Towards a Digital Industrial Policy for South Africa: A Review of the Issues

Industrial Development Think Tank[1]

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Acronyms

AI	Artificial Intelligence
AV	Autonomous Vehicle
CAD	Computer Aided Design
CAM	Computer Aided Manufacturing
CNC	Computer Numerical Control
CSIR	Council for Scientific and Industrial Research
CTFL	Clothing, Textiles, Footwear and Leather
DIPF	Digital Industrial Policy Framework
DTI	Department of Trade and Industry
EEV	Energy Efficient Vehicle
EFT	Electronic Funds Transfer
ERP	Enterprise Resource Planning
EU	European Union
GDP	Gross Domestic Product
GVC	Global Value Chain
IDC	Industrial Development Corporation
IIoT	Industrial Internet of Things
IPAP	Industrial Policy Action Plan
IoT	Internet of Things
ICT	Information and Communications Technology
MES	Manufacturing Execution System
MNC	Multinational Corporation
OEM	Original Equipment Manufacturer
PLM	Product Lifecycle Management
R&D	Research & Development
RFID	Radio Frequency Identification
SaaS	Software as a Service
SETA	Sector Education and Training Authority
SMME	Small, Medium and Micro Enterprise
T-a-a-S	Transport as a Service
UK	United Kingdom
UNCTAD	United Nations Conference on Trade and Development
VAT	Value Added Tax
VET	Vocational Education and Training
3DP	3 Dimensional Printing

Executive summary

The world economy is undergoing a period of structural and technological transformation, sometimes described as the 'Fourth Industrial Revolution'. At the centre of this is the digitalisation of economic activity, which is being experienced differentially across the globe.

At the same time, with persistent mass unemployment and very high inequality, South Africa represents an extreme case of a set of challenges faced by middle-income countries. In South Africa digitalisation is occurring in an economy that has prematurely deindustrialised and is performing poorly. The country is, therefore, at an important juncture and there is an urgent need to develop policy responses to these challenges and opportunities that are promotive of the broader objective of inclusive growth.

This paper sets out key policy issues for a digital industrial policy. It builds on detailed industry-level research, dialogues with industry stakeholders, and a colloquium held in November 2018.

Notwithstanding overall poor industrial performance, South Africa has areas of excellence in which firms are embracing the opportunities provided by digitalisation for efficiencies and supply chain integration. These examples point to what is possible and at the same time reveal gaps and shortcomings in the local institutional environment, especially with regard to the formation of appropriate workforce skills. Without a major increase in skills in essential cross-cutting fields such as data science and software engineering, along with much higher rates of investment, the examples of excellence will remain islands of industrial success.

The New Digital Economy and Development

Digitalisation brings together new and existing technologies in ways that transform production systems. These changes can be placed in four main categories:

- *Digitalisation and integration of supply chains.* Digitalisation of production and supply chains is the minimum requirement for participating in the new digital economy. These technologies allow for coordination efficiencies, real time monitoring and process optimisation both within firms and along supply chains.

- *Design, rapid prototyping and customisation.* The combination of artificial intelligence (AI)-assisted design software, additive manufacturing and material science has significantly reduced the time it takes to develop prototypes, produce tooling and allows for mass customisation of products.

- *Advanced manufacturing and automation.* These can be understood as fully-integrated, collaborative and highly responsive manufacturing systems that adapt in real time to meet changing demands in the factory and the supply network.

- *E-commerce, online search and social media platforms.* Online platforms have the potential to open-up routes to consumers for small, medium and micro enterprises (SMMEs), by lowering entry barriers. But, at the same time, the platforms have substantial market power and can skew the playing field. These tensions are evident in the ways in which e-commerce is changing the face of retail internationally.

The major technological changes require business models which can cope with the growing complexity of systems based on digital ICT. This is achieved through *modularity*, where sub-components can be added or subtracted without redesigning entire systems, *open innovation*, where pre-competitive R&D resources and reference designs can be shared, and *platforms*,

which can link large networks of buyers and sellers without the platform owner making direct investments in the goods and services bought and sold.

Implications for production systems and value chains

Digital technologies are being taken up within South Africa's industrial ecosystem, although at uneven speeds. At present, applications are mainly in small, experimental, or niche areas, such as three-dimensional printing for prototypes, while more incremental changes are being made across sectors and firms. Established manufacturing models remain dominant within all the major value chains studied and implementation of last generation process innovations, such as enterprise resource planning software, lean production, and total quality management, is still incomplete.

While South African industrialists are acutely aware of the potential consequences of digital disruption in the value chains within which they operate, there are uncertainties with regard to the speed, scale and scope of these changes. The industry studies and dialogues undertaken as background for this report show how the nature of value chains in specific industries (including cost profiles, market requirements, export orientation, technology levels and supply chain complexity) shape how digital tools are adopted.

The adoption of digitalisation to improve supply chain integration is the over-riding priority for industry in South Africa. This requires coordinated strategies across skills, investment and technology to support the largely incremental changes required to realise efficiencies and improve competitiveness. There are both transversal and value chain specific issues.

Key principles and priorities for industrial policies and institutions

Five principles are proposed for the design and development of an effective South African Digital Industrial Policy Framework.

- Digital industrialisation opportunities are about both incremental changes in production and disruptive technological innovations.
- Digital industrialisation is sustainable and inclusive only if it creates conditions for more domestic value creation and distribution.
- Systemic changes call for systemic policy frameworks that support the emergence of the new 'industrial ecosystem'.
- Strategic targeting, coordination and policy alignment are critical for effective implementation.
- New coalitions for change forged around better aligned productive interests are necessary for the successful implementation of industrial policy.

Digitalisation requires prioritising a number of enabling sector-specific and cross-sectoral interventions.

- The *cost, speed and reliability of ICT infrastructure* (bandwidth) urgently needs to be improved, including through the rapid release of spectrum.

- A *digital skills policy* needs to be developed and should include: rapid development of large-scale programmes for cross-cutting skills in software engineering, data science and related ICT skills; a priority skills list; and reform of the incentives and organisational structure with Vocational Education and Training institutions.

- *Digital technology policy* needs to be integrated with industrial policy and should include measures such as the provision of manufacturing and digital extension services, demonstration projects, and testing and scaling-up facilities such as accelerators for digital start-ups and SMMEs.

- *Financing and investment* to support upgrading of capital equipment and supply chain integration. The development finance institutions have a key role to play in supporting higher investment, through the design of appropriate financing mechanisms for the digital economy.

- *Linkage development policy.* Addressing the poor participation of small and medium-sized firms in industrial supply chains requires supporting second and third tier companies in accessing affordable digital technology licences and de-risking SME investments in new technologies and products.

- *Economic regulation, data and competition policy.* Appropriate regulation for digital platforms needs to ensure the playing field is level for local businesses. South Africa also needs to develop a clearly defined set of policies on data ownership, data quality, data categorisation and anonymity. On the other hand, South African firms and consumers must retain access to global technologies and platforms.

- *Trade and tax policies.* South Africa must work with other countries at the WTO to ensure trade policies can continue to be effective and that digitalisation does not exacerbate base erosion and profit shifting. A key question is how the government plans to tax and regulate imported and domestic digital products and services and to incentivize local productive activity, training and employment.

1. Introduction

The world economy is undergoing a period of structural transformation encompassing the adoption of a range of technologies that encompass the physical, digital and biological worlds. Part of this transition, sometimes described as the 'Fourth Industrial Revolution', relates to the digitalisation of production. Associated with this transition is the development of new "platform" business models and modes of value creation.[2] The key technologies underpinning this 'Fourth Industrial Revolution' are at different stages of maturity. They include advanced robotics and factory automation, data from mobile and ubiquitous internet connectivity (sometimes referred to as the Internet of Things, IoT, and Industrial Internet of Things, IIoT), cloud computing, big data analytics, machine learning and artificial intelligence (AI).

South Africa is facing these changes at a time when its economy has performed poorly in terms of industrial development compared to its upper middle-income peers. Like many resource-dependent economies, the country has failed to diversify and move to higher productivity and more complex activities (Andreoni and Tregenna, 2018). Aside from a few 'islands of capabilities', there has instead been a regression back to an export-basket biased towards resource-based industries (Bell et al, 2018). Unemployment remains at very high levels, while societal inequality persists.

The South African economy is therefore at an important juncture. To benefit from the technological advances of digitalisation, South African based businesses need to be investing in the innovation processes driving the development of new industrial ecosystems. At the same time, the developing industrial ecosystems need to link new firm-level value creation processes to a broader social system of interdependent activities involving organisations, institutions, governments and markets that works to ensure the socially-inclusive structural transformation of the South African economy (Andreoni, 2018).

This paper sets out key policy issues for a digital industrial policy that focuses on achieving the outcomes articulated above. It is intended to complement other initiatives across government aimed at effectively responding to digitalisation and the 'Fourth Industrial Revolution'. It builds on detailed industry-level research, dialogues with industry stakeholders, and a national colloquium held on 12-13 November 2018.[3] These processes secured input from international experts and industry representatives, and provided critical insights into the development of technology platforms and appropriate policy.

The technologies and business models emerging in the Digital Economy have already disrupted traditional industries and created entirely new ones, such as social media. These changes are expected to continue. They raise concerns about the dislocation and job losses that might result from technologies such as robotics and artificial intelligence (Hallward-Driemeier and Nayyar, 2018; Lütkenhorst, 2018; Ford, 2015). Many of the technological changes are also skills-biased and may undermine the ability of developing countries to

[2] See UNCTAD (2018), Schwab (2016, 2018), Sturgeon (2017).

[3] The 11 briefing papers and inputs to the colloquium are available at https://www.competition.org.za/idtt/digital-industrial-policy . The papers are based on primary and secondary research undertaken in September and October 2018 and build on earlier work. The four digital dialogue sessions were hosted with key South African manufacturing sectors, covering the automotive assembly and components; fresh fruit; machinery and equipment; and clothing, textiles and footwear sectors.

compete in traditionally labour-intensive industries that have supported their industrialisation (Rodrik, 2018).

Countries such as South Africa are far from centres of core innovation (in places like Silicon Valley and manufacturing regions in Germany) making it more difficult to participate in the high value segments of these fast-moving new industries. In addition, there are major emerging regulatory challenges associated with the ownership and control of data which provide major platforms their power and associated commercial value in areas such as search, ride hailing, performance monitoring and management, e-commerce and social media (Singh, 2018; UNCTAD, 2018; Polson and Scott, 2018; McAfee and Brynjolfsson, 2017). There are also important implications for international trade. The USA has pushed for multilateral commitments (the so-called 'Digital 2 Dozen') which would prevent countries from implementing measures that would support local businesses in competing with the international 'technology titans', such as a prohibition on customs duties for digital products.[4]

On the other hand, the technologies and platforms underpinning the Digital Economy hold great promise for increasing the productivity and global connectedness of South African industry. A key benefit for South African industry could be better coordination efficiencies and process optimisation across supply chains. Digital tools can also improve design, prototyping and customisation processes. Importantly, digital platforms can lower costs for smaller businesses to market their products and services.

As a result, there is an urgent need to identify and develop policy responses to emerging challenges and opportunities. This includes establishing an enabling environment for skills development and key infrastructure such as broadband connectivity. Examples from the sectoral research conducted for this paper demonstrate that South African firms *can* substantially improve their competitiveness and that of their suppliers through both disruptive and incremental changes. South Africa is positioned to lead the southern African region in developing industrial policies to ensure Digital Economy technologies form an integral part of an inclusive growth strategy.

The paper proposes a framework to understand the organisation of production and technological changes for addressing the challenges of digitalisation. The framework includes the identification of key transversal enablers, such as skills, connectivity, supplier and quality assurance management, investment in productive capabilities for digitalisation, and the development of appropriate regulations. The emphasis is on locating the digitalisation challenge within a framework that builds both firm and broader societal capabilities. In this way a digital industrial policy for South Africa is a necessary *catalyst* for more sustained, inclusive and thus sustainable industrial growth. This is entirely consistent with the approach taken by Schwab (2016, Schwab and Davis, 2018) when reflecting on the role of government policy in supporting the transition to the 'Fourth Industrial Revolution'.

The paper comprises six sections. The second and third sections locate the South African economy within an international context and introduce the key technology platforms and business models underpinning the country's major digitalisation challenges. Section four then explores emerging technology platforms followed by an interrogation of the major implications

[4] The 'Digital 2 Dozen' were part of the Trans-Pacific Partnership, see https://ustr.gov/sites/default/files/Digital-2-Dozen-Final.pdf, although the Trump administration reversed the USA's ratification.

for South African production systems and value chains in the fifth section. The sixth section provides a set of Digital Economy principles and identifies key industrial policy and associated institutional priorities to support the successful transition of the South African economy as it embraces structural digital transformation.

2. Locating digitalisation and structural transformation of the South African economy in the international context

2.1 Digitalisation in the context of deindustrialization and GVCs

The current wave of technological change is taking place in the context of globalisation. An important share of international trade is also of intermediate goods, reflecting the importance of global value chains (GVCs) which are governed by large and internationalised corporations. While participation in GVCs can enable developing economies to upgrade capabilities, create employment and support more inclusive growth, the emerging evidence is that GVCs have further polarised income and wealth distribution in both developed and developing countries (UNCTAD, 2018). The reasons given for this include the nature of technological change (Rodrik, 2018; Ford, 2015) and the concentrated market structure and dominance of trade by large transnational corporations (UNCTAD, 2018).

Where there have been benefits to participating in GVCs, these have been uneven. The automotive sector in South Africa is a case in point. Though there has been targeted industrial policy to support participation in automotive GVCs, and long-term investments made by global lead firms and suppliers, there have been limited spill-overs to the domestic component manufacturing industry (Barnes et al, 2017). In machinery and equipment, strong productive capabilities in mining machinery in South Africa have not been leveraged into broader-based competitiveness in the industry (Bell et al, 2018).

The challenges of positioning and building capabilities in global value chains are part of the reason why most middle-income countries remain in a 'middle-income trap' (Andreoni and Tregenna, 2018). As countries develop strategies for digitalisation, policies to encourage widespread transfers of technology and promote the accumulation of technological capabilities are crucial. These policies are required to ensure that developing countries are not only located in low value assembly production in GVCs (UNCTAD, 2018). Together with selected, high value, manufacturing processes, the upstream (R&D and design) and downstream stages (marketing, branding and related services) generally account for higher value-added activity within the chain. With a few notable country exceptions, advanced economies have tended to retain control of higher value-added activities.

The challenge for a middle-income country like South Africa is to grow capabilities in the more technologically sophisticated segments of value chains, thereby allowing it to break from the 'middle-income trap', while simultaneously creating large numbers of jobs, including in related service activities. For upgrading to be sustainable in countries like South Africa, it is essential that technologies are widely diffused and embedded in a way that rapidly builds skills within interdependent domestic industrial ecosystems (Andreoni and Tregenna, 2018).

2.2 Locating the South African economy in the international context

South Africa represents an extreme case of the set of challenges that are faced by middle income countries. The economy has prematurely deindustrialised with the contribution of manufacturing to GDP declining from 21% in 1994 to 13% in 2016. South African industry value-added grew at an average annual rate of just 1.6% over the period 1994 to 2016 compared with the average for all upper-middle income countries of 5.5%.[5] Investment levels have also been much weaker in South Africa with gross fixed capital formation averaging around 18% of GDP over the period compared with 27% for all upper middle-income countries, and efforts to improve skills in South Africa have had limited success. The growth of the South African services sector has moreover been biased towards low value, often welfare-based services. The relative decline of the domestic manufacturing sector has been identified as a key reason for the poor performance of the South African economy (DTI, 2018; Andreoni and Tregenna, 2018). Re-energising manufacturing is consequently recognised as a major development challenge, especially as the sector drives technology-driven productivity growth and has strong inter-dependencies with other high value activities, especially high value-added services.

South Africa's manufacturing export basket remains biased towards resource-based industries (Bell et al., 2018). The undiversified nature of South Africa's exports is reflected in mineral and resource-based sectors continuing to account for around 60% of merchandise exports. Labour-absorbing medium-technology industries, outside of the automotive sector, have performed very poorly. South Africa is thus missing out on the gains from international technological integration and from improved competitiveness and 'learning through exporting' in diversified manufacturing industries. Instead, there are 'islands' of export capabilities, such as in mining machinery, which have not been built upon (Kaziboni et al, 2018). While the automotive sector, which has been highly incentivised under successive industrial policies, stands out in terms of the value of exports, these have been mainly of fully assembled vehicles and a narrow range of components (Black et al, 2018). In food, there have been notable successes in some high value fruit exports such as citrus, but not across a broader range of products (Chisoro-Dube et al, 2018).

The premature de-industrialisation dynamic observed in South Africa is mirrored by a set of challenges in the government policy framework. The fragmentation of government has affected the coordination and implementation of policies across mining, energy, trade, development finance, competition, technology, sector industrial development and procurement. Fragmentation has increased the space for lobbying by large businesses and has aided rent-seeking activity – to the detriment of industrial development.

2.3 Positioning of lead firms and industry groupings

Lead firms can play a critical role in learning and building capabilities across their supplier networks. It is important to understand the characteristics of the lead firms that already have capabilities in South Africa and the circumstances under which these were accumulated. The Digital Industrial Policy Briefs completed for this project identified leader firms, followers and laggards in terms of the adoption of new technologies. The picture that emerges is that

[5] Moreover, in South Africa, industry growth lagged growth in overall GDP (of 2.9%), while in upper middle-income countries industry growth led overall GDP growth (of 5.0%).

international technology relationships are critical for learning. Moreover, drawing on these relationships requires a long-term view on investment by firms in skills and technological and organisational capabilities.

Notwithstanding poor overall industrial performance, South Africa has areas of sectoral excellence which are embracing the opportunities provided by digitalisation for efficiencies and supply chain integration. These groups of firms have built skills through on-the-job learning, private training initiatives and collaborations with universities. They have made prudent investments in up-to-date capital equipment and have worked out where they can be leaders in incremental product development.[6] The corporate culture tends to be one of shared learning and capability development, whether they participate in formal cluster initiatives or not. These positive examples highlight what is possible. However, without a massive increase in essential skill fields such as data science and software engineering, along with much higher rates of investment, these examples will remain islands of industrial success.

3. The New Digital Economy

3.1 Transversal technologies

Digitalisation brings together a range of new and established technologies (Table 1) that give rise to major economic changes. The nature of the changes can be incremental (e.g. improving supply chain integration across firms) as well as disruptive (e.g. fundamentally changing the way products and services are created and delivered). The collection of vast troves of data is a characteristic feature of digitalisation. Data can be collected through sensors in production as well as from users through their use of the product or service, as well as from their online search and purchasing activities.

Table 1. Cross-cutting technology areas in the Digital Economy, with key features

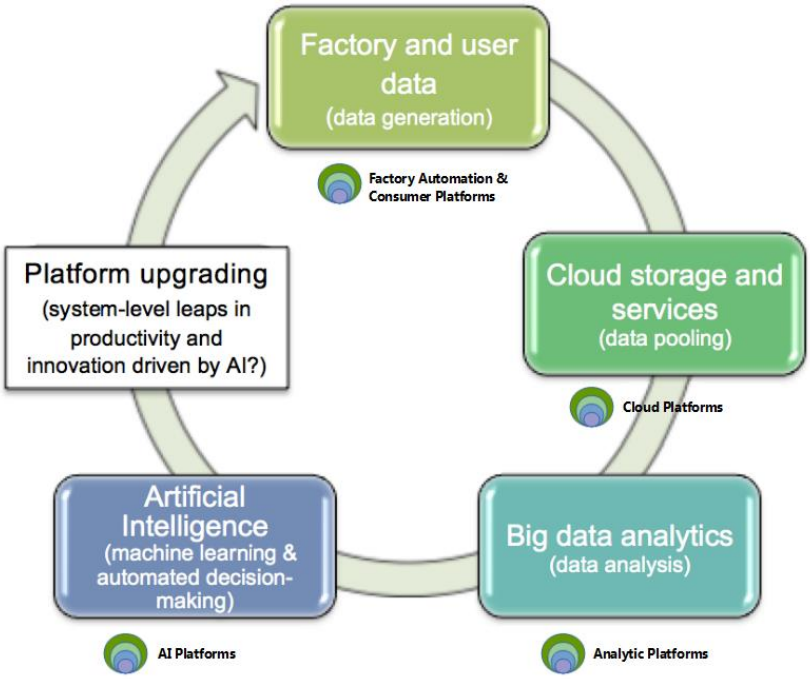
Cross-cutting technology areas	Key features
1) Advanced manufacturing: learning robotics and autonomous factory automation systems	• Machine learning and autonomy, augmented and virtual reality • Rising functionality in entry-level machinery and software (e.g., very low cost 3DP, drones, robot arms) • Ubiquitous measurement of processes (sensors), connected factories and supply chains
2) New mobile and internet-connected data sources	• Industry (IIoT) and consumer (IoT), sensors, clickstreams, location data, and ubiquitous video, etc.
3) Cloud computing	• Storage, SaaS, mobile access and constant updating of software and systems
4) Big data analysis	• Huge sample sizes can lead to robust results, new insights, and high fault tolerance
5) Artificial intelligence (AI)	• Machine learning, prediction, self-maintenance, regulation, and replication • Experienced by consumers, but rapid adoption in industry largely unseen by the public

With digitalisation, “big data” and its collation and analysis, it is possible for firms to track performance across multiple production sites and distribution channels and gain novel insights into consumer behaviour, and to provide new services such as the real time monitoring of

[6] See examples of these industrial firms in machinery and equipment, fresh fruit, clothing and textiles, and yellow metals.

product use and/or performance. This is often referred to as the Internet of Things (IOT and industrial IOT). IOT-enabled digital systems make use of cloud storage, big data analytics, and, increasingly, artificial intelligence, as highlighted in Figure 1.

Figure 1: Data flow across key transversal technologies in the Digital Economy



Source: Sturgeon, 2017

Digitalisation enables a dynamic cycle of continuously improved efficiency that is increasingly being driven by the rapid advance of machine learning (artificial intelligence). Maintaining competitiveness means adopting the incremental changes to build capabilities of clusters of firms and within value chains. Any effective digitalisation strategy will need to address this fundamental set of incremental requirements. More dramatically, disruptive changes can manifest in demand (such as the emergence of autonomous vehicles), entirely new processes of design and production (3-D printing), entirely new sales and marketing models (channel access, pricing and packaging) and the emergence of alternative business models (for example, the rise of the sharing economy).

The more members or users in a production system using a platform, the more data is collated and the greater its value in respect of data aggregation and analysis. These effects (known as 'network effects') imply potentially major barriers to smaller and independent competitors attempting to enter the market. Platform effects can give rise to increased levels of concentration and potential abuse of market power in the absence of an appropriate regulatory and policy framework, as explored below. Data itself is an asset and the ownership and control of data is an important determinant of power relations in value chains and over markets.

3.2 Business models

The major technological changes in the New Digital Economy require business models which can integrate, coordinate and control value-creation across businesses and link effectively

with other institutions and complementors. These include public or quasi-public organisations that set standards needed to support the interconnection and integration of components and subsystems into larger systems.

Three business models have been identified as key to support these goals (Sturgeon, 2017).

- *Modularity* describes a business model based on interchangeability, where sub-components can be added or subtracted without redesigning entire systems. On the factory floor different subassemblies with shared interfaces can be substituted in the assembly of larger products. In product design off-the-shelf or lightly customized modular components can be designed-in as elements of larger systems. In supply chains, standards and protocols allow for complex information about products, production and logistics to be exchanged across organizational and geographic boundaries.[7]

- *Open innovation* refers to the pre-competitive pooling of R&D activities and design criteria, either through consortia, or through the voluntary "crowdsourcing" efforts of engineers and technologists interested in creating free resources for their communities. For example, nearly all the world's major computer programming languages, such as Python, are open sourced and free. Like modularity, open innovation helps companies "vertically specialize", that is, develop a strategic focus on a specific bundle of competencies, while still providing customers with a rich set of fully functional products and solutions. Open innovations are by definition widely available, including to firms and researchers in South Africa.

- *Platforms* provide services for networks of users. There are typically different groups of users such as those using the platform to sell (for example, hotel bookings) and those looking to find and purchase goods and services, who typically use it for free. The platform owners charge others (such as advertisers) and benefit from aggregating user data (as Google does from all the users of Google Maps). The platform owners can also integrate into those offering the goods and services, such as through having an ownership stake[8]. They can then channel consumers to the platform's preferred services.

Advanced manufacturing systems are mainly comprised of modular components and machinery, including those based on inputs from open innovation. They can act as platforms upon which third party complementors can offer specific fixtures and tools. Cloud computing services are then used to integrate production and design data, with the cloud itself operating as a platform upon which additional modules, such as data analytics and AI services, can be developed and distributed. It is worth noting that there can still be a very skewed division of revenues with platform 'sharing' and 'open platforms' as the gatekeeper of the platform is able to unilaterally set commissions if the platform is the critical route to users. .

4. Technology platforms: priorities for South Africa

The research and industry dialogues completed for this project indicated a clear prioritisation of cross-cutting/transversal technologies for South African industry.

[7] The standards and protocols supporting value chain modularity are often embedded in digital ICT systems such as CAD/CAM and ERP.
[8] This is what the regulation which came into force in India on 1 February 2019 sought to prevent (see https://www.reuters.com/article/us-india-ecommerce/walmart-amazon-scrambling-to-comply-with-indias-new-e-commerce-rules-idUSKCN1PP1PN)

A. Digitalisation and integration of supply chains

Digitalisation of production and supply chains appears to be the minimum requirement for participating in the new digital economy and needs to be the first priority. Digitalisation involves the convergence of 3rd industrial revolution technologies such as ICT and manufacturing software (Box 1) with sensors and the internet of things (IoT) to create complete visibility of the supply chain. These technologies allow for coordination efficiencies, condition monitoring and process optimisation, both within firms and along supply chains.

Box 1. Manufacturing software and systems

Manufacturing execution systems (MES) are computerised systems used in manufacturing to track and document the transformation of raw materials to finished goods.

Enterprise resource planning (ERP) is the integrated management of core business processes, often in real-time and mediated by software and technology.

Product lifecycle management (PLM) is an information management system that can integrate data, processes, business systems and, ultimately, people in an extended enterprise. PLM software allows this information to be managed throughout the entire lifecycle of a product, efficiently and cost-effectively from ideation, design and manufacture through service and disposal.

Within the firm, digitalisation can result in more efficient production processes and/or improved productivity. When firms can monitor the entire process, then machines and other resources can be allocated more efficiently, problems can be identified quickly, and actions can be taken to reduce bottlenecks, optimise processes and reduce defects. Along supply chains there has been a rapid adoption of sensors in lead firms across industries as part of their initial digitalization strategies. For example, the construction, agriculture and mining vehicles industry has been monitoring the conditions of vehicles on a real-time basis for an extended period,[9] while the mineral processing industry is using digitalisation together with machine learning for condition monitoring and predictive maintenance.[10]

Although large and lead firms are starting to adopt the new technologies and have been using the manufacturing software for years, there are many firms that are being left behind. The challenge is how to drive adoption by 2nd tier and 3rd tier firms so that the entire supply chain can reap the benefits. Software engineering and data science skills are essential, along with support for the necessary investments and attainment of standards.

Key priorities for a digital industrial policy include reliable digital infrastructure which enables firms to better manage operating systems and monitor data remotely, thereby remaining relevant in a highly competitive global market place (see DTI, 2018). However, access to high speed data, which is a function of latency, bandwidth and cost, remains a challenge in South Africa.

[9] Automotive industry dialogue, 25 October 2018.
[10] DIPF policy brief 1 and Machinery dialogue, 11 October 2018.

As data and its analysis becomes more important in production and an increasing source of value creation, there is a need to develop a regulatory framework to govern data ownership and secure data protection to ensure that the returns accrue to the right firms. It is particularly important to support local firms that are participating in value chains and which may have limited bargaining power. The digitalization of value chains and associated data integration processes have important implications on how the shared information is used by whom and for what purposes. Existing evidence in the sustainability realm suggests that, where enhanced informational demands have been placed on suppliers by powerful buyers (usually lead firms), buyers obtain far more information about the cost structure of suppliers than are necessary for efficiencies and can use this in negotiations and to extract a greater share of the value created. The data regulatory framework must consider the extent to which supplier data can be ringfenced against 'data raiding' by global buyers.

B. Design, rapid prototyping and customisation

The combination of design software, additive manufacturing and material science has significantly reduced the time it takes to develop prototypes and produce tooling. For example, a lead mineral processing machinery manufacturer has reduced its product development times from 6 to 8 weeks to only 2 to 3 days.[11] This is important for industries demanding a high degree of customisation and where speed to market is crucial for competitiveness.

South Africa has lagged in terms of tooling capabilities and battled to meet the lead times of European and Asian countries. Additive manufacturing thus presents an opportunity to 'leapfrog' on tooling.

Though additive manufacturing is mostly used for pre-production activities, for example, producing prototypes, it is increasingly being used for production and post production activities. Additive manufacturing for production could disrupt the organisation of value creation in value chains (Rehnberg and Ponte, 2017). Advanced economies are already developing strategies to leverage additive manufacturing for re-shoring activities that were typically outsourced to less developed economies.

South Africa has already made substantial investments in additive manufacturing in public institutions and in some firms. Global leaders in the adoption of additive manufacturing have been the aerospace and automotive industries. The benefits in these industries have been proven in terms of process and product upgrading (Table 2), both within firms and along value chains, as highlighted in the research on South African firms.

Table 2: Additive manufacturing upgrading in aerospace & automotive GVCs

	Pre-production	*Production*	*Post-production*
3DP in Aerospace	*Process-upgrading* • Product development cycles shortened *Product-upgrading* • Freedom of design and new materials • Product life cycles extended	*Process-upgrading* • Tooling costs reduced • Assembly reduced • Economies of scope reduces cost for low batch production • Material waste reduced • Digitalisation reduces errors	*Process-upgrading* • Lead times to market reduced • Supply chain costs in packaging, warehousing, logistics and transportation reduced *Product-upgrading* • Mass customisation

[11] DIPF policy brief 1.

3DP in Automotive	*Process-upgrading* • Product development cycles shortened	*Process-upgrading* • Tooling costs reduced	*Process-upgrading* • Lead times to market reduced

Source: Rehnberg and Ponte 2017

An effective South African digital industrial policy needs to consider two key issues:

- ***Wider use of public facilities supporting the adoption of advanced technology***. The challenge is to develop strategies for ensuring access by traditional manufacturing to the existing public institutions and support for adoption by individual firms of technologies for rapid prototyping. This is especially the case for smaller firms that may not be able to invest in the latest 3D/4D printers.

- ***Impact of additive manufacturing on value distribution in GVCs and implications for trade.*** In the future, trade of intermediate goods may decline as firms make use of 3D printing facilities located closer to their customers. One of the benefits of additive manufacturing is the ability to print a finished good in one stage. Given South Africa's distance from most markets and sources of supply, this will have implications for trade and value addition. In addition, as imports into the country will be of designs rather than actual products this will pose challenges for collection of tariff income.

C. Advanced manufacturing and automation

Advanced manufacturing and automation can be understood as fully-integrated, collaborative manufacturing systems that respond in real time to changing demands and conditions in the factory and the supply network. Though this typically relates to 'smart factories', it is equally applicable in agriculture, commonly referred to as 'precision farming', or even mining or construction. Advanced manufacturing is made possible by a combination of technologies including robotics, sensors, machine learning and IoT. Industrial robots linked to advanced manufacturing are automatically controlled and operate on their own. They are multipurpose (reprogrammable) and capable of doing different kinds of tasks rather than simply repeating the same tasks.

Internationally, the adoption of industrial robots has been concentrated in a few sectors including automotive (accounting for 40% of the total), computers and electronic equipment, electrical equipment, appliances and components, rubber, plastics and chemicals, and industrial machinery (UNCTAD, 2018). There has been slow uptake of robotics in South Africa, although it varies greatly by sector.[12] For example, the large and lead firms in the food processing industry have adopted robotics in their packaging lines which has allowed for more precision and flexibility.[13] Here, robots are substituting for low-skilled labour.

Precision farming entails the use of satellite imagery and high-resolution crop sensors to inform application of the right amounts of irrigation or fertiliser, while optical sensors or drones are used to identify crop health across the field.[14] Adoption of precision farming has been further stimulated by the recent droughts in South Africa and the threats of climate change. By

[12] Of the 400 firms that responded to 'The Mobile Corporation in South Africa' survey only 6% indicated they were using robotics while 13.4% indicated using big data and machine learning, 13.6% virtual reality and 33.9% IoT.
[13] DIPF policy brief 4.
[14] DIPF policy brief 4.

improving competitiveness, low-skilled jobs are sustained. Larger and better resourced farmers have been able to adopt precision farming methods, but they are not yet widespread.

D. E-commerce, online search and branding via social media platforms

E-commerce is changing the face of retail internationally. Along with online search and social media platforms, the routes to customers are increasingly through one of a very few 'technology giants'. These online platforms bring together consumer data and analysis, logistics and payments. Firms such as Amazon and Alibaba have immense scale, strong brand identity, supplier networks and data capabilities. There are substantial first-mover advantages which make it difficult for smaller rivals to compete; although the largest e-commerce platform in South Africa is the local Takealot.com.[15]

At present, online retail in South Africa makes up a mere 1% of total retail turnover, while the most developed online markets such as the UK approach 20% of retail spend. This has been attributed to having densely populated markets of customers with fast internet access, credit cards and a willingness to pay extra for delivery. In comparison, South Africa has a shopping mall culture, consumer concerns relating to sharing credit card details online, and expensive delivery by an inefficient postal service.

Online platforms have the potential to open-up routes to consumers for small and medium enterprises, with lower entry barriers. But, at the same time, the platforms have substantial market power and can skew the playing field if they and international producers have a much more favourable tax regime than local businesses. There are important implications for international trade, such as the 'Digital 2 Dozen' agenda which has been pushed by the USA and seeks commitments to zero duties on digital goods and services. Concerns about market power, control over consumer searching and data have also led to competition inquiries around the world and consideration of alternative means of taxation.[16]

Many of South Africa's larger retail groups see omni-retailing or seamless integration of in-store and online experiences as core to their future growth. Developments in websites are being combined with the digital transformation of other aspects of their retail businesses (such as integrated inventory systems, digital payments and the integration of store payment cards into their online shopping offer).

The priority appears to be an appropriate regulatory and policy regime to ensure that local businesses can interface with and layer their own platforms on top of those of the global giants and that they can compete on equal terms.[17] Regulations need to be fit for purpose to address the convergence of payments systems, retail, logistics, customer information and marketing and telecoms through a flexible and responsive regulatory regime. In addition, an enabling environment for the digitalisation of business, including more reliable and cheaper connectivity

[15] Owned by Naspers, which also has a 31.2% stake in China's Tencent, owner of WeChat.
[16] See, for example, Australian Competition and Consumer Commission (ACCC) preliminary report of the Digital Platforms Inquiry; EU competition cases into Google and Facebook; Indian e-commerce regulations coming into force on 1 February 2019; move by the UK to impose a tax of 2% on turnover of digital platforms and legislation to make Amazon jointly and severally liable for its suppliers with regard to VAT.
[17] Digital platforms have been found to aggressively reduce taxation in various ways including how services are structured and through the use of tax havens, which means that they have advantages over local businesses.

and an urgent upgrading of the skills pool in big data analytics, is urgently required to open-up markets to local entrepreneurs.

5. Implications for production systems and value chains in South Africa

The range of digital technologies are clearly manifesting within South Africa's industrial ecosystem, although at uneven speeds, and in distinctive ways that appear to be strongly influenced by specific value chain dynamics. In this section, we explore the nature of these digital disruptions and their consequences for South African industry.

5.1 Key transversal issues

While South African industrialists are aware of the consequences of digital disruption in the value chains within which they operate, uncertainties relate to the speed, scale and scope of the emerging disruptions. The risks and rewards associated with embracing new digitalisation technologies are consequently not sufficiently understood to support aggressive investment in these technologies, hence the continued dominance of traditional industrial processes, products, and service models.

The key transversal themes that relate to this challenge can be summarised into four main categories:

1. The extent to which digital disruptions are likely to be efficiency enabling as opposed to only value chain disrupting;
2. The extent to which digital disruption will impact on economic activity in the purely digital space, relative to the cyber-physical space, and the purely physical space;
3. The extent to which entirely new value chain models develop; and
4. The extent to which digital disruption will shift the structure of GVCs, and the role of lead multinational firms in organising their global activities.

Efficiency enabling versus value chain disrupting

The transition to digitally enabled firm-level business models is likely to incorporate both major and minor adjustments, and it is critical that these are both understood. If not, South Africa is likely to end with a divide between academic and government institutions operating in the realm of the digitally dramatic, and firms operating in the realm of more subtle incorporation of digitalisation technologies to enhance competitiveness.

In terms of dramatic digital disruption within value chains, the advent of autonomous electric vehicles is set to cause upheaval not just in automotive manufacturing and vehicle consumption, but across the entire automotive ecosystem. This includes energy supply and the broader transport sector. South Africa will undoubtedly be affected. South Africa's leading Articulated Dump Truck manufacturer, Bell Equipment, is already exploring the development of fully autonomous vehicles.

At the opposite end of the spectrum, many of the positive examples of digital progression in South Africa are less dramatic, encompassing efficiency-enabling interventions, such as improving the effectiveness of cold chain management within the agriculture-food processing value chain using IoT; improving machine reliability through the application of machine learning; or supplying fashion retail markets with more desirable products on the basis of IoT-enabled data analytics and supply chain coordination.

Atlantis Foundries, which manufactures commercial vehicle engine blocks for several major international truck brands represents an excellent South African example of the application of AI to eliminate sub-surface defects. The use of AI has reduced customer scrap and rework rates by up to 90%.

Digital disruption across the cyber-physical space

The extent of digital disruption is linked to how digitalisation transverses the purely cyber versus the cyber-physical and mainly physical value chains. For example, digital books or games that can be downloaded are primarily digital transactions (although recognising that a physical product is ultimately required to read or play). Cyber-physical products are items such as household appliances, electronic goods or vehicles where an increasing amount of digital technology is embodied within these products. The way consumers use them may change as service-platforms (like Uber) replace private vehicle ownership, and appliances push usage decisions. Finally, there are also primarily physical products or services which may be significantly augmented by digitalisation in future but will remain primarily physical activities.

Seen through this lens, certain value chains are likely to be more disrupted than others. This is recognised by firms. For example, one of South Africa's leading clothing retailers has taken a relatively cautious view on "digital disruption", having tested several innovations across the business. Their advances into e-commerce have not yielded the anticipated results, although the group is seen as a leader in this space in South Africa. The focus of their digitalisation effort has, therefore, increasingly been on big data analytics to *enhance* marketing strategies in response to rapidly changing consumer preferences and the need to improve on customer experiences.

In mineral processing machinery, digitalisation enables machinery manufacturers in partnership with engineers to provide mines with a total cost of processing service. Systems and processes are customised to specific mines, the wear of parts is tracked enabling optimal replacement and performance is monitored across plants. While the companies are moving to selling a service, competitive capabilities still involve embodying knowledge in the physical products being manufactured. The lead firms are increasingly employing additive manufacturing and simulation in design and product development to optimise the mineral processing solutions being supplied.

New value chain models

A critical consideration that emerges in respect of all the industries studied is the extent to which new value chain models will evolve because of digitalisation. As the role of machines increases (displacing the centrality of human to human interaction), platforms take a greater share of economic activity from products (pay-for-use displacing merchandise transactions),

and market intelligence shifts from tightly controlled company cores to the 'digital crowd'. These changes can fundamentally alter how value chains are organised.

The primary challenge that South African industrialists appear to have is not in understanding individual digital technologies, nor the individual business model shifts explored above, but rather in understanding how the technologies and associated business model shifts combine in the value chains within which their firms operate. For example, rapidly advancing automotive telemetry, which effectively plugs vehicles into the Internet of Things, while also allowing vehicles to "see" their immediate environment through advanced sensor technology, has provided the basis for the development of Autonomous Vehicles (AVs). This will change the components and materials cars are made of.[18] Even more fundamentally, the technical dimensions of the AV may become superfluous to the passenger such that vehicle ownership no longer remains important.

The implication is that transport-as-a-service (TaaS) providers could have fleets of autonomous electric vehicles and drive the value chain. One projection is that these providers could supply 95% of USA passenger miles by 2030 with Europe following a similar path (Arbib and Seba, 2017).

Global Value Chains

A final set of critical transversal considerations relate to the position of South African firms within complex GVCs. Many larger South African based manufacturers are subsidiaries of MNCs, operate under license to MNCs, or are independent, but supply MNCs. These firms often have limited agency, with the technologies they use and the products or services they offer prescribed for them by the lead firms that they are ultimately answerable to.

In clothing and textiles, advances in digital fit software combined with rapidly advancing additive manufacturing technologies, such as Carbon's Digital Light Synthesis technology, currently in use by Adidas, will have a significant impact not only on product development but all functional areas of the value chain from design to prototyping and ultimately volume production. It is currently possible to go directly from computer aided design of a shoe, to the sharing of that design to anywhere in the world, to the printing of the shoe last on an additive printer; and for the upper to then be prototyped, with the sole being instantly printed also on an additive printer.

For many South African firms, the only scope to embrace new digital technologies is in process improvements, which fall into their ambit of control. For the balance of opportunities, the South African firms are ultimately dependent on how the lead firm in their GVC embraces the new digital technologies and then "trickles these down" through their global networks.

This raises two important transversal issues for digital disruption within the South African industrial ecosystem. Will digitalisation result in further consolidation of GVCs and the continued growth and dominance of MNCs as lead firms, or will it facilitate GVC fragmentation, and the expansion of opportunities for independent SMMEs? For example, will online retailing replace the dominance of brick and mortar stores with new and potentially even more

[18] AVs will not need steering wheels or driving aids (no driver), air bags or side impact bars, highly engineered accident crumple zones or seat belts (no chance of crashing), nor powerful engines or associated componentry, such as large brake disks (they will drive at exactly the speeds specified by law). AVs will potentially also not need to be made of steel or aluminium. If they cannot crash, biodegradable textile skins may be the future.

dominant lead firms, like Amazon, or will digital platforms like Etsy “democratise” market access? There are good reasons to believe that tendencies to concentration will prevail in the absence of proactive policies to better enable local firms to link into, and build-on, international platforms.

5.2 Value chain specific issues

The dynamic interplay between transversal and value chain-specific digitalisation issues is one of the most striking aspects of our analysis. This suggests that cross-cutting support, such as skills development, needs to be combined with industry specific responses to digitalisation as embedded in sector strategies.

In food value chains it appears that changing market and regulatory conditions, particularly concerns around food safety, are the key drivers of digitalisation. In fresh fruit, there is huge potential to grow exports and employment with the application of digitalisation, however, export market access and related standards are a major obstacle. Blockchain technology and radio frequency identification (RFID) tags have caused major disruptions in the food industry by addressing the core challenges around transparency and traceability along the value chain. For example, a local grower and producer of citrus fruits, Katlego Sitrus, is exporting fruit with stickers which have a quick–response barcode that consumers can scan.

Within the South African clothing, textiles, footwear and leather value chains, the availability of big data and AI-enabled analytics is shaped by the need for enhanced market research. Increasing consumer awareness of rapidly emerging environmental issues is also a potential major source of disruption within the value chain. Those value chains that export most of their output to developed economy markets, such as the automotive industry, are likely to be far more vulnerable to digital disruption than those only supplying the domestic market. The substantially greater progression of digital disruption in developed economy markets is clearly being felt by South African exporters, with this becoming an even greater challenge when firms straddle supply into rapidly advancing markets and a largely non-dynamic local market.

The automotive and yellow metal industries provide evidence of this challenge. The South African automotive industry presently exports nearly 60% of its production, with 70% of this total focused on European Union and North American markets. These markets require fuel qualities and associated engine technologies that are multiple generations more advanced than the poor fuel qualities available in South Africa; and are also starting to transition to alternative Energy Efficient Vehicle (EEV) technologies, that are not yet available domestically.

A leading South African yellow metal manufacturer which is applying advanced telemetry requires different ICT equipment to be installed to operate in each country given the lack of common standards. If all regions, including South Africa, were to migrate to a 5G network, this would enable the use of a single 5G modem that could be fitted on all machines and operated in different regions without difficulty.

In mining machinery, the growing regional market in Southern Africa provides an important base from which locally-based companies have been able to build capabilities. The advantages of proximity and location specific knowledge require partnerships with the engineering procurement and construction management firms which lead mine design. The

companies must simultaneously learn from global developments and provide regional solutions in, for example, predictive maintenance which requires reliable data transfer.

The ability to absorb new digital technologies depends in part on the factor cost profiles that dominate activities within specific value chain linkages. For example, where labour costs represent a small proportion of total production costs, and are comparatively cheap internationally, the incentive to invest in new digital technologies is greatly reduced. While the introduction of AI-enabled robotics is growing rapidly in automotive assembly plants located within high labour cost, developed economies, the most advanced automotive plant in South Africa still has no co-bots, despite its sister plant operating with dozens of them. Similarly, the South African clothing and footwear industries, which have low comparative labour costs, only have automation in key capital-intensive nodal points, like materials cutting and plant performance monitoring. All assembly activity is still being undertaken manually.

5.3 Summary of the South African position

The research and industry dialogues undertaken as part of the project provide a rich tapestry of digital transformation evidence across key South African value chains. They highlight a tension between firms grappling with potentially existential technology-induced value chain shifts (e.g. the emergence of autonomous vehicles) to the efficiency-seeking digital disruptions that are likely to significantly shift the position of firms within value chains (e.g. the adoption of digital technologies that enhance services, products and processes). Somewhere in the middle of this spectrum are new technology developments, particularly those adopted by MNCs and leading local firms, which will require suppliers and service providers across the value chain to invest in digitalisation capabilities in order to maintain their position within value chains. Examples of these technologies are blockchain traceability, smart labels, and IIoT-enabled reporting and monitoring platforms. In all cases, firms need to operate in a digitally-enabled environment. This requires:

- The ubiquitous availability of cheap, fast, broadband in South Africa; and
- The availability of ICT, software engineering and data science skills capable of managing and mining the IoT and IIoT platforms that are emerging.

These are essential for South Africa to benefit from the AI-based machine learning, virtual reality digital twinning, additive manufacturing, and e-commerce benefits that are rapidly materialising in developed economies. The frustrations expressed by South African firms in respect of these basic enablers being either missing or severely underdeveloped domestically is a key reason for the firms having only a limited perspective on the potential for digital disruption.

6. Key principles and priorities for industrial policies and institutions

New industrial policy principles must reflect the need for more strategic coordination among (and within) the public and private sectors; improved targeting and policy alignment; and the introduction of feasible policies, as is already foreshadowed in the 2018 Industrial Policy Action Plan (IPAP) (DTI, 2018).

A digital industrial policy for South Africa should aim at shaping a new “industrial ecosystem” in which the opportunities and challenges of new digital industrial technologies are fully

captured. This means identifying and targeting areas within and across sectors in which the deployment of digital technologies allows firms to:

a) Improve products and their digital content, changing product system functionalities, to move towards higher value product segments;

b) Diversify products and activities by deploying digital industrial technologies transversally across sectoral value chains;

c) Increase productivity via process upgrading along the value chain and the local production system;

d) Link up with domestic and international firms, and diversify market access; and

e) Develop industrial competitiveness in new global sectors by leveraging South African resources.

6.1 Principles for policy development

Five principles are proposed here for the design and development of a Digital Industrial Policy Framework.

- **Digital industrialisation opportunities are about both incremental changes in production and disruptive technological innovations**

Industrial policy must be "appropriate". It must address the technical and organisational capability requirements without which the wide range of digital innovation opportunities cannot be effectively deployed and diffused across the industrial ecosystem.

- **Digital industrialisation is sustainable and inclusive only if it creates conditions for more domestic value creation and distribution**

Digital technologies provide new platforms for developing linkages in the local production system. Governing the technological, competition and regulatory processes to encourage these linkages is critical for sustainable value addition and inclusive wealth creation in the economy.

- **Systemic changes call for systemic policy frameworks**

Digital industrialisation is about systemic transformation of the economy, that is, the emergence of a new "industrial ecosystem". The effectiveness of digital industrial policy will depend on interventions that address both the specific conditions of existing sectors and the wide range of new opportunities emerging across them.

- **Strategic targeting, coordination and policy alignment are critical for effective implementation**

Systemic transformation cannot only be achieved with generic policy frameworks. Strategic choices must be made to unleash the potential that digital technologies offer for the innovative industrial renewal of existing sectors and their associated value chains, and the emergence of new competitive players in the industrial ecosystem. For effective policy implementation, these choices must be effectively coordinated and aligned.

- **New coalitions for change forged around better aligned productive interests are necessary for the successful implementation of industrial policy**

The design of industrial policy must consider the different interests, capabilities and distribution of power within and among different organisations and constituencies in the broader economy, as well as within specific Global Value Chains; and find ways in which South African policies can lead to better alignment of productive interests. Without such alignment, policies will fragment, undermining enforcement and making the environment vulnerable to unproductive rent capture.

6.2 Key industrial policy priorities

The digital industrial policy principles highlighted above point to the need for both sector-specific digital industrial policy as well as cross-sectoral interventions. Not all industries are affected in the same way and prioritisation is essential for impact.

- **Improved cost, speed and reliability of ICT infrastructure (bandwidth)**

South Africa has expensive, comparatively slow and unreliable ICT infrastructure and industrialists deem this to be a major limitation to the adoption of more advanced digital technologies. The potential efficiencies along value chains, from digitalisation, enabling data analysis and tracking of performance across plants and markets, are undermined by poor connectivity. AI-enabled machine learning systems, which are particularly data intensive, appear compromised as a result of this limitation, especially for SMMEs that do not have the resources to invest in bespoke infrastructure, such as microwave links. The key requirement is to release spectrum for improved connectivity.

- **Digital skills policy**

Embracing new digital technologies in South Africa is comparatively expensive for firms because of substantial skills gaps. This requires both scaled-up skills development programmes and the attraction of skilled immigrants in key areas.

Priorities include:

  - Ramped up incentives for cross-cutting skills development in software engineering, data science and related ICT skills, both in respect of on-the-job training and higher education;
  - The establishment of a priority skills list for essential industrial activities in digitalisation, CAD/CAM, management of MES/ERP/PLM. The list needs to direct public digital skills expenditure and should be updated annually in recognition of the rapidly moving digital skills frontier;
  - The development of sector-specific digital skills in partnership with private sector industry associations and Sector Education and Training Authorities (SETAs);
  - The reform of incentives and organisational structure within Vocational Education and Training (VET) institutions to incentivise firm-driven training beyond narrow certification-driven training. More private sector involvement is essential to create a closer alignment with rapidly changing requirements. Greater use of internships is also important;

- The linking of digital skills policy to broader technology policy to provide less resourced firms with complementary support in training, technology absorption and associated organisational development.

- **Digital technology policy**

The systematic restructuring of technology policy and institutions is required in respect of three areas: digital technology absorption; integration; and, deployment. One such opportunity is the development (or conversion) of technology centres, science councils (e.g. CSIR), incubators, and university units into a digital industrial technology network of "technology intermediary institutions" organised around the main digital technology platforms and supporting technology absorption, integration and deployment.

The key elements of each are:

- *Technology absorption*: This requires the provision of manufacturing and digital extension services (including organisational and operational systems), demonstration projects, beta factories, access to data and infra-technology (metrology, standards), and access to additive manufacturing for by-passing tooling.
- *Technology integration*: This necessitates the provision of scaling-up facilities such as accelerators for digital start-ups and SMMEs, standardisation and data, retrofitting services and legacy system integration into digital platforms, rapid prototyping facilities, and virtual design.
- *Technology deployment*: This would be enabled through the provision of standardisation services and data, infra-technologies, testing and certification facilities.

Incentivising firms to incorporate digital technologies within their business models is also a key requirement, and yet the evidence from the sector cases suggests that South Africa's Research and Development (R&D) tax-based incentives define the opportunity so narrowly that most firms do not qualify for support. For example, the South African government's tax-based incentive administered in terms of Section 11D of the Income Tax Act, defines what constitutes R&D but then notes numerous exclusions, including market research, market testing or sales promotion; administration, financing, compliance and similar overheads; and routine testing, analysis, information collection and quality control in the normal course of business. It is critical that South Africa's R&D incentives support both efficiency seeking and value chain disrupting digital technology absorption, and yet there appears limited evidence of either being supported.

- **Financing and investment**

Digitalisation requires investment in upgraded capital equipment. In addition, there are working capital consequences to the changes in the way in which value chains will operate as firms move to providing end-to-end service solutions for customers as opposed to selling products. For example, South African mining machinery manufacturers are contracting with mines to deliver processed tonnes of ore rather than the supply of machinery. This has potentially serious balance sheet consequences for firms, with concomitant financing requirements.

Appropriate financing for investment is essential for the upgrading and supply chain integration which digitalisation enables. It is also necessary for the specific industry implications, as highlighted above, to be incorporated in industry plans. Development finance institutions, such as the Industrial Development Corporation (IDC), have a lead role to play in offering the appropriate financing required.

- **Linkage development policy**

As a country with generally weak industrial supply chains, particularly regarding the role of SMMEs in these supply chains, digitalisation represents a major opportunity to promote the adoption of supply chain tools (such as ERP and MES) for better supply chain integration. Key to this promotion is supporting second and third tier companies in accessing affordable digital technology licenses or creating alternative models to reduce the licencing burden. The creation of a "Catalogue of Digital SMME Suppliers" via an open and competitive digital market platform to match specific technology and production services demand and supply along and across sectoral value chains could be of huge value to SMMEs. De-risking SMME investments in new technologies and products using combined technology services and hybrid financing models (such as matching grants and pre-commercial procurement) could support the inclusion of these firms within South Africa's industrial value chains.

- **Economic regulation, competition policy and data**

Digitalisation means the convergence of platforms and networks across telecommunications, finance, retail and logistics. It is well recognised that the economics of platforms means that there are substantial scale and first-mover advantages. Where there are local demand specificities, South African platforms can develop to rival multinational platforms, as we have seen in e-commerce. However, a smart and flexible regulatory framework needs to ensure that dominant platforms cannot abuse their position to undermine local rivals, while an enabling framework supports local platforms and applications including building onto international platforms where appropriate.

South Africa's regulatory bodies, as for most other countries, are still organised as if the digitalisation convergence is not underway. Appropriate regulatory and competition rules for digital platforms, including addressing data privacy and ownership, need to be designed drawing on international experience such as the measures taken recently by the EU and India to ensure a level playing field for local businesses in e-commerce and online search. The 2018 amendments to the South African Competition Act introduce provisions relating to buyer power and strengthen those relating to price discrimination with guidelines to be introduced regarding their application.

The generation, ownership and analysis of data is key for competitiveness and market power and, at the same time, raises fundamental questions about domestic consumer rights and privacy. What cybersecurity protocols will need to be adhered to in respect of the swathes of data being collected within ever larger platforms? What data ownership laws will prevail? How will they be enforced? Will there be data sovereignty, or will the large-scale service platforms created exclusively outside of South Africa be subject to laws in other countries? South Africa needs to develop a clearly defined policy on data ownership, data quality, data categorisation and anonymity. The creation of affordable solutions by service providers is critical in this

regard, and as such there is a case for considering incentives to encourage the development of these database platforms.

- **Trade and tax policies**

South Africa must work with other countries at the WTO to resist the push by the global technology companies for digital transactions to be exempt from tariffs. The advance of digital technologies potentially weakens the position of industrialising countries as international firms can bypass import duties, local taxes and regulations. For example, additive manufacturing may simply require the transfer of code from a data cloud to a home-based printing machine and the transfer of the code is free of import tariffs (and other taxes such as VAT and ad valorem excise taxes) and adherence to regulations relating to the safety or health properties of the product. Similarly, e-commerce and platforms such as Uber and Airbnb raise challenges for the levying of duties and taxes. South Africa should urgently work with other countries which have taken steps to regulate and tax digital transactions, including e-commerce.[19]

A key question is how the government plans to tax imported digital products and services to enable and protect local productive activity. In principle, digital technologies can also be used to better protect the domestic market and consumers. For example, clothing, textiles and footwear products entering South Africa could be required to have Radio Frequency Identification (RFID) tags that prove their provenance, such as where they were manufactured, and at what price they were exported from the country in which they were produced.

6.3 Strategic policy and governance framework

The effectiveness of sectoral and cross-sectoral interventions across key policy areas will depend on the extent to which the government is able to align interventions and develop a governance framework beyond policy silos. To achieve this strategic policy alignment:

- Industry-specific and cross-cutting technology and skills data are critical, both in the policy design and alignment processes;
- Financing reforms and new budgetary models may need to be deployed so that resources are allocated around key policy priorities (and not around government institutions); and
- The implementation of a coordinated digital industrial policy requires the establishment of high-level coordination capacity, institutionalised private sector inputs and appropriate monitoring and evaluation systems.

While policy design and the governance framework are critical, the effective implementation and enforcement of any industrial policy will depend on enhanced government capacity and more effective cooperation with the private sector. Overall, digital industrialisation will also raise potential trade-offs and new conflicts in the economy, for example with respect to

[19] See also the work on Base Erosion and Profit Shifting by the OECD, and the tax challenges arising from digitalization (http://www.oecd.org/tax/beps/)

employment. Given the challenges faced by SMMEs, if not guided appropriately, digital technologies can exacerbate the divide between big and small firms, to the detriment of industrialisation and inclusive growth. Digital industrial policy must therefore ensure that the digital industrial dividend is widely distributed across different firms, their employees and broader South African society.

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