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TIPS RESEARCH REPORT FOR

DEPARTMENT OF TRADE AND INDUSTRY

WORLD ECONOMIC FORUM AND THE FOURTH INDUSTRIAL REVOLUTION IN SOUTH AFRICA

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ABOUT THIS PUBLICATION

This working paper*, World Economic Forum and the fourth industrial revolution in South Africa,* was commissioned by the Future Industrial Production Technologies Chief Directorate of the Department of Trade and Industry (the dti). This unit is focused on preparing South African industry for the fourth industrial revolution.

It is the second paper in a series and focuses on the fourth industrial revolution and the concept as promoted by the World Economic Forum (WEF), international consultancies, governments and multinational.

Other papers in the series are *Framing the concepts that underpin discontinuous technological change, technological capability and absorptive capacity; Mapping the meso space that enables technological change, productivity improvement and innovation in the manufacturing sector;* and *Technological change and sustainable mobility: An overview of global trends and South African developments.*

Saul Levin (TIPS) directed the project, and Dr Shawn Cunningham of Mesopartner was the lead researcher and author.

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TABLE OF CONTENTS

List of figures

List of tables

ABBREVIATIONS

4IR	Fourth Industrial Revolution
BMWi	Federal Ministry for Economic Affairs and Energy
BRICS	Brazil, Russia, India, China, South Africa
CID	Harvard Centre for International Development
CSIR	The Council for Scientific and Industrial Research
DEI	Digital Evolution Index
DST	Department of Science and Technology
dti (the)	Department of Trade and Industry
EIIR	European Institute of Interdisciplinary Research
FIR	Fourth Industrial Revolution
HS	Harmonised System
ICT	Information and Communication Technology
IDC	Industrial Development Corporation
MIT	Massachusetts Institute of Technology
PCI	Product Complexity Index
RCA	Revealed Comparative Advantage
R&D	Research and Development
R&D&I	Research and Development and Innovation
RSA	Republic of South African
UAE	United Arab Emirates
US	United States of America
WEF	World Economic Forum

EXECUTIVE SUMMARY

The report provides a critique of the World Economic Forum's country readiness assessment of South Africa. It provides a brief summary of the main elements of the so-called fourth industrial revolution, with a specific emphasis on the role of government. It unpacks how South Africa was assessed by the WEF in 2018 and highlights some key insights provided by the WEF.

The report points to some critique of the concept of the fourth industrial revolution. However, the authors found that despite weaknesses in the WEFs methodology of assessment, their placement of South Africa in the nascent domain is probably correct as other global assessments have also identified that the country is not as prepared for technological and digital change as it should be. These include the global technological capability assessment, the global digital capability assessment and the Harvard Atlas of Economic Complexity instrument.

1 INTRODUCTION

This report introduces the fundamental elements of the fourth industrial revolution theme promoted by the World Economic Forum in recent years. The intent of this section is to simplify and provide the conceptual grounding for the Department of Trade and Industry (the dti). This will help the dti engage with their public and private sector counterparts to assess and better cope with disruptive technological change in the country, and to ensure institutional resilience and technological readiness.

The first mention of the Fourth Industrial Revolution can be traced back to the 1940s. Since then claims have often been made about a next revolution. What makes the message by the WEF different from previous claims is the widespread media and political interest in the current discussions.

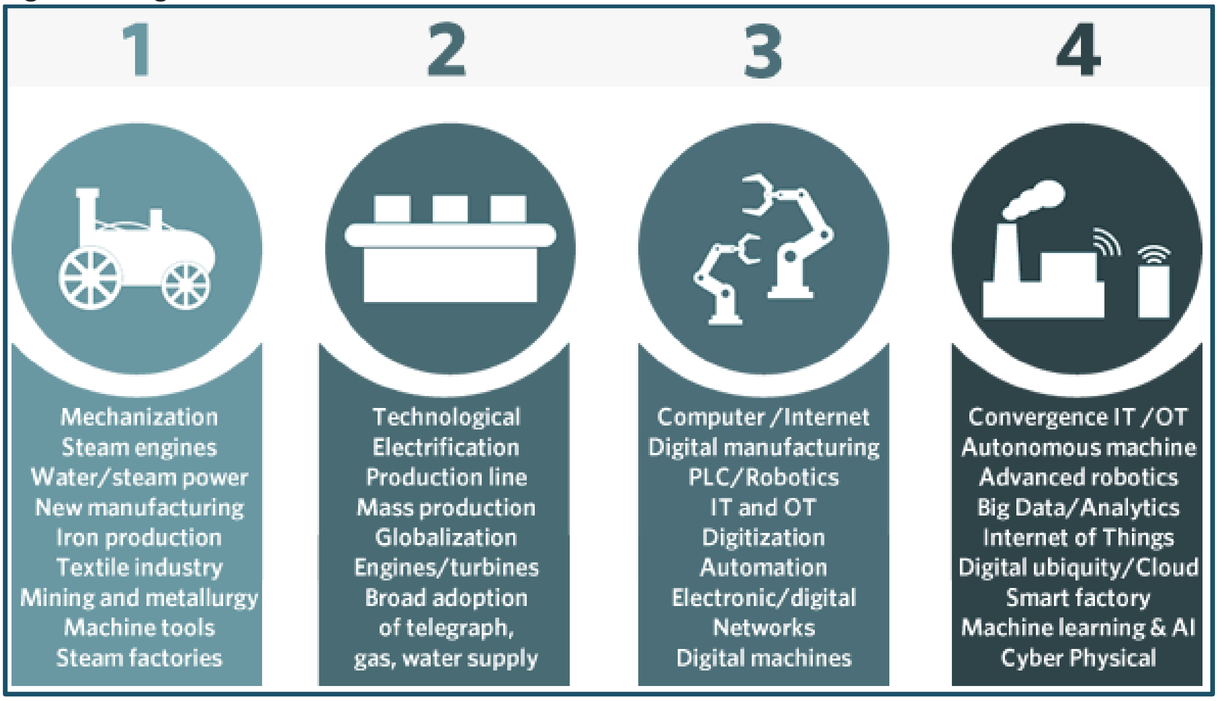
Industrial revolutions generally describe periods in modern human history where technological innovation resulted in a drastic shift in the socio-economic status of people. There is a broad agreement that the global economy has experienced three major industrial revolutions, and is, as argued by the likes of the World Economic Forum, is in the fourth stage.

In the period 1760 -1840, steam locomotive power and mechanised textile manufacturing created the first industrial revolution. From the end of the 19th century to early 20th century, the advent of electricity, mass production, and division of labour brought about the second industrial revolution. The third industrial revolution took place during the early 1980s with the introduction of electronics, IT, and automated production. We are now entering a fourth industrial revolution based on the technologies, convergences and production changes described below. There are, however scholars and others who disagree with the WEF's take on the Fourth Industrial Revolution. Chapter 5 of this document will unpack some of the different opinions.

The new catchphrases for the Fourth Industrial Revolution are "industry 4.0", "smart industry", "intelligent industry", "smart factory", "smart manufacturing" or in general "fourth industrial revolution". Sometimes these phrases are used interchangeably and as synonyms, while at other times each term is used separately. In academic and practitioner literature, these terms can be traced back over 40 years and clearly have different groundings and backgrounds. For instance, the term "factories of the future" has existed since the 1980s. This means that in this revolution not only do technologies converge, so too do interests and concepts.

According to Schwab (2017), "*the fourth industrial revolution is fundamentally different from the previous revolutions as it is characterised by a range of new technologies that are fusing the physical, digital and biological worlds, impacting all disciplines, economies and industries*". There is a strong message of convergence with a keen focus on the pervasiveness of digital technologies.

Figure 1: Stages of industrial revolutions



Source: i-scoop. Downloaded from https://www.i-scoop.eu/industry-4-0/ in April 2018.

As Table 1 below shows there is an increasing discourse in the use of the terminology around the fourth industrial revolution, often used together with or interchangeably with the term "industry 4.0". In the literature, it seems as if the Fourth Industrial Revolution phrase describes a global phenomenon that can be observed as digitisation, connectivity, and new scientific discoveries cascade through industries and applications, while Industry 4.0[1] refers to pro-active strategies by governments and industries to digitalise and modernise their industries.

Table 1 contains several definitions of Industry 4.0 that illustrates the widely differing interpretations.

Table 1: Different descriptions of Industry 4.0

Industry 4.0 according to Wikipedia Industry 4.0 is the current trend of automation and data exchange in manufacturing technologies. It includes cyber-physical systems, the Internet of things and cloud computing. Industry 4.0 creates what has been called a "smart factory".
Industry 4.0 according to McKinsey Industry 4.0 is the next phase in the digitisation of the manufacturing sector, driven by four disruptions: the astonishing rise in data volumes, computational power, and connectivity, especially new low-power wide-area networks; the emergence of analytics and business-intelligence capabilities; new forms of human-machine interaction such as touch interfaces and augmented-reality systems; and improvements in transferring digital instructions to the physical world, such as advanced robotics and 3-D printing.

[1] The term "Industrie 4.0" originates from a project in the high-tech strategy of the German Federal Ministry for Economic Affairs and Energy, which promotes the digitisation of manufacturing BMWi (2014). The German government established "Plattform Industrie 4.0" to support German SMEs by helping them understand and exploit Industry 4.0 strategies and opportunities, particularly in the areas of standardisation and norms, security, legal frameworks, research, and workforce transformation. For more information visit https://www.plattform-i40.de/I40/Navigation/EN.

Industry 4.0 according to German Trade and Invest (GTAI)
Smart industry or "INDUSTRIE 4.0" refers to the technological evolution from embedded systems to cyber-physical systems. Put simply, INDUSTRIE 4.0 represents the coming fourth industrial revolution on the way to an Internet of Things, Data and Services. Decentralised intelligence helps create intelligent object networking and independent process management, with the interaction of the real and virtual worlds representing a crucial new aspect of the manufacturing and production process. INDUSTRIE 4.0 represents a paradigm shift from "centralised" to "decentralised" production – made possible by technological advances which constitute a reversal of conventional production process logic. Simply put, this means that industrial production machinery no longer simply "processes" the product, but that the product communicates with the machinery to tell it exactly what to do. INDUSTRIE 4.0 connects embedded system production technologies and smart production processes to pave the way to a new technological age which will radically transform industry and production value chains and business models (e.g. "smart factory").
Industrie 4.0 according to the German Federal Ministry for Economic Affairs and Energy Industrie 4.0 refers to the intelligent networking of machines and processes for industry with the help of information and communication technology through for instance: flexible production, convertible and reconfigurable factories, customer-oriented solutions, optimised logistics, use of data and a resource-efficient circular economy

2 UNPACKING THE ELEMENTS OF THE FOURTH INDUSTRIAL REVOLUTION

The World Economic Forum is raising the awareness of global leaders of the expected changes in society as the 4th industrial revolution expands. Klaus Scwab, the founder and executive chairman of the World Economic Forum, claims that this fourth industrial revolution is different from the preceding revolutions because of its velocity and exponential rate, breadth and depth of convergence and its systems impact on industries, firms, governments and whole societies (Schwab, 2017). The recent annual and regional meetings of the WEF have focused on the effect, the reach and the pervasiveness of this revolution.

Production has long been a major driver for growth, prosperity and innovation, and many economies have experienced accelerated growth and development through industrialisation. However, the traditional industrial development models that have supported growth in the past may not be viable models in the future (WEF, 2018a). This explains why developing countries are eager to not fall further behind or even to leapfrog other countries. Developed countries are also under pressure as falling behind could also have enormous economic and social consequences.

The fourth industrial revolution is seen to have profound effects on many spheres, not least of which is jobs and employment. The WEF observes that new industries are creating fewer jobs, and those jobs require advanced skills (WEF, 2017). Furthermore, technologies such as artificial intelligence and robotics may destroy or disrupt many jobs in the services sector and in labour-intensive industries. Increased digitalisation will also necessitate more attention being paid to associated risks such as cybersecurity, privacy and data security, to name a few.

According to the WEF, the Fourth Industrial Revolution is bringing about the development of new techniques and business models which will fundamentally transform production process, government decisions, industry and the society at large, as they will be confronted by a new set of challenges and uncertainties. This shifts the attention from physical technologies towards adaptive social technologies, an area where trust, policy networks, learning by doing, and collaboration between different social actors are critical success factors. These are also the areas where developing countries have the most challenges, with inequality, low trust between social actors, centralised government, industry concentration and higher costs of search, discovery and failure. Despite this understanding, a review of the WEF website and WEF reports shows that most of the attention is on physical and data technologies and how they will affect industries, productivity, costs and societies, with only occasional reference to the importance of, among others, fostering new social technologies and governance arrangements.

This “new” phase of technological advancement is forecasting the widespread application of robotics and automation, artificial intelligence, nanotechnology and material sciences to traditional and new industries. This is expected to change future production processes significantly and as a result affect the development and implementation of future industrial strategies.

Table 2 highlights some of the aggregate or high-level technologies that are commonly described as fourth industrial revolution key technologies.

Table 2: Technologies promoted under the Fourth Industrial Revolution

Technology	Description
Artificial intelligence and robotics	Development of machines that can substitute for humans, increasingly in tasks
Ubiquitous linked sensors	Also known as the "Internet of Things". The use of networked sensors to remotely connect, track and manage products, systems and grids.
Virtual and augmented realities	Next-step interfaces between humans and computers involving immersive environments, holographic readouts, and digitally produced overlays for mixed-reality experiences.
Additive manufacturing	Advances in additive manufacturing, using a widening range of materials and methods. Innovations include 3D bioprinting of organic tissues.
Blockchain and distributed ledger technology	Distributed ledger technology based on cryptographic systems that manage, verify and publicly record transaction data; the basis of "cryptocurrencies" such as bitcoin.
Advanced materials and nanomaterials	Creation of new materials and nanostructures for the development of beneficial material properties, such as thermoelectric efficiency, shape retention and new functionality.
Energy capture, storage and transmission	Breakthroughs in battery and fuel cell efficiency; renewable energy through solar, wind, and tidal technologies; energy distribution through smart grid systems; wireless energy transfer; and more.
New computing technologies	New architectures for computing hardware, such as quantum computing, biological computing or neural network processing, as well as innovative expansion of current computing technologies.
Biotechnologies	Innovations in genetic engineering, sequencing and therapeutics, as well as biological computational interfaces and synthetic biology.
Geoengineering	Technological intervention in planetary systems, typically to mitigate effects of climate change by removing carbon dioxide or managing solar radiation.
Neurotechnology	Innovations such as smart drugs, neuroimaging and bioelectronic interfaces that allow for reading, communicating and influencing human brain activity.
Space technologies	Developments allowing for greater access to and exploration of space, including microsatellites, advanced telescopes, reusable rockets and integrated rocket-jet engines.

Source: The WEF and A.T Kearney (Schulz, Gott, Blaylock and Zuazua, 2018)

As argued by WEF and firms such as AT Kearney, among others, at the heart of this technological shift is the convergence of several trends. The first is a shift from mass manufacturing to the increased efficiency, flexibility and cost effectives of **mass customisation**. This trend is for instance fuelled by rapid advancements in 3D printing (additive manufacturing), new materials development, and smarter customisation techniques enabled by the digitalisation of manufacturing. The second shift that has been recognised and aligns with the physical technologies is about **mass personalisation**, enabled by social technologies, better data processing capabilities, and the better integration of customer preferences into purchasing, production and logistics. A third shift is toward the increased use of

artificial intelligence to complement and in many instances substitute human thinking, often based on accumulation of mass data (and the ability to manage and process that data) as well as using advances in technology (such as sensors and robots) to implement it.

These trends are supported by widespread **advances in information processing capabilities**, not only in computing power, but in connectivity, integration of different platforms, and automation. What were previously separate technological domains, like power generation, production, and agriculture, are now all becoming interdependent on connectivity, reliable energy, integrated supply chain management, and direct engagements with end consumers. These advances have a direct bearing on firms – big and small – and may require fundamental shifts in their production process.

The list of technologies outlined in Table 2 all appear to be standalone process technologies that can be acquired off-the-shelf. However, the real challenge to business is that these technologies require a fundamental rethink of the business and how it relates to customers, suppliers and network partners. Textbox 1 provides an example of how additive manufacturing requires a rethink of organisational design and the manufacturing process.

Textbox 1: Re-thinking an organisation to absorb a new technology

A technology like additive manufacturing (or 3D printing) does not replace one link or function in a process, it requires a complete re-think of the design, simulation, prototyping, manufacturing and maintenance chain within and between organisations. The science behind additive manufacturing makes it possible to completely rethink shapes and manufacturing as the technology allows shapes to be created that cannot be made affordably with conventional fabrication processes. Furthermore, these technologies are not just easily placed within an existing manufacturing plant. They often require specialised infrastructure, stable (clean) energy, climate control, high quality raw materials, proximity to clients, suppliers and supporting knowledge-intensive service providers. Lastly, additive manufacturing is not only confined to making components and end technologies, it is a powerful process, tool, jig and prototyping technology.

Source: Author

In another assessment, the WEF (2018b:6) outlines four radical shifts that are expected in the short to medium term:

1. Manufacturing will become self-organising and more autonomous due to a new class of factory workers or a highly connected and smart shop floor;
2. Value chains will be seamlessly connected end to end, allowing manufacturers to drive product innovation twice as fast as today;
3. Supply chains will connect to a broader supplier ecosystem that will function as a single platform, enabling business-to-business integration; and
4. Data will drive the creation of new services and innovations in business models.

Underpinning these shifts are huge changes in connectivity (sensor technology, the internet of things and mobile devices), intelligence (computing power, big data, image and speech recognition) and flexible automation. This is enabled by a wide range and depth of specialised functions in ICT, science, technology and management, sufficient funding invested in longer term research and development processes as well as proximity to sophisticated demand.

3 THE ROLE OF GOVERNMENT

The WEF (2018b:19) contends that the Fourth Industrial Revolution will lead to a new type of competition between and within countries, along with growing uncertainties across manufacturing nations. They continue that country leaders will have to be more intentional about specific efforts to diffuse and adopt technology, often aggregated under an umbrella national programme. They report that in the last six years, eight of the top 10 manufacturing countries have launched national efforts – best known as Industry 4.0 strategies – to capture productivity gains and strengthen their position globally for the future. The reasons behind this increased focus on production, with technology as a key foundational pillar, include the following:

- Countries can leapfrog their industrial development and journey to modernise by accelerating adoption of new technologies;
- For industries to adopt technologies at scale, an enabling environment including infrastructure, IT connectivity, and appropriate intellectual property laws must be developed; and
- An economy's success depends on promoting research and development and innovation (R&D&I) so that technology can be adopted and diffused at a lower cost for large, medium and small enterprises.

The WEF identifies seven types of government-led national efforts to adopt and diffuse new production technologies (WEF, 2018b:21). These need to be customised for country-specific nuances and a nation's industrial sector mix and include:

- Building awareness by communicating the importance of national initiatives and programmes to industrial policy, and by sharing success stories and lessons from technology and innovation adoption journeys for pioneering companies;
- Establishing financial incentives, such as tax credits or public loans, that support the acquisition and development of Fourth Industrial Revolution technologies for large, medium and small enterprises;
- Creating a robust legal framework to regulate areas impacted by new technologies (e.g. intellectual property, data protection, cross-border flows);
- Spurring accreditation of companies that successfully adopt Fourth Industrial Revolution technologies, nationally and internationally, thus supporting the technology and industry ecosystem;
- Expanding connectivity and data-security protection with specific efforts in production, for example creating dedicated taskforces, institutions and frameworks on cybersecurity;
- Promoting R&D&I for Fourth Industrial Revolution technologies applied to production;
- Setting up new talent and education programmes adapted to the future of the production workforce.

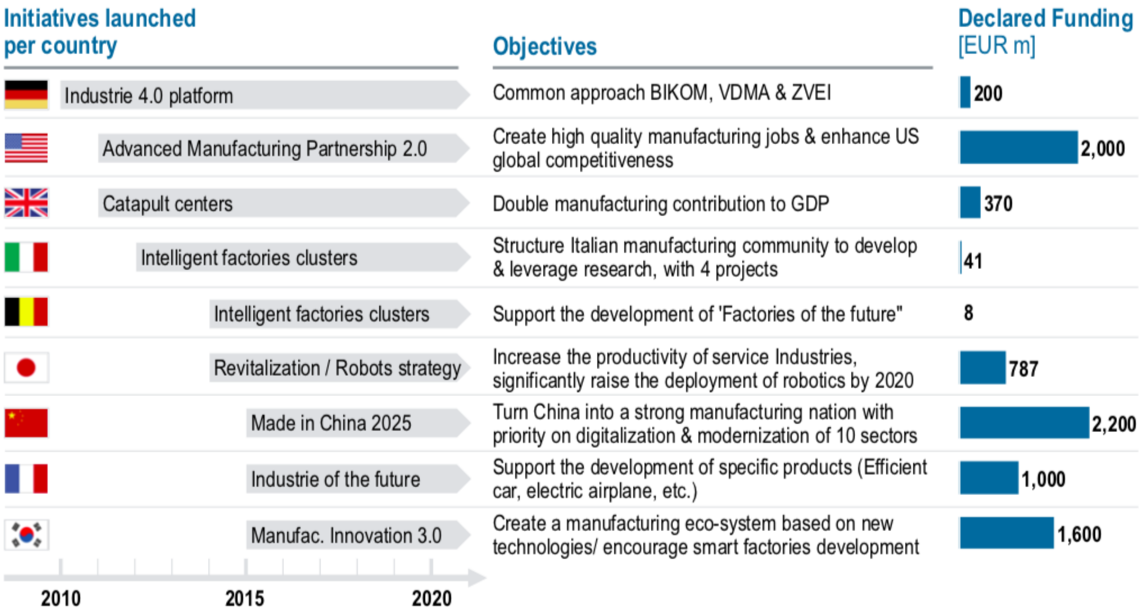
It is foreseen that the Fourth Industrial Revolution will result in a further shift from labour-intensive production to knowledge and skills-intensive production. Countries will need an adequate pool of available digital, technical, commercial and management expertise to propel the immediate adoption and use of emerging technologies (Schulz *et al.*, 2018:22). Although automation leading to job loss is a significant concern, the WEF argues that technology can make the remaining jobs more productive and even create new jobs. Human ingenuity and creativity may become more, not less, important in the future of production. The immediate near-term need, particularly for countries with a large production workforce today, is to train and re-train current employees to fill skills gaps created by job changes (Schulz *et al.*, 2018:23).

Much of the focus of the popular WEF dialogue is on the role of business and government leaders. The role of adaptation and the role of civil society is also important.[2]

While advanced economies are focusing the discussion on the potential of new technologies to improve quality of life, competitiveness and wealth, developing countries are seeking opportunities to catch up or even leapfrog technological barriers.

While the term “Fourth Industrial Revolution (FIR)” appears to be well accepted in South Africa, the description and focus of national FIR-type initiatives differs markedly from country to country. The notion of proactively preparing for a next industrial revolution originated in Germany where the paradigm was termed ‘Industrie 4.0’. This spawned a proliferation of similar, related terms such as ‘Operator 4.0,’ ‘Factory 4.0,’ ‘Services 4.0,’ etc. Selected Industry 4.0-type initiatives and their objectives are shown in Figure 2, and the rationales for these initiatives are shown in Figure 3.

Figure 2: Selected Industry 4.0 initiatives globally



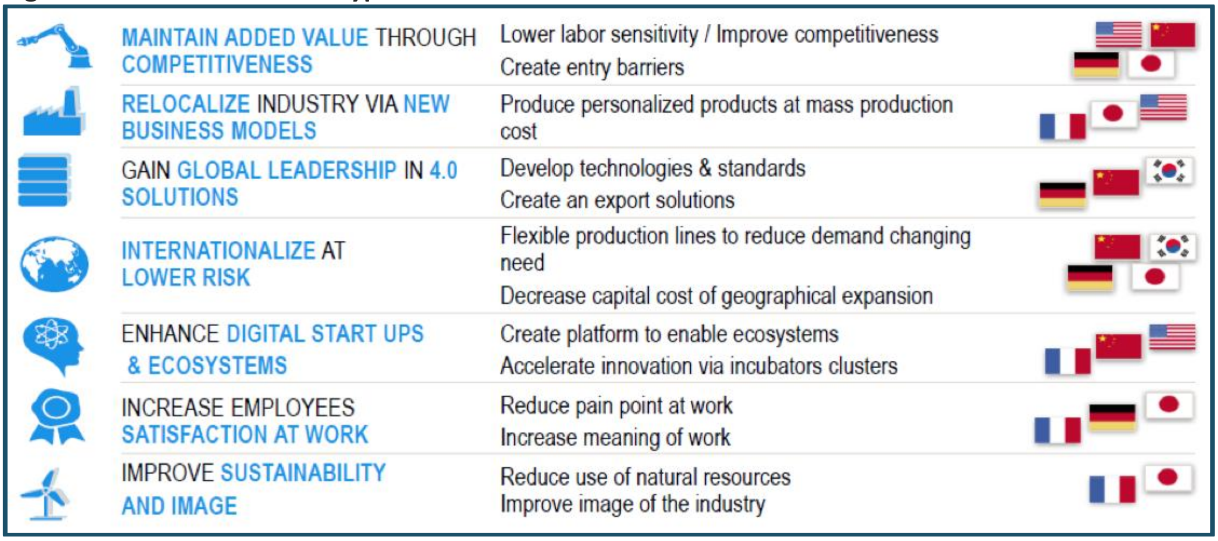
Source: Roland Berger (2018)

While the overall theme of these initiatives is about positioning and international competition, these “revolutions” and strategies in different countries have emerged from different social contexts. For instance, in Europe there is a shortage of young employees interested in technical trades. Furthermore, many European countries are falling behind in digitalisation, with countries like Singapore, the UAE and others overtaking them in digital competitiveness. The changing age demographics in many OECD countries are also shaping their interest in developing labour-saving technologies.

[2] See for instance https://www.weforum.org/agenda/2017/12/5-challenges-facing-civil-society-in-the-fourth-industrial-revolution/

In South Africa, the situation is very different. The demographic composition leans towards the youth. Unemployment is at an all-time high, with a decline in jobs in manufacturing and mining. The social contexts are also very different with regards to social nets, education levels, costs of transport, rising inequality, etc.

Figure 3: Rationales for FIR-type national initiatives



Source: Roland Berger (2018)

The WEF contends that the institutions that have traditionally had the responsibility of shaping the societal impacts of these technologies – including governments, companies and civil society organisations – are struggling to keep up with the rapid change and exponential impact (WEF, 2018a). Increasingly the demand is that governance be more agile, adaptive and flexible. The implication is that policy processes must be re-thought and redesigned, that the political nature of technologies must be better understood, and lastly that values that promote societal benefits and well-being as priorities for governance can be directed to the development and use of emerging technologies.

> *The current situation of trying to incrementally and linearly manage institutions, policies and programmes while technological change is accelerating exponentially has huge consequences for public sector management and governance.*

The increasing pace and effect of technological change at the levels of products/services, processes, and business models demands that government departments and programmes increase the speed and intensity of collaboration to strengthen the economy, governance systems and the regulatory environment.

4 THE WEF ASSESSMENT OF SOUTH AFRICA'S READINESS FOR THE FOURTH INDUSTRIAL REVOLUTION

The World Economic Forum in collaboration with A.T. Kearney developed the Readiness Diagnostic Model Framework (Schulz et al., 2018). It is described by its authors as a benchmarking framework, diagnostic tool and data set aimed at helping countries and their policy makers to evaluate their level of readiness for the future of production, so that they can identify key opportunities and challenges as they transition to future technologies. The WEF describes production as involving a broad spectrum of economic activity related to manufacturing products and goods. A full end-to- end appraisal of what it entails reveals the following sequence: Design-Source-Manufacture-Assemble-Distribute-Service-End of use-cycle.

Advanced manufacturing refers to the use of innovative technology to improve processes and products, while traditional manufacturing relies more on the use manual or mechanised techniques.

There are two key hypotheses and working assumptions that govern the assessment:

> $\boldsymbol{H_0}$: *The most important drivers of future readiness are technology and innovation, human capital, institutional framework, and global trade and investment. These drivers have the strongest correlation with economic complexity. The needs within each driver will evolve as we shift from current to future production paradigms, but the overall drivers will remain significant.*
>
> $\boldsymbol{H_1}$: *Scale is not a prerequisite for future readiness. Economic complexity is more important than scale for readiness for the future of production. The ability to gather, combine and use knowledge embedded in people and technology to create a range of unique products will become an increasingly important competitive advantage. Thus, small countries such as Switzerland or Singapore are not necessarily at a disadvantage against global giants with larger scale.*

In this context, readiness is defined as "the ability to capitalise on future production opportunities, mitigate risk and challenges and be resilient and agile in responding to unknown future shocks". Elsewhere, the WEF explains that readiness represents the extent to which a country has capacity and is well positioned today to do the following in the future (Schulz *et al.*, 2018:3):

1) Capitalise on advanced manufacturing opportunities;

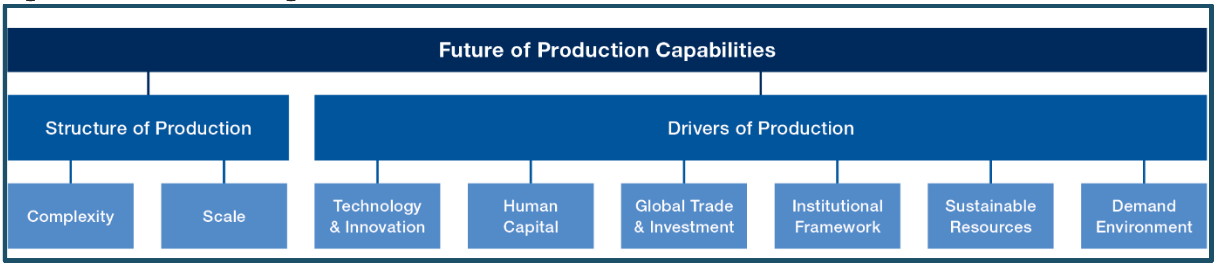
2) Mitigate risks and challenges; and

3) Be resilient to future shocks and the unknown.

The authors continue: "To enhance readiness and prepare for the future, decision-makers need to assess their current capabilities, identify new capabilities required to benefit from and succeed in a new production paradigm, and develop collaborative and customised solutions to facilitate transformation."

The benchmarking framework measures readiness for the future of production across two different components: the structure of production and drivers of production. The structure of production represents a country's current baseline of production. The drivers of production are the key enablers that position a country to capitalise on the fourth industrial revolution to transform productive systems. Countries with a large, more complex structure of production today are more prepared for the future in that they already have a production base to build upon.

Figure 4: Readiness Diagnostic Model Framework



Source: Schulz et al. (2018)

Six main drivers of production were developed through a consultative approach (See Figure 4). These include:

- Technology and Innovation: Assesses the extent to which a country has an advanced, secure, and connected ICT infrastructure to support the adoption of new technologies in production. Also measures a country's ability to foster innovation and commercialise innovations that have potential application in production.
- Human Capital: Assesses a country's ability to respond to shifts in the production labour market triggered by the Fourth Industrial Revolution by looking at both current labour force capabilities as well as the long-term ability to cultivate the right skills and talent in the future work force.
- Global Trade and Investment: Assesses a country's participation in international trade to facilitate the exchange of products, knowledge and technology, and to establish global linkages. Also measures the availability of financial resources to invest in production-related development as well as the quality of infrastructure to enable production-related activities.
- Institutional Framework: Assesses how effective government institutions, rules and regulations contribute to shepherding technological development, novel businesses and advanced manufacturing.
- Sustainable Resources: Assesses the impact of production on the environment, including a country's use of natural resources and alternative energy sources.
- Demand Environment: Assesses a country's access to foreign and local demand to scale production. Also measures the sophistication of the consumer base, as this can drive diverse industry activity and new products.

While the WEF claim that the benchmark is data driven, several of the factors are based on interview data of a panel of experts[3] The WEF cautions that the instrument is limited in that it is designed to look at the mid-level of production and that it does not look at overall economic strategy across sectors or specific sub-sectors. Furthermore, the instrument does not differentiate between sub-regions in a country – it measures overall readiness at an aggregate level. (Schulz *et al.*, 2018:3).

The WEF concedes that it is inherently difficult to measure or predict uncertainties that come with an unknown future, and that "there is a lack of empirical evidence about the topic, given we are still in the process of understanding the factors and conditions that have the greatest impact on transforming production systems" (Schulz *et al.*, 2018:9).

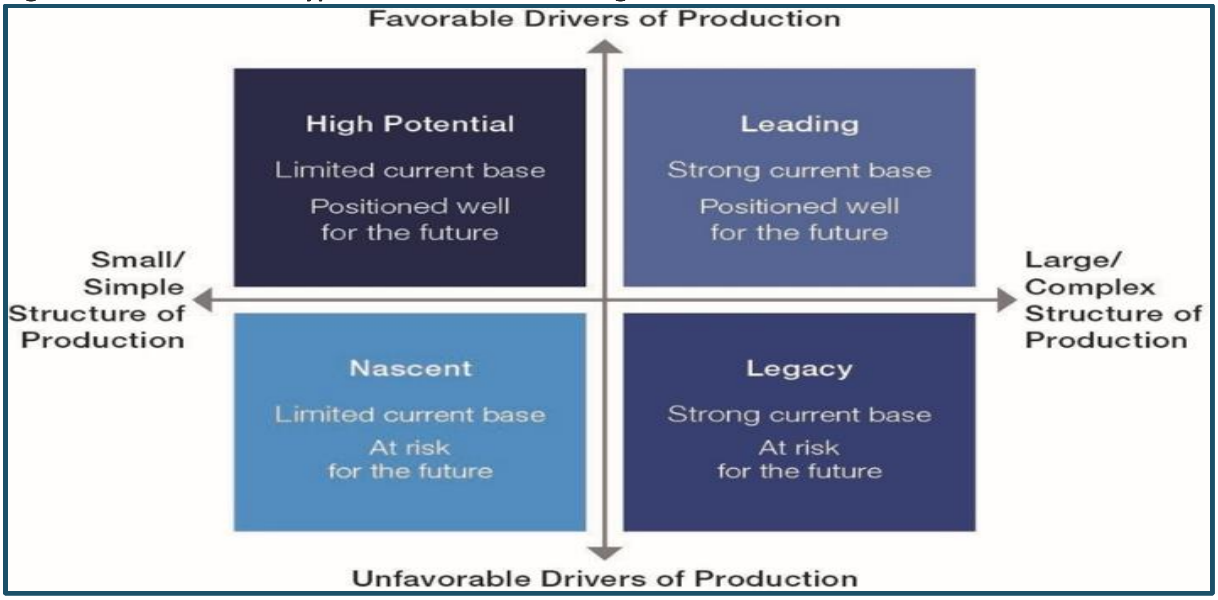
[3] Appendix C in Schulz, Gott, Blaylock and Zuazua (2018) outlines the technical notes of how each indicator was calculated.

A sample size of 100 countries and economies is used, and each country is then assigned to one of four archetypes based on its performance in the benchmarking framework, that is the structure of production (x-axis) and drivers of production (y-axis).

The four archetypes, leading; legacy; high-potential; and nascent and are shown in Figure 5 and are defined as follows:

- **Leading**: *"Countries with a strong production base today that exhibit a high level of readiness for the future through strong performance across the Drivers of Production component. These countries also have the most current economic value at stake for future disruptions."*
- **Legacy**: "*Countries with a strong production base today that are at risk for the future due to weaker performance across the Drivers of Production component."*
- **High-potential**: *"Countries with a limited production base today that score well across the Drivers of Production component, indicating that capacity exists to increase production in the future depending on priorities within the national economy."*
- **Nascent**: *"Countries with a limited production base today that exhibit low-level readiness for the future through weak performance across the drivers of production component"*

Figure 5: The four archetypes of the Readiness Diagnostic Model Framework



Source: Schulz et al. (2018)

South Africa is assessed by the WEF to be in the **nascent quadrant**[4] . The assessment argues that South Africa's manufacturing share of GDP has decreased since the early 1990s to approximately 12% today as its services sector has expanded. Nevertheless, the country has the strongest Structure of Production within Africa. Across the Drivers of Production component, South Africa's performance is mixed. On the one hand, the ability to innovate is one of South Africa's greatest strengths, as the country has a strong innovation culture, and entrepreneurial activity is supported by a sophisticated financial sector. On the other hand, human capital remains the most pressing challenge in preparing for the future of production, as there is a shortage of engineers and scientists as well as digital skills. It will also be critical for South Africa to improve its Institutional Framework to effectively respond to change, offer a stable policy environment and direct innovation.

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[4] *See Schulz et al,* 2018: 19 and 220)

Other studies have also questioned South Africa's readiness for the Fourth Industrial Revolution. In a recent research report on the structural transformation of South Africa it was found that South Africa's market concentration is blocking liberalisation (Bell, Goga, Mandliwa and Roberts, 2018). The authors assert that South Africa is not ready for Industry 4.0. They further contend that there is a leadership and coordination challenge in government; while technologies are converging government departments, programmes and economic support is fragmenting. The authors caution that technological change may worsen the economic divide rather than bridge it.

Deloitte interviewed 16 representatives of the CSIR-Meraka Institute, Department of Science and Technology, Industrial Development Corporation (IDC) and Manufacturing Circle and with executives from Bigen Africa, Ford, Hulamin, Nampak, Nissan, Toyota South Africa and other manufacturing companies (Deloitte, 2015). They found that while the interviewees saw promise in Industry 4.0-related technologies for South Africa, they also saw risks and challenges. The biggest challenges in Africa/South Africa remain connectivity and accessibility, as well as insufficient skills. However, the study found that South Africa has an advantage over the developed markets because it is not weighed down by infrastructure legacy issues and may have little difficulty in embracing change.

Deloitte also found that the adoption level of smart technologies that accelerate industry 4.0 remains at a foundation stage in the South African manufacturing industry overall, with some sector differences. For instance, it is reported that a stronger usage of advanced analytics exists within the automation and automotive sectors, compared to others. However, the real opportunities of advanced analytics are generally not yet explored by manufacturers. The respondents in their survey argued that the adoption of cloud solutions is driven by consumers more than businesses, with cyber-crime fears and privacy issues cited as main business concerns. Advanced sensor technologies are, with some exceptions (e.g. automotive industry), still at a foundation stage. However, manufacturers show a great deal of interest in better leveraging the potential for monitoring, controlling, tracking etc. Usage of robotics is mostly at an automated stage and not yet at a smart or advanced stage. Within the South African manufacturing industry 3D printing has not yet been widely adopted, although awareness of the significance and the potential of this exponential technology is high.

5 QUESTIONS ABOUT THE CONCEPT OF THE FOURTH INDUSTRIAL REVOLUTION

It could be argued that the WEF narrative presents technological change in a deterministic[5] (almost fatalistic) fashion. While it is broadly acknowledged that long-run economic growth is determined primarily by productivity growth, which in turn is driven by technological change[6] created by scientific, technological and knowledge-based capabilities, a deterministic perspective on technological change discounts other societal forces. It is perhaps more appropriate to adopt a socio-technical systems transition approach[7] or a neo-Schumpeterian evolutionary theory of technological change approach (Nelson, 2015; Nelson and Winter, 1982), wherein change takes place in a co-evolutionary fashion, involving complex reciprocal interactions between scientific, technological, economic, social and cultural change. In both these approaches it is understood that sociotechnical change and alignment (co-evolution) are needed at multiple levels for new technologies to be absorbed, developed or disseminated in a society. Thus, the focus is not on technology only, but also on the socio-political change that accompanies the absorption and further development of new ideas.

Scholars such as Jeremy Rifkin do not agree with the velocity, scope and systems impact and the speed of breakthrough arguments by Schwab and the WEF. Rifkin claims that the world is still coming to grips with the third industrial revolution that is being built on the internet and renewable energy, and that humanity is being led forward into a post-carbon era (Rifkin, 2011). However, some of Rifkins' arguments resemble the WEF's message that in this new era centralised operations of previous revolutions will increasingly be subsumed by distributed technologies and practices and that the traditional, hierarchical organisation of economic and political power will give way to lateral power organised nodally across society. Rifkin argues that new technologies will free up humanity through technological surrogates, resulting in the dominance of the not-for-profit civil society. Martin Wolf argues along similar lines that not much will change and that the pace of economic and social transformation has in actual fact slowed down in recent decades, and that the current technological change is not extraordinary (Wolf, 2015).

There are also scholars, like Carlota Perez, who argue that humanity is in the 5th industrial revolution. What makes her views valuable is that her research is focused on ways that developing countries can enable or harness these technological revolutions to improve quality of life, reduce inequality and mitigate our negative impact on natural resources and the environment.

The European Institute of Interdisciplinary Research (EIIR) questions whether the fourth industrial revolution is an inflection point, entropy or interregnum (Damaskopoulos, 2017). For some analysts, often referred to as techno-optimists, we seem to be entering a period of momentous historical transformation that is fundamentally changing the way we live, work, and relate to one another. In summary they argue:

- The scale, scope and complexity of what we are witnessing amounts to a Fourth Industrial Revolution, an Inflection Point of exponential growth, which is unlike anything experienced

[5] Technological determinism in its most radical and reductionist form asserts that technological development is autonomous and that societal development is determined by technology, i.e. technology shapes society. The concept is attributed to Thorstein Veblen (1857–1929), an American sociologist and economist. See also Bijker (2010).

[6] The traditional factors of production, viz. labour and capital, together contribute only about a third of observed growth over the long term, see Schumpeter (1934), Solow (2000), Freeman (1992).

[7] See for instance Geels and Schot (2007).

before. Its dominant economic manifestations are clusters of technologies that generate profound shifts across all industries and business models, as week as disruption of incumbents and the reconfiguration of production, consumption, transportation, logistics and delivery systems.
- For others we seem to have entered a protracted structural crisis. According to this view we are facing a long process of generalised economic and social decay of capitalism driven by long-term dynamics with no credible alternative to replace it. The clusters of technologies that the techno-optimists identify as the drivers of exponential growth are seen here as a harbinger of long-term decline, a state of entropy.
- What might be called the *Interregnum*[8] position argues that humanity is at a mid-point between "installation" and "deployment" of technologies in economic and social processes.

Adopting a global political economy perspective, the EIIR study argues that these options will be shaped by the dynamic interactions of three forces:

- *Technological advances* and the specific ways they will be deployed across economy and society;
- The future of *globalisation*, specifically the degree of its compatibility with socially and environmentally sustainable development; and
- The role of the *state*, specifically in mediating and taking an active role in the creation of "enabling frameworks" for the diffusion and adoption of the technologies, the management of globalisation, and their collective disruptive and destabilising consequences for economic and social systems.

The EIIR argues that realizing the potential of IR4, as in previous revolutions, requires the formation of a "direction". For policy-makers the key point to be taken from this is that this direction is neither pre-determined nor automatically given by the technologies involved. Historically such direction has been the result of an "enabling framework" that has been typically marked by the constellation of lifestyle-shaping goods and services made possible by the new technologies; the ability of entrepreneurs, investors and governments to recognise the potential of these products; the political ideologies of those with the power to affect deployment and infrastructure development and shape the socio-historical context in which they emerge in ways that facilitate broad societal acceptance and adoption.

South Africa's readiness

The previous sections have unpacked the notion of the fourth industrial revolution, raised some pertinent questions about it, as well as considered the WEF review of South Africa's readiness. If we agree with some of the reservations raised about the Fourth Industrial Revolution, what does this mean for South Africa and how does it translate into South Africa being ready for a more digital, complex and higher value added economy? If we agree that there is some kind of a convergence between technological domains, is South Africa ready to absorb these new ideas and apply them to improving the economy, reducing inequality, creating jobs, and building a modern state?

[8] Miriam-Webster dictionary defines an interregnum as the time during which a throne is vacant between two successive reigns or regimes.

In this chapter three other data-based benchmarks are used to assess South Africa's readiness for a more advanced technological future. These instruments were chosen because they all look at the economy from different angles.

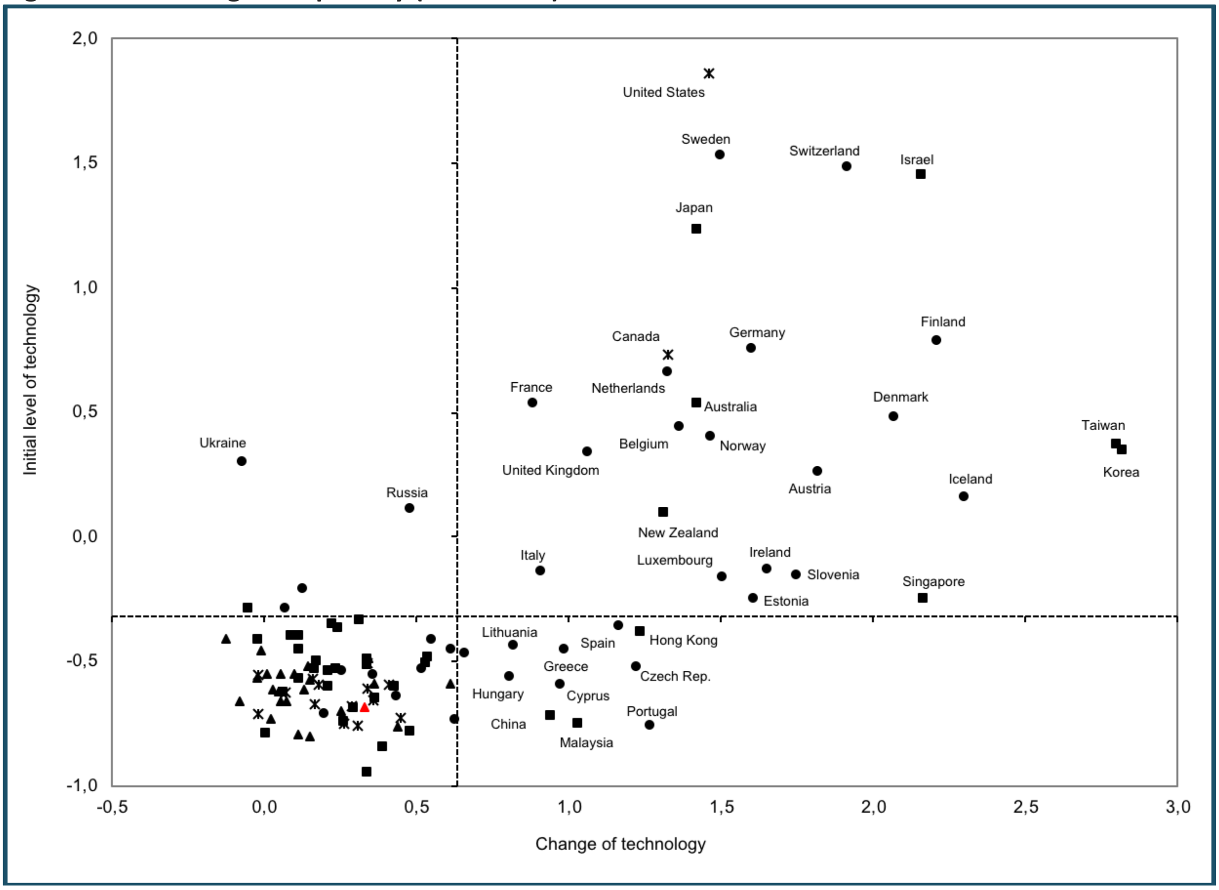
5.1 South Africa's performance in a global technological capability assessment

The ability of developing countries to absorb new technologies, knowledge and to catch up with the global technology frontier is important. Fagerberg and Srholec (2017; 2009) have developed a methodology to assess the technological capability at a high level with a particular focus on developing countries. In the case of technological capability, the indicators taken into account in their model include the quality of a country's research system (as reflected in scientific publications), invention and innovation (as measured by patent applications and R&D expenditure) and development of the ICT infrastructure (proxied by Internet users). On social capability, the authors included two broad dimensions, the first of which is the skills level of the population (as reflected in primary, secondary and tertiary attainment and literacy). A second dimension refers to the quality of the governance in a country. Indicators taken into account in this case include measures of how effective the government is, the extent to which corruption is a problem and, finally, whether law and order prevails[9].

Fagerberg and Srholec plotted their analysis in Figure 6, with the position of South Africa marked in red in the bottom left quadrant.

[9] The authors conducted a factor analysis that resulted in the identification of three different capabilities, labelled Technology, Education and Governance, respectively. Technology is highly correlated with R&D, patenting, scientific publication and the proliferation of the Internet but also, to a lesser extent, with tertiary and secondary attainment. Education loads particularly highly on the two most basic education indicators, literacy and primary attainment, but also on secondary and tertiary attainment. Finally, governance is highly correlated with government effectiveness, (lack of) corruption and the prevalence of law and order

Figure 6: Technological capability (1995-2013)



Source: Adapted from Fagerberg and Srholec (2017)

The graph plots the development of a country's technological capability over the period 1995–2013 against its initial level in 1995. In this way four quadrants appear. Up to the left, in the quadrant labelled 'losing momentum', we find countries with a high but stagnating (or declining) technological capability. Few countries appear in this category. In contrast, the countries in the top right quadrant combine a high initial capability level with an above-average capability increase. Hence, these are countries that are moving ahead technologically. Korea, Taiwan, Israel and Finland are examples of countries that particularly excel, but many other developed countries also belong to this category. Another group of countries with above-average performance can be found down to the right. These countries, a mixed crowd of Asian (China, for instance) and European countries (from the Southern and Eastern part of the continent), are catching up technologically from a relatively low initial level. Finally, in the quadrant down to the left we find countries that are falling behind technologically, i.e. countries that combine a low initial level with below-average performance. Many countries in Africa, Latin America and Asia belong to this category. South Africa falls in this area. Fagerberg and Srholec (2017) conclude that technological and social capabilities cannot be untied and are closely related. Firms not only draw on technological capabilities to innovate and adapt, they also draw on the social environment, local resources, the legal frameworks and so on.

In addition, Fagerberg and Srholec (2017:916) have also found that in many countries with a medium to low level of development, the major contribution tends to come from diffusion of ICTs. This is particularly notable for the catch-up and transition groups. This is typically achieved through, for instance, technology demonstration, education and making technology available to firms through interventions such as technology extension. For this reason, Section 5.2 will look at South Africa's performance in the Global Digital Capability Assessment.

Fagerberg and Srholec (2017:916) further find that at a higher level of development, growing 'innovation capabilities as reflected by increases in science, R&D and patenting are of much larger significance, as about three-quarters of their high increase comes from such sources. While much of South Africa's science, technology and innovation focus is aimed at these kinds of activities, it would appear that more emphasis should be placed on diffusing technologies and encouraging uptake through experimentation and extension.

5.2 South Africa's performance in a global digital capability assessment

In 2015, a research team from the Fletcher School at Tufts University reported their first assessment of the global digital economy in the Harvard Business Review (Chakravorti, Tunnard and Chaturvedi, 2015). This was followed by an expanded version of their instrument, called the Digital Evolution Index in 2017 (Chakravorti and Chaturvedi, 2017). The intention of the index is to assess how countries compare in readiness for the digital economy.

The Digital Evolution Index is a data-driven, holistic evaluation of the progress of the digital economy across 60 countries, combining more than 100 indicators across four key drivers:

- Supply conditions,
- Demand conditions,
- Institutional environment, and
- Innovation and change.

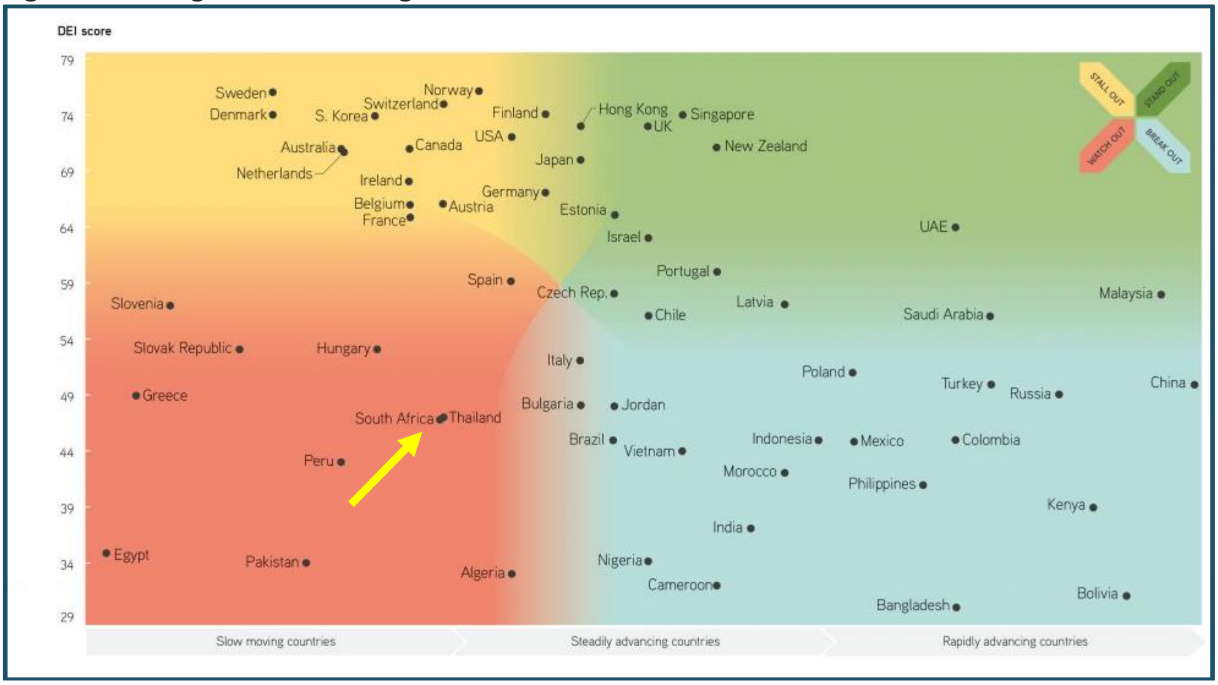
The resulting framework captures both the state and the rate of digital evolution and identifies implications for policy, investment and innovation.[10] The index classifies countries into four segments:

- Stand out countries are both highly digitally advanced and exhibit high momentum,
- Stall out countries enjoy a high rate of digital advancement while exhibiting slowing momentum,
- Break out countries are low-scoring in their current states of digitalisation but are evolving rapidly, and
- Watch out countries face significant challenges with their low state of digitalisation and low momentum, and in some cases these countries are even moving backwards.

The big picture of the 2017 Digital Evolution Index is illustrated in Figure 7.

[10] The 2017 DEI index also highlights the importance of building digital trust, but unfortunately South Africa was not included in the 42 country list assessed.

Figure 7: The Big Picture – the Digital Evolution Index 2017



Source: Chakravorti and Chaturvedi (2017)

Figure 7 shows three countries in the far-higher right of the stand out category: Singapore, New Zealand and UAE. Each is reported to have a unique policy-led digital strategy and a narrative that may be considered by other nations as worthy of emulation or adoption.

Germany and the US are in the overlapping segments of Stand Out and Stall Out, hence their strong focus on Industry 4.0 and digitisation strategies.

South Africa's BRICS peer countries are all in the Break Out segment, with China showing the highest momentum, followed by Russia and India. Nigeria is also in the break out segment, showing faster momentum than South Africa, but starting from a lower base.

South Africa is in the Watch Out Segment and falling further behind its peers.

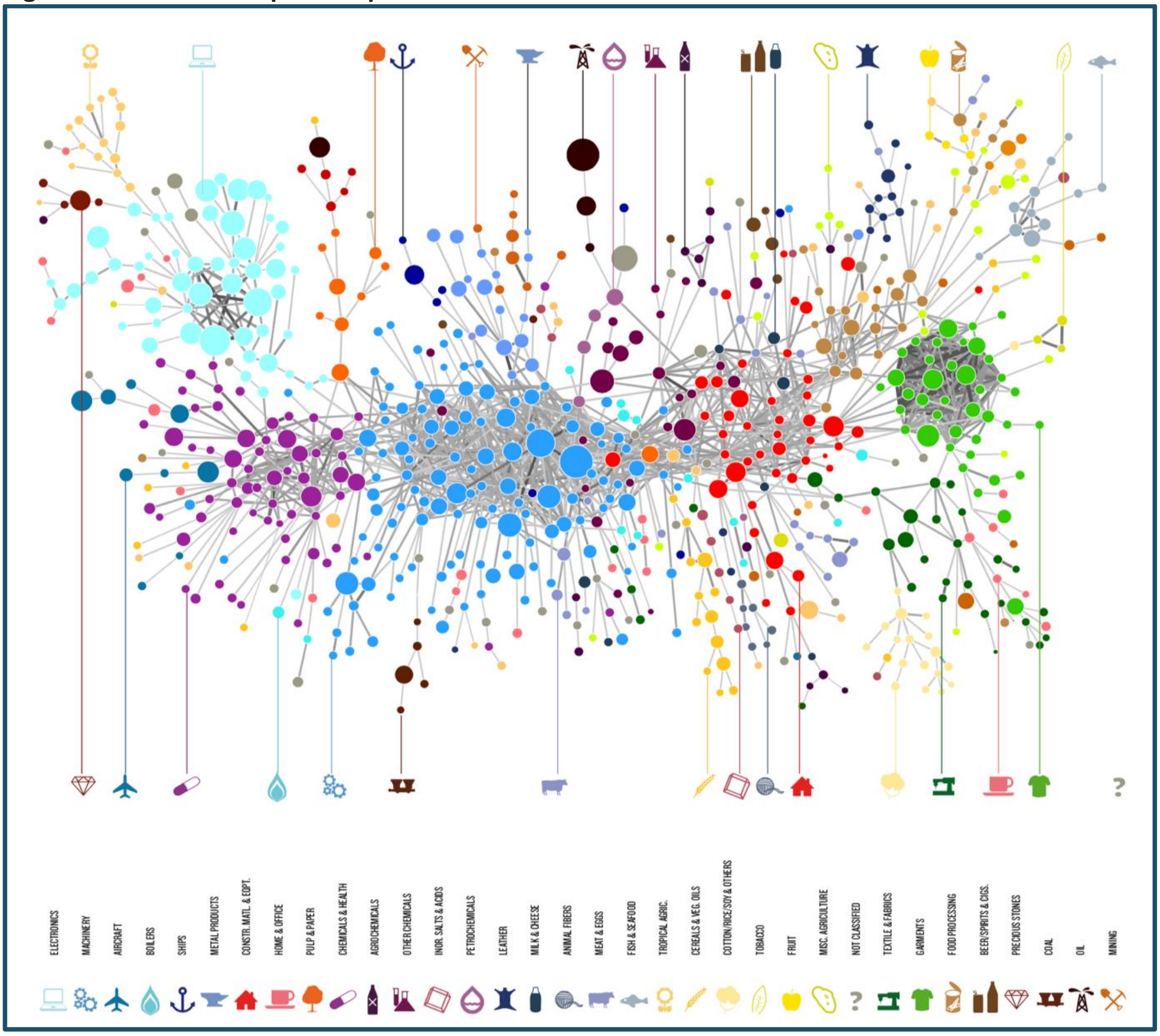
In the same study, particular attention was paid to the Digital Trust Economy. South Africa was not included in the 42-country survey due to insufficient data to complete the country profile. This does not bode well for South Africa's integration into global supply networks that require high levels of data security, network integration and privacy laws.

5.3 South Africa's performance in the Atlas of Economic Complexity

During the last 10 years, a promising approach has emerged from the Centre for International Development (CID) at Harvard University and Macro Connections at MIT Media Lab. It is called the Atlas of Economic Complexity (Hausmann, Hidalgo, Bustos, Coscia, Simoes and Yildirim, 2013). It is a powerful interactive tool that enables users to visualise a country's total trade, track how trade dynamics change over time and explore growth opportunities for more than 100 countries worldwide.

The Atlas offers a different view of economies, structural change and progress. It attempts to measure the amount of productive knowledge that each country holds, and reveals potential paths for industry development. Hence it is a useful instrument for policy makers, economic development practitioners and entrepreneurs to find upgrading, investment and leverage points in an economy. From an evolutionary or complexity economics perspective, it is desirable to increase the economic complexity of a country. More complex economies are those that can weave vast quantities of relevant knowledge together across large networks of people so as to generate a diverse mix of knowledge-intensive products. Simpler economies, in contrast, have a narrow base of productive knowledge and produce fewer and simpler products, which require smaller webs of interaction (Hausmann and Hidalgo, 2011:18). The tool reveals areas where knowledge spill-overs or capabilities can be strengthened to make experimentation, search and discovery easier, or where industry and technology support programmes may not be effective.

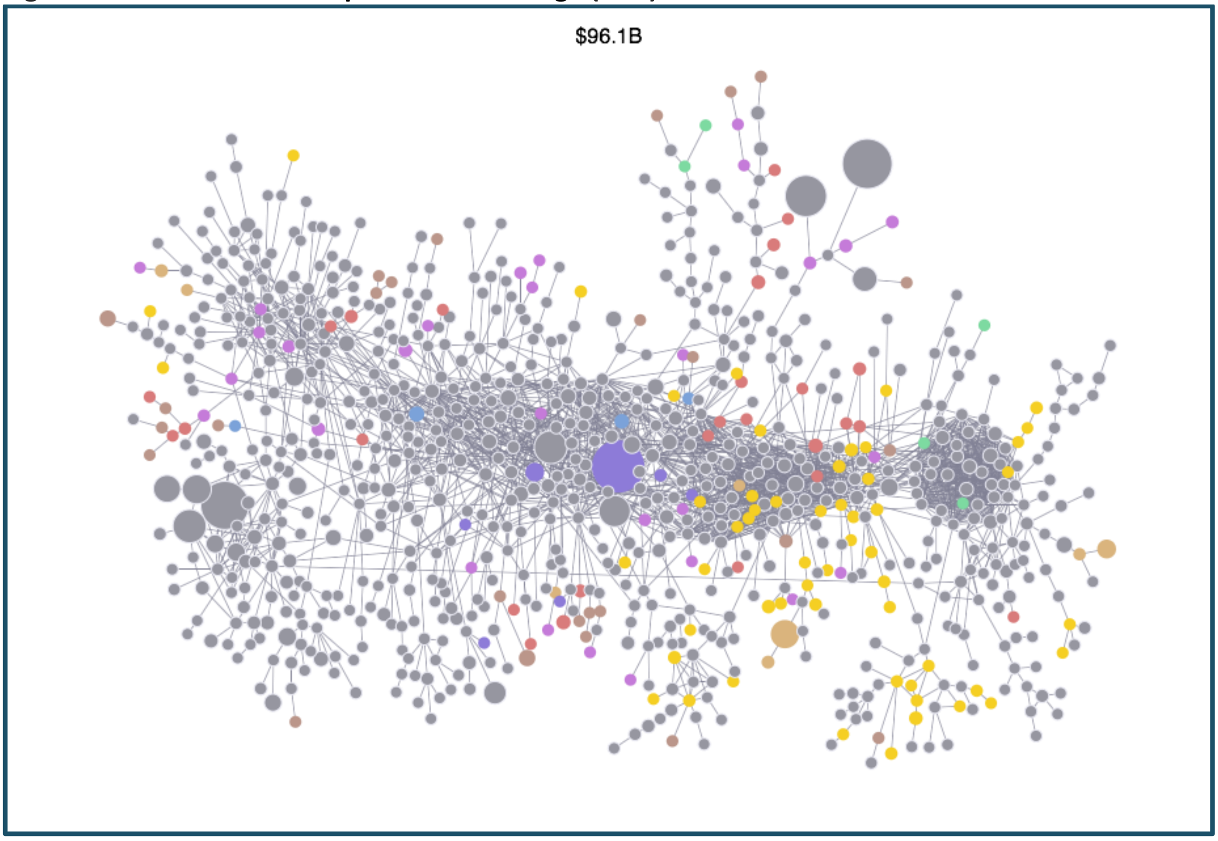
Figure 8: The Product Space map



Source: http://atlas.cid.harvard.edu

One of the visualisation instruments is the Product Space. It represents all products known to humankind in a relational network map and shows how networked each product group is in terms of the capabilities needed to produce the products. Nodes in this network map represent the knowledge needed to produce a specific product. The maps build on a background of overall possibilities highlighting those products in which a specific country is competitive on the world market (see Figure 8). For instance, products that are assessed to be competitive show up in a colour that represents the broad product classification. In the visualisation of the Product Space there is a dense interconnected region representing mainly machinery, metal products, chemicals and capital-intensive goods. To the left of the map lies the electronics cluster, and to the right of the map there is a cluster of apparel, textiles and clothing. All around the dense cluster there are branches reaching out into open space. These outlying products are more disconnected from the dense core. They include, for example, tropical agriculture, oil and mining. They reach into sparsely populated space because they offer low spill-overs: knowledge in these economic activities is not easily adapted to adjacent activities.

Figure 9: RSA Revealed Comparative Advantage (RCA) at 1.0

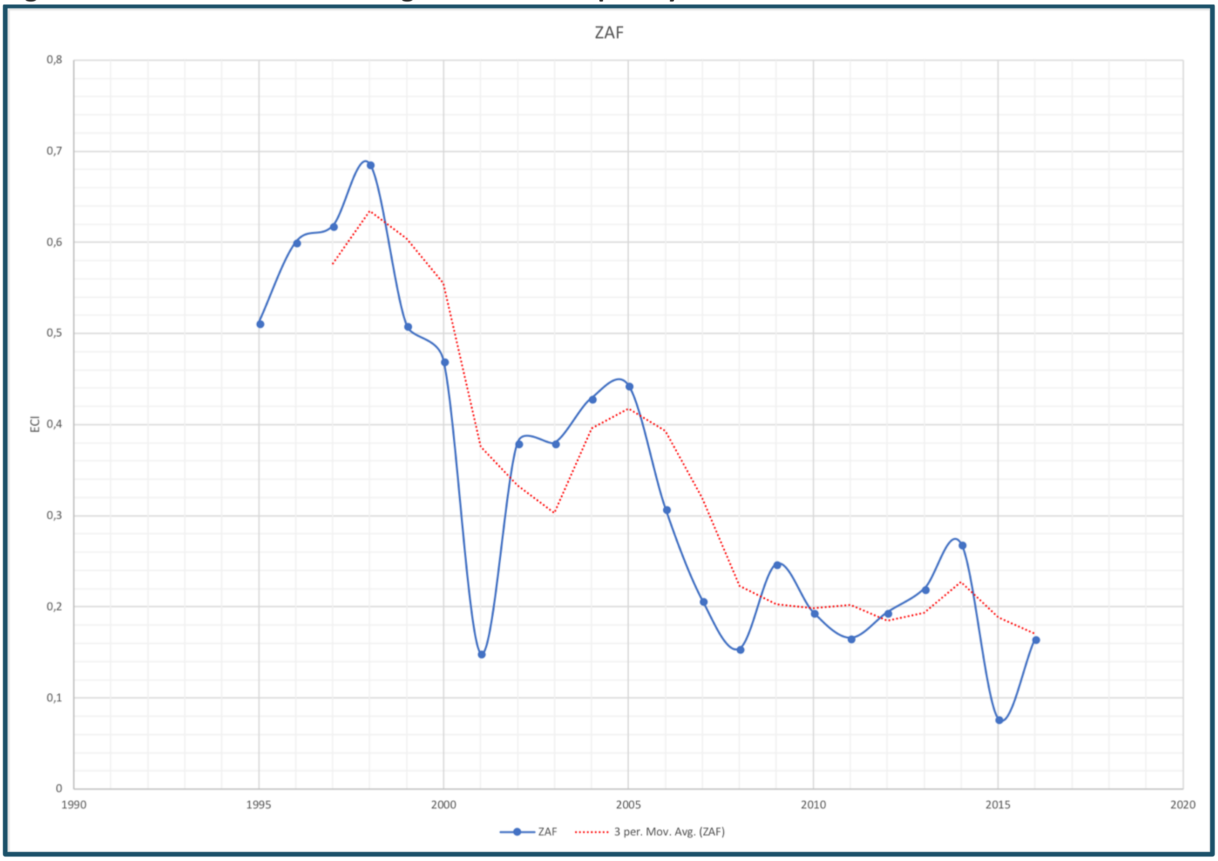


Source: http://atlas.cid.harvard.edu

In Figure 9, the Product Space of South Africa reveals many relative comparative advantages on the periphery in many agricultural commodities, mining and manufacturing. When looking at the change over time a trend of de-industrialisation is shown. Each country's product space is different. It reveals areas where countries have accumulated sufficient expertise to produce products in a way that makes them competitive and allows them to trade with other countries. This makes it possible to detect areas of strength, innovation, competitiveness and suggest opportunities for future investment.

The analysis shows clearly that between 1995 and 2016 South Africa's Economic Complexity Index decreased markedly from 0.512 to 0.165 (See Figure 10). In terms of country rankings, South Africa slipped from 38th in the world in 1995 to 49th in the world in 2016.

Figure 10: South Africa's declining economic complexity

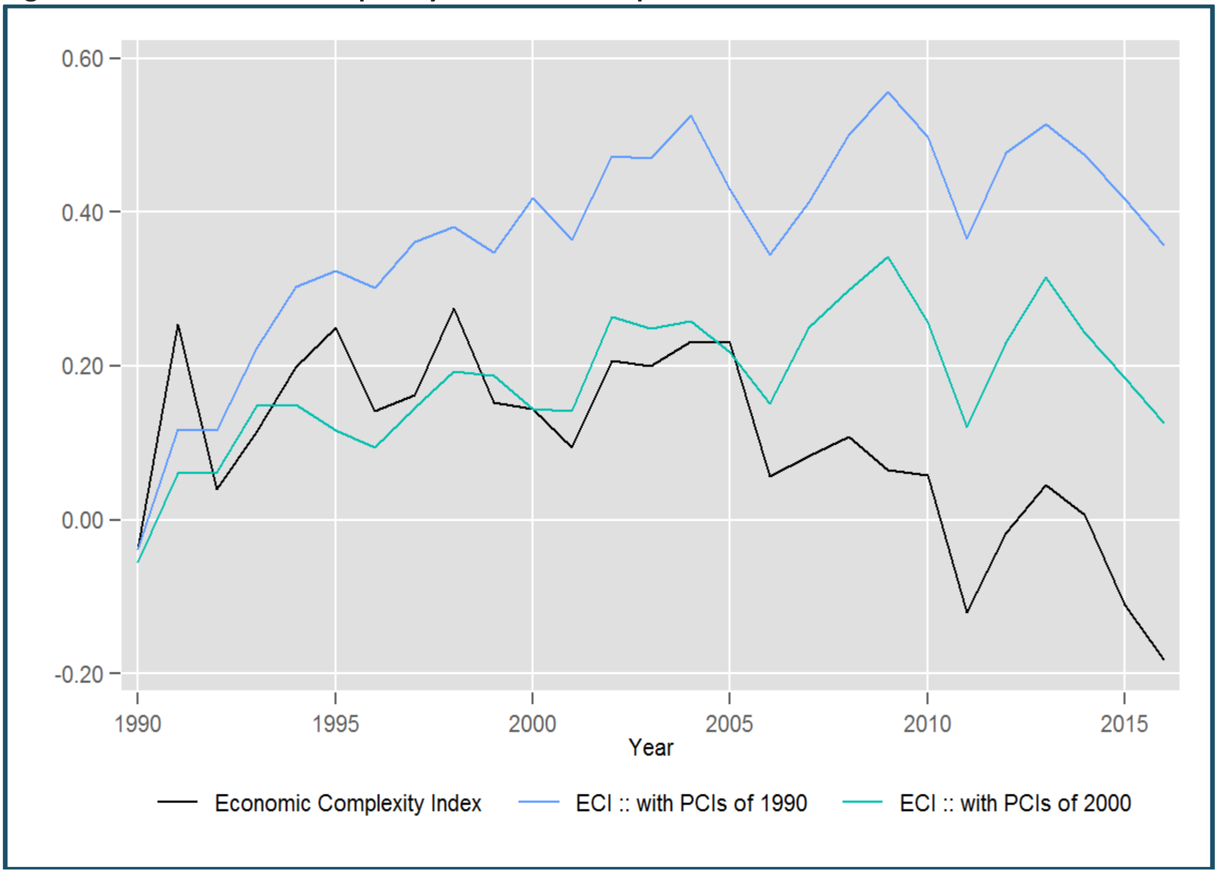


Source: Authors own calculation based on Harvard CID data

A further possible area of investigation is the complexity of major economic sectors. A first attempt at such analysis is shown in Figure 11 below. The graph was created by comparing the economic complexity of the products in the HS Codes of the 1990s with the economic complexity of newer products introduced into the HS Code table in the 2000s.[11] The graph suggests that the products in which South Africa has become competitive used to be relatively complex by 1990 standards, but are becoming less complex by 2000s standards. If the products were as complex as they were in the 1990s, by year 2016 South Africa would be 0.4 standard deviations above the average of the country (at the levels of Bulgaria or Turkey) as opposed to the current complexity that is 0.2 standard deviations below the mean.

[11] This measure is known as the Product Complexity Index (PCI). It is calculated based on how many other countries can produce the product and the economic complexity of those countries. In effect, PCI captures the amount and sophistication of know-how required to produce a product.

Figure 11: The economic complexity of new and old products



Source: Dr Sebastian Bustos, Harvard CID, correspondence with author

This analysis means that other countries have been more successful than South Africa in building adaptive industries and institutions that could respond to the newer applications of know-how. Much more analysis is needed to understand whether this decline is due to South Africa's market selection, South Africa's technological capability (represented by public institutions and private investments) or a lack of entrepreneurial search and discovery.

6 CONCLUSION

Whether the Fourth Industrial Revolution is or is not a revolution is contested. However, it is clear that countries need to be geared for a rapidly changing environment or risk stagnating or falling behind their peers. In theory, new technological paradigms should allow countries like South Africa to leapfrog some of the older established economies: in practice, it would take an immense effort of public sector coordination, education and private sector mobilisation to get the enabling factors in place. By all analyses South Africa is in the unenviable position of having low technological capability, inadequate and stagnating digital readiness and economic complexity that is falling.

An important critique of the WEF approach to the Fourth Industrial Revolution is the non-linear nature of these technologies and changes, as well as socio-political change that accompanies the absorption and further development of new ideas. Thomas Kuhn argued that paradigm shifts cannot be predicted. Yet, when trends are analysed certain things do become clearer. So, while we may question the extent of the “revolution”, the convergence, deepening knowledge base and digital reach is clearly intensifying.

By its own admission, the supposed science of assessing readiness for the next revolution is still in its infancy. Yet, the WEF (and others) are making compelling arguments that certain factors are more important than others. These factors are overcoming fragmentation in the public sector, paying careful attention to the economic and innovation ecosystem, and strengthening the resilience of a range of public and private institutions. A more technology-intensive and digital future will require better education, better infrastructure, and legal frameworks that protect data and monitor competitive and anti-competitive behaviour.

Further analysis is required on the appropriate way to modernise or advance the industrial base of the country, its alignment with existing industrial policy, and the specific state interventions needed to create suitable social conditions and the enabling environment in which industry can adopt, absorb and implement these new technologies and approaches.

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