption could expand the use of unsustainable practices. 4IR improvements can result in rapid changes that can make products obsolete more quickly. If unsustainable production, use and disposal systems are used, then these rapid changes can result in increasing levels of environmental damage. In addition, as digital systems require electricity, the use of environmentally damaging power sources for these systems could also create further damage.

5. Effects on Employment

4IR also has potential to create significant effects on employment prospects. A key overarching opportunity is that the potential that has been identified for the growth of businesses can also result in the creation of new jobs. With the wide range of new products and services being created, multiple business opportunities exist, which can create future jobs.

Such growth can also trigger wider spread job growth. Specifically, the growth of new businesses can result in the creation of new jobs related to support services and supply chains. Through such processes, numerous spillover jobs could be created.

4IR-related innovation can also create a variety of improvements in work processes. A major one is decreased health and safety risks. Changes can benefit workers and can also extend to the users of end products. Improved health and safety outcomes were reported by 27% of South African businesses that engaged in product or process innovations between 2014 to 2016 (CeSTII 2020). Another change could be that unskilled or lower-skilled workers can work with advanced digital technologies through the creation of easy-to-use and intuitive user interfaces. Furthermore, advances in technology can increase productivity per worker. Through such changes, companies can and are maintaining employment levels by expanding production. Another opportunity is the creation of higher skilled, better paying jobs. With increased demand for such jobs, higher education institutions could expand their offerings of related programmes.

4IR also creates risks related to employment. A major risk is that increased automation and the use of AI can decrease the need for human labour in the future. For some job types, this is already inevitable. PC4IR (2020) notes that plans need to be made for workers who will lose their jobs in the short term.

Another risk is that, as more processes become automated, the remaining jobs will require more sophisticated skills. Some factory-based employment and drivers have notable risks related to this issue. This challenge is a particular problem for South Africa, as the country has high levels of unemployment among people with less formal education.

Another risk is that, as mentioned in the first paper in this series (Alexander, 2021a), benefits from growth can be held by a small group. If changes are not managed well, employees may end up receiving low incomes as jobs become more streamlined. This could result in both precarity and an increase in competition.

A final challenge is that disparities exist between different groups related to employment. Access to opportunities varies widely by region. Without planning, 4IR may create further divergence between regions. In relation to digital entrepreneurship in South Africa, the World Bank (2018c) recommends creating stronger links between the Gauteng and Western Cape entrepreneurship ecosystems by incentivising joint applications; reducing the rural-urban divide by supporting extension programmes; and providing active support to promote diversity in digital entrepreneurship. The World Bank (2018b) also recommends reinforcing the spatial integration between economic hubs where jobs are located and underserviced informal settlements in order to address poverty issues.

Overall, across the areas of general economic outcomes, environmental outcomes and employment outcomes, a diverse set of opportunities and risks can be identified. As 4IR spreads in South Africa, these risks need to be managed. In some cases, public policy is needed. In others, private actors can find opportunities in providing solutions.

6. Conclusion

This working paper series has explored the dynamics surrounding the spread of 4IR in South Africa. This revolution involves the growth of digital technology and a fundamental shift in how businesses behave. It has ramifications for all levels of society. Two key issues were addressed in the series. One is the identification of the dynamics through which South African businesses are adopting 4IR technology and systems. The other is an exploration of the types of changes that may occur as 4IR spreads.

4IR is seen as spreading through innovation in a national innovation system. Key features of South Africa's innovation system were mapped. In addition, a more detailed examination was carried out related to the experiences of two sectors, which were each explored by looking at the experiences in two case studies.

The first sector considered was connectivity services, which involve infrastructure, infrastructure services and other services (e.g. logistics and cloud services). The case studies within this sector were communication services and transportation services. The second sector was manufacturing, with the case studies covering automotive manufacturing and mining equipment manufacturing.

Considering features of the innovation system and the experiences found in the case studies, multiple factors that shape the prospects for businesses to innovate and adopt 4IR technology and systems were identified. Some of these challenges require public intervention. However, some create 4IR business opportunities.

Key barriers and challenges identified include:

- Some sectors are dominated by large firms that can stifle competition
- A lack of sufficient infrastructure creates barriers for businesses to develop and expand 4IR systems
- Some businesses do not want to automate and incorporate 4IR because it would result in job losses within their business
- South Africa has a skills gap
- Large segments of the population have low incomes and consequently low purchasing power
- Local procurement policies exist, but often do not achieve their targets
- A high risk of crime can inhibit innovation
- In some areas, legacy systems can inhibit the introduction of 4IR systems
- Many firms have traditional business models that can be difficult to upgrade
- Many large firms have low levels of innovation experience
- Many firms experience difficulty getting financing, especially smaller firms
- A lack of connections between research organisations and the private sector
- A lack of awareness and use of existing support services
- Some support services are of low quality
- A lack of central planning for 4IR development

- Corruption and mismanagement in the public sector
- A lack of capacity in some public sector agencies
- Low levels of collaboration
- In some cases, businesses' positions in production networks limit their ability to innovate

These barriers and challenges result in a number of opportunities, which include:

- A lack of existing infrastructure creates opportunities to develop 4IR-enabled infrastructure
- The risk of crime has created opportunities for 4IR businesses providing security services
- The lack of legacy systems in some areas can create opportunities for innovation
- An opportunity exists to improve the services of public research institutions to better cater to businesses needs
- Building stronger local networks
- Increasing collaboration within clusters
- Building stronger connections to global value chains

In addition, several drivers pushing the adoption of 4IR were identified, which include:

- As markets have opened, there is more competition and working in competitive environments promotes 4IR innovation
- Growing demand for products and service with 4IR features
- Large system of risky jobs can create a driver for developing 4IR systems, which can reduce risk

Furthermore, a series of additional opportunities and emerging trends can be seen:

- Existing global technologies are available for South African firms to import
- Incorporating the large numbers of people who are currently not working (e.g. members of the black population, youth, and those with lower levels of formal education) into the workforce can provide a diversity of experiences and perspectives that can stimulate innovation
- Stocks of metal and minerals have potential to provide inputs for 4IR technology
- 4IR start-ups are emerging
- Funding systems can be better coordinated
- Improving the education and training systems to take the needs of 4IR into consideration, including managerial skills, technical skills, creativity, critical thinking and lifelong learning
- South Africa has strong research institutes
- Ecosystem of private consultants and business-to-business (B2B) companies promoting 4IR
- Developing smart infrastructure (e.g. smart cities)

While the dynamics listed above are cross-cutting, the case studies identified sector-specific dynamics. A key factor shaping innovation dynamics and the adoption of 4IR was found to be the structure of the production networks. These structures created different situations for each of the case studies.

Connectivity infrastructure is limited by tender design. Improved tender design can promote the increased incorporation of innovation and 4IR systems. Plans to develop smart cities are a positive development related to utilising the benefits of 4IR.

Connectivity services are limited by the capacity of existing infrastructure. Improving infrastructure can create more opportunities for these businesses. Regulatory restrictions can also create barriers. However, some services require regulation to ensure equitable access. These businesses generally have many opportunities and have the potential to engage in organisational, product and process innovation.

The manufacturing sectors explored involve different dynamics. Notably, in the automotive industry, technological developments tend to flow from the lead firms (buyers) down to their suppliers. In contrast, for mining equipment manufacturing, technology tends to flow from the producers to the mines (buyers). However, these are not completely unidirectional relationships and involve knowledge and ideas flowing both ways.

Automotive sector producers are limited in their ability to engage in product innovation because of their position in global value chains. Some are also restricted in process innovation, as the lead firms want uniform global production systems. However, some businesses, particularly second- and third-tier firms, have freedom to engage in process and organisational innovation.

Mining equipment firms often do not use high levels of 4IR technology. However, a lot of opportunities exist for these firms, and frontrunners are developing diverse new products and services. These firms have freedom to engage in product, process and organisational innovation.

Overall, the progression towards adopting 4IR has the potential to create diverse effects on South Africa's economy. Potential effects of 4IR expansion related to challenges in South Africa's general economy and its influences on the environment and employment were identified.

In terms of general economic outcomes, a number of risks related to 4IR were identified. These include:

- Data created and collected through 4IR systems can be mismanaged
- Existing inequalities can be enhanced
- South Africa may not be able to compete with global frontrunners in some industries

Nevertheless, opportunities include:

- Improving the efficiency and competitiveness of firms
- Businesses with 4IR connectivity services can be facilitators of improvements across other sectors
- 4IR can allow activities to become fragmented, creating more opportunities for small businesses and start-ups

- Start-ups with 4IR innovations can break into previously closed markets and create new markets
- 4IR creates opportunities for building local supply chains
- Building local manufacturing can create economic spillovers

Environmental outcomes face a risk related to the fact that 4IR may increase levels of production and consumption in ways that create more environmental damage. However, multiple potential environmental opportunities were identified, which include:

- 4IR can create infrastructure that functions more harmoniously with natural systems
- New products and processes can be more sustainable
- Environmentally friendly power sources can replace fossil fuels
- Systems can be developed based on a circular economy model

Finally, 4IR creates a number of risks related to employment outcomes. These include:

- Increased automation could reduce the number of jobs
- New jobs may be skewed towards high skill levels, creating a mismatch with South Africa's workforce
- Benefits of economic growth may be held by a small group and not felt by workers
- Existing inequalities between regions may be exacerbated

In addition, several employment opportunities were identified, including:

- The development of new industries and technologies can create new jobs
- Growth of new industries can create spillover jobs
- Health and safety risks in jobs can be reduced

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Annexure A: Overview of Interviews

A key source of data for this paper is a set of 51 interviews conducted with businesses and key stakeholders involved in connectivity services and manufacturing in 2019 and 2021. An overview of companies that were interviewed is provided in Table 2, and an overview of the stakeholders that were interviewed is provided in Table 3. The interviews typically were with one or two representatives of the organisation. Interviews were recorded and transcribed.[2] Transcripts and notes were reviewed and coded using qualitative data analysis software to systematically draw out key findings.

Table 2: Companies Interviewed

Firm Identifier	Interviews	Type	Firm Size[3]
F01	I01	Lighting manufacturer	Small
F02	I02	Parts manufacturer 1 (machine and spare parts manufacturer)	Medium
F03	I03	Robot manufacturer 1 (collaborative robots)	Micro
F04	I04	Logistics 1 (packaging and logistics provider)	Large
F05	I05	Parts manufacturer 2 (automotive and locomotive parts)	Large
F06	I06	Engineering software producer	Small
F07	I07, I08, I09	Consulting for 4IR 1 (digitisation and design)	Large
F08	I10	Automotive OEM 1	Large
F09	I11, I12	Logistics 2	Large
F10	I13	Traffic management 1	Medium
F11	I14, I15, I16	Automotive OEM 2	Large
F12	I17, I18, I19	Parts manufacturer 3 (car parts)	Large
F13	I20, I21, I22, I23, I24, I25	Consulting for 4IR 2 (mechanical engineering design and prototype services, also transportation management projects)	Medium
F14	I26, I27, I28, I29	Parts manufacturer 4 (car parts)	Large
F15	I30	Mining equipment manufacturer 1	Large
F16	I31, I32	Consulting for 4IR 3 (VR)	Small
F17	I33	Consulting for 4IR 4 (automation)	Small

[2] Except for one respondent, who did not want to be recorded, and one interview, during which the recording failed. In both cases, detailed notes were taken.

[3] Size is measured by number of employees. Micro is less than 10, small is 10 to 49, medium is 50 to 249, and large is 250 or more.

Firm Identifier	Interviews	Type	Firm Size[3]
F18	I34	Consulting for 4IR 5	Missing
F19	I35	Mining equipment manufacturer 2	Medium
F20	I41	Robot manufacturer 2	Small
F21	I37, I38	Traffic management 2	Large
F22	I39	Automotive OEM 3	Large
F23	I43	Consulting for 4IR 6 (mining)	Medium
F24	I44	Consulting for 4IR 7 (logistics)	Small
F25	I46	VR training	Micro

Table 3: Stakeholder Interviews

Stakeholder Identifier	Interviews	Description
S01	I36	4IR-focused industry association
S02	I42	Government agency
S03	I45	Mining industry association
S04	I47	Government agency
S05	I48	Government agency
S06	I49	Government agency
S07	I50	Logistics industry association
S08	I51	4IR-focused industry association 2
S09	I40	Automotive industry association

Annexure B: Perspectives on the Future of 4IR

4IR is an emerging phenomenon. Its boundaries and future are still developing, and its implementation may also be affected by how it is perceived. Consequently, at this point in time, it can be helpful to explore people's perceptions.

In a global scale survey conducted by Forbes Insights in the second half of 2017[4], South African executives differed from the average in a number of ways (Deloitte 2018). Specifically, South African executives were more likely to feel that technology would replace rather than augment human labour, and had low levels of confidence related to their organisations being prepared to address 4IR issues. The South African respondents were also less likely to expect the emergence of new business or delivery models to affect their organisations in the next five years. While global firms had low levels in these questions, South African respondents had half or less than half of the average levels related to feeling highly prepared to address the emergence of new business or delivery models, blurred lines between industries, more powerful and tech-savvy customers, uncertain influence on workforce, and smart and autonomous technologies. Also, only 5% of South African respondents felt their organisations were highly capable of incorporating advanced technologies sufficiently into their operations to foster the effective movement of goods and services across their supply networks, compared to an average of 20% across the survey. Furthermore, only 19% of South African respondents felt their organisation was highly capable of enabling the mobilisation of a larger and more diverse ecosystem of participants to deliver value to their customers.

Participants in the interviews reviewed for this working paper series described a variety of potential benefits from 4IR. One major factor was the ability to reduce waste and costs. One issue mentioned was that automation could bring benefits to the management level as well as the production level (i.e. payroll, supply chain management) (F14-I29). Another opportunity mentioned was that creating simulations of products can facilitate custom orders and reduce the need to set up showrooms (F16-I31). One respondent commented on the potential to reduce waste and use less working capital.

> *If you look at the fourth industrial revolution, what does it do? It actually says, by connecting the devices with a certain amount of logic, [you] can make a decision of how to optimise the environment, or to help make it more efficient, or how to improve it … It helps us to reduce inventory. It helps us to reduce human intervention. So, [there's] less people intervention, because it's scanning it …. Less errors coming in through that. It helps us to understand that capacity. So, the next thing is, 'How do we optimise transport? … But, all of this, at the end of the day, leads to reducing working capital.* (F04-I04)

[4] The survey included 100 South African respondents, and covered 1 603 global executives representing firms with a revenue of US$1 billion.

Respondents across the interviews shared a variety of opinions and ideas related to the future of 4IR in South Africa. A selection of these opinions is shared in this annex. The first section focuses on ideas related to the speed and inevitability of change. The second focuses on ideas related to the businesses of the future. The third shares ideas related to jobs of the future. Finally, the fourth section presents expectations the respondents shared about the role of the government in the spread of 4IR.

2A: Speed and Inevitability of Change

The respondents interviewed for this working paper series shared a variety of perspectives related to the speed and inevitability of change related to 4IR. Some respondents saw great potential for 4IR and felt things were changing quickly.

> *I think [the market for 4IR services] is growing and it's growing fast. The phase that we need to get past which I see as a hurdle is that the initial excitement on the sensational part of the 4IR narrative needs to pass first and then the next phase after that will [have] very stable growth.* (F07-I07)

Others were more sceptical about the short-term impact.

> *Smart Cities is the other big thing. Yeah, it's a buzzword, and always makes me think about 20 years ago, when we started with this intelligent transport systems in South Africa … I called it the [nonsense] bubble. But it was a bubble. So, we all knew we wanted to do this, but we didn't know where to start. So, it took us a few years to know where to start to turn around projects. Smart cities is now the latest [nonsense] bubble. But also, we want to throw money at it, and then we want to be smart. But the cities do not know what they want … What happens is you get the Huawei's of the world, the PWCs and they come with flashy slides, and whatever, they write another strategy and they write another policy. So, before they actually get stuff on the ground that makes a difference in the lives of people, that's a 10-year process. I mean, these things [are] just long. Like IoT, this Internet of Things, we started talking to the industry … It's a magical tool to track vehicles, and to monitor devices. But we're not there yet.* (F10-I13)

For some respondents, the adoption of automated systems is an economic need and inevitability.

> *But the future of any country, in a manufacturing environment has to be automation. As simple as that. The only way an economy can grow is manufacturing. Not the only way [but] a huge factor is manufacturing … from a South African perspective, it's our lifeblood … And we see it in every aspect. You know, from the simplest of manufacturing industries.* (F20-I41)

Another respondent spoke about change towards 4IR filtering down from automotive lead firms to lower tiers of the automotive industry. He also expressed concern that smaller businesses would not be able to keep up as change happens.

> *So, the OEMs - I think, it's purely because they have the input from the main*

> *companies in Europe or Japan or whatever - will be there, or there about, as far as readiness goes. Whether the locals accepted or not, that's where head offices [are] going and they'll follow suit. But I think for the tier ones, it's very difficult. And especially when it comes to high level automation, high-cost equipment. They're so restricted with money. What I'm saying [is] that the OEM is really squeez[ing] them and that this is coming from them … I think it makes it difficult for the smaller guys. The biggest guys that owned the bigger tier ones that are owned by big companies offshore, that'll obviously filter through. And, for example, some of the tier-ones, if they're building stuff for OEM one, all that equipment that they're building, those parts will match the same as the plant. So, they have to have skill with that. But if they're building for OEM two, who doesn't have the exact same standards, then they're pretty much free to do whatever they want to. So, I think the tier-ones are going to be quiet, it's going to be quite tough for them to get up to speed and to keep up to speed.* (F05-I05)

Respondents also spoke about planning for future systems. One commented that new investments need to bear in mind the production methods and products of the future.

> *Manufacturing is important … so we can then start to uplift the manufacturing side of our country … If we're operating with an old 1990s, 2000s mentality, where we're saying, 'Okay manufacturing, we are going to manufacture automobiles. We are gonna manufacture stuff that's back from those days'. And, we spend huge amounts of money on building factories that are going to be irrelevant by tomorrow, then … that was a waste.*
>
> *Nobody needs diesel cars anymore. No one wants petrol cars anymore. They all want electric cars. You should have been focusing on that instead of building factories. So, there is an issue here.*
>
> *Like, for instance around manufacturing, we got all this money that we're popping into developing this infrastructure, especially economic zones, etc. But they might become totally irrelevant. So, that's the issue here. It's that people are making decisions around this stuff on the government level. [From a] government level, what do we do first? Where do we go? Where's our strength?* (F06-I06)

With large change expected, respondents also highlighted that firms have to be prepared. One respondent said that companies see the many 4IR opportunities and are trying to figure out the best path forward and described this as a process involving strategic planning at the senior management level.

> *We're seeing that there is a hunger and a thirst for knowledge. And the biggest thing is what do we do next? Which of those nine or 10, or 32 4IR technologies do we deploy first? Do you deploy cyber security first, artificial intelligence first, augmented reality first, IoT devices first? What do you deploy first as a CEO or the CFO? What do you do first? And that's where the big issue is. Like, how much money do we put into this stuff? Do we go with American technology, German technology? Can we trust South African local technology? Or do we help develop local South African technology? What must we do?* (F06-I6)

2B: Businesses of the Future

Respondents shared a variety of ideas about how 4IR will affect businesses of the future. One respondent described that existing models, which have been based on low-cost, large-scale production, may not be viable in the future. He highlighted the importance of new businesses being agile and flexible.

> *One example I have is the manufacturer of packaging, like plastic water bottles. So, they would manufacture the plastic water bottles. Their production line was 30 maybe 40 years old. So, they were definitely up for renewal. Because when that production line was installed, they were taking orders in the millions per product. Now, they're taking orders of 230 000 and less. So, their production line cannot cope with that amount of change. They don't have that flexibility. And I think this is where the 4th industrial revolution is not about automation. It's about flexibility of being able to adapt being, I hate to use the word agile, but yes, to be agile. Automation was 10, 15 years ago, that ability to make something at [a] very low cost. Now it's about trying to be flexible. That company, when they didn't implement or they didn't renew their production lines, because it would have been costly, it would have cost too much to replace that production line … They decided they'll just keep going on with what they've got. Now, what will happen with them in the future, I cannot predict.* (F13-I20)

Another noted that older production models may still be appropriate in some cases. He proposed that businesses could incorporate new systems in a limited capacity with a focus on solving specific problems.

> *Industry 4 is coming … depending on where [in] the world you are … you get a spread between industry 4 and industry 1, almost … So, I've been in talking to people and in conferences where, it's literally been if you're not part of it, you're gonna be left behind, and you're going to die. And everybody's running to the mountains, because everybody's going to lose their jobs. Because AI and machine learning is going to take over everything. And it's just going to be horrible for everybody. Where now they go, 'It's too expensive to do all this'. It's not practical for a company to throw out everything and go full industry 4. It's not practical. Nobody has that money. Unless you are Bosch, you're Siemens, you're ABB. Those are the guys that actually sell the stuff. Yes, they've got this nice factory set up and everything's automatic, and there's almost no human and everything just happens. And that's yes, you can go there. And that is sort of … a path and you can do that. Depending on how much money you have, and what type of thing you design. Yes, but usually it's much more going to be somewhere in the middle. And that's sort of, I guess, our realisation as well. So, when we speak to customers, it's never a question of yes, let's do industry 4 with you. And I still have customers when people come to me say we want to do industry 4 and I don't know what that is, because you can't do industry 4, you have to have a problem that you need to solve. And then you could go, 'How do you solve that problem?' Maybe it is [to] train your people better. Done. Maybe it is you've got the ideal case to actually automate and*

> *really push … how much of industry 4 you're going to implement. Maybe that's the solution for your problem. Usually, it's somewhere in between.* (F13-I22)

Another respondent expected that new systems would create more room for SMEs in South Africa's economy.

> *I do believe that small and medium-sized companies need to gain importance in that whole economic process because they are cornerstones of the success of that process.* (F17-I33)

Respondents also spoke about a need for more entrepreneurs and an opportunity to make intermediary components and provide services locally.

> *Local SMEs can attach to be able to provide [services to manufacturing businesses]. Otherwise, only those that have their own international connections will be able to survive.* (F22-I39)

Another respondent spoke about the wide variety of changes that were happening and highlighted that 4IR involved bringing together technologies that have already become widespread in recent years. He also spoke about his company seeking to be aware of the potential for how technologies can be combined to create disruptive change. He emphasised the importance of seeking to identify the business models of the future.

> *So, let me give you my view of it. And maybe that's slightly controversial. For me, the challenge with all these [4IR] technologies is not - there's nothing new about them - it's about how they converge. So IoT is not new. We've had tracking devices, or as many as five tracking devices … for 10 years. That is IoT. And we've had them because if you don't have them, and somebody steals your track with all this product on you need to find your track. So, the IoT, as a technology, is not new.*
>
> *The challenge is, if you can use IoT and combine it with big data and combine it with … machine learning … or with smart contracts in terms of block chain, you can create a new business model, you can create a disruption.*
>
> *So, I think there's a lot of people that think that … the list of 4IR technologies is the hoo-ha. It will change things. In the automotive industry, it is the convergence of battery technology, with computing power with the whatever you call surveillance technology that has the ability - or even a shared economy. So how do you bring that together? That will totally disrupt the market, and then it will happen quite quickly.*
>
> *So, we've identified a very specific list of technologies that we think will disrupt us or that we know is already disrupting us. But when we're looking at the disruption, we're actually saying, 'Well, how could we bring them together to create a new proposition or a new business model or a new business … where they converge, rather than on their own' … On their own, they'll drive efficiency, but I think the bigger opportunity lies in conversion … it allows you to fundamentally shift the value chain. I think then something happens.* (F09-I11)

Increased collaboration was also a major theme that respondents highlighted. One respondent described that all the skills needed for 4IR systems of the future will not be held within individual companies and that increased collaboration will be necessary.

> *There is not a single company that can have all the skills that are required to provide future offerings.* (F18-I34)

One respondent speculated that product design would become increasingly modularised.

> *The component tree is going to be, where originally a lot of the components were owned by the motor manufacturers, the motor manufacturers did all the design everything themselves of every little part and they put it together. What's going to happen in the future is a lot of this is going to be systemised. So, for example, a conditioning system, the motor manufacturer won't design it anymore. You'll send it up to the specialist, or a central door locking system.* (F22-I39)

A key 4IR business model involves businesses moving from selling equipment to selling the services of the equipment. One respondent described how, in this model, businesses will have the benefit of being able to monitor users' behaviour and potentially gain other rewards from the data generated.

> *They'll put down a machine you can use it to manufacture but it's almost a pay per use. It's not about the machine anymore. It's about the use and the data they get from it.* (F13-I22)

Another issue is that the development of new infrastructure can change the opportunities of the future. One respondent spoke about infrastructure development leading to businesses' changing abilities to implement 4IR systems.

> *Because the robot also fits into the IoT, Internet of Things, which means it will always be connected. And that's something we do have a problem with in Africa … I can definitely see a lot of benefit if we do get 5G. And not even just for my project, just in general industry. Many or most of our applications or solutions we provide require total transfer at high speeds. And even if it's just for fault finding in the factory. No humans involved just with sensors … even if just the tool is moved from one room to another room, tracking that tool … so there's a lot we can do.* (F13-I21)

A further issue mentioned was that changing demands in new 4IR systems will change the type of manufacturing businesses that are needed for intermediary products. One respondent discussed how he thinks new vehicle technology will affect the viability of some businesses in automotive supply chains, and that this process is already happening.

> *If we're talking about the industry as a whole, I mean, it costs nothing now for the car to drive itself. The car to book in its own services. The car does everything. It's literally autonomous, completely. And with the legislation in the automotive industry, globally, at the moment, where they're trying to reduce the emissions and the carbon footprint, where they're going battery operated, you find less and less*

> *of the vehicles requiring heavier springs, you see? So that means they … are going to be lighter and stuff again.*
>
> *… Lots of guys, specifically, like you get the exhaust, the catalytic guys, they're going to lose a lot of business. Because if you don't need exhausts anymore for the engines, the engine manufacturers, because it's all battery and motor operated.*
>
> *And I'll give a typical example. One of guys … they've now moved their core business to building hospital beds because they realised that their business is going to be dead [in] five years' time. So, now they've moved to produce [a] range [of] hospital beds. And, it's becoming more profitable for them. [So,] it's still a welding operation. You still use the same machinery with a little bit of investment and a modification.*
>
> *… We are in the fourth generation at the moment … cars are all hooked up, connected. I mean, if you buy a latest car now, [it] tells you when you need to go for the service. And with your cell phones all interlinked and integrated … Toyota has opened up a company globally just to handle data from all the vehicles.* (F14-I28)

Finally, the experience of change is not expected to be universal. Changes in different industries will happen at different paces. One respondent discussed some of these differences.

> *I think some of the industries are more receptive to new technologies than others and some have already progressed somewhat and some have to play catch up and those who are playing catch up also in some instances were actually [better off] … because now the technology is much better, the availability is better, affordability is better. For instance … mining will lag behind when it comes to adaptive technologies … at this point in time, really there is very much technology [that] is affordable. It has skills acquired now. [It's a] bit more decentralised than it was before … So, the GPS tracking a few years or quite a number of years ago [people] installed those gadgets in their cars. And that infrastructure is now improved. And the guys who are only adapting that technology now are getting much better technology, much cheaper, much more advanced*. (F07-I07)

2C: Jobs of the Future

As employment levels are a major concern in South Africa, the effects of 4IR on employment were often a key issue for the respondents. A wide variety of perspectives were shared about the effect 4IR will have on the jobs of the future. Some respondents were more optimistic, while others expected high levels of job loss.

One respondent highlighted a fundamental aspect of 4IR as involving a decreased need for human labour.

> *The revolution part for me comes, where you start to directly replace a person doing a job … what we do that's maybe part of that revolution is the implementation and possibly further development of, of technologies that are*

> *considered part of it. So, the machine learning aspect and the AI aspect of all of that. But yes, I would call it a revolution. I think it would be stupid not to do that. And I think the scope of that is yet to be determined.* (F21-I37)

Another respondent described job losses as being inevitable.

> *I got involved with the discussions with some of the unions around the labour impact on South African companies, which of course, labour is a big thing here. We just got the stats yesterday of 29% and they're scary. The truth of the matter is that direct labour will inevitably be impacted.* (F20-I41)

Other respondents did not expect a very large impact.

> *[A] gradual move, as opposed to be something very sudden, and there's a huge sharp edge. And I'm a bit of a cynic. I look at all these arguments … all the hype about technology changing jobs … one is disappeared, the lift elevator guy. The rest of this shifted from being a telegram operator to a telephone operator to a call centre … I'm very sceptical. I'm not seeing it at least in my business.* (F07-I08)

One respondent described how technology has been changing the nature of jobs for years, but the same people are able to adapt and do jobs with different day-to-day aspects, such as a secretary managing files on a computer instead of in a filing cabinet.

> *We haven't reduced our workforce, because we have adopted a particular technology. I personally avoid that … She's still there in front. The lady who sits there is still there in front but her job has changed. Instead of making sure you're filling in this book, we're improving the quality of her job, and we've taken something manual … her job has been enriched; she does more things that are different.* (F07-I08)

However, this respondent did acknowledge some types of jobs could be replaced completely and actually felt they should be replaced by technological solutions.

> *So, I do agree that technology does displace … It's not so bad because they should have been doing that in the first place. I'd wait for a time when I mean … If you go underground 4,2 kilometres … Robots should be doing that. Absolutely. Will people lose their jobs? Yes. But then this is why policymakers should be ahead of the game, to make sure you find ways of absorbing those people.* (F07-I08)

Another perspective is that 4IR will create new types of jobs that do not currently exist.

> *So, by changing from old landlines, IP phones to mobile phones, certain jobs have been displaced, but certain jobs have grown. So, on a net basis, technology creates jobs. It doesn't, at least in my experience, it doesn't kill jobs.* (F07-I08)

A common perspective was that some jobs might disappear but new ones will be created.

> *Guys in the bottom [they're] gonna be called a universal worker. He's going to be able to do all sorts of stuff wearing goggles and the goggles will tell him what to do. But middle management's going to disappear.*

> *… There should be an increase in employment to handle the new complexities. That's another key word … 'Complexity'. So, it's introduction of complexities because of all this 4IR. All that noise has introduced [a] huge amount of complexity. And nobody can handle it. So, we need new skill sets to try to understand all these complexities and see it in the different layers that you know, fractals and fractals, so that you're talking about fractals, and then you're smashing it with a hammer and then you driving over it, and then you're blowing it up again … So, it's a mess. To try and understand all of that you're going to have very specific types of skills to try and see these pictures and tease out the different things.*
>
> *… We need more people. We need more software developers, because we need more people to create solutions on software side. We need more badly. So, we need it but on your process plants, if you're automating, [there] will be a reduction of certain skills, but increasing [of] others skills. But we don't know what the balance is. Because it can change. You know, it has to be very flexible, agile.* (F06-I06)

Another respondent highlighted that, while new jobs will be created, people in current positions will lose their jobs.

> *I think it depends on whose point of view you look at it from. If you look at it from the production side, introducing robotics will reduce the requirement of the labour, because it starts to substitute what you're doing manually. So, if you look at it from a pure production operation, it starts to have an impact on your employment. But if you look at it from an industry point of view, as a whole value chain, I think it has a different picture, because now you're creating a whole new industry.* (F22-I39)

The respondent above who described job losses as inevitable also said that, overall, new jobs would be created through increased technology. However, he cautioned that those new jobs may not be in South Africa.

> *Labour generally does increase after the fact. And it's not always visible. And it's not always in the same industry … So, the indirect impact is global. So, it might not be realised right here. And it might not be accepted that it happens, because it's not right here.* (F20-I41)

Another dynamic that was described was that there would be a shift in where jobs will be needed.

> *With regard to my experience experienced in recent projects, but I do have a quite a strong and more realistic opinion. And that is the, this whole fear of jobs being lost to automation is kind of silly. I mean, all throughout history, as technology has progressed, people had certain jobs, and then technology comes and makes their job easier. And then people find other ways to stay busy. And it's usually in a more productive way. And it gets better and result for society. So, I mean, in the short, a short term, maybe some people will lose jobs. But I think if you look at it very big picture, holistically the world, the technology, you can't stifle technology, because you're the development and progression of technology, because you're replacing some people's jobs, there's going to be new jobs that are created, and so forth*.

(F13-I25)

Another issue was that employment may be created from new types of businesses. One respondent highlighted that job creation in the future may rely more on smaller firms than it currently does.

> *Today, South Africa's economy is running on large corporates. But I do believe that there are gigantic opportunities for small and medium sized companies to provide the jobs of tomorrow that still need to be invented. And I cannot answer that question what type of jobs we are talking about, because they still need to be invented. But I do know that they will be invented … So, I think if you talk in in the domain of app suppliers or software in general, I do believe that there is a lot of potential … Do we have the right skills to get there? That's another discussion.* (F17-I33)

Emphasising that there would always be need a for human labour, one respondent described that humans will always be needed to have opinions and make creative decisions.

> *Robots can't think … The problem is an operator is not a thinker. It's just an inefficient robot, right. So, but … there's certain things that machines could never take away.*
>
> *… Looking at running our operation, so, the engineering side of things, you could probably draw stuff from a library automatically get it in, but to interact with the clients, even if you sent something that's almost perfect, he's always going to want to put something of his own touch … and you need that human interface to go 'Well, maybe it won't work or yes, it will work. That's a great idea'. You know, that that kind of thing.* (F05-I05)

One perspective was that 4IR can be a way to improve the quality of people's jobs. One respondent described the potential for technology to help people see things in new ways.

> *In this environment of much more data, you want to know that things are happening in a certain way, and you want to read from it so that you can learn from it. Because machine learning is going to give you certain … Who's going to program a machine-learning algorithm to learn in a certain way and exclude [or] include other things? It will come from the person that analyses the data … critical thinkers … at the end … they will end up in machine learning. And it will still be challenged. I don't believe a machine will ever outperform a human mind. People will just see more trends, or they will see things they've never seen before. It will be easier. So, then our employees can have less stressful jobs. If they're not here the job is still running.* (F04-I04)

In some cases, when people begin to learn how to incorporate 4IR technologies they build on their existing skill set.

> *This is why we never had any union issues, because they saw the positive impact. It's an up skill; it's an indirect labour increase, also productivity. And all of those things, of course, are very combined.* (F20-I41)

Another concern about the future of work and the expansion of 4IR systems was the growth of technological monitoring systems. One respondent highlighted this issue.

> *We developed something that was rejected by the unions … Our mistake was to put a camera in front … The unions rejected that.* (F07-I08)

Another issue that arose was the need to manage the changes that will be created through the expansion of 4IR systems. Soft skills were described as playing a pivotal role in how 4IR develops.

> *Soft skills I think are far more important than technology skills at the back of this.* (F06-I06)

Overall, a variety of new skills were expected to be needed by the workers of the future. In addition to speaking about the need for more 'soft skills', respondents also highlighted the need for more technical skills.

> *We will now need people [with] more softer skills. Universities will shift … In South Africa today, I need more tech people. Because we don't have them in the same numbers as what may be happening in France, perhaps. We have we [been] producing I don't know what the numbers are … but I know by far the majority of the people that we produce are in the humanities not sciences … We need to go the opposite direction. Otherwise, yes, jobs will be displaced to the north. And then [we will] remain consumers of technology.* (F07-I08)

Some respondents also described the creation of 4IR jobs that would not require high levels of skills.

> *Where we're maturing with regards to some of the IoT sensors … in any of our countries, Ghana, Nigeria, Kenya, Malawi and the skills are actually easily transferable. So, for a person paper picking today, you will be able to teach them to scan pick tomorrow.* (F09-I11)

Another respondent described that, as technologies become more developed, people will need fewer skills to work systems that previously involved high-level computer skills.

> *If you really do dig deep into what's going on in, call it the blanket term sort of AI research. Fundamentally, it has the capability of uprooting a lot of the stuff that we do.* (F21-I37)

As mentioned in the second working paper in this series (Alexander 2021b), this respondent went on to say that, in cases where a business used to need a team of software engineers, new developments were providing systems with simple user interfaces that businesses buy ready-made.

Another issue that some businesses may face is the need to hire more qualified workers. In a survey by PWC and the Minerals Council South Africa (PWC 2021), mining businesses said they anticipated significant increases in per capita productivity and expected that their future workforce will have a higher skill base and be more expensive. Almost all mining leaders

surveyed (95%) believe there would be a change in the workforce in the next five years. While some were concerned with the expectation of increased costs, most expected that increased productivity would more than offset the costs.

2D: Respondents' Expectations for the Role of Government

Interviewees for this working paper series also expressed diverse perspectives related to their expectations for the role played by the government in managing changes related to 4IR. One key issue was that 4IR would require more cooperation between different stakeholders. One respondent described this as a necessity.

> *[Individual firms] don't have the muscle. It doesn't make sense just for one company. So there has to be industry bodies that have to come together and say, 'Okay, what do we need to carry this economy forward? What is the future generation that we need to define from this country as a whole?' and we need to translate that into an action plan.*
>
> *But also, regulations, legislation, that guides the industry, going forward as a whole. And even to the point that says that, if you train 10 young engineers on becoming data scientists, you will get sort of [a] tax rebate, and you set up a company. There has to be some government incentive that drives that behaviour, ultimately. Singapore is a world-class example of how it's actually done. China's done tremendously well; we are lagging in that space at this point in time. And forget about the nine years that we've wasted in this country. And I'm hoping the president does push that agenda going forward. But there has to be collaboration between government between the private sector and sort of non-profits, organisations, bodies to drive institutions. Absolutely.* (F07-I09)

Several respondents spoke about the importance of government policies in driving forward developments related to 4IR.

> *But that comes back to a government intervention or government policy to say, 'Guys, let's do this'. Like, exactly what Nigeria is doing. They're spending a lot of money on robotics. A lot of money in Ghana. Government-sponsored departments of science … So, you know, our government talks like [a] toothless dog around industry 4.0. and we need to engage.* (F20-I41)

One respondent described hope in positive outcomes coming from the PC4IR.

> *Unfortunately, we don't have an enabling legislation. Let's hope our current president will put that together. He has put together this panel of experts [the PC4IR].* (F07-I09)

Another respondent highlighted the potential value of subsidies.

> *The end goal is to be more productive, and more effective with the same amount of time and resources. And considering that it could affect the turnover of local engineering companies, if their equipment … was more industry 4 ready, and they could do more in a shorter amount of time, then I would say the government could*

> *subsidise them to actually equip themselves or enable their company to be more industry 4 ready.* (F13-I25)

As discussed throughout this working paper series (Alexander 2021a, 2021b, 2021c), a key factor for improving the development of 4IR systems and businesses is access to the needed infrastructure. Respondents also shared expectations for the government related to providing adequate infrastructure.

One respondent spoke about investing in broad-ranging infrastructure and support systems that can help South African industry to grow.

> *If you look at countries like that have really grown the automotive industry like Thailand, Turkey … they've made fundamental decisions at a country government level to say, okay, we're going to be, we're going to be the attractive site for automotive. And this is how we're going to do it.*
>
> *And they've also then said, okay, government will put in a proper R&D learning site and creation. They're putting the testing facilities to make sure they can validate the parts and things. So, they build this infrastructure.*
>
> *Then they've said to the auto motors, okay, if you want to come and do business in our country, you have to do this. You have to localise these kinds of parts … They made it attractive.*
>
> *So, they put [in] the resources, infrastructure. And it's cost competitive for them. In South Africa, we don't have that country strategy that makes South Africa attractive to be the next automotive player, if I can put it that way. Look in Morocco, and they're all growing now. They're making fundamental decisions, from a government point of view on how to set up the infrastructure, electricity, power, roads, rail, everything. The ports are set up. They've got proper trade agreements set up with countries they need to trade with. They're bringing the technology in. They're bringing the skills in and they're training the people. Morocco is probably going to be one of the next big, big automotive hubs, if you look at them and the way they're going. And unfortunately, we're kind of still far behind.* (F22-I39)

Respondents also described other roles that the government can play. One respondent spoke about the expectation for the government to deal with the loss of jobs that would be caused by increased automation.

> *Government has a big role. They come up with the policies that allow us to operate. That's the job of government. Enabling empowerment, to deal with the issue of jobs that are repetitive, that will be displaced.* (F07-I08)

Another issue is the role of the government as an employer. As a large employer, the government's decisions can have an effect on the types of jobs people have and train for.

> *Because if you look at [it] from a manufacturing perspective, that's where the majority of employment happens, right? If it's mining or parastatals be it Transnet*

> *or Eskom or anybody. Those are employment hubs. So those are the areas and markets and industries … I believe should be targeted.* (F20-I41)

Respondents also expressed a variety of expectations of how the education system should respond to the growth of 4IR. One respondent said that educational changes were needed to change the perspectives of the industry players.

> *It comes back to [a] question … What is the market about? How does the market see it? It's the maturity. It's customers. It's government. It's educational institutes. To adopt a vision of, and it's not a vision of the future, it's a vision of what's currently happening everywhere in the world … how archaic many of our systems actually are. And they are fortunately, certainly certain individuals in the South African context that are trying really hard … And using robotics and using robotic technologies, as a tool to almost entice industry, if that makes sense. And try and engage with government and at least try and prepare policies that will, again, enhance from an educational perspective. The next step, and this is the biggest thing … It takes a person in power to implement something. And it all starts at school, university, and government level, because then all the gaps get filled in.* (F20-I41)

A number of respondents spoke about the need for people to have diverse skills and be able to engage across clearly defined disciplinary barriers. One respondent provided a series of recommendations related to education.

> *We need to make sure that absolutely everybody's got access to the internet. There's so much online learning that you can do that's available. That must be [a] very structured approach to getting the absolute best teachers in the world to come and teach our kids by internet …. So digital teaching needs to take off. Then that means that everybody's got equal value because they've got equal learning through an equal system. The digital teaching and education mustn't only be restricted to these fancy schools and so on. It must be that little kid under the thorn tree in Giyani. [He] must have the same access to the best online teaching as the kid in Cornwall or one of these private schools. [It] must be the same.*
>
> *Then technically speaking, we need to have like lab facilities and that there are some people that are going [to] mobile lab facilities for [the] science side of things. That needs to be available to everyone. It's not that difficult.*
>
> *Your curriculums, in that the way we're imparting knowledge, it's garbage. It's been garbage since I was in school. I hated school, because it's in a square box. This is art. This is how you draw a straight line. And this is how you colour in this thing. That's boring. This is the Greeks …. Then you pass. Now you an artist. So, that's garbage. That needs to be changed.*
>
> *… I think art needs to be compulsory right through to matric. Everybody needs to be [taught the arts] because that's the only way we're going to get people creative. Music, arts and culture, movie making, all of that. So, we can get the imagination going again because people don't have imagination. They've lost their imagination. And if we don't have imagination, I can't connect these dots and I can't connect*

> *them up to create new solutions. So, we need imagination. We need dreamers. School has to create dreamers. Dreaming must be encouraged, has to be encouraged.* (F06-I06)

Another respondent described the need for education systems to keep up to date to prepare students for skills that will be needed in the future.

> *A self-driving car. So, it's coming. We should be training our kids now. How to master this technology. So, when the time comes, they are ready. They should be the innovators. Voice activation. We don't have to press buttons anymore. We talked to the machine and the machine does. That's reality. It's coming. All of that. We should be gearing the education towards those kinds of things. But I'm not sure we do that.* (F12-I18)

The need to improve training to support industry in the future was highlighted by another respondent. This was described as part of South Africa being able to compete with other countries.

> *[Training at multiple occupational levels] has to happen. The way that we are now, our markets, especially in the automotive, all the decisions are being made on a global level.*
>
> *… So, if we don't embrace this, and don't become as technologically efficient, or savvy as the likes of America, or Germany or Thailand, then we won't have jobs. So, it's something that we have to do.* (F14-I29)

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