Digital Industrial Policy Brief 1

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MACHINERY, EQUIPMENT AND ELECTRONIC CONTROL SYSTEMS: LEADING REINDUSTRIALISATION IN SOUTHERN AFRICA

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Introduction

Integrated machinery, equipment and electronic control systems are key industries for digitalisation and related technology changes, and combine a range of sophisticated and complex technologies. South Africa's machinery and equipment sector has a developed industrial base and encompasses the manufacture of machinery such as mineral-processing equipment, pumps, valves and earthmoving equipment. Machinery, equipment and electronic control systems have strong backward linkages to the metal products industries. The entire value chain accounts for the largest source of formal employment in South African manufacturing, contributing 250,000 direct jobs in total, of which the machinery and equipment accounts for 42%.[4] The industry also has strong linkages with supporting industries such as transport and logistics, financial and engineering services, inducing further employment.

However, the South African machinery and equipment sector has been losing capabilities and competitiveness, reflected in its losing market share in the region to deep sea imports.[5] This is due to various factors, including weak productive skills, dilapidated infrastructure, lack of access to development finance, and high energy and input costs.[6] The lead firms that have maintained market share in the region and elsewhere have continuously upgraded their capabilities and this includes investing in the latest technologies. As such, there is a need to strengthen the local production system that is at the heart of industrial development in South Africa including importantly through leveraging developments in technology.

To remain close to the technology frontier, lead firms in South Africa are investing in world class machinery and equipment, adopting technologies from more advanced economies (such

[1] DNA Economics.
[2] Centre for Competition, Regulation and Economic Development, UJ.
[3] Centre for Competition, Regulation and Economic Development, UJ.
[4] Kaziboni, Rustomjee & Steuart. (2018). Structural transformation along metals, machinery and equipment value chain – Developing capabilities in the metals and machinery segments. CCRED Working Paper 2018/7. Available here: https://www.competition.org.za/s/IDTT-MME-Final-Project-Report.pdf.
[5] Langa, E., Mondliwa, P. & Nkhonjera, M. (2018). Maintaining and building capabilities in capital equipment and related industries in Mozambique and South Africa. CCRED Working Paper 2018/1
[6] See Kaziboni, Rustomjee, Steuart (2018).

as Germany) and upskilling their workforce. Overall, there are groups of technologies that are 'changing the game' and enabling local companies to rise to international standards. The main technology driven changes in the industry include predictive maintenance and monitoring systems, additive manufacturing for rapid prototyping and tool making and robotics in production. This brief engages with these issues.

Key technology disruptions

Predictive maintenance and monitoring systems

The biggest technology driven disruption in the South African machinery and equipment industry has been predictive maintenance and monitoring systems.[7] Through reliable internet connectivity, mineral processing companies can collect real time data on the health and performance of machinery and equipment remotely, and how the environment including temperatures, pressure and humidity, affect its wear and tear. This uses a combination of industry 4.0 technologies including sensors, big data, cloud computing, data analytics, internet of things and artificial intelligence. Sensors have allowed firms to remotely monitor their equipment, and schedule repair and maintenance ahead of failure. Predictive analytics and the application of condition monitoring systems use cloud based programs that can be installed on most processing equipment.[8] Monitoring equipment and real time feedback has occurred on the back of falling costs of sensors that continuously transmit data with low power and bandwidth requirements. For firms such as Weir Minerals, such technology platforms are a key focus, allowing their customers (mining houses) to reduce downtime and improve longevity of equipment.[9] Predictive maintenance and monitoring systems have allow mines and other customer to reduce costs by preventing unplanned downtime, inspecting wear rates, indicating possible design improvements, and reducing manufacturing waste with pre-determined sizing.[10] It is important to for firms to demonstrate predictive maintenance capabilities to be able to win new business and, in the near future, firms that do not have these capabilities will be competitively irrelevant.[11]

The extent of technology used in predictive maintenance and monitoring systems currently depends on the installations. The newer installations of equipment include capabilities for machine learning such that the machines will automatically recalibrate to suite the observed weather conditions, as an example, while, in older installations, the analytics prompts humans to intervene. As older equipment gets replaced over time all installations will be equipped with artificial intelligence.

Within mining machinery and equipment industry this is a stepwise change as the aftermarket services are a key part of the business. For processing equipment, the size of after-market revenues can be between 13 and 15 times the initial capital cost and installation, hence they offer sustainability for firms.[12] Aftermarket services, together with quick lead times are critical

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[7] Firm interviews.
[8] http://www.miningweekly.com/article/pumping-solutions-positioned-to-address-most-pressing-needs-2018-02-02
[9] See footnote 8.
[10] https://www.multotec.com/content/condition-monitoring.
[11] CCRED Industry 4.0 Machinery and Equipment Dialogue, 11 October 2018.
[12] Fessehaie (2015) Regional industrialisation project: Case study on the mining capital equipment value chain in South Africa and Zambia. CCRED Working Paper 1/2015.

determinants of firm competitiveness.[13] With advances in technology, firms have moved from simple installation and repairs to the use of monitoring, control and predictive analytics systems, which are becoming part of a package of capabilities in the provision of aftermarket services.[14]

In the South African context the adoption of predictive maintenance and monitoring systems raises a number of key issues.

- First, the cost and availability of bandwidth in South Africa lags behind most countries.
- Second, operating these machines and analysing the data requires specific skills such as IT, data analysts, scientists and artisans with IT capabilities, which South Africa lacks. While such a technological leapfrog can result in substantial economic benefits, it needs to be complemented by skills, especially IT-related competences.[15]
- Third, data ownership. An important question that relates to big data is who owns the data? If an OEM is collecting information on the integrity of their machinery at their own cost, then the data is owned by the OEM. However, if the OEM decides to share the data with a third company, the customer would need to grant permission and the OEM would need to anonymise the data. In South Africa, this closely resonates with the Protection of Personal Information (POPI) Act. Accessing this information can yield different competitive outcomes, where firms that have access to data will be substantially more competitive, and are able to tailor solutions to the industry, while smaller companies that cannot afford to collect and store the data will be left behind.

Additive manufacturing and rapid prototyping

Additive manufacturing, commonly known as 3D printing, marks another frontier that is rapidly changing conventional production processes, creating new design and prototyping opportunities and improving supply chain dynamics. Value creation in the mineral processing industry requires customisation, hence the importance of continuous, rapid prototyping capabilities.[16] Lead firms in the machinery and equipment industry are adopting additive manufacturing for prototyping and this has reduced time spent on manufacture and testing a prototype from six to eight weeks to two to three days.[17] The competitive gains from this are evident: lower material waste and reduced processing time, which accelerates speed to market, which is critical in the industry. With virtual simulation of the production process, the design of the product can be tested to ensure peak performance, without 3D printing a prototype.[18] Once the simulation is satisfactory, the design can then be manufactured, eliminating waste and reducing production time. 3D printing is also being combined with machine learning, allowing 3D printers to correct for errors while manufacturing to reduce waste.

[13] Fessehaie, J. (2015).
[14] Interview with Multotec, 12 July 2018.
[15] http://www.smallake.kr/wp-content/uploads/2017/05/P020161223538320477062.pdf.
[16] https://www.multotec.com/content/3d-prototyping.
[17] Interview with Multotec, 7 August 2018.
[18] Interview with VUT, 24 October 2018.

Currently, the materials for 3D printing are being imported. However, various institutions are researching the potential for making some additive materials locally. Technologically sophisticated firms have also made significant investments in optimum material manufacture. In the aerospace industry, demand for lighter and more durable composites means tier 1 firms like Aerosud are continuously developing unique composite manufacturing technology to improve speed and reliability (in Aerosud's case this refers to the Cellular Core Technology).[19]

Tooling design is a crucial part of product manufacturing and its initial investment can cost more than the value of a machine. In protecting intellectual property, larger firms keep this task in-house.[20] Multotec has over the years invested extensively in new tooling to respond to market demands for specialised and complex applications.[21] 3D printing technology also allows firms to produce prototypes before any investments in tooling are made.[22] At a broader scale, South Africa's tooling industry is losing competitiveness and, despite the National Tooling Initiative, the industry is weakening. This is in stark contrast with Germany's tooling industry that is highly efficient and produces quality tooling that complements the high performance of its machinery, equipment and electronics industry.[23]

The combination of 3D printing and tooling suggests that efforts should be made in sourcing materials that are better suited to 3D printing. Polymers, wax, sand and metal powder can be used to manufacture moulds with relative ease, and at reasonable costs – metal 3D printing is in its infancy, and is still relatively expensive.[24] Previously sand suitable for 3D printing moulds used in sand casting was imported from Germany. This obviously resulted in high costs given the density of sand and associated shipping costs. VUT devised an import-replacement solution. The sand on the shores of Western Cape, when combined with an acid is suitable for manufacturing moulds. This development reduced the costs of sand from R1 000 per tonne to approximately R25. The next stage is to undertake 3D printing of material products that require metal dust. Localising sand and metal dust for 3D printing moulds can create new industries and substantially increase competitiveness for local companies in rapid prototyping. In the next year or so, VUT is planning on locating a sand 3D printing station close to a number of foundries, to reduce travel time and cost as well as damage given the fragility of sand moulds.

In some markets, firms are already using additive manufacturing for production of customised parts and high value intricate parts. It is predicted that in the next ten years the bulk of manufacturing of certain components will be done through 3D printing.[25] This illustrates that additive manufacturing presents a lower barrier to entry into manufacturing[26] since manufacturing replacement parts, that is, once-off parts or smaller production batches, has become cheaper given that parts can be manufactured at lower units without setting up a production process that requires scale. Moreover, given the high costs of steel and energy in

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[19] https://www.aerosud.co.za/research-and-development.
[20] Interview with Multotec, 7 August 2018.
[21] http://www.miningweekly.com/article/company-announcement-multotec-expands-cyclones-technology-into-non-traditional-minerals-market-2012-12-04/rep_id:3650.
[22] https://im-mining.com/2018/07/16/3d-printing-helps-multotec-develop-test-spirals-cyclones/.
[23]https://werkzeugbau-akademie.de/wp-content/uploads/sites/17/2015/06/Webversion-Tooling-in-Germany.pdf.
[24] Interview with VUT, 24 October 2018.
[25] Interview with VUT, 24 October 2018.
[26] https://www.arnoldmachine.com/6-exciting-advances-manufacturing-automation/.

South Africa, 3D printing gives component manufacturers more scope to manufacture efficiently, even setting up shop closer to their customers.

Additive manufacturing allows for customisation, without the need for economies of scale. The degree of customisation varies across the machinery equipment and electronic systems industries. While mineral processing equipment manufacturers supply mining houses (and other customers) with customised equipment, the aerospace industry's tier 1 manufacturers are prescribed designs. For example, Aerobus and Boeing (the main customers) send the specifications of the parts and components to tier 1 suppliers.[27] The tier 1 manufacturers then have some leeway to innovate the production process given that proof of compliance is met, and regular compliance audits are undertaken. Aerosud automated the manufacture of a particular component, which required them to undergo approval processes. Such requirements can be onerous on smaller firms that have limited resources to not only automate, but also adhere to such expectations.

Internet of things and blockchain integrating production systems

The IoT and blockchain are integrating ecosystems and changing business models, which can accrue significant benefits. Lead firms in South Africa can tap into more advanced ecosystems (e.g. Germany and China) and draw information that can be used to strengthen local capabilities. For example, in the manufacture of certain airplane components, specialized grades of polypropylene are imported from overseas. An integrated system allows a supplier in Asia for example, to track the inventory levels of the OEM's polypropylene in South Africa. When the material is running low the supplier receives an automated order to prepare shipment. Not only does this allow just-in-time delivery of inputs, but the OEM will be able to meet its order without any snags. Speed to market is achieved through this connectivity. In South Africa, speed to market and connectivity is undermined by slow internet, lack of bandwidth and high data costs. Bell Equipment estimates that 5% of their machines in South Africa have a successful data transmission rate, while customers require 97%.[28] This clearly slows down data transmission to customers, thereby undermining their competitiveness.

Monitoring innovation and compliance, where traceability is important, can be leveraged off the IoT. In the mining industry the source of the ores or concentrates need to be closely tracked from extraction to processing.[29] Blockchain technologies have been identified as having the capabilities for more efficient mechanisms for traceability in such industries.[30] Similarly, local companies (usually tier 1) that are integrated in global value chains need to be able to track components. In aviation, Aerosud needs to manufacture high quality products that meet the standards and requirements for Boeing and Airbus.[31] Should these lead firms need to know where a particular component was manufactured, Aerosud would need to trace the manufacturing details of the part they have manufactured with ease, but also the details of the materials that were used in their manufacturing process from the appropriate supplier(s) out

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[27] CCRED Industry 4.0 Machinery and Equipment Dialogue, 11 October 2018.
[28] CCRED Industry 4.0 - Automotives Policy Dialogue, 25 October 2018.
[29] https://www.weforum.org/agenda/2018/07/4-ways-blockchain-will-transform-the-mining-and-metals-industry/.
[30] https://m.ca.investing.com/news/stock-market-news/rwanda-hosts-first-tantalumtracking-blockchain-1296713?ampMode=1.
[31] CCRED Industry 4.0 Machinery and Equipment Dialogue, 11 October 2018.

of the roughly 300 suppliers across the globe. Again, this speaks to the need to be able to access high speed data at lower costs.

Robotics for precise manufacturing

In the machinery and equipment industry, the deployment of more sophisticated robots are automating tasks from loading, welding and maintaining equipment, to engaging in advanced manufacturing capabilities including the fabrication of material, assembly, sorting and engraving. Robots have been adopted to take on precise processes, such as is the case with robotic welding. Welding of the internal frames of screens (for mineral processing) requires precise manufacturing and can be susceptible to defects. Locally, robotic welding has reduced defects in products, resulting in efficiency gains.[32] Interestingly, the robotic welding is being done by a small component manufacturer that supplies an original equipment manufacturer (OEM), indicating the role of technology in upgrading production processes and integrating firms within an eco-system.

Despite advances in robotics and automation, companies are finding ways to integrate old technologies with the latest machines in the production process. Multotec, still uses injection moulding machines and rubber pressers that are approximately 50 years old. This machinery is still able to provide the adequate pressure and temperature required for the manufacturing of screen panels. However, the machines tooling is updated frequently to ensure that the technology stays up-to-date. At the same time, new co- injection moulding machines are being used for rubber panels. These two processes require upskilling and, in this case, investing in knowledge transfer between locals and international experts.[33]

Changes to production systems and ecosystems

An important consideration is that technology in itself does not provide a competitive advantage, rather, how it is applied can lead to firms upgrading production systems for stepwise changes in efficiency. While optimists perceive technology as an opportunity to leap-frog to a more advanced stage of development, pessimists have raised concerns around a 'digital divide' that could potentially widen the gap in usage and access to technologies. We argue that technology adoption should rather be viewed as an enabler of competitiveness - through building smart and connected firms that are more flexible and responsive. Also, it is important to note that without keeping up with the international technological changes there is a risk of further losing competitiveness and the current jobs.

The impact of the industry 4.0 technologies differs across and within sectors, as is the case in machinery, equipment and electronic systems industries. The main technological changes that are bringing about improvements in competitiveness and offering opportunities to grow the industry are discussed above. First, predictive maintenance and monitoring systems has been a game changer and a firm that does not offer these capabilities will be competitively irrelevant in the next 5 to 10 years. Wider adoption of the technologies that support these capabilities is a crucial component of a strategy to regain regional markets and achieve international competitiveness.

[32] Interview with Multotec, 29 May 2018.
[33] Interview with Multotec, 29 May 2018.

Second, additive manufacturing is improving efficiencies and helping firms to achieve speed to market. Lead firms in South Africa have invested in 3D printers in order to achieve these efficiency gains. It is important that the rest of the industry follows in order for the country to win back lost markets. This is particularly important in the machinery and equipment industry as customisation is a key part of the business. Firms that are using older ways of prototyping are going to lag by about six weeks in producing prototypes and this may make them competitively irrelevant in the future. The machinery and equipment industry is currently using additive manufacturing for pre-production (prototyping) and to a very limited degree for production. However, given the high need for customisation in the industry there are opportunities to increase additive production. This would also allow firms to print components closer to the customers thereby cutting down on delivery time. Additive manufacturing can also be used to print tools such as moulds which South Africa has failed to achieve competitiveness despite multiple interventions. In the next 5 to 10 years interventions should focus on supporting the industry to use additive manufacturing more widely to improve competitiveness along the lines discussed. There are existing public institutions such as the science parks in the Vaal University of Technology and the Central University of Technology that can support this, however, there has been limited collaboration with industry.

Third, the internet of things and blockchain is allowing firms to integrate systems bringing about efficiency gains. The level of information sharing that is taking place on these integrated platforms is allowing firms within a production ecosystem to support capability upgrading.

Fourth, increased use of robotics for precision manufacturing. The local industry has taken a cautious approach in using robotics in the manufacturing processes with robots being adopted where there are potential safety hazards for humans and where precise manufacturing can be achieved. Autonomous operations will likely create job losses and at the same time create substantial operational gains for the industry and mean firms win back market share and grow their business, creating employment.[34] How can government manage this balance?

In South Africa, where there are high levels of unskilled labour, employment displacement is a concern. While some firms have sought to balance mechanisation with labour absorption, others are reducing local production and increased import. Firms that are balancing mechanisation and minimising employment losses have a more flexible approach in how their factors of production are combined.[35] This is the case for some local lead firms in the machinery and equipment industry. Increased efficiency means local producers can expand overall through winning back market share in South Africa and the region from imports and this can be a platform for job creation along with higher output and improved efficiencies.

Where there have been some job losses due to technological upgrading given the productivity gains to be derived from automation and AI, firms have generally re-absorbed the employees in different divisions if they can achieve overall improved growth. Firms have, however, indicated that reskilling employees for future work is a challenge that they are grappling with. There is need for responsible leadership in managing the impact of industry 4.0 and at the same time, government needs to implement a longer-term approach towards science,

[34] The White Paper on the *Digital Transformation Initiative in the Mining and Metals Industry* by the World Economic Forum (2018).
[35] Rodrik, D. (2018). New technologies, global value chains and the developing economies. Pathways for Prosperity Commission on technology and inclusive growth, Background Paper 1.

technology, engineering and mathematics (STEM) subjects, including IT, that will equip displaced workers, and prepare them for redeployment into new areas.

What skills are critical to the machinery and equipment value chain? Technical and artisanal skills including electrical and mechanical technicians, mechanical and process engineers, draughtsmen and tool & die makers need to be developed in light of industry 4.0 requirements, so that firms are able to respond to technological advancements.

Efficiency gains will be made by both small and large firms, since they will be able to serve customers effectively, undergo faster product development, and prototype new products at lower costs, as in the case of 3D printing. The integration of production systems allows firms to support capability upgrading in the ecosystem as a whole.

The constant requirement to stay up-to-date and operate the latest machinery and equipment can result in a polarisation of the industrial base where smaller firms are not able to afford the technological upgrading required.[36] For example, Computer Numerically Controlled (CNC) machining is replacing manually operated machines and this requires strong support for new equipment financing to allow firms to leverage technological changes. To remain competitive, small firms can also leverage off the tier 1 firms, for example, as where Aerosud is able to communicate with their suppliers on their inventory levels through a simplified ERP system. Affordable and supportable design software (CAD software), Product Life Management software (PLM), Manufacturing Execution Software (MES) and Enterprise Resource Planning software (ERP) are essential in the aerospace industry and more so for greater ecosystem integration.

The importance of connectivity underpins the digital era where speed to market, supported by connectivity, can be a distinguishing competitive advantage. In the absence of relatively high speed, reliable and low cost internet data services, the local industry risks losing competitiveness to foreign equipment and component manufacturers. Closely linked to speed to market is dilapidated export infrastructure. This among other constraints will continue to undermine regional trade. But, if applied effectively and efficiently, technology advancements can boost the competitiveness of local firms, reducing import penetration and regaining lost export markets, such as in Zambia's Copperbelt.[37]

Developments in technologies will also introduce new business models and diversify value streams. Robotics automation, for example, has created new forms of efficiency, while 3D printing is shifting traditional production processes. This is creating technological convergence between industrial and service processes. Firms that previously had manufacturing as a core-competence, are able to enter other stages of the value chain. With lead firms being able to adopt industry 4.0 technologies, there is evidence that industry is equipping their ecosystem around how to develop the appropriate capabilities and competencies internally.

[36] Sturgeon, T. (2018). The new digital economy and development. United Nations Conference on Trade and Development, UNCTAD technical notes on ICT for development.
[37] Kaziboni et al (2018).

Potential policy responses

Successful policy responses require a quid-pro-quo relationship between government and business.[38] This relationship would entail government committing to removing bottlenecks, and firms' commitment to using domestic resources and investing in the local economy. Furthermore, the uncertainty around these technology disruptions requires a flexible and agile approach by government, where short-term achievable goals are set, and reviewed on a regular basis.

In light of this, what preliminary policy responses could create positive gains for the machinery, equipment and electronics ecosystem, and the national innovation system at large?

- Access to high speed data, which is a function of latency, bandwidth and cost remains a challenge in South Africa. Reliable **digital infrastructure** improves speed to market and inter-connectivity, enabling firms to better manage operating systems and monitor data remotely, and remain relevant in a highly competitive global market place.

- The use of advanced technologies requires a pool of skills and capabilities. Addressing the country's **skills constraints** and taking a long-term approach to developing STEM skills, in particular, will be a critical enabler. The local pool of artisanal and technical skills are limited such that lead firms have had to internalise training. In-house training is largely driven by the lack of appropriately skills coming from South Africa's training centres and FET colleges, along with the need to equip individuals with firm-specific skills. Bridging the gap between what firms require and the current education offering is an important test of how government and business can collaborate.

- Universities have traditionally offered **research and development competencies** that inform industry of the latest technology developments, and their likely impact of production processes and product development. Funding specific undergraduate and postgraduate studies will not only provide useful information for firms, but it will also create a repository of skills from which firms can draw.

- In the process of adopting technology, the cost of **licensing software and new machinery** is high, and acute for small firms. This is an area where government can support the costs incurred by firms and the related investment in machinery through appropriate incentive programmes.

- Despite South Africa being well connected to the global economy (links via the ports and rail and road network into Africa), the state of **export infrastructure and cost of transportation** remains high. Simple interventions, including an e-system for monitoring shipments can go a long way in reducing the time spent at points of entry. Shipment tracking systems using wireless technology is fast becoming common for industrial application. IoT tracking systems today can generate close to real-time, location based data, reducing costs and allowing firms to have more control of their supply chain, irrespective of remoteness.[39]

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[38] Rodrik (2018).

[39] https://www.inboundlogistics.com/cms/article/shipment-monitoring-technology-picking-up-the-signals/.

- In the digital era, strengthening (upgrading) the local **ecosystem** can improve competitiveness and co-creation in the machinery and equipment industry. This would require a combination of skills and supplier development programmes, technology incubation as well as links to universities, research centres (CSIR and Mintek) and international centres. Research and development is especially vital for building a strong ecosystem that supports innovation and linkages to industry (as in the case of skills). In the case of additive manufacturing, centres such as VUT are important open access facilities for firms. Given that industry is still in the process of responding to "smart manufacturing" and changes in production systems, leveraging existing resources and adequately capacitating universities will help create an environment conducive for adaptation, learning and innovation.