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AN ASSESSMENT OF THE STATE OF THE CHEMICAL INDUSTRY: INDUSTRY 4.0 PERSPECTIVE

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Abstract

Industry 4.0 is challenging and leading to the transformation of tasks and skills across different industries. This paper assesses the state of the South African chemical industry in the context of industry 4.0, to understand the skills landscape within the Chemical Industry Education and Training Authority (CHIETA) and its subsectors. The paper draws data from the CHIETA database, which captures employee and company's information, levies and mandatory grants, and the firm-level data collected from the Digital Skills Survey. The objective was to understand how digitalisation changes and shapes the organisational and institutional context in which people work. The Digital Skills Survey contributed to our understanding of technology adoption within CHIETA sub-sectors and the implications for skills. The results highlight the current technological infrastructure prevailing across business functions in the industry, and suggest that the sampled firms are primarily driven by manual- and semi-automated technologies and processes, with few firms having implemented advanced processes linked to digital-enabled systems.

Keywords: chemicals, manufacturing, skills, industry 4.0, digitalisation

JEL codes : L6 ; L65 ; O33

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1. Introduction

The world economy is undergoing structural and technological transformations driven mainly by the 'Fourth Industrial Revolution' (4IR). The degree of digitalisation and automation of economic activities - shown to differ across sectors and economies- are changing the nature and type of skills and capabilities required to undertake specific tasks. As a result, developing economies are embracing the new era of manufacturing and business in order not to be further left behind. However, a key challenge facing middle-income countries, like South Africa, is how to grow and adapt digital capabilities and skills in the more technologically sophisticated segments of value chains to break from the 'middle-income trap' and spur digital industrialisation.

Building skills within interdependent domestic industrial ecosystems is fundamental in this process (Andreoni and Tregenna, 2018). This often requires coordinated strategies across skills, investment, and technology to support incremental changes required to realise efficiencies and improve competitiveness and stepwise changes (Barnes, Black and Roberts, 2019). Indeed, skills upgrading is critical to support productivity growth necessary for escaping the middle-income trap (Sen and Tyce, 2019; DHET, 2019).

However, the persistent mismatch between the skills required by industry and those produced by learning institutions has been a continuous challenge for South Africa (Beare, et al., 2014, Bell, et al., 2018; DHET, 2019). As such, several strategies have been adopted to address the skills issues.[1] However, there has been little coherence between technology, skills, and industrial policy which has led to poor industrialisation outcomes, with small firms often bearing the brunt of the problems as larger firms can more easily privatise the necessary skill training (Bell, et al., 2018). This paper assesses the Chemical Industries Education Training and Training Authority (CHIETA). It discusses the sub-sector's current skills landscape, educational levels, and technology adoption in a specific context given the link between Industry 4.0, the changing nature of work, and the importance of the chemicals industry within the larger economy.

The paper proceeds as follows. Section 2 discusses the methodology and data employed in this research. Section 3 reviews recent literature on the changing nature of work and skills in the context of Industry 4.0; Section 4 analyses skills gaps identified by various skills development policies. Section 5 provides an overview of the chemicals industry in South Africa and its subsectors. Section 6 provides an analysis of CHIETA skills, training and education, grants and levies by sector. Section 7 analyses technology adoption in the chemicals sector using evidence from Digital Skills Survey. Section 8 concludes the paper.

[1]The general skills policy framework for South Africa is in the form of the Skills Development Act of 1998. From a macroeconomic perspective there was the Accelerated Shared Growth Initiative of South Africa (AsgiSA). At a more microeconomic level, policies aimed at skills development took the form of the Joint Initiative on Priority Skills Acquisition, and the Human Resources Development Strategy for South Africa. In the last 10 years, a number of other policy documents have also made skills development their priority. These include the National Skills Accord (2011), the White Paper for Post-School Education and Training (2013), the Third National Skills Development Strategy (2016), and the Professional Development Framework for Digital Learning (2017).

2. Methodology and Data

As noted, the paper seeks to understand the skills landscape within CHIETA and its subsectors. To do this, we analysed employee- and firm-level data that was obtained from CHIETA. We supplemented our analysis with Quantec and UNIDO data and data gathered from the Department of Higher Education and Training (DHET). The CHIETA data covers employees and levies at the firm and sub-sector and chamber levels from 2016-2019. The authors cleaned the data to correct for any errors in consultation with CHIETA, and the authors also ensured the accuracy of the data and analysis.

Quantec standard industry data (output, value addition, gross fixed capital formation [GFCF], and employment) was then matched with the CHIETA sub sectoral data, using standard industry classification codes and CHIETA Chambers' descriptions (See Appendix 1). This process allows us to analyse possible links between SETA interventions and subsector performance at the sub-sector level. CHIETA's Chambers include petroleum and basic chemicals; fast-moving consumer goods (mostly made up of consumer chemicals such as cleaning products and cosmetics) and pharmaceuticals; explosives and fertilisers; speciality chemicals and surface coatings; and glass. When combined, CHIETA's Chambers make up the petroleum products, chemicals, rubber, and plastics industry and correspond closely to Quantec.[2]

The data provided by CHIETA for this study was at the individual firm-level, and data on each firm's monthly levy and mandatory grant payments for March 2016 to April 2019 was obtained.[3] Of the approximately 2 600 firms that provided data, the majority (52% in 2018/19) operate in the other chemical products sector. The employee data presents a range of data on 145 000 workers within CHIETA and its subsectors. For this study, the data we utilise on these employees cover their equity levels, NQF levels, and age. CHIETA matches the equity levels to the Organisation Framework for Occupation (OFO) codes.

The OFO codes are matched to descriptions of the critical skills we identify from the CHIETA dataset (see Appendix 1). From the range of skills available in the data, we have identified the following skills as critical for the chemical manufacturing sector's competitiveness and in 4IR technological upgrading; tool making, engineering, artisans, technicians and information communication and telecommunications. The skills were based on our understanding of factors that drive firm competitiveness, based on in-depth firm-level research in various sectors. We have grouped qualifications according to the reported National Qualifications Framework (NQF) into three categories to determine the average skill level in each sector and how this level has changed in the past four years. These are Matric and below (NQF 0-4), Certificate/Advanced Diploma/Degree (NQF 5-7), and Postgraduate-Honours/Masters/Doctorate (NQF 8-10).

We identified the following possible issues relating to accuracy and consistency across the entire dataset. First, there are notable discrepancies in individual employees' job titles, highest qualifications, and equity level data. These were mistakes on the part of firms in the

[2] We note that the rubber and plastics industries are part of MERSETA. The individual sector contributions to the Petroleum products, chemicals, rubber and plastic [QSIC 33] are 36% (Coke, petroleum products and nuclear fuel [QSIC 331-333]), 28% (Other chemical products [QSIC 335-336]), 24% (Basic chemicals [QSIC 334]), 8% (Plastic products [QSIC 338]), and 4% (Rubber products [QSIC 337]).

[3] CHIETA's financial year-end runs from March to April.

submission of the data, which may impact our accuracy. Second, there are numerous entries where employees were described as having an "undefined" educational level. These were instances when firms did not have the required information on their employees.[4] Here we have made our best attempts to clean the dataset by removing unnecessary data points and errors from capturing the data from the firm responses to ensure that our analysis is accurate. We have excluded data on firms engaged in non-manufacturing activities such as petrol, service, or filling stations. These were removed, and thus the data only included those firms involved in manufacturing chemicals, chemical products, and glass and glass products.

We complement the above data with the digital skills survey data. The Digital Skills survey was designed to capture both the current status quo and the firm's ambition regarding their technological upgrading. Moreover, the survey also tried to understand, from a firm level, which skills are crucial to the firms' operations in these various SETAs in the context of differing technological adoption rates. The data was collected in March 2021 using a standardised online survey questionnaire. In the chemical industry a total of 73 firms took part in this survey that had 516 responses.

3. Industry 4.0 and the Changing Nature of Skills and Technological Upgrading in South Africa

The advent of Industry 4.0 and its associated advanced technologies and production methods profoundly impact the manufacturing environment. These transformations, in turn, are driving demand for a different skillset in the industry (Chenoy, et al., 2019), bringing with it an ever-more complex business, operational, and production systems to which firms must adapt. Industry 4.0 encompasses and combines a range of previously diverse yet interrelated fields and industries and can lead to the creation of new and more complex products and markets. To adapt to these new methods of production, and to join existing and new markets, firms require technological and skills upgrading (World Bank, 2019).

Technological and skills upgrading requires technological capabilities. Technological capabilities extend far beyond possessing necessary skills, and it is determined by the level of knowledge, experience, and institutional structures and linkages inherent in a firm or industry. These can be accumulated and developed by the firm, either internally or through external institutional relationships (Bell & Pavitt, 1995). For purposes of this paper, we place a particular focus on skills and how these relate to technological upgrading and competitiveness. This necessitates knowledge about the dynamics of skill accumulation and how this links with literature on capabilities (Hechman & Corbin, 2016), and thus dynamic capabilities (see Teece, et al., 1997).

Industry 4.0 can assist chemical firms' supply chains in two ways (CHIETA, 2019). Firstly, sensors and a network of connected systems can give firms an unprecedented view of their supply chains, helping mitigate risks and inefficiencies. Secondly, advanced analytic tools usher in the ability for predictive supply and maintenance. Additional benefits from Industry 4.0-linked technologies include enhanced collection, analysis, communication, and use of data. This is important given the complexity of capital-intensive chemicals manufacturing plants (Barnes & White, 2018).

[4] Based on communication with CHIETA.

Within the chemicals sector, the employment of Industry 4.0 technologies will require a changing nature of skills to complement these new advancements. Thus, the new technology era necessitates qualifications and acceptance of technology and digitally-minded workers (CHIETA, 2019). Table 1 identifies some of the critical technology areas and job descriptions in the chemicals industry. The key technology areas that emerging are additive manufacturing, advanced analytics, predictive asset management, product simulation and the Internet of Things.

Table 1: Key technologies and the changing nature of skills in the chemicals industry

Key Technology Areas	Job Description
Additive manufacturing	Scientist
Advanced analytics	Big data specialist/developer/engineer, data scientist, big data manager
Predictive asset management	Asset managers/consultant
Production Simulation	Simulation environment architect, simulation scientist, simulation engineer, data scientist
Internet of Things	Data scientist; IP network engineer; digital systems developer (specialising in hardware interfacing); mobile application developer; UI/UX designer; information security specialist; cybersecurity specialist

Source: Authors adaptation of key technologies from CHIETA (2019) and Barnes and White (2019).

Additionally, the introduction of advanced communication and production networks (inherent within Industry 4.0) has resulted in a decentralisation of the workplace. For example, a firm could produce components in one location, assemble them in another, and sell them from a third (World Bank, 2019). This constant evolution is forcing workers, firms, and governments to seek comparative and competitive advantages in new areas, many of which are not yet conceived. As a result, there is need for a coordinated approach from firms, employees, industry associations and government to realise the advantages brought about by Industry 4.0.

Within CHIETA, there is a strategic focus on Industry 4.0, termed Chemistry 4.0. The main driving factors forcing this strategic focus include changing raw materials used in production, the increasing need to transition from energy-intensive machinery given the precarious energy situation in the South African economy, and the push towards digitisation and connectivity across the supply chain. The rapid pace of change in the chemicals industry requires workers that can quickly integrate new skill sets (CHIETA, 2019).

This implies an increased need to focus on skill adoption and rapid learning for workers not to be left behind and manufacturing to be offshored. The transition to Industry 4.0 and Chemistry 4.0 will not be immediate (Benešová & Tupa, 2017). Moreover, it is reasonable to expect some lags in this process. Through the enhancement of skills, workers and firms broaden their respective opportunities. This highlights the vital role of tertiary education in South Africa. Quality tertiary education is a necessary precursor for advancing the industrial ecosystem of any country in terms of gearing the workforce will the requisite skills and knowledge to effectively usher in a new manufacturing era. The impact on the current working environments by Chemistry 4.0 could be far-reaching because there is a need for improved qualifications, an acceptance of the use and role of technology by all stakeholders, and digitally focused workers (CHIETA, 2019). Also, there needs to be an emphasis on quality, not the cost of talent and creating and engaging in efficient workplace interactions.

4. Skills gaps identified by various skills development policies

The various skills development strategies address a range of challenges identified within the South African labour force. For example, the National Skills Development Strategy (NSDS) III, a subcomponent of the Human Resource Development Strategy, aims to address the skill inadequacy and poor work readiness of younger school-leavers. This is important in the current context of South Africa's desire to re-industrialise the economy and propel the economy into the digital age and Industry 4.0, following the National Development Plan (NDP) and the Industrial Policy Action Plan (IPAP). The skills focus in these newer documents appears to echo previous economic strategy documents that called for greater training opportunities for new entrants into the labour market to achieve a more flexible labour market and attract more significant foreign direct investment (GEAR, 1996). The skills shortages alluded to in the NDP and IPAPs also have not changed since 2007 (ASGISA, 2007). From this, it looks as if South Africa has struggled to tackle its overarching skills issues and shortages that have plagued the economy's growth and development over the last 20 years.

Considering the failure to achieve skills development at a macroeconomic level, the purpose of the NSDS III is to provide an overarching guide for skills development and offers direction for sector-specific skills training and instruction through the SETAs (NSDS, 2011). Currently, 21 SETAs in South Africa cover a diverse range of industries (Appendix 1). The SETAs are the go-to authority on individual sector labour markets and work to deliver the sector-specific skills interventions to assist in achieving the targets identified by the NSDS III and earlier iterations of policies aimed at skills development in South Africa (NSDS, 2011).

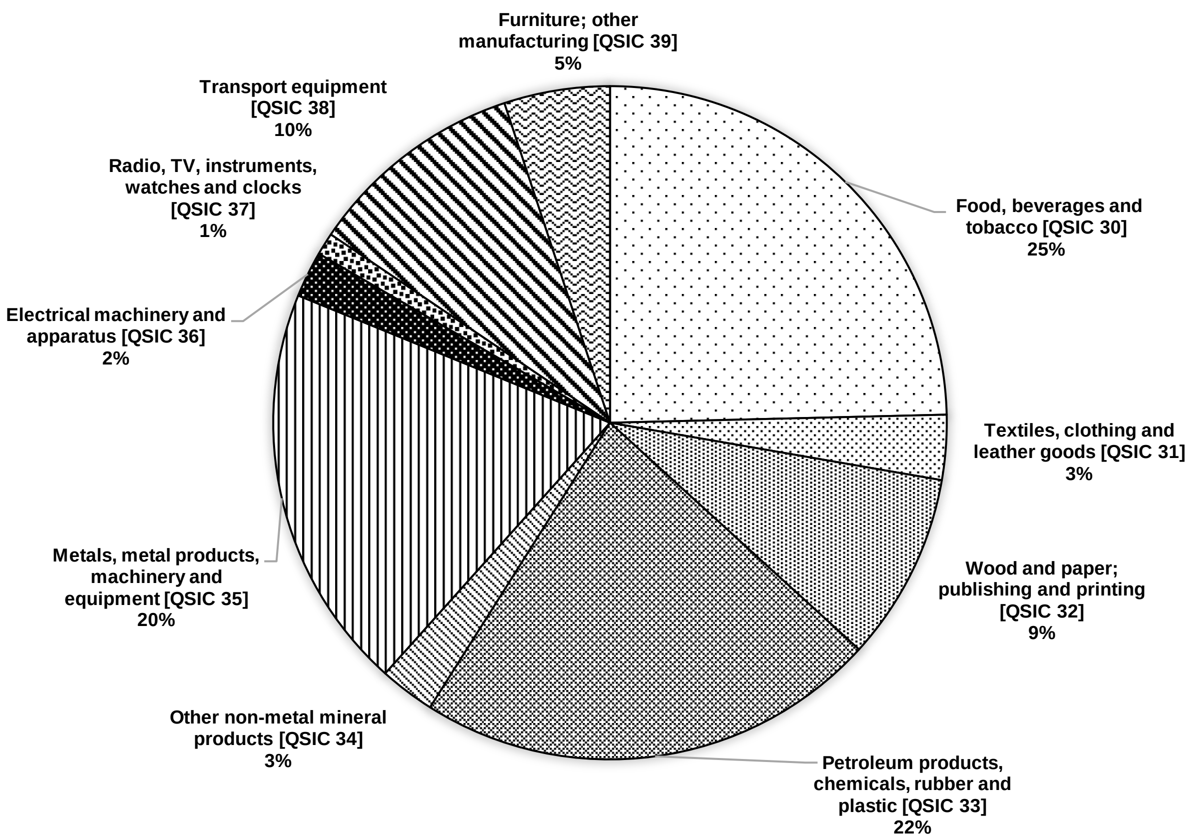
The SETAs are tasked with achieving their goal of skills development through their respective skills plans (SAQA, 1998). Each SETA implements its skills plan by establishing (but not limited to) learning programmes, allocating grants, and monitoring educational and skills development provision in the sector (SAQA, 1998). In the latest iteration of its Sector Skills Plan (SSP), CHIETA set five strategic priorities based on the needs of the overarching Chemicals Industry (CHEITA, 2018). These key priorities include the enhancement of the skills possessed by the existing workforce; the support of the development of skills of new entrants into the Chemicals Industry; response to changing sectoral needs and priorities within the industry; focusing on the strengthening and expanding partnerships to maximise sustainability and impact of skills interventions; and, lastly, to support national transformation goals.

As much as Industry 4.0 marks a dramatic shift in the technological landscape, it also marks a dramatic shift in the type of workers required. Therefore, an investigation of the current skill and education level within the sub-sectors of CHIETA with an underlying expectation of introducing Industry 4.0 and Chemistry 4.0 from an employee perspective is critical. The paper analyses the types of occupations prevalent in South Africa's chemicals industry, the age distribution, and level of qualification across the sub-sectors. The intention is to highlight whether the chemical industry is seeing a general improvement in the skill of its workforce. Furthermore, the paper analysis the levy payment process in greater detail at the sub-sector level and compare these to the trends in skills and skill attainment.

5. Overview of the Chemicals Industry and CHIETA in South Africa

From 2001 to 2014, the South African chemicals industry grew at an annual rate of 3.7%, outperforming the broader manufacturing sector, which achieved 1.1% annual growth over the period (Barnes & White, 2018). 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 (B&M Analyst, 2017). The share of total manufacturing output for petroleum products, chemicals, rubber and plastics (QSIC 38) industry contributing in 2020 was 22% (Figure 1). The liquid fuels sub-sector remains the largest contributor to the chemicals industry's output, followed by basic chemicals and then pharmaceuticals.

Figure 1: Manufacturing sectors share of total manufacturing output, 2020



Source: Quantec

The petroleum products, chemicals, rubber and plastics (QSIC 38) industry, petroleum products and other chemical products account for the majority of output (35% each respectively) and value addition (45% and 31% respectively) in 2020 (Table 2).[5] The capital-intensive nature of basic chemicals (QSIC 334) and petroleum products (QSIC 331-333) means that they account for 38% and 33% of gross fixed capital formation (GFCF), respectively, in the sector. The relatively more labour-absorptive other chemical products (QSIC 335-336) account for 55% of total CHIETA employment. The smallest contributor to CHIETA in all aspects is glass and glass products (QSIC 341).

[5] SASOL is the dominant player within the petroleum products sector in south Africa and thus represents the majority share of its performance.

Gross fixed capital formation (GFCF) can be used as a proxy for upgrading or machinery and equipment. Data on the GFCF from 1994 to 2018 shows only slight increases in these levels for petroleum products and basic chemicals before 2007. However, since 2008 the GFCF for these sectors has declined to around the same levels in 1994. In stark contrast, the other chemical products sector has experienced a significant decline of around 40% in real terms between 1994 and 2018, and this implies the sector has undergone a significant decline in its technological capabilities. The glass and glass products sector's GFCF remained relatively stable, reflecting an unchanging capital intensity.

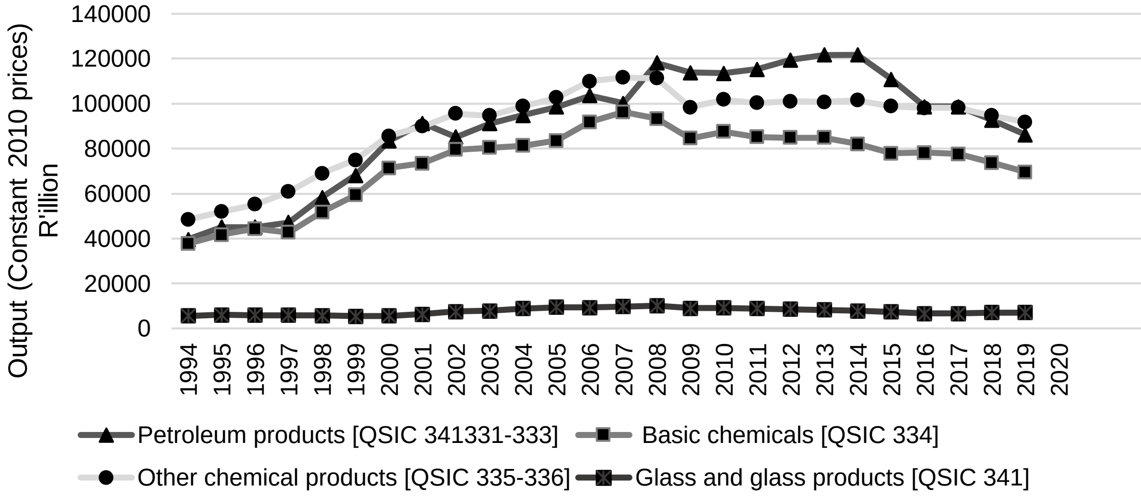
Table 2: CHIETA sub-sector performance, 2020

	Output		Value Addition		GFCF		Employment	
	Value (R'Millions)	Share	Value (R'Millions)	Share	Value (R'Millions)	Share	Value (R'Millions)	Share
Petroleum products (QSIC 331-333)	515	1%	35,619	45%	11073.37	34%	27,887	19%
Basic Chemicals (QSIC 334)	23,187	39%	16,686	21%	11010.63	34%	28,007	19%
Other chemical products (QSIC 335-336)	24,475	42%	24,939	31%	4,699.41	14%	79,991	55%
Glass and glass products (QSIC 341)	341	1%	2,585	3%	6040,32	18%	9,970	7%
Sector Total	**58,781**	**100%**	**79,829**	**100%**	**32823.73**	**100%**	**145,855**	**100%**

Source: Quantec

Since 1994, the three most significant sectors within CHIETA (petroleum, basic chemicals, and other chemical products) registered modest levels of output growth until 2008. Petroleum, basic chemicals, and other chemical products sectors grew at a compounded annual rate (CAGR) of 8%, 7%, and 6%, respectively (Figure 2). The growth of the petroleum products and basic chemicals sectors is likely linked to the commodity cycle between 2000 and 2008, driven by demand from the Chinese economy. However, the glass and glass products sector grew more slowly over this same period, recording only 4% growth over the 14-year period. Since 2008, however, output levels fell by between 2% and 3% in real terms for all of CHIETA's sectors. However, petroleum products experienced more growth during this period, rising to their highest output level in 2014. Nonetheless, since this record high level, output in the petroleum products sector fell by 6.5%.

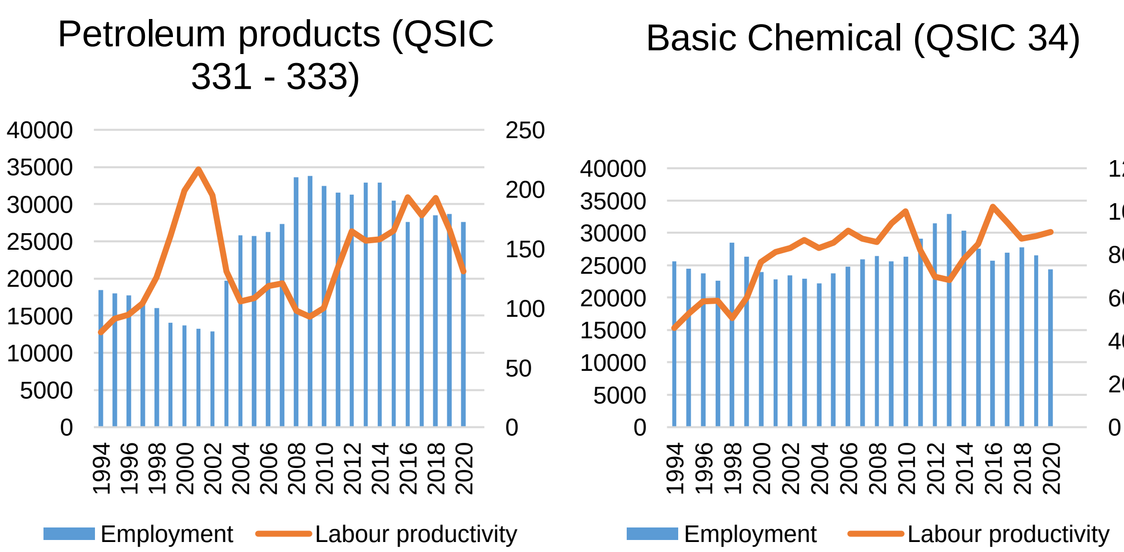
Figure 2: Output in CHIETA Sectors, 1994-2020

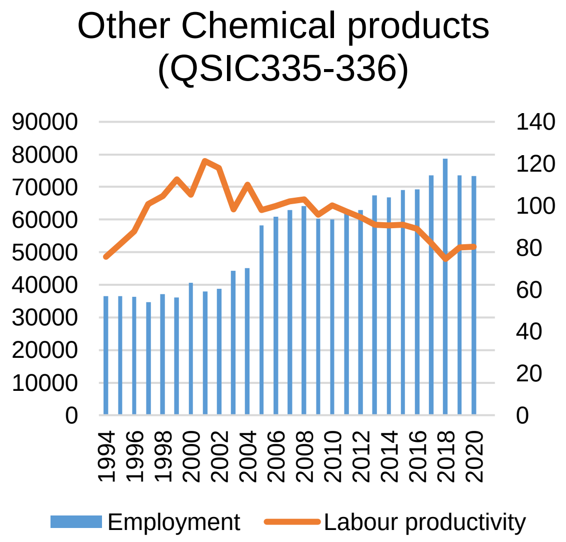


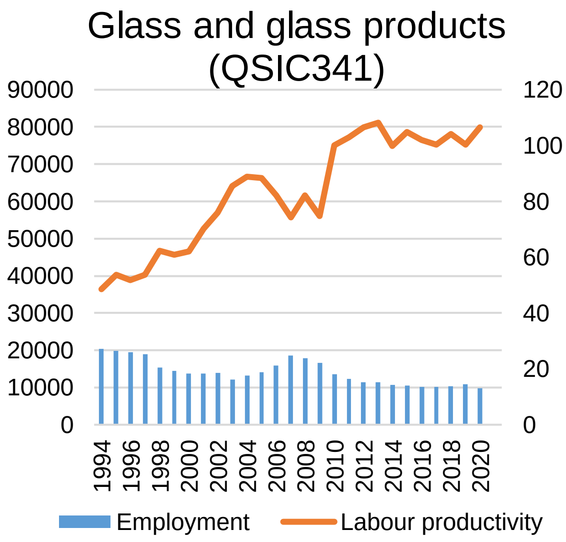
Source: Quantec

Analysing how trends in output have impacted employment in the sector is vital in the context of this research. Data on employment for the CHIETA sectors shows that other chemical products have remained relatively more labour absorptive. Most notably, during the 2000-2008 period when output was growing at its fastest rate, employment grew by 5.8% compounded annually. Nevertheless, after 2008, when output in the other chemical products sector fell, employment grew by around 2.3% (Figure 3). This countercyclical employment trend is interesting given poor employment growth for the other CHIETA sectors. For instance, employment declined in the petroleum products and glass and glass products sectors by 1.7% and 5.5% since 2008, where they have remained near their lowest levels in this period. Basic chemicals managed to maintain their employment level, growing marginally by 0.7% since 2008.

Figure 3: Employment and labour productivity in the CHIETA sectors, 1994-2020







Source: Quantec

Economic theory would argue that more employment would result in lower labour productivity given the same capital infrastructure. This is seemingly true in the other chemical products and petroleum products sector, where employment declines commensurate with gains in labour productivity. Labour productivity can also be increased through improving the technology the labourers utilise in producing their output. Improving skills can also increase labour productivity, and this increased productivity should result in increased levels of output. However, from Figure 3 above, labour productivity for the other chemical products shows that while employment has increased in the last four years, overall labour productivity has declined. Other sectors such as basic chemicals have seen their labour productivity increase as their employment rose after 2010. While at the same time, output from this sector was falling. These contrasting employment, output, and labour productivity trends may speak to the differing political settlements[6] that characterise the various sectors within CHIETA.

Within the CHIETA subsectors, firms are predominantly classified as small and micro enterprises, with a small fraction classified as large firms in 2018 (Figure 4).[7] The overwhelming number of small and micro-sized firms in the CHIETA subsectors has essential implications for the ability of these firms to internalise skills training and other issues around firm governance and technological upgrading. Smaller firms will struggle more than large firms to realise skills and technological upgrading due to their limited resources making them more reliant on government and private training institutions.

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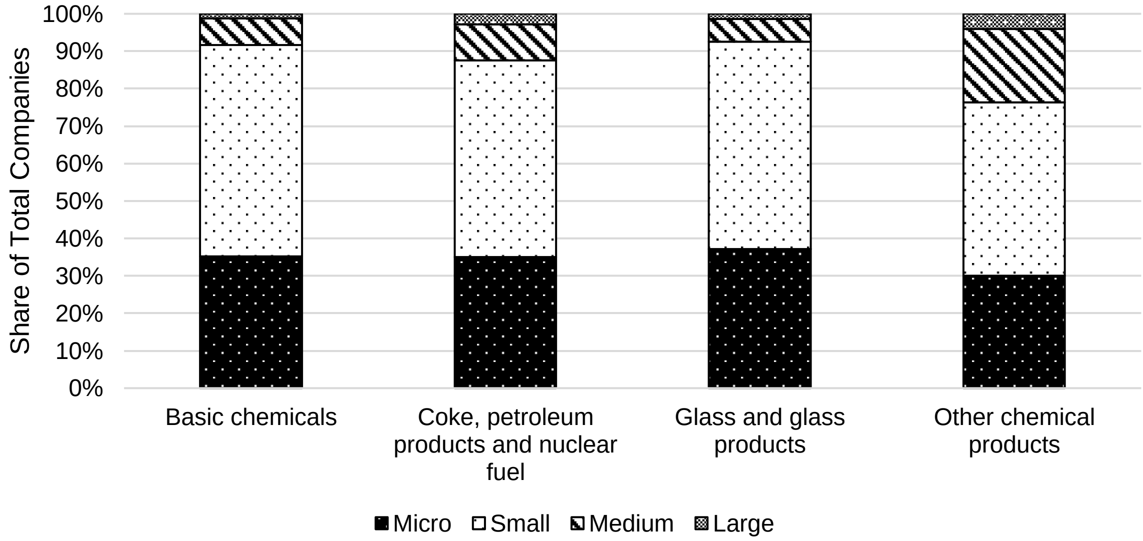
[6] The political settlements framework argues that the distribution of organizational power is important for understanding the economic and political effects of institutions and policies. Institutions and policies describe rules that in turn determine resource allocation, and these can affect different types of organizations in very different ways (Khan, 2010).

[7] Firm size is based on the size of their total levy payments in the specific period. Firms are classified as "Micro" if their total levy payments are less than R10 000; "Small" if their levy payments are greater than R10 000 but less than R100 000; "Medium if their levy payments are greater than R100 000 but less than R1 000 000; and "Large" if their levy payments are greater than R1 000 000.

Figure 4: Firm size by CHIETA subsector, 2018



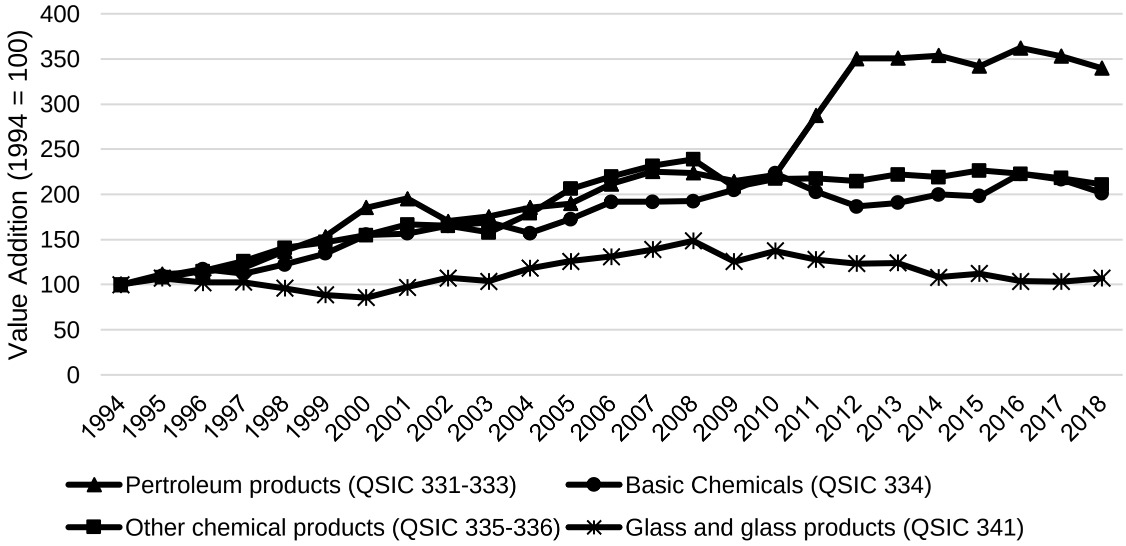
Source: Authors' calculations using CHIETA data

The ability of the other chemical products sector to grow its employment is impressive given that the sector has run, and continues to run, a sizeable trade deficit of around R25 billion as of 2018 figures. Trade deficits are common throughout the CHIETA sectors, with petroleum products trade deficit amounting to R73 billion in 2018. Additionally, trade deficits in basic chemicals and glass and glass products were R12 billion and R1.5 billion in 2018, respectively.[8] These trade deficits have important implications regarding the production capacity of the local industry. Import penetration speaks to the need for imports in order to meet local demand. This can be by volume, type, or complexity of the imported products compared to those produced by the local industry.

Another key metric for evaluating the development of a sector is value addition. Value addition is the difference between the sale price of a good and the cost of the good and can be increased through investments in better technologies that result in increased productivity, both capital and labour. Increased labour productivity results in more output given the same labour inputs so that value addition would increase because the per-unit labour cost is declining, increasing the relative value that labour imposes on the final good. Data on value addition for the CHIETA sectors shows that the petroleum sector's value addition has grown enormously since 1994, followed by solid levels of value-add growth in the basic chemicals and other chemical products sectors (see Figure 5).[9] In contrast, the glass and glass products sector has not realised much growth in its value addition. Improving skills is another critical determinant of improving value add for a particular product or industry. This is because as firms seek out new markets through increased value addition, they must upgrade the skills of their workforce (Verma, 2012).

[8] The reason that the trade balance for basic chemicals is persistently in deficit is because South Africa does not produce a number of key inputs that feed into the rest of the chemicals value chain.
[9] The large jump in the petroleum products sector is a result of the opening of SASOL's Project Turbo which had some additional benefits such as petrochemical beneficiation on top of its main focus on clean fuels.

Figure 5: Value addition in CHIETA sectors (1994 = 100)



Source: Author's calculations using Quantec data

Import penetration (import-domestic demand ratio) for the other chemical products sector, for example, has remained around 30% in recent years after falling sharply before 2008, and then increasingly thereafter. This implies that firms within the other chemical products sector are competitive. However, a growing trade deficit could speak to a decline in export competitiveness over time and may not be due to capacity constraints. While at the same time, falling import penetration speaks to increased export competitiveness. On the other hand, an increasing import penetration speaks to a lack of necessary capabilities and capacity to meet local demand. The trend in declining output and a growing trade deficit that has characterised the last ten years coincides with a general decline in the gross fixed capital formation (GFCF)[10] for all sectors within CHIETA. This will further dampen the capacity to expand production into export markets and may also increase import penetration.

In recent years, the petroleum products, chemicals, rubber and plastics sector has struggled to realise significant levels of growth as it attempts to compete with international competitors in terms of price, technological advancement, and the complexity of its products. The technologies associated with the fourth industrial revelation improve efficiencies and productivity of firms, and if South Africa does not keep up, it runs the risk of falling further behind. Therefore, the requisite skills to adapt to these fast-paced and ever-changing operational and business environments in key to thriving in the new industrial age.

[10] GFCF is used as a proxy for investment.

6. Analysis of CHIETA Skills, Training and Education, Grants and Levies by Sector

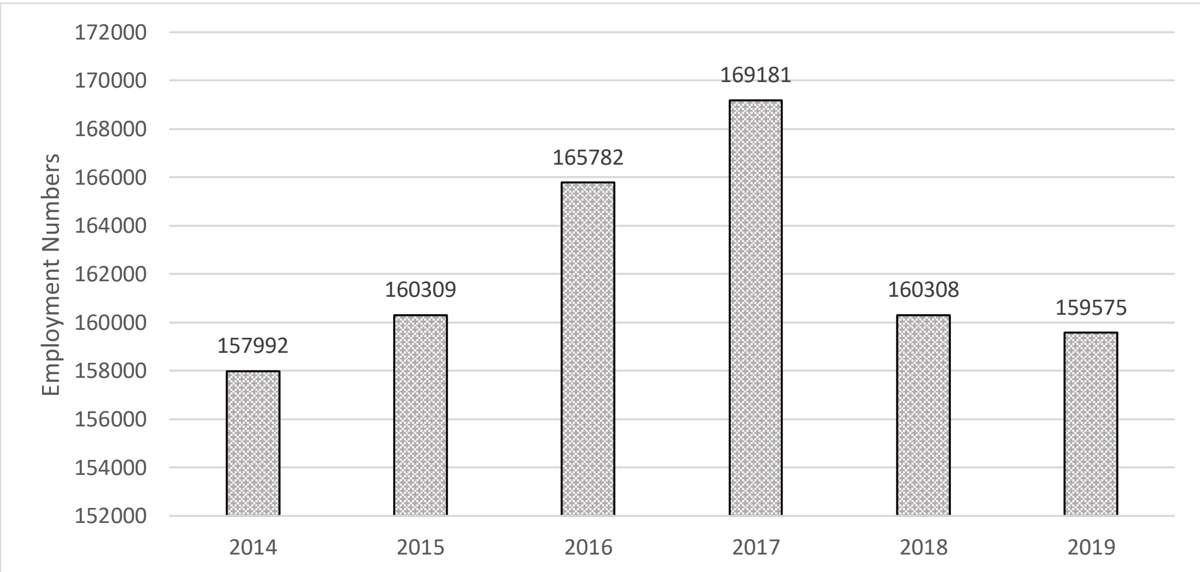
The Chemical Industries Education and Training Authority (CHIETA) was established through the Skills Development Act of 1998 to foster skills development in the chemical and manufacturing industries.[11] CHIETA facilitates the development of the necessary skills through various training programmes and supports industry players, chambers, and sub-sectors (Appendix 1).

5.1. Overview of Employment and Skills in CHIETA

A deep dive into the sub sectoral data of CHIETA enabled this analysis to look closely into the distribution of employees across the chemical industry, focusing on the educational qualifications, age, distribution of essential skills such as engineering, artisans, toolmakers, technicians and information communication and technology professionals. This was made possible by the CHIETA database, which is a collection of individual employee records from firms as part of their mandatory grant applications (Workplace Skills Plans (WSPs) and Annual Training Reports (ATRs). The objective was to identify the skills composition in specialist/contextual knowledge and artisan development, engineers, toolmakers, ICT professionals. This is important to facilitate interventions in solving the skills challenges experienced in the sector.

The chemical industry is a crucial source of employment. The employment figures include all employees with permanent appointments as well as those on temporary contracts. Employment in 2014 was estimated at 157 992 and rose to 160 309 in 2015. At the end of 2017, it had increased to 169 181. However, in 2018 employment dropped to 160,308, consequently reducing the growth in employment over the total period by 1.5%, suggesting a contraction of the sector.

Figure 6: Number of employees in the chemical industry



Source: CHIETA

[11] https://www.chieta.org.za/About-CHIETA

A further breakdown of employees in the chemical industry indicates that in 2018 the petroleum subsector employed the largest contingent of workers in the chemicals industry, representing about 37,586 (23%) of the total workforce. The base chemicals subsector is the second largest, with 17% of the workers in the sector. This is followed by Pharmaceuticals (14%) and Speciality Chemicals (14%), the FMCG subsector with 10% and the Glass subsector with 6% of the workers. The other subsectors employ 7% or fewer of the workers in the sector (Chemical Industries Education and Training Authority (CHIETA), 2019). However, aligning these subsectors to how it is recorded in South Africa, Quantec data reduces them to only four broad categories: base chemical, coke, petroleum and nuclear products, glass and other products encompassing pharmaceuticals, speciality chemicals, the FMCG. This makes the largest number of employees fall into the broad category of other products.

5.1.1. Occupational distribution of CHIETA employees

The occupational analysis and classification systems help to understand work and how it is changing and shaping the organisational and institutional contexts in which people work. Furthermore, the occupational composition also tracks the changing nature of work and considers the attributes of the persons who perform work and the processes by which they perform it. Information on occupation describes the set of tasks and duties carried out by or can be assigned to one person. The chemical industry's occupational composition is categorised into five groupings: professionally qualified and experienced specialists and mid-management, semi-skilled and discretionary decision-makers, skilled technical and academically qualified workers, junior management, supervisors, foremen, and superintendents, senior and top management and unskilled and defined decision-makers.

The number of professionally qualified and experienced specialists and mid-management in 2016 accounted for 14.8% of total employees, but in 2019 there has been a drop by 0.9 points (Table 3). These are employees who are competent or skilled in a particular activity, such as engineering professionals, accountants and analysts. In the skilled technical and academically qualified workers, junior management, supervisors, foremen, and superintendents account for 30% of the total employees, while semi-skilled and discretionary decision makers constitute 34% of total employees. The unskilled and defined decision-makers in the three years make up 14% of the number of employees in the industry.

Table 3: Occupational composition of the chemical industry

	2016		2017		2019	
Occupation Level	N	%	N	%	N	%
Professionally qualified and experienced specialists and mid-management	21,585	14.8	21,010	13.5	21,824	13.7
Semi-skilled and discretionary decision makers	49,715	34	54,346	34.9	55,025	34
Senior management	5,491	3.8	6,315	4.1	5,390	3.4
Skilled technical and academically qualified workers, junior management, supervisors, foremen and superintendents	44,731	30.6	49,013	31.5	52,203	32.7
Top management	1,845	1.3	1871	1.2	2,186	1.4
Unskilled and defined decision makers	20,826	14.2	23,109	14.8	22,947	14.4

Source: CHIETA

5.1.2. Age distribution in CHIETA

An ageing workforce has implications for productivity, adaptation, and innovation. Unlike a younger workforce that is more adaptable, an ageing workforce slows down productivity. To increase industry competitiveness, the ability of employees to innovate and adapt to changing conditions is crucial (National Research Council, 2012). Therefore, monitoring the age of employees in an industry is important to keep track of the transformation taking place. In the case of the chemical industry, the employee age groups are categorised into four main groups. The first group consists of employees aged less than 30 years; the second group consists of employees between 30 to 45 years, the third group comprises employees between 45 to 60 years, and the last group comprises all employees more than 60 years.

According to the CHIETA database, most of the workforce is between the ages of 30 to 45 (Table 4). This age group in 2016, 2017, and 2019 accounted for 50% of all workers in the chemical industry. This age group represents the most productive and professional employees who have now developed their trade and are the backbone of the industry. The second most represented age group was the 45 years to 60 years, averaging about 25% of the total employees in the chemical industry during 2016-2109. This age group is made up of employees that have amassed significant experience and know-how in the industry.

Table 4: Age Distribution in the chemical industry

	2016		2017		2019	
Age	**N**	**%**	**N**	**%**	**N**	**%**
<30	26,919	18.4%	29,716	19.1%	29,903	18.7%
30-45	75,345	51.5%	80,522	51.7%	83,528	52.3%
46-60	38,394	26.2%	39,460	25.3%	39,664	24.9%
60+	5,646	3.9%	5,966	3.8%	6481	4.1%
Total	**146,304**	**100%**	**155,664**	**100%**	**159,576**	**100%**

Source: Authors illustration using CHIETA Data,

In 2016, employees below the age of 30 and below was 18.4%. This rose to 19.1% in 2017, before experiencing a slight decline in 2019 to make up only 18.7% of the employees in the industry. This age group customarily comprises people who have just come out of school, colleges, and universities and are still learning their trade. However, this is a vital age group since it plays an essential role in the industry's future development. Hence, the need to build capabilities at this level is critical in shaping the industry's future.

5.1.3. Educational distribution of the critical skills in CHIETA

The capabilities that industries need most have evolved, but methods of building those skills have not, and there is still a dependence on the national qualification framework (NQF) in assigning jobs (SAQA, 2000). It is argued that higher levels of education lead to a more skilled and productive workforce, producing more efficiently and a higher standard of goods and services, which in turn forms the basis for productivity and innovation now and rising living standards (Toner, 2011). Some of the critical job titles that can aid the development of the industry include Artisans, Engineers, Technicians, Toolmakers and ICTs related). The CHIETA database revealed that most of the chemical industry employees have a certificate/advance diploma/ degree in engineering.

For instance, in 2017, 1 697 engineers had at least a certificate, while in 2019, this number had increased to 2 172 (Table 4). This depicts a general increase in the number of skilled workers. For instance, in 2019, engineers who have gone through to postgraduate level stood at 917, a significant increase from 586 in 2017. The absorption of engineers into the chemical industry who have gone through technical colleges and universities is essential in the driving development of the industry. However, the data also revealed that some engineers had a qualification of Matric and below. This number in 2019 was 1 448. This category includes employees who have attended the National Certificate Vocational programmes (NCV) (Civil Engineering and Building Construction) programme at Levels 2, 3 and 4 of the NQF.

Table 5: Distribution of NQFs across job titles

Education level	Matric and below[12]			Certificate/Advanced Diploma/Degree			Postgraduate-Honours/Masters/Doctorate		
Job title	**2016**	**2017**	**2019**	**2016**	**2017**	**2019**	**2016**	**2017**	**2019**
Engineers	326	984	1,448	1,579	1,697	2,172	682	586	917
Technicians	1,202	1,259	1,454	1,583	1,725	2,109	197	79	4

[12] The category 'matric and below' encompasses AET 2 / Std 3/4, Grade 5/6, Std 8 / Grade 10, NATED 1 / NCV Level 1, Std 9 / Grade 11, NATED 2 / NCV Level 2, Std 10 / Grade 12, NATED 3 / NCV Level 3

Toolmakers	34	25	24	31	47	47	4	6	7
Artisans	2,167	3,558	3,191	1,988	4,028	3,750	16	16	10
ICTs	120	60	61	203	130	168	51	36	43
Total	**3,849**	**5,886**	**6,178**	**5,526**	**8,011**	**6,168**	**950**	**723**	**981**

Source: Authors illustration using CHIETA Data

A majority of technicians had at least attained Matric and below. According to this database, in 2017, there were 1 259 technicians with Matric and below, while 1 725 had a certificate or degree. There was a considerable decline in the postgraduate technicians in 2016; there were 197 technicians who had a postgraduate qualification, but this dropped significantly to record only four employees in 2019 that have this qualification. Concerning Toolmakers, there are generally few of them in the chemical industry. In 2016, the data revealed that only 91 employees in the industry were in this occupation. Only 34 of these had a matric and below qualification, 21 had certificate or degree while four had a postgraduate qualification.

The number of artisans in the chemical industry has been gradually increasing due to a robust National Artisan Development program, which seeks to produce 30 000 qualified artisans by 2030 (DHET,2019). In 2016, 56.3% of the artisans had a qualification of "matric and below", which encompasses vocational programmes at the national certificate level 3 or 4, while 31% of the employees had certificate/degree or postgraduate qualification, respectively.

Regarding ICT professionals, the chemical industry does absorb relatively few employees, with most of them in possession of either a certificate or degree. For instance, in 2016 they were 203 employees in this category, while in 2019, the number had decreased to 168. The numbers are lower at the postgraduate level, with only 43 employees who had gone through postgraduate schooling in 2019.

Across these skills, the low numbers of employees at the postgraduate level and those occupying the senior and top management positions are consistent throughout the above table. These have an implication of a less skilled and productive workforce which may hinder efficiency. However, these also provide a platform for post-school education and training to offset the mismatch between employee qualifications and industry needs.

5.1.4. Sectoral distribution of key skills in CHIETA

Science, technology, engineering and mathematics (STEM) skills have been portrayed as vital skills for tackling the fundamental changes in industrial work in the future (Siekmann & Korbel, 2016). These skills and knowledge are critical in supporting the nation's productivity, prosperity and competitiveness on the international platform (Trilling and Fadel, 2009). The skills or jobs in the chemical industry related to the STEMs- engineers, artisans, technicians, toolmakers and individuals in the information and communication and technology space - revealed their increasing importance in reshaping the context of changing work environments. Furthermore, the skills mentioned above also facilitate contribute to the success of the subsectors for 4IR. The inclusion of toolmakers was informed by previous research in the plastics sector, which indicated that firms with their tool rooms with toolmakers tend to perform better (CCRED,2019).

The coke, petroleum, and nuclear products sector absorb most of the engineers in the industry more than all other industries. In 2016, the subsector had 1 753 engineers, and by

2017 the number had reached 1 995 (Table 5). The FMCG and Pharmaceuticals also absorb more engineers with 402 and 528 in 2016 and 2017, respectively. The base chemicals industry had 11 toolmakers in 2016, but those rose significantly in 2017 to 30, while the petroleum subsector had 8 and 14 in 2016 and 2017, respectively. The subsector which had most of the toolmakers was the Speciality Chemicals and Surface coatings subsector which had 38 in 2016 and then dropped to 17 in 2017.

Table 6: Job titles by sector

	Engineers		Toolmakers		Artisan		Technicians		ICT	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Base Chemicals	393	482	11	30	1,382	1,483	660	643	36	32
Petroleum	1,753	1,995	8	14	3,486	5,960	1,121	1,517	109	128
Glass	170	197	10	12	134	79	393	483	21	19
Explosives and Fertiliser	249	288	7	7	286	181	238	288	5	65
FMCG and Pharmaceuticals	402	528	10	10	301	274	591	578	44	35
Speciality Chemicals and Surface coatings	268	208	38	17	33	71	1,048	916	19	22
Total	**3,235**	**3,698**	**84**	**90**	**5,622**	**8,048**	**4,051**	**4,425**	**234**	**301**

Source: Authors illustration using CHIETA Data[13]

The petroleum subsector employed the most number of Artisans, Technician and ICTs followed by Base chemicals, FMCG and Pharmaceuticals. These are important towards the embracing of Industry 4.0 and the ability to improve the competitiveness of the chemical industry. In South Africa, these skills are hard to fill and the shortage has been attributed to the poor linkages between the formal education and skills systems and weak vocational education and training system in skills such as engineering, artisans and technicians, toolmaking (HRDCSA, 2013). This shortage is expressed in the low numbers of skilled people emerging from either the formal education system or skills development programmes, and finally in the mismatch between the skills of those qualifying and the skills needs of employers. South Africa can draw lessons from the Netherlands skills systems that exemplify 'best practice' in alignment between the skills councils and the regional colleges. Employers are essentially the 'starting point' of this joint system. They work through sectoral skill bodies, called the 'Kennicentra' (Knowledge Centres), to identify and express the sector's required skills. Their diagnoses of what skills and curricula are needed are then fed through to BVE Raad (the Dutch Council for Vocational and Adult Education, the umbrella body for the regional technical colleges), which then feeds this through to the regional colleges in order to develop a curriculum primarily based on the standards and requirements set by the employers (Kraak, et al., 2013).

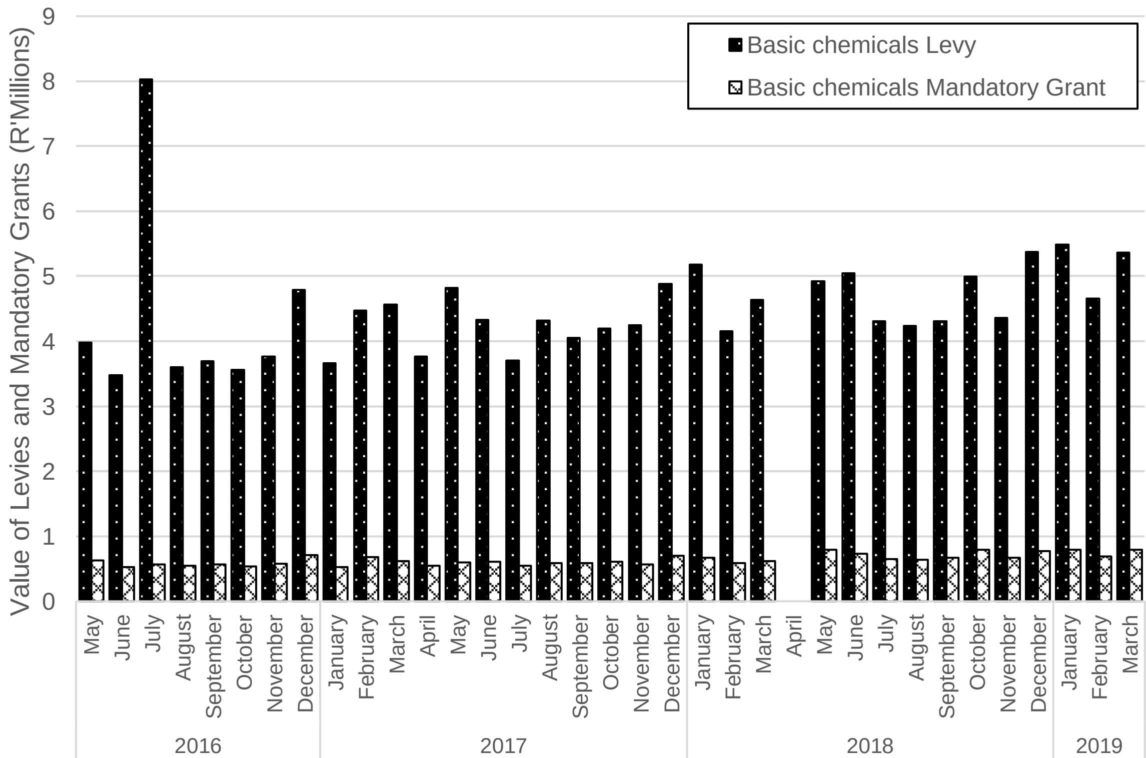
[13] Engineers consist of employees with "engineer" in their job title. Tool makers include everyone with "tool" in their job title similarly with Technicians and Artisans. With respect to information communications and Technology the following occupations were considered (ICT, Information Analyst, Software Developers, Computer network and system analyst).

5.2. Comparison of levies and mandatory grants paid in each sector

The Skills Development Levy (SDL) are paid by companies who are registered with a SETA to encourage learning and skills development in South Africa. A company's salary bill determines the SDL. Companies whose salary bill is expected to be above R500 000 within 12 months pay 1% of this total salary bill towards the SDL (SARS, 2020). The SDL is then distributed between the appropriate SETA (80%) and the National Skills Fund (20%). Firms can then recover the total amount of the levies paid in the form of mandatory grants, which are paid to employers quarterly (CHIETA, 2018). However, firms must claim mandatory grants within a specific period or risk their SETA transferring the unclaimed mandatory grant into the discretionary grant fund.

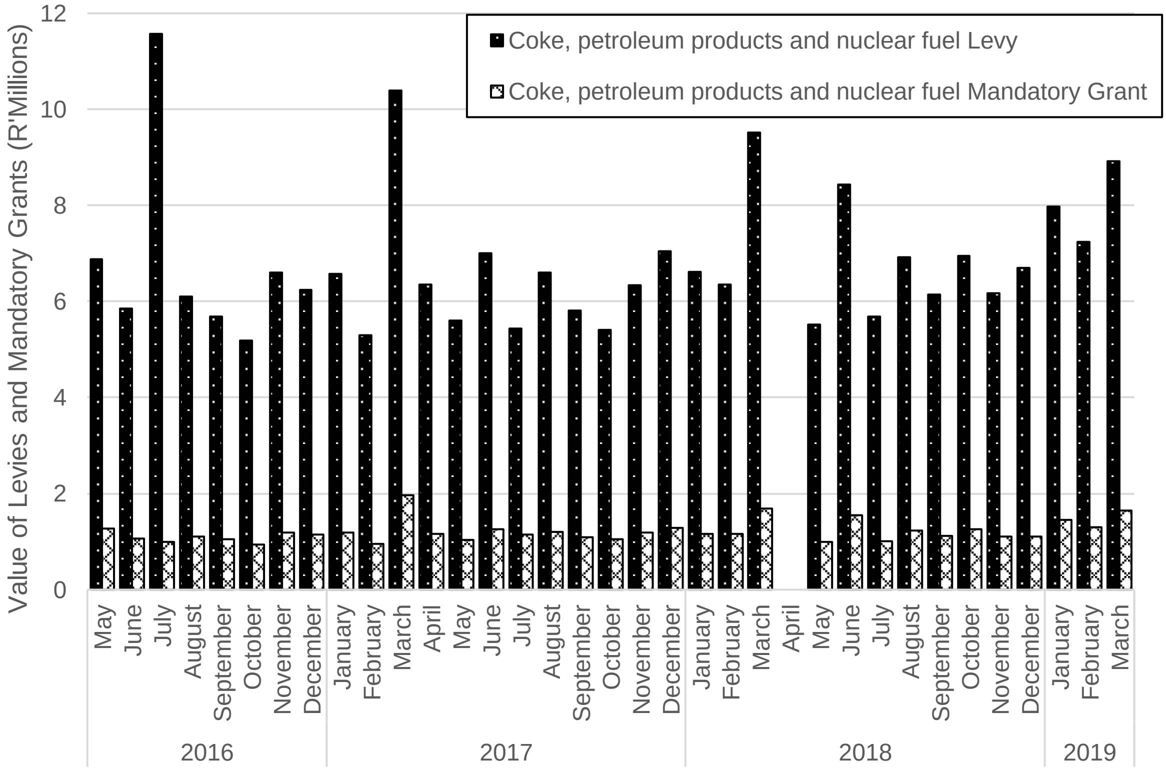
Data on both the levies and mandatory grants shows differences in the levels of levy payments. For example, the average total levy paid by firms within the other chemical products sector was R23 million for the period we have data (May 2016 to March 2019). This average total levy is four times the next highest levy contributing sector – the coke, petroleum products and nuclear fuel sector. The relative size of each of these sectors is important to note because the skills levy is directly determined by the size of a firm's monthly salary payments. However, this does not ignore the possibility of specific sectors paying higher average salaries while employing fewer workers. Nevertheless, the data for employment does seem to confirm the initial correlation between higher numbers of workers and higher average levy payments into CHIETA.

Figure 7: Basic chemicals sector levies and grants



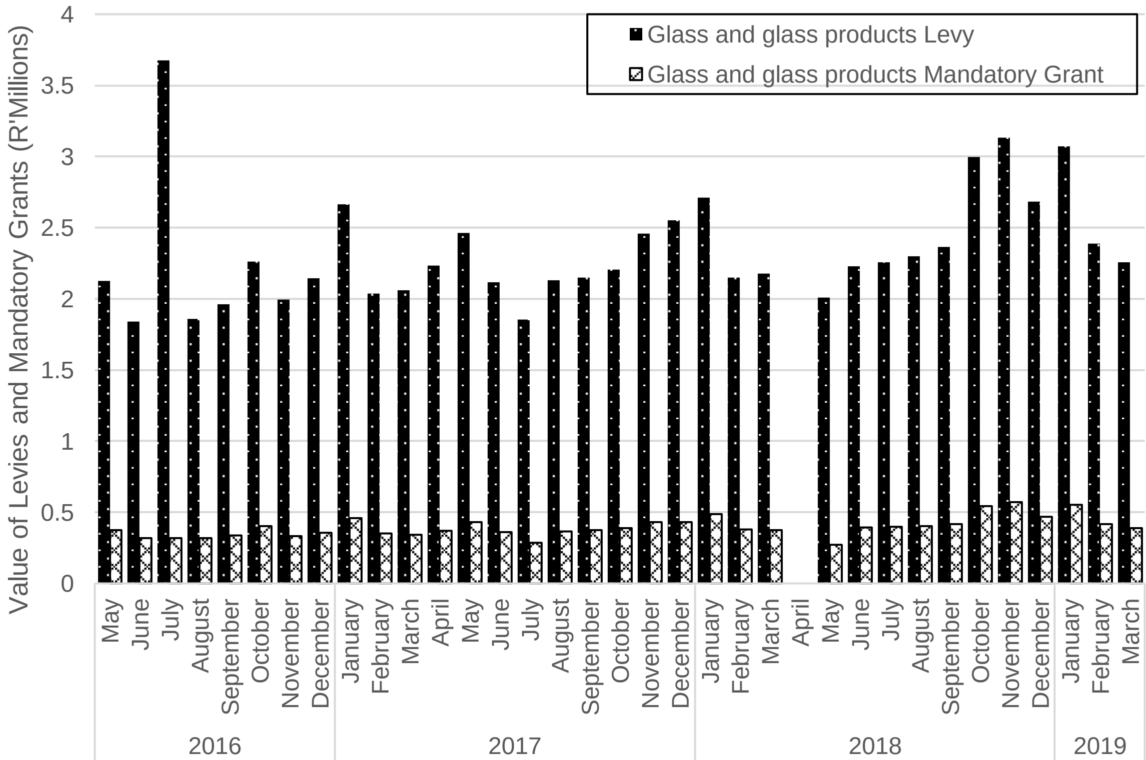
Source: CHIETA

Figure 8: Coke, petroleum products and nuclear fuel sector levies and grants



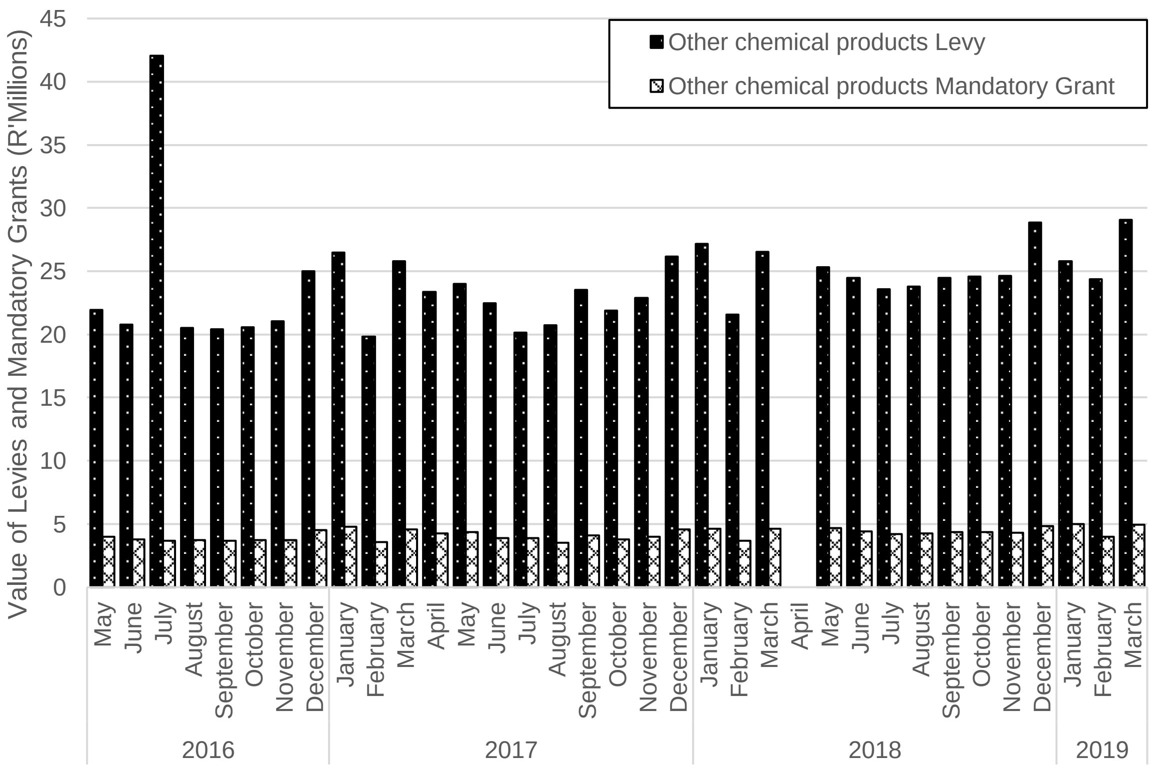
Source: CHIETA

Figure 9: Glass and glass products sector levies and grants



Source: CHIETA

Figure 10: Other chemical products sector levies and grants



Source: CHIETA

The data shows a massive discrepancy between the mandatory grants paid back to firms over three years (Figure 5 – 8). For all four sectors, the mandatory grants paid to firms averaged between 14% (for basic chemicals) and 18% (for coke, petroleum products, and nuclear fuels). The other chemical products and glass and glass products sectors both averaged 17% of the levies paid back as mandatory grants. These low payback percentages are concerning from the perspective of firms as they are effectively losing money to utilise in their operations in many different ways directly. Why the mandatory grant payback percentage is so low is unclear without first-hand accounts from both the firms and CHIETA. This would have to be delved into further through surveys and interviews with individual firms to gain more significant insights into why the gap between mandatory grants and levies is so large.

7. Technology adoption in the chemicals sector – Evidence from Digital Skills Survey

This section analyses the readiness and preparedness of firms affiliated to CHIETA to adopt technologies, using data from the Digital Skills Survey (2020/21). We further leverage the firm's responses in the survey on production methods- both current and future ambitions – to understand the firm's constraints in adopting digital technologies.[14] In light of the growing assertions around the transformative potential of automated and digital-enabled processes in improving efficiency and competitiveness, this section attempts to understand

[14] 73 CHIETA-linked firms that participated in the survey

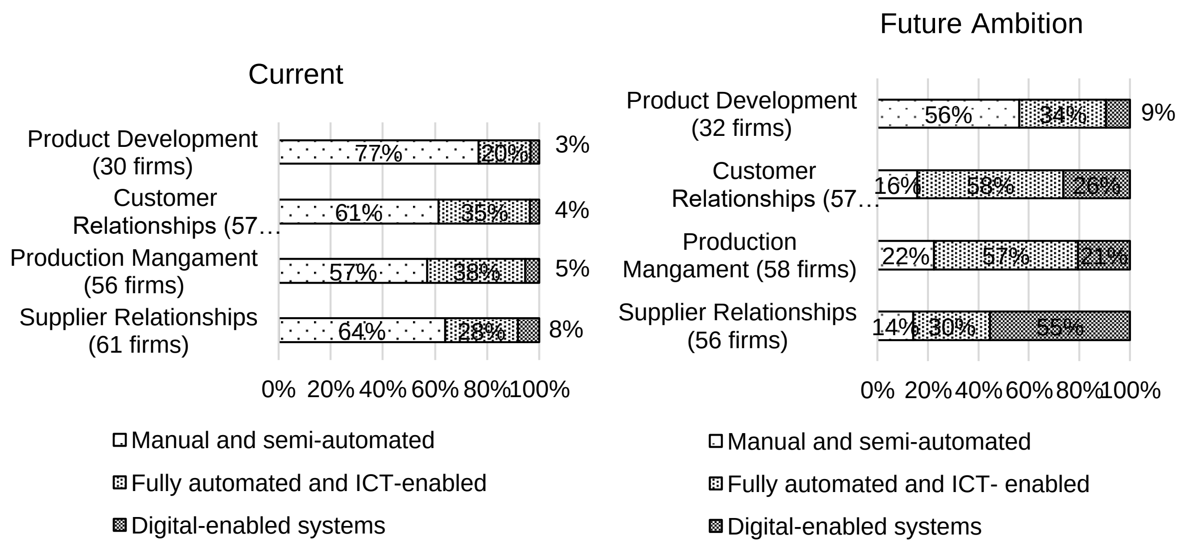
the readiness and preparedness of CHIETA firms concerning their technological infrastructure in the context of industry 4.0.

6.1. Current and future technological infrastructure of CHIETA firms

The firms in the Digital Skills Survey were required to indicate their current technology infrastructure and their future ambitions regarding upgrading this infrastructure in the next 5-10 years across four interrelated business functions. The business functions are drawn from Kupfer et al. (2019), who define different generations of technologies (from manual - generations zero- to generation four) that operate in each business function: supplier relationships, customer relationships, production management, and product development. For analytical ease, the technological generations were consolidated into three distinct categories. The first generation referred to **manual- and semi-automated processes** is used to explain the use of analogue and rigid processes. The second-generation referred to as **fully automated and ICT-enabled processes**, describes lean production processes. The last generation referred to as **digital-enabled systems,** depicts the use of integrated and smart processes. The results offer some high-level insights into the current complexity of the CHIETA firms surveyed with direct implications for digital skills.

The current technological infrastructure prevailing in the industry points to the fact that most of the surveyed firms' business functions are primarily driven by manual- and semi-automated technologies and processes (Figure 11). The data shows that some firms have adopted fully-automated and ICT-enabled processes, with a small proportion having already implemented advanced processes linked to digital-enabled systems. An overall assessment suggests the industry is potentially lagging in the context of Industry 4.0. The results are more pronounced once we delve into the respective business functions. For instance, the product development business function (also referred to as research and development) had the highest percentage (77%) of its processes conducted under manual and semi-automated processes. Whereas production management emerged as the relatively more advanced business function with around 43% of its processes fully-automated, ICT-enabled, or employing digital-enabled systems. These results would appear to suggest that CHIETA firms perceive the production management function as the business function most crucial for their competitive edge in the product market.

Figure 11: CHIETA current and future technological adoption

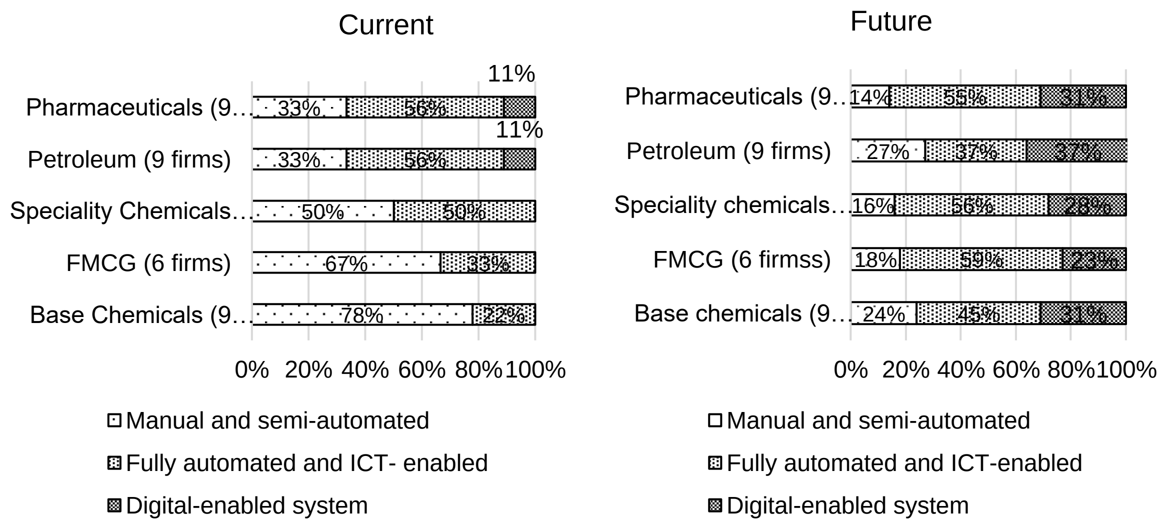


Source: Authors' illustration using survey data[15]. Notes: Number of observations in brackets

In terms of the future ambitions of the CHIETA firms, there is a marked and significant drop in desire to continue operating with manual- and semi-automated processes across all the business functions. Firms appear to be very ambitious about their future technological infrastructures. In particular, the customer and supplier relationship business functions were earmarking significant upgrades in these functions towards embracing fully-automated, ICT-enabled, and digital-enabled systems. Similarly, a more significant proportion of firms are looking to upgrade their production management function in the future. These results show that these firms are positive about their future operations and suggest that CHIETA firms are cognizant of the importance of innovation and new technologies in transforming the workplace in the next 5 to 10 years.

We delved into the industry-level breakdown to better and more fully understand technology's current and future landscapes among CHIETA firms (Figure 12). This was critical in determining the technological industry leaders at the forefront of driving the adoption of digital technologies while at the same time allowing us to identify the laggard industries. The results from the survey suggest that base chemicals emerged as the sector with the highest percentage of its processes being manual- and semi-automated methods. This was followed by the fast-moving consumer goods and speciality chemicals. These are mainly labour-intensive industries, and may explain why these sectors are laggards in their current technological infrastructure. On the other hand, the pharmaceuticals, petroleum, and speciality chemicals industries (generally all capital-intensive industries) were relative leaders in their current technological adoption, with at least 50% of their processes fully automated and ICT-enabled. There are also some instances where industries have already adopted digital-enabled systems, a suggestion that these industries are at the forefront in championing technological adoption among CHIETA firms. Therefore, in the context of Industry 4.0, these sectors could be more receptive to the adoption of new technologies and innovative processes across their operations.

Figure 12: CHIETA firms current and future technological infrastructure ambitions by industry



Source: Authors' illustration using survey data

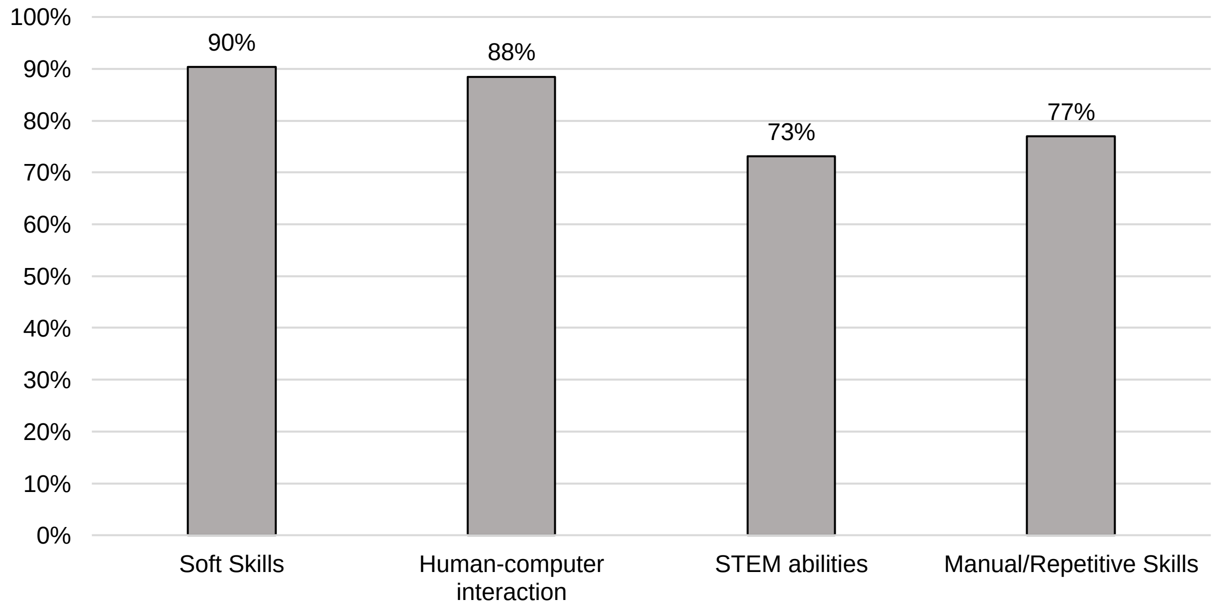
[15] Based on the 73 firms that participated in the survey

Note: Sectors with only one response and sectors that mentioned one category i.e. glass, surface coatings, fertilisers, explosives and rubber are excluded.

The future ambitions of firms are in line with CHIETA's forecasts of a transition to fully automated and digital-enabled systems that will transform the workplace in the next 10 to 15 years, as people begin engaging with smarter machines (CHIETA, 2020). Advanced technology is critical in the chemicals sector because global competition and pressure to innovate has forced them to consider introducing new manufacturing technologies and processes (Kamath, 2021). However, the ability to engage in technological upgrading is strongly linked to various firm-specific factors. These can range from being exporters to their age, but most often, the ability to adopt more advanced technological infrastructures is due to an individual firm's size (Avenyo & Bell, 2022 forthcoming). The survey of CHIETA firms showed that medium and large firms in CHIETA were leading in adopting fully-automated, ICT-enabled, and digital-enabled systems. This may be due to differences in budgets and other resource advantages attributable to medium and large firms that afford them the capacity to be leaders in new technologies, unlike micro and small firms.

Another factor that explains the current technology adoption status shows why the manual and semi-automated processes dominate is linked to the skills the firms identified as important. Soft skills were identified as necessary for 90% of the CHIETA firms that participated in the survey. These soft skills include problem-solving, communication, and interpersonal skills. The firms also regarded human-computer interaction skills are crucially important in their hiring decisions (88%), followed by manual or repetitive skills (73%) and Science, Technology, Engineering, and Mathematics (STEM) abilities (73%).

Figure 13: Important skills for CHIETA firms when hiring



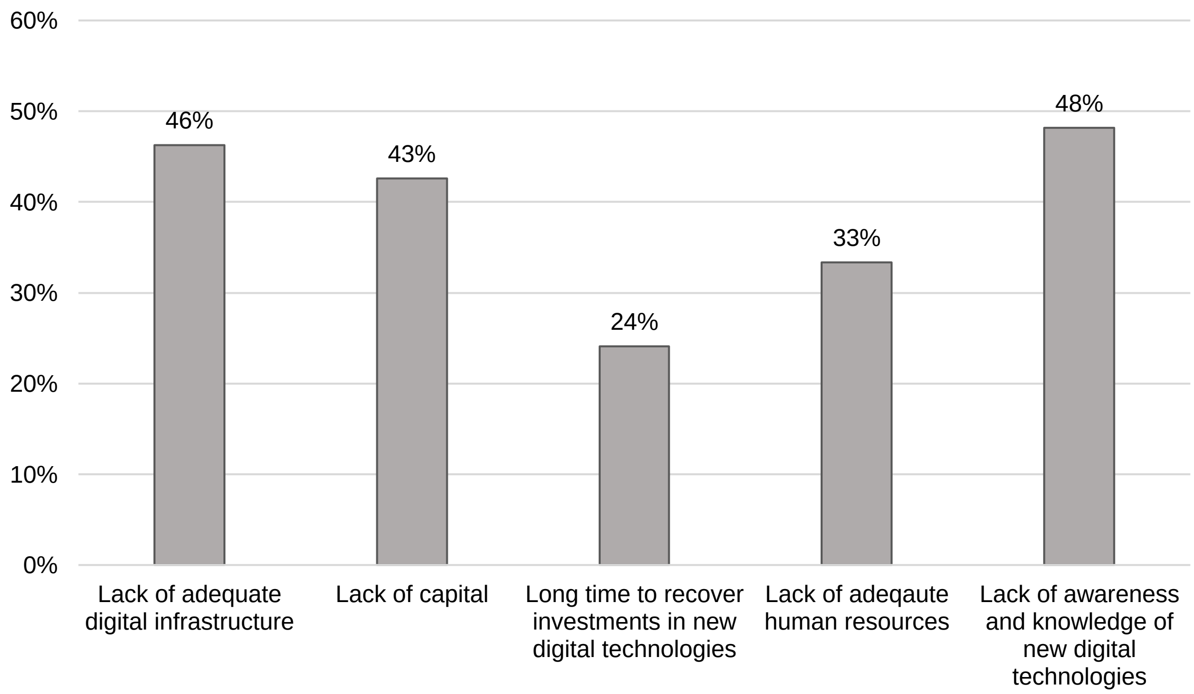
Source: Authors' illustration using survey data

The skills breakdown supports our earlier finding that most of the CHIETA firms' existing methods and processes across all their business functions are dominated by manual- and semi-automated methods and technologies that do not require advanced skills levels. A critical inference from this is that the current importance placed on less technologically-inclined skills (STEM abilities) can play a crucial role in the ability of firms to realise their future technological ambitions and transition toward fully-automated, ICT-enabled, and digital-enabled systems, all of which require STEM abilities. From the industry-level perspective, CHIETA firms, on average, possess a greater affinity towards STEM skills. From the perspective of CHIETA firms, this affinity towards STEM skills could also be more forward-looking as most of their firms appear more bullish on their future technological infrastructures and the adoption of more advanced technologies. The leading subsectors across the crucial skills when hiring was, pharmaceutical, petroleum and base chemicals identified.

6.2. Challenges in technological adoption in CHIETA firms

The lack of digital skills is a strong determining factor in the ability of firms to adopt more advanced technological infrastructures and increase the complexity of their operations. However, firms were asked to identify additional factors that they consider as obstacles to their ability and capacity to engage in technological upgrading and change. Of these additional factors, the surveyed firms highlighted the lack of awareness and knowledge of new digital technologies (48%), lack of adequate digital infrastructure (46%), and lack of capital (43%) as the biggest obstacles that are hindering their adoption of advanced technologies (Figure 13).

Figure 14: Obstacles to technological adoption



Source: Authors' illustration using survey data

The lack of awareness and knowledge of digital technologies among the surveyed CHIETA firms potentially speaks to potential information gaps between the firms and the various institutions and associations. Closely linked to this was an identified lack of adequate digital infrastructure. The transition from manual and semi-automated processes to fully automated and digital-enabled systems is dependent on the existing technological infrastructure supporting these new technologies (Bell, et al., 2019). Previous studies reiterate this finding, indicating that South Africa has an expensive, comparatively slow, and unreliable ICT infrastructure, and industrialists deem this to be a major limitation to the adoption of more advanced digital technologies (CCRED, 2019). The lack of capital is an obvious hindrance to adopting new technology that requires investment in upgraded capital equipment. However, there are working capital consequences to the changes related to adopting new technologies with long payback periods. To alleviate these and other issues requires coordinated institutional assistance from development finance institutions and CHIETA.

8. Conclusion

The improvements in manufacturing productivity depend primarily on the ability of firms to innovate and adapt to technological changes. The upgrading of skills is a critical ingredient in improving manufacturing productivity and competitiveness, and the adoption of new technologies particularly in the chemical industry.

This paper provides an assessment of the state of South Africa chemical industry in the context of industry 4.0, using CHIETA database on employee and company's information, levies and mandatory grants, and complemented with firm-level data from the Digital Skills Survey. Our analyses revealed a plethora of issues. Primarily, our results revealed a shortage of skills such as engineers, artisans and toolmakers. This is attributed to poor linkages between formal education and skills systems and weak vocational education and training systems. Furthermore, this was expressed in the low numbers of skilled people emerging from either the formal education system or skills development programmes and in the mismatch between the skills of those qualifying and the skills needs of employers.

Secondly, the data on levies and mandatory grants highlighted a significant problem wherein firms are not getting their mandatory grants back. This has implications on the firm's skills training and needs with further implications for the firms' skills upgrading efforts. Therefore, there is a need to address the gaps between levies paid and mandatory grants received and allow firms to use these funds toward upgrading their operations from a technology and skills standpoint.

Thirdly, drawing from the Digital Skills Survey (2020/21), our findings suggest that the current technological infrastructure prevailing in the industry business functions in surveyed firms are largely driven by manual- and semi-automated technologies and processes, with few firms having implemented advanced technology processes linked to digital-enabled systems. As a result, the industry is potentially lagging in the context of Industry 4.0. The firms attributed this slow uptake in new technologies to a lack of awareness and knowledge, digital technologies infrastructure, and human resources.

These findings have immediate implications for the competitiveness of the chemicals industry given the global trends and shifts towards more integrated, fully-automated, ICT- and digitally-enabled systems across entire operations and business functions. To smoothen the transition from manual- and-semi automated processes to digital-enabled systems require the skills and technology planning in the chemical industry to be very intentional in achieving this objective. To achieve this objective would require a multifaceted approach combining the mandates of several institutions. For starters, skills development programmes need to be scaled up and in instances where skills are lacking, the industry needs to attract skilled personnel in key areas.

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10. Appendix

Appendix 1: Job titles and OFO codes

Job Titles	OFO Code	Description
Engineers	214 215	Engineering Professionals (Excluding Electro technology), Electro technology Engineers
Artisans	214 313 671	Engineering Professionals (Excluding Electro technology), Artisan Gr2: Process Electrical Equipment Installers and Repairers
Information, Communications and Technologies (ICTs)	251 252 351 352	Software and Applications Developers and Analysts, Database and Network Professionals Information and Communications Technology Operations and User Support Technicians Telecommunications and Broadcasting Technicians
Technicians	311 313	Electrical Engineering Technician Process Control Technicians
Toolmaker	652 653	Toolmaker Mechanical Fitter

Source: Organisation Framework for Occupation (2019)

Appendix 2: Table of CHIETA Sectors, Chambers, and Quantec Classification

SIC Code	Scope of Coverage/Description	Chamber	Sub-sector	Quantec Sector Classification
33410	Manufacture of basic chemicals, except fertilisers and nitrogen compounds	Petroleum and Base Chemicals	Base Chemicals	Basic Chemicals
33430	Manufacture of plastics in primary form and of synthetic rubber			
34000	Manufacture of other non-metallic mineral products			
41210	Manufacture of industrial gases in compressed, liquefied or solid forms			
33100	Manufacture of coke oven products		Petroleum	Coke, petroleum products and nuclear fuel
33200	Petroleum refineries/synthesisers			
61410	Wholesale trade in solid, liquid and gaseous fuels and related products			
87140	Industrial research, e.g. fuel research			
33501	Chemically based general household and personal care products	Fast Moving Consumer Goods and Pharmaceuticals	Fast Moving Consumer Goods	Other chemical products
33541	Manufacture of soap and other cleaning compounds			
33543	Manufacture of beauty products			
33530	Manufacture of pharmaceuticals, medicinal chemicals and botanical products		Pharmaceuticals	
33592	Manufacture of explosives and pyrotechnic products	Explosives and Fertilisers	Explosives	
11600	Production of organic fertiliser		Fertilisers	
33420	Manufacture of fertilisers and nitrogen compounds			
33421	Manufacture or raw materials and chemical compounds used in agriculture			

33502	Manufacture, sale and/or distribution of diversified speciality chemicals for industrial use	Speciality Chemicals and Surface Coatings	Speciality Chemicals	
36400	Manufacture of accumulators, primary cells and primary batteries			
33520	Manufacture of paints, varnishes and similar coatings, printing ink and mastics		Surface Coatings	
39005	Powder coating			
34110	Manufacture of glass and glass products	Glass	Glass	Glass and glass products
34112	Manufacture of glass containers; glass kitchenware and tableware; scientific and laboratory glassware, clock, and watch glasses and other glass products			

Source: CHIETA (2018) and authors

Appendix 3: List of SETAs in South Africa

SETA Name	Abbreviation
Agriculture sector education and training Authority	AGRISETA
Banking Sector Education and Training Authority	BANKSETA
Chemical Industries Education and Training Authority	CHIETA
Construction Education and Training Authority	CETA
Culture, Arts, Tourism, Hospitality and Sport Education and Training Authority	CATHS SETA
Education, Training and Development Practices	ETDP
Energy and Water Sector Education and Training Authority	EWSETA
Fibre Processing and Manufacturing Sector Education and Training Authority	FP&M SETA
Financial and Accounting Services Sector Education and Training Authority	FASSETA
Food and Beverages Manufacturing Industry Sector Education and Authority	FOODBEV
Health and Welfare Sector Education and Training Authority	HWSETA
Insurance Sector Education and Training Authority	INSETA
Local Government Sector Education and Training Authority	LGSETA
Manufacturing Engineering and Related Services Sector Education and Training	MERSETA
Media, Advertising, Information and Communication Technologies Sector	MICT
Mining Qualifications Authority	MQA
Public Service Sector Education and Training Authority	PSETA
Safety and Security Sector Education & Training Authority	SASSETA
Services Sector Education and Training Authority	SERVICES SETA
Transport Education and Training Authority	TETA
Wholesale and Retail Sector Education and Training Authority	W&RSETA

Source: DHET (2020)