Digital Industrial Policy Brief 5

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REPOSITIONING THE FUTURE OF THE SOUTH AFRICAN CHEMICALS INDUSTRY

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Industry Background

The global chemicals sector grew at a healthy 6% on average over the period 2006 to 2015. However, China contributed most of this growth, growing at an average 18% per year. As a result, its share of global chemicals production grew from 13% to 37%. Capital investment within the global chemicals industry is fully aligned with this trend, with 73% deployed in Asia-Pacific in 2013, up from already dominant 54% in 2006.[3] The rise and now dominance of China in the chemicals manufacturing sector is significant for the future of the sector globally.

While China's growth has been concentrated in low-profit commodity sub-sectors, more recent evidence reveals that it is climbing the technology ladder and increasing its market share in higher-technology, and traditionally higher margin sub-sectors such as technical polymers and battery materials. The increasing dominance of Chinese chemicals manufacturing has placed inordinate pressure on the balance of the global chemicals industry. Innovation and efficiency-seeking organizational re-alignment have become key drivers within the global chemicals value chain, as depicted in Figure 1.

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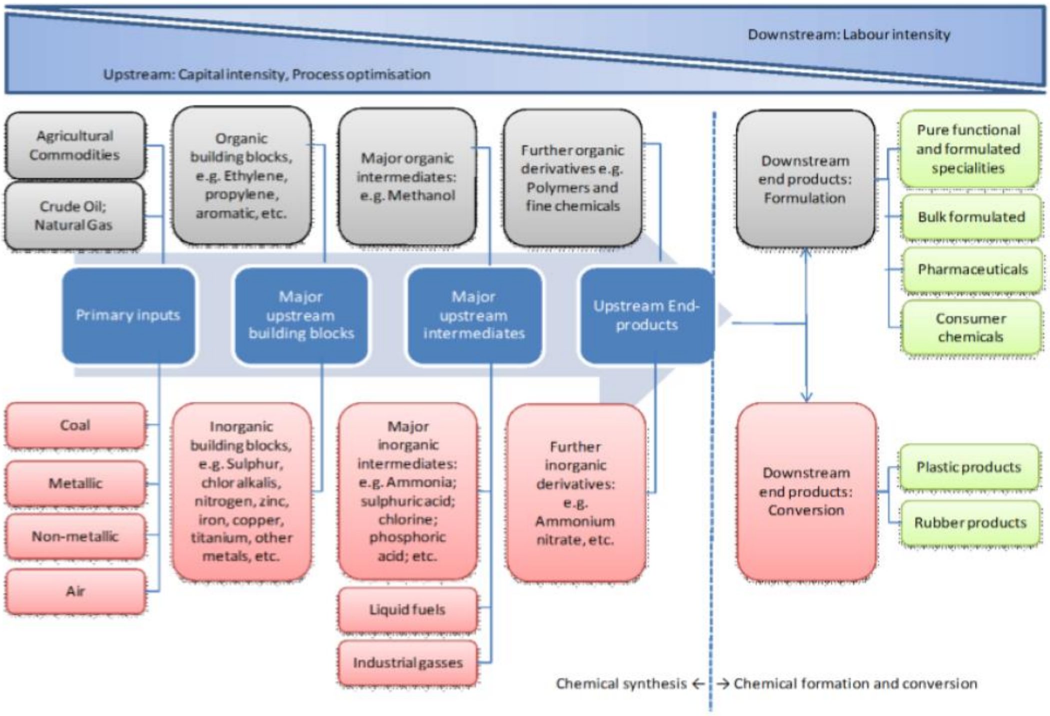
[3] B&M Analysts (2017) Chemicals Sector Strategy. Report for the dti.

Figure 1: Chemicals value chain overview



Source: B&M Analysts (2017)

The chemicals sector draws inputs from a broad range of sources, employs a wide range of processes and displays a long, often highly globalised and increasingly commoditised value chain. It delivers integral inputs into many sectors (and end-markets) ranging from automotive to agriculture, construction and pharmaceuticals. The scope for digital disruption within the chemicals sector is therefore broad, both in terms of the complexity and length of the chemicals value chain itself, and in terms of the multiple sectors and end-markets the chemicals value chain typically services.

Introduction

No significant digital disruption has yet occurred within the chemicals value chain, nor is there any short-term indication of such disruption. The position of the chemicals sector consequently appears quite different to that of digitally disrupted service sectors, such as banking and entertainment; or other manufacturing sectors, such as the automotive and the retail-facing clothing and textiles industry, which appear to be in the early throes of major disruption because of Industry 4.0.

The scale requirements, diversity and interlinked nature of the sector as well as inbuilt technology intense processes have and continue to protect the chemicals industry, to a degree, from new entrants and business models. There are however isolated but increasing examples of value being created and shared in very different ways within the chemicals value chain that may render more fundamental disruption within specific sub-sectors and end-markets. ‘Chemicals as a service’ is one such example. There are also promises of breakthrough manufacturing methods, such as digital light synthesis in additive manufacturing, and significantly enhanced supply chain coordination and optimisation through the application of the Internet of Things (IoT), and the associated use of big data, machine learning and Artificial Intelligence.

Nano-technology and chemistry go hand in hand and nano-technology is increasingly being used to optimize chemicals manufacturing processes. Swiss scientists "have found a way to construct catalytic model systems - that is, experimental set-ups - accurate to one nanometre and then to track the chemical reactions of individual nanoparticles[4]".

Product innovations are continuous and varied with chemicals innovations facilitating product advancements in downstream sectors. As examples, the consumer electronics boom is in large part facilitated by advanced plastics and adhesives and other products allowing larger, smarter, thinner screens; the move to light weighting in auto and aerospace industry in driven by advances in plastics that are smarter, stronger and lighter. While the rate of innovation will likely accelerate due to Industry 4.0, process and product innovation are central to the chemicals industry and are not foreseen to fundamentally disrupt it.

Process optimisation focus; driven by big data and the Internet of Things (IoT)

Already generating and managing significant amounts of data through valves, sensors, flow meters, heat and pressure gauges, vessel pressure and level monitors distributed throughout plants, highly automated chemicals manufacturers have long been on a path to 'digitalisation', a commonly used sector term relating to Industry 4.0. These efforts have been piecemeal however and largely focused on augmenting current or investing in new solutions to drive internal process efficiencies. This trend will only accelerate as computing power and machine learning algorithms continue to advance at a rapid pace. As evidence of firms' commitment to driving process improvements, a large-scale global survey[5] indicated that chemical companies plan to invest 5% of their annual revenue (or approximately half their average operating profits) in digital advancements within their operations over the period 2016 and 2021.

Big data and the Internet of Things (IoT) create significant opportunities for process optimisation. With complex and interlinked processes that are generally contained in liquid or gas form, increased process visibility will improve the availability of capital and facilitate process improvements. Enhanced, real time process data, as well as machine-based data analysis is anticipated to drive further efficiency gains within manufacturing processes, heightening competitiveness pressures within chemicals value chains.

One of the focal points of this efficiency-seeking digitalisation is the reduction of waste, specifically heat, which is a significant input cost to most chemical plants. Modelling of the many data points in real time can develop and maintain the most optimal energy plan and identify other potential applications for the surplus heat being generated in the conversion process. The growing phenomenon of industrial symbiosis, particularly prevalent in the chemicals sector which includes the trading of waste, byproducts and excess resources between firms will be supported and accelerate through big data and IoT. The renowned

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[4] Paul Scherrer Institute (2017). Nanotechnology enables new insights into chemical reactions, https://phys.org/news/2017-01-nanotechnology-enables-insights-chemical-reactions.html#jCp. Accessed 27 October 2018/.

[5] PWC (2016) Industry 4.0: Building the digital enterprise Chemicals key findings.

Kalondburg Symbiosis in Denmark consists of 12 co-located entities that collaborate through industrial symbiosis. IoT is being utilized to optimize this longstanding industrial symbiosis by amongst others enhanced water management practices.[6]

Manual oversight and interventions can either be avoided or substantially reduced through pre-emptive automated interventions driven by data analysis and artificial intelligence. Where required manual intervention can also be optimized and made significantly safer through factory staff being empowered with real time process information (and guidance on corrective actions).

Assisting to pre-empt breakdowns, shortening machine changeover times, reducing shortages/overproduction, and avoiding safety incidents are amongst the many benefits of the enhanced collection, analysis, communication and use of data within complex, capital intensive chemicals manufacturing plants. Digital solutions to gather or improve data collection, interpret results, and direct responses are generally packaged as augmentations to existing systems, as opposed to fundamentally disruptive new technologies.

Generally, procured from third parties, such as Siemens and ABB, and based on which interventions secure the quickest financial return, firms recognise the risk that systems will not be integrated and that the full benefits available may not be realised. Legacy assets and systems and continuous technology change make this the most viable approach although increased fragmentation is a significant risk as more data is collected across disparate systems. These process focused responses to Industry 4.0 disruptions are clearly transformative but not revolutionary. They are incremental and can at best drive small margin improvements, although new experiences, competencies and an appreciation of future opportunities are gained through implementation, opening the space for potentially greater levels of future disruption.

Further and more disruptive operational opportunities relate to the use of big data to simulate scenarios ranging from the production of new formulations, testing for risk incidents, delivering training, or augmenting product characteristics – all without impacting on the physical plant. Experiences in these areas are however presently limited to larger multinational corporations (such as Dow and BASF). Siemens is a leader in the field of digital twinning and offers Dulux Australia as a case study of a fully digital plant, including a digital twin. It cites savings of 75,000 manual interventions per year (over the previous plant), energy savings of 25%, batch size reductions and production speeds increased up to eight times amongst other benefits.[7]

BASF, the world's largest chemicals company by turnover ($75 billion in 2018[8]) categorises Industry 4.0 opportunities in five areas[9]. The first is Smart Manufacturing with the focus on process optimisation as outline above. This approach does reach beyond the factory with connectivity into the market an increasing focus. This is further focused on in their Smart Supply Chain area where they detail how big data can impact on customer interfaces, while

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[6] Smart water solutions now possible thanks to IoT, data www.asmag.com/showpost/23464.aspx. Accessed 27 October 2018.

[7] Siemens. The digital transformation as a success factor www.siemens.com/global/en/home/company/topic-areas/digital-plant.html. Accessed 27 October 2018.

[8] Forbes. www.forbes.com/companies/basf/#72451b210136. Accessed 27 October 2018.

[9] BASF Digitalisation (online) https://www.basf.com/en/company/about-us/digitalization-at-basf.html. Accessed 10 October 2018.

also being used to drive supply chain efficiencies; thereby improving planning, stock holding, and better aligning value adding processes with direct customer or even end consumer demands.

Maintaining strong inter-firm linkages has generally been a priority for the lead firms that dominate Global Value Chains within the chemicals industry, although the explosion of data availability (e.g. weather, traffic, Point of Sales data, etc.) and machine learning technologies capable of automatically analysing the data is generating substantial additional value through optimized logistics, improved planning and enhanced operational visibility, amongst other benefits. While greatly beneficial, the increased integration and leveraging of data across suppliers, customers and from third parties creates further complexity in terms of systems integration, while also raising questions of data ownership within complex value chains and the framing of value chain responsibilities.

BASF's third focus area is Smart innovations, using Industry 4.0 to boost their R&D efficacy and impact. Here the focus is again on process efficiencies, but within the R&D process itself. BASF is focused on enhancing data usage to drive more effective R&D activity. This is being done by creating digital twins of plants to model new formulations prior to physical prototyping, and by digitally integrating with customers. BASF is using shared data to better inform and drive its own internal R&D processes in alignment with the "voice of the customer".

Despite its formidable size and depth of available technologies, even BASF is less clear as to how to drive their fourth focus area, which is Digital Business Models – the paradigm shifting opportunities involving entirely new digitally-based business models. Case studies focus on improved customer service delivered via on-line platforms and increasing value addition and customer loyalty through real-time data analysis, but these are not necessarily paradigm shifting. With relatively less progress evident in this area, BASF's fifth focus area of driving start-ups becomes understandable. BASF have a significant programme to attract and support small innovative firms that they can collaborate with on their digitalisation journey. This strategy is evident in other environments, such as the automotive and aeronautics industry, and represents recognition that major disruption is as likely to emerge from outside of the established chemicals industry as it is from the major corporations that presently dominate global production.

At its Smart factory pilot plant in Kaieserlautern BASF produces fully customised shampoos and liquid soaps. As a test order is placed online, radio identification tags attached to empty soap bottles on an assembly line simultaneously communicate with production machines what kind of soap, fragrance, bottle cap colour, and labelling is required. Each bottle has the potential to be entirely different from the one next to it on the conveyor belt. The experimental layout relies on a wireless network through which the machines and products communicate, with the only human input coming from the person placing the sample order[10].

Relatively few examples exist of chemicals firms changing the entire paradigm of their offering, although this could accelerate once the commercial advantage of doing so is established. Offering a complete service rather than selling a chemical product may not be feasible in all industrial applications although there are increasingly examples of chemicals firms servicing

[10] Germany develops 'smart factories' to keep an edge (2014) www.marketwatch.com/story/germany-develops-smart-factories-to-keep-an-edge-2014-10-27. Accessed 20 October 2018.

the market in this manner. An example is water treatment services where this is already an entrenched model. United Nations Industrial Development Organization (UNIDO) is driving this model in line with the 2030 Sustainable Development Goals through its Chemical Leasing programme which lists successfully implemented examples of chemicals leasing across several sectors[11]. This concept is based on aligning the outlook of both buyer and seller of chemicals to reduce consumption and maximize efficiencies, rather than the traditional model whereby the seller looks to increase consumption and the buyer to reduce it.

Additive manufacturing

Additive manufacturing offers an array of opportunities for chemicals firms. Commercially, the opportunity exists for chemicals manufacturers to supply rapidly emerging chemicals requirements in the additive manufacturing space. For example, Adidas is using Digital Light Synthesis, a chemicals-based process, in its new commercially scaled Fast Factories[12], which have recently been built in Germany and the United States. As additive manufacturing shifts from a largely heat-based sintering process to a chemicals-based one, major commercial opportunities emerge for the chemicals industry. A further opportunity relates to synthetic biology (e.g. the development of bio-inks that permit the manufacture of organic manufacture using chemical process). The materials used in these processes will evolve rapidly over the next few years, but their chemicals base is unlikely to change, opening an entirely new market for chemicals manufacturers while also challenging others operating in sectors that may be displaced. The concept of highly decentralised production enabled by additive manufacturing also raises a range of risks and opportunities for chemicals manufacturers. Who in the evolved value chain will control it and enjoy the benefit?

Less dramatically, additive manufacturing also presents major opportunities for capital intensive chemicals manufacturers to cost effectively design and test solution prototypes prior to their confirmation for volume production, while also providing firms with the means to manufacture critical pieces of capital equipment on-site (potentially as directed by IoT-based algorithms that can predict the failure of the capital equipment), thereby obviating the need for the holding of large amounts of expensive additional capital equipment.

An example can be found in a University of Glasgow project[13]. A team at the university 3D printed a polypropelene reaction vessel that could serve as a cost-effective alternative to conventional steel reactors. While successful up to 150 degrees Celsius, the largest batch it produced was only 20 millilitres. While this is some distance from commercial application, the signs of potential major future disruption are evident.

Skills implications

Vastly new skills sets are clearly needed by chemicals manufacturers to respond to the challenges and capture the opportunities embedded within the transition to Industry 4.0. A move away from lower skilled workers is clear given the increasing sophistication of chemicals

[11] United Nations Industrial Development Organization (UNIDO). www.chemicalleasing.org. Accessed 27 October 2018.

[12] Inside ADIDAS' Robot-Powered, On-Demand Sneaker Factory www.wired.com/story/inside-speedfactory-adidas-robot-powered-sneaker-factory/. Accessed 29 October 2018.

[13] Deloitte. Industry 4.0 and the chemicals industry Catalyzing transformation through operations improvement and business growth. Deloitte University Press 2016.

plants. It is necessary for leadership within firms to drive a culture of research and development and create an environment conducive for the speculative testing of emerging digital technologies to capture emergent opportunities. Skills development priorities below the executive level are project management skills, to scope and implement Industry 4.0 projects successfully; technical skills in areas of systems integration; and data analytics and interpretive skills to make optimal use of the new systems and capture the value that is possible through Industry 4.0 adoption. Engineers will require increased exposure to computer coding to set up, customise and manage new systems. Operations staff will require the skills to interpret an increasing amount of increasingly complex data and input back into new systems.

There are very mixed estimates on the impact of Industry 4.0 on employee numbers. It is clear however that with increasingly smart and connected factories more can be produced with less. This creative destruction will create new jobs elsewhere, but this will only be the case in countries that support the creation of these new jobs through significant skills development programmes.

Extent of Industry 4.0 adoption

Before turning to consider the implications for South Africa it is useful to review current Industry 4.0 adoption in leading markets. Industry 4.0 is subject to much hyperbole and Mckinsey's[14] 2016 Industry 4.0 Global Expert Survey casts a useful and pragmatic light on the extent of adoption to date.

While surveyed firms in Germany, Japan and the United States were optimistic about Industry 4.0 adoption, only 16% of the surveyed manufacturers had an Industry 4.0 Strategy in place; only 24% had assigned clear responsibilities to it; and in only 19% of firms was the Industry 4.0 strategy being driven directly by the CEO. Industry 4.0 applications that companies had made the most progress in implementing over the last year included smart energy consumption, real-time supply chain optimisation, remote monitoring and control, digital quality management, and digital performance management.

While the South African chemicals industry would likely lag these indicators, and while South African examples of Industry 4.0 adoption are limited and often foundational (as are the most common implementation examples in developed economies surveys) it is sobering that the developed world is some distance from mastering Industry 4.0 nor advanced so significantly that the gap with South African firms is immutable.

South African consequences

The key questions relating to digital disruption for the South African chemicals value chains can be summarised as:

- The competitive advantage that leading chemicals manufacturers in major international economies will develop through Industry 4.0, and the gap that may open with South African (SA) manufacturers, as well as the SA market, which may also fall

[14] McKinsey & Company (2016). Industry 4.0 after the initial hype Where manufacturers are finding value and how they can best capture it McKinsey Digital.

behind the international frontier, or shift its procurement model to greater levels of international sourcing.

- How rapidly SA manufacturers and the SA market will follow, and adapt to digital disruptions?
- The impact of emerging gaps on the health of the chemicals value chain in SA?

The SA chemicals industry grew at an annual rate of 3.7% from 2001 to 2014, outperforming the broader manufacturing sector, which achieved 1.1% annual growth over the period. However, annual growth in local chemical sales of 8.8% from 2001 to 2015 substantially outpaced production growth, contributing to the deterioration of the country's chemicals trade balance, which is now negative. The liquid fuels sub-sector remains the largest contributor to the chemicals industry's output, followed by basic chemicals and then pharmaceuticals. Employment has remained stable at approximately 100,000 people, biased to three chemicals sub-sectors: basic chemicals; functional, speciality and fine chemicals and consumer chemicals sub-sectors which employ 25,000 people each.[15]

Furthermore, the chemicals sector has significant impacts on downstream sectors important to the South African economy including the automotive, textiles, plastics and agro-processing[16] sectors. Any digital disruptions within the chemicals industry are therefore likely to impact these sectors, and their comparative positioning within the complex Global Value Chains that they compete in. It is also important to emphasise that South Africa's chemicals production landscape is highly skewed by its largest firm. Sasol is highly globalised, vertically integrated and diverse. It has annual chemicals revenue of approximately $10 billion, ranking it as the 37th largest chemicals manufacturer globally[17].Other large multinationals operate in the refinery space, while firms become both smaller and increasingly locally owned further down the value chain (and closer to end consumers). For example, South Africa's second largest chemicals manufacturer, AECI has total turnover of approximately R 10 billion[18] (or approximately only 7% of Sasol's chemicals revenue)).

Addressing the challenges and capturing the opportunities of Industry 4.0 will be a significant challenge for leading chemicals firms in developed economies, but what are the consequences for smaller firms in less developed economies? This is amplified in South Africa's case by weak recent economic fundamentals, a bleak growth outlook and uncertain economic policy, which negatively impacts on the propensity of business owners to invest. While there are several multinationals with a presence in South Africa they are biased to blending and packaging operations. As such, no Industry 4.0 related R&D is undertaken or trialled. Investments are, in fact, largely kept to a minimum and in accordance with domestic (or regional) market demand growth the chemical products.

The draft national chemicals strategy of the Department of Trade and Industry (the dti) (2020 to 2035) has a range of objectives, including securing annual chemicals manufacturing growth of 6% over the period, associated employment growth of 50% in absolute terms, an increase in local content, developing industry competitiveness to levels of leading international

[15] See footnote 3 above.
[16] dti, Industrial Policy Action Plan 2018/19-202/21.
[17] Chemical and Engineering News Global Top 50 chemical companies https://cen.acs.org/articles/93/i30/Global-Top-50.html. Accessed 20 October 2018.
[18] AECI (2018). AECI Annual Report 2017.

comparator nations, transformation of the chemicals value chain, as well as enhancing R&D activities and skills in support of sustainable competitive advancement.[19] And yet, these objectives, which were all deemed realisable when developed through a robust industry consultation process in 2017 are likely to be fundamentally challenged by the digital disruptions covered in this briefing note. Except for Sasol, the balance of the domestic chemicals industry appears poorly positioned to respond to the emerging disruptions, whether big or IoT, or the host of other potentially significant disruptors, including nano-technology, new "green" materials, machine learning, Artificial Intelligence, robotics, and additive manufacturing.

Herein lies the South African chemicals industry's challenge. When will all of this happen? And when it does, what form will it take place? As developed economy disruptions manifest, what are the consequences for chemicals production in an economy such as South Africa's? Will industry development opportunities be created, thereby supporting the realisation of the South African chemicals industry's potential, as identified in the dti's Chemicals Masterplan, or will opportunities be closed off as the industry shrinks in the face of the disruptive technologies and heightened international competition?

Some preliminary responses?

Defining appropriate local policy responses to digital disruptions within chemicals industry is a daunting challenge. While many of the digital disruptions referenced in this briefing note are transversal, and agnostic of specific manufacturing value chains, it is also clear that the way the disruptions combine and become existentially disruptive will be value chain specific. An appropriate South African government response consequently appears to require four mutually reinforcing dimensions.

First, any response needs to be adaptable. Following Dani Rodrik's framework for an effective 21st century industrial policy (Rodrik, 2004), South African industrial policies will need to be constantly reviewed and reoriented in alignment with the development and associated combination and recombination of disruptions.

Second, engaging with specific disruptions is a transversal challenge that aligns best with a country's national system of innovation, as opposed to individual GVC-specific industrial policy frameworks. The digital disruptions reshaping the trajectory of the global chemicals industry are not chemicals-specific. If South Africa is to shift its marginal position in relation to the specific digital disruptions that are recasting industrial activity, transversal skills development and technology policies will need to be developed and deployed.

Third, how the disruptions manifest in the chemicals industry is a sector specific challenge, requiring clear knowledge of how digitalisation will combine and then recombine to shift the nature of chemicals production. As this represents the primary commercial and social interface between digital disruption and the physical production and commercial market space, the role of sector-specific (or perhaps rather value chain-specific) industrial policy is likely to remain critical.

Fourth, and perhaps most importantly in the context of the pace of digital disruption, it seems highly appropriate for the South African government to collaborate with the private sector in

[19] See footnote 3 above.

navigating value chain complexities. Returning to Rodrik (2004: 4): *"The right model for industrial policy is… strategic collaboration between the private sector and the government with the aim of uncovering where the most significant obstacles to restructuring lie and what type of interventions are most likely*

to remove them. Correspondingly, the analysis of industrial policy needs to focus not on the policy outcomes—which are inherently unknowable ex ante—but on getting the policy process right." The domestic industry's marginal position globally makes it both extremely vulnerable to digital disruption, and potentially well positioned to play a role in the testing or piloting of emerging technologies. If South Africa is to gain from the combining and recombining of digital disruption within the chemicals industry, a public/private institutional approach is clearly required: an approach where the public and private sector collaborate on the proactive positive positioning of South Africa within the chemical industry's evolving digital space.

While the future profile of the global chemicals industry is unclear, this brief review of digital disruptions within the industry, raise some clear medium-term lessons for the South African chemicals industry that potentially lay a starting framework for the development of a proactive response.

1. The future of chemicals is increasingly automated, connected and data driven. Vastly different skills sets are required if the South African chemicals sector is to follow this global trend and remain competitive and relevant.

2. Technology, as it is currently, will be controlled by multinationals. The vast sums of money being invested by the world's leading chemicals manufacturers and technology providers is unlikely to lead to major fragmentation of the industry's dominance by a few players.

3. Chemicals manufacturing processes are unlikely to fundamentally change in the near to medium term although accelerating adoption will undoubtably be observed.

Supporting the South African chemicals industry as it incorporates these technologies will be essential to its long-term success. Many of the digital disruptions cut across all manufacturing sectors and need to be supported at that level, but their specific combinations within the chemicals industry also need to be understood and responded to.

It is these types of chemicals-specific developments that require a GVC-specific response on the part of national government and local chemicals industry stakeholders. The South African chemicals industry is no different to any other small, second tier chemicals economy globally: it is both vulnerable and potentially well positioned in relation to digital disruptions. Whether the industry wanes or prospers is dependent on the actions taken by stakeholders.