Understanding the Economic Complexity of the MER Sector with a Focus on SMMEs

A Synthesis

By Caitlin Allen Whitehead, Haroon Bhorat, Robert Hill, Timothy Köhler and François Steenkamp

DPRU Working Paper 202204
December 2022

DPRU
DEVELOPMENT POLICY RESEARCH UNIT

DPRU

DEVELOPMENT POLICY
RESEARCH UNIT

Understanding the Economic Complexity of the MER Sector with a Focus on SMMEs

A Synthesis

DEVELOPMENT POLICY RESEARCH UNIT

CAITLIN ALLEN WHITEHEAD
HAROON BHORAT
ROBERT HILL
TIMOTHY KÖHLER
FRANÇOIS STEENKAMP

Working Paper 202204

December 2022

Abstract
The South African economy has experienced premature deindustrialisation, contributing to its long-term economic stagnation with minimal GDP per capita growth over the past two decades. This contrasts sharply with the industrial growth seen in other developing countries, particularly in Asia, which have leveraged industrialisation for rapid economic advancement. The Manufacturing, Engineering, and Related Services (MER) sector, a significant part of South Africa's manufacturing base, has also seen a decline in its contribution to GDP, employment, and exports. This research analyses the MER sector through the novel and innovative lens of economic complexity and industrial relatedness theory to identify diversification opportunities and address capability constraints. Using a data-centric approach to identify industrial diversification opportunities in the sector, we identify capability constraints hindering the emergence and growth of these industrial diversification opportunities. The findings provide evidence-based industrial policy recommendations to revitalize the sector and, by extension, the broader South African economy. We also provide a unique policy calculus that quantifies the potential economic outcomes that may emerge should the MER sector realise the industrial diversification opportunities identified. In the context of a deindustrialising economy locked in a long-run economic growth trap, there is a clear policy imperative to bring about the growth and diversification of the industries within the sector.

Keywords:
Manufacturing, Engineering, and Related Services (MER) sector; deindustrialisation; economic stagnation; economic complexity; industrial relatedness; South Africa

JEL classification:
O13; O14; O25

Acknowledgements:
This research project was commissioned by the Manufacturing, Engineering and Related Services Sector Education and Training Authority (merSETA).

Corresponding authors
Dr François Steenkamp
francois.steenkamp@uct.ac.za

Recommended citation
Allen Whitehead, C., Bhorat, H., Hill, R., Köhler, T. and Steenkamp, F. (2022). Understanding the Economic Complexity of the MER Sector with a Focus on SMMEs: A Synthesis. Development Policy Research Unit Working Paper 202204. DPRU, University of Cape Town.

Table of Contents

List of Figures

List of Tables

1 Introduction

The premature deindustrialisation of the South African economy is one of the key factors behind the country being locked in a long-run economic growth trap.[1] Over the past two decades, GDP per capita growth has averaged 0.95 percent per year.[2] This lacklustre growth performance is put into perspective when considering that the corresponding average annual per capita growth rates for the global economy, as a whole, and for the sample of middle-income countries, was 1.71 and 4.26 percent, respectively. Over the corresponding period, the South African economy has been deindustrialising, although arguably, and as shown in Bhorat, Lilenstein, Oosthuizen and Steenkamp (2022), this process has been underway since the 1980s.[3] This pattern of structural transformation is troubling as developing economies – mostly in Asia – have experienced rapid economic growth and graduated to higher levels of economic development; and achieved this through the industrialisation of their economies (Rodrik, 2016).

The manufacturing, engineering and related services (MER) sector, a grouping of industries that constitute approximately half of the South African manufacturing sector, has not been immune to the secular decline of the broader manufacturing sector. The MER sector's approximate share of total gross value added stood at 7.7 percent in 1995 and has subsequently declined to 7.2 percent in 2017.[4] Similarly for employment, the sector's approximate share of employment declined from 5.2 to 3.8 percent over the corresponding period. The sector's contribution to total merchandise exports also declined from 31.5 percent in 1995 to 30.2 percent in 2017.

It is within the context of a deindustrialising economy locked in a long-run economic growth trap that the *Understanding economic complexity in the MER sector space with a focus on SMMEs* research project was commissioned by the Manufacturing, Engineering and Related Services Sector Education and Training Authority (merSETA).[5] The project analyses the MER sector through the novel and innovative lens of economic complexity and industrial relatedness theory, applies this theory using a data-centric approach to identify industrial diversification opportunities in the sector, and then identifies capability constraints hindering the emergence and growth of these industrial diversification opportunities, which in turn provides evidence-based industrial policy considerations and recommendations.

[1] The notion of the South African economy being stuck in a long-run growth trap, or middle-income growth trap, has been described in, amongst others, Bhorat, Cassim & Hirsch (2014) and in Andreoni & Tregenna (2021).

[2] Average GDP per capita growth rates are calculated for the period 2000 to 2021 using data from the World Bank's World Development Indicators (World Bank, 2022).

[3] In 1980, the manufacturing sector's share of employment was at its historical height of 16.5 percent (Timmer et al., 2015). The deindustrialisation pathway shows a consistent decline in the sector's share of employment, reducing to 13 percent in 2000, 11.4 percent in 2010, and 9.3 percent in 2018 (Timmer et al., 2015; De Vries et al., 2021).

[4] Gross value-added estimates are taken from Statistics South Africa's Gross Domestic Product Statistical Release (Statistics South Africa, 2022). The estimates are a summation of the following 2-digit SIC chapters: Petroleum products, chemicals, rubber and plastic; Metals, metal products, machinery and equipment; Electrical machinery and apparatus; Radio, TV, instruments, watches and clocks; Transport equipment. The reported values of the MER sectors gross value addition are likely to be overestimates since the 2-digit data does not allow us to separate the petroleum and chemical industries from the rubber and plastics industries, with the former industries not falling within the MER sector.

[5] It is worth noting up front that the research focuses on the manufacturing industries located within the MER sector, which include the Auto Manufacturing, Component Manufacturing, Metals and Engineering, Plastics Manufacturing and Tyre Manufacturing chambers. The scope of the research project does not incorporate the services-orientated Motor Retail chamber.

This paper – Report 4 – synthesises the various research elements that comprise this multi-phase research project. These elements are depicted in Figure 1, which provides an overview mapping of the research project, by showing the phasing, questions (blue), broad research methods (green) and research outputs (orange) of the project. This mapping informs the structure of this paper.

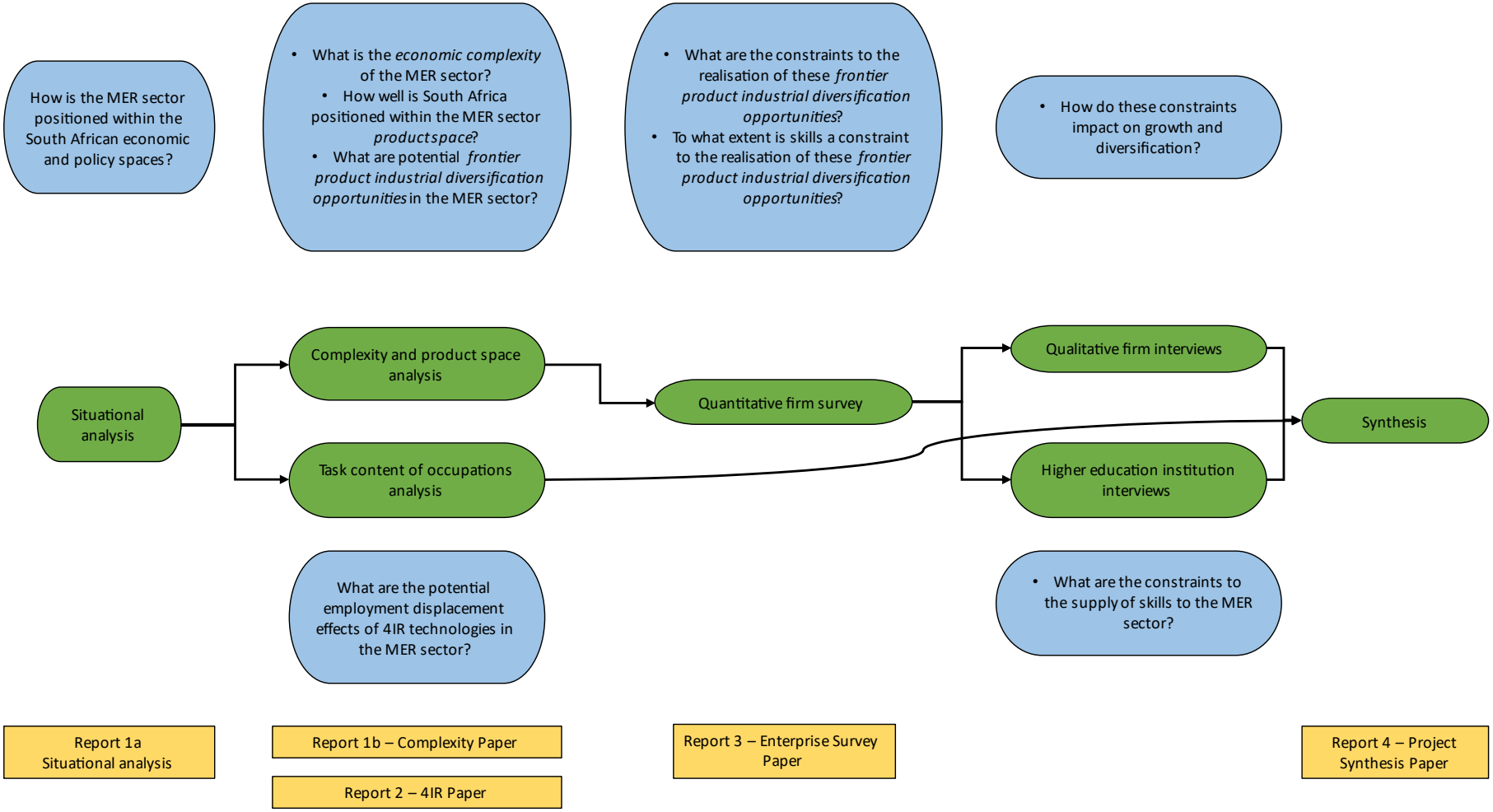
Drawing on the Situational Analysis (Report 1a), compiled by Bhorat, Hill, Köhler, Monnakgotla and Steenkamp (2020), Section 2 positions the MER sector within the South African economic and policy landscape. Section 2 details the economic size of the MER sector in relation to the broader South African economy and examines whether trends in the sector align with the overall deindustrialisation pattern that has emerged in the South African economy. The section also describes how the MER sector is placed within South Africa's overall economic policy framework.

Section 3 is informed by the economic complexity and product space analysis in Allen Whitehead and Bhorat (2020) (Report 1b), which examines the industrial positioning and potential of the MER sector through the lens of economic complexity and industrial relatedness theory. The section considers the economic complexity of the MER sector and its position within the MER sector product space. Finally, economic complexity and industrial relatedness theories and metrics are applied to identify industrial diversification opportunities using an endogenous data-centric industrial policy approach.

Section 4 discusses the constraints that hinder firms in the MER sector from realising these industrial diversification opportunities. The section uses establishment-level quantitative data from the MER Sector Enterprise Survey, and subsequent analysis by Allen Whitehead, Bhorat, Hill, Köhler and Steenkamp (2022a) (Report 3), to detail the constraints facing firms in the sector. This analysis is augmented by qualitative data from firm and industry body follow-up interviews that are used to unpack the nuances associated with how these constraints hinder firm growth and diversification. Section 4 starts by discussing exogenous constraints: constraints that firms have little ability to influence directly – which include labour regulatory constraints, infrastructure constraints, business regulatory constraints and export regulatory constraints. The section then shifts focus to endogenous constraints: constraints that firms have some ability to influence directly – with particular focus on skills constraints. The skills constraint is first considered on both the demand side, where skills gaps and skills mismatches in the sector are discussed. This discussion is furthered by considering work by Allen Whitehead, Bhorat, Hill, Köhler and Steenkamp (2021) (Report 2), which looks at how 4IR technologies may potentially impact of skills demand in the future. The skills constraint is also examined on the supply-side, by considering the challenges facing higher education institutions (HEIs) in supplying the requisite skills to the labour market. This information is informed by qualitative data from interviews with various higher education institutions that supply skills to the sector.

Section 5 of the paper brings together the research learnings across the project, which allows for the formulation of evidence-based industrial policy considerations. The section also provides a unique policy calculus that quantifies the potential economic outcomes that may emerge should the MER sector realise the industrial diversification opportunities identified by Allen Whitehead and Bhorat (2020).

Figure 1: Mapping of the MER Sector Economic Complexity Project - Phasing, Questions, Methods and Outputs



2 Locating the MER Sector within the South African Economic and Policy Landscape

In this section, drawing on the Situational Analysis (Report 1a), compiled by Bhorat, Hill, Köhler, Monnakgotla and Steenkamp (2020), we position the MER sector within the South African economic and policy landscape. First, we place the MER sector within the broader context of a manufacturing sector that is undergoing a process of deindustrialisation. Second, we detail the MER sectors relative contribution to the South African economy. Finally, we locate the sector within South Africa's economic policy landscape.

2.1 Deindustrialisation and the MER Sector

The seminal work by Dani Rodrik (2016) reveals that developing economies, apart from a collection of South-East Asian economies, are undergoing a process of premature deindustrialisation. South Africa is no exception. Rodrik (2016) shows that developing economies are running out of industrial opportunities sooner and at much earlier stages of economic development than early industrialisers (i.e. developed economies). Bhorat, Lilenstein, Oosthuizen and Steenkamp (2022), show that the South African economy reached peak industrialisation in 1980, with the manufacturing sector comprising 23.7 percent of gross value addition and 16.5 percent of employment. Since then, the South African manufacturing sector has experienced steady decline – consistent with the Rodrik (2016) thesis. Table 1 shows that the corresponding values for gross value added and employment stand at much lower levels of 13.6 and 10.8 percent in 2017, respectively,

This pattern of deindustrialisation suggests that South Africa has not undergone manufacturing-led structural change in the post-apartheid period. We depict this pattern of structural change in Figure 2 where we plot relative sectoral productivity against the change in employment share by sector over the period 1995 to 2017.[6] The size of the bubble representing each sector is representative of that sector's employment share in 2017.[7] Sectoral productivity measured relative to overall productivity of the economy allows for the identification of those sectors that are relatively more productive – these would be the sectors for which the log of relative productivity is greater than 0.[8] By comparing the relative productivity of sectors to shifts in employment, it is possible to determine the nature of an economy's structural change. A country undergoing growth-inducing structural change would present with decreasing shares of employment in low-productivity sectors – i.e. bubbles in the south-west quadrant – and increasing shares of employment in high-productivity sectors – i.e. bubbles in the north-east quadrant. This would result in a positively-sloped regression line, indicating that employment has been reallocated towards higher-productivity sectors. Non-growth inducing structural

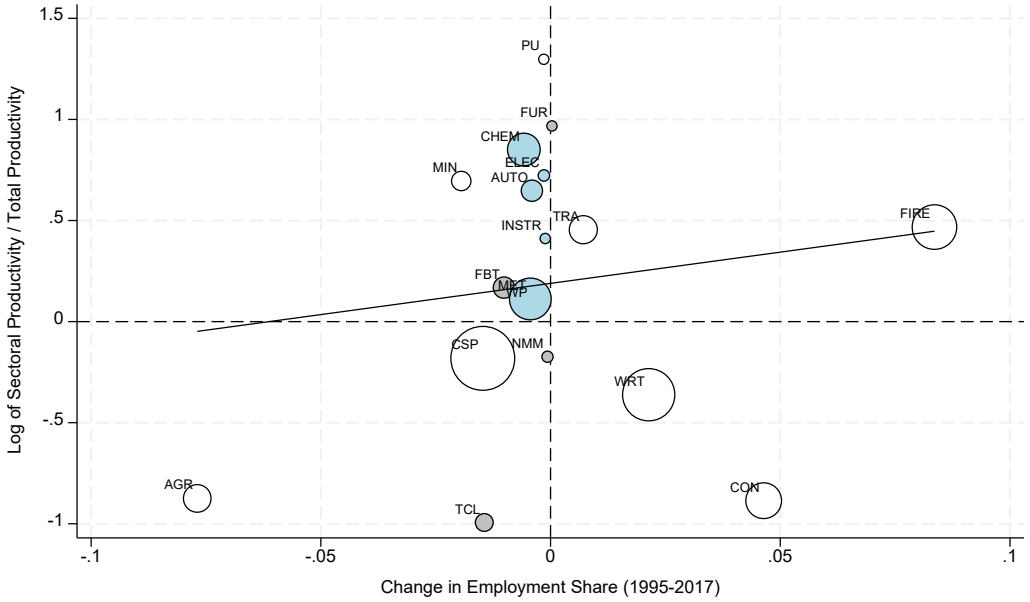
[6] Sectoral productivity is measured as the GDP in each sector divided by the number of employees in that sector. Relative productivity of a sector is then calculated as sectoral productivity divided by the productivity of the entire economy. For scaling purposes, the natural log of this value is used in analysis.

[7] Depending on the data source, we use 2016 or 2017 data for the end period because this report draws upon and synthesises analyses that were conducted using these data at a stage when these data were the latest available. It is important to note that the use of more recent data is unlikely to change the overall narrative of the discussion.

[8] If a sector, X, is just as productive as the economy as a whole, then sector X would present with a relative productivity of 1. By logging this measure – as has been done in this paper – a sector as productive as the aggregate economy would present with a value of 0.

transformation would present with a negatively-sloped regression line, indicating a decrease in employment share for high-productivity sectors, while increasing the employment share of low-productivity sectors.

Figure 2: Sectoral Productivity and Changes in Employment in South Africa, 1995-2017



Source: Authors' calculations using gross value-added data from Statistics South Africa (2022) and employment data from Kerr et al. (2019).
Notes: 1. Size of circle indicates employment share in 2017. 2. β=2.10 (t-stat=0.49; p-value=0.63) 3. AGR = Agriculture; MIN = Mining; PU = Utilities; CON = Construction; WRT = Wholesale & Retail Trade Services; TRA = Transport Services; FIRE = Business Services; CSP = Community, Social and Personal Services; TCL = Textiles, clothing and leather goods; FBT = Food, beverages and tobacco; WP = Wood and paper, publishing and printing; CHEM = Petroleum products, chemicals, rubber, plastic; NMM = Other non-metal mineral products; MET = Metals, metal products, machinery and equipment; ELEC = Electrical machinery and apparatus; INSTR = Radio, TV, instruments, watches and clocks; AUTO = Transport equipment; FUR = Furniture and other manufacturing.

South Africa's pattern of structural change has not been growth-inducing, which is consistent with the notion of the country being stuck in a long-run economic growth trap (Bhorat, Cassim & Hirsch; 2014; Andreoni & Tregenna, 2021).[9] The location of the majority of manufacturing sub-sectors in the north-west quadrant, indicates a shift of productive resources away from these high productivity sub-sectors – i.e., deindustrialisation. This stands in direct contrast to the manufacturing-led East Asian model of development, which would be depicted with the high-productivity manufacturing sector being located in the north-east quadrant – i.e., industrialisation. Instead, we observe the tertiarisation of the South African economy, with a shift of productive resources toward services (Bhorat, Rooney & Steenkamp, 2018; Bhorat et al., 2022).

However, Figure 2 also shows that the sub-sectors comprising the MER sector (blue bubbles) are high productivity industries and are thus, from an industrial policy perspective, strategically important. We observe in Figure 2 that the chemicals (CHEM), within which rubber and plastics resides, the electrical machinery and apparatus (ELEC), the automotive and transport equipment (AUTO), and the metals and machinery (MET), manufacturing sub-sectors are all

[9] The regression line in Figure 2, while having a slight positive slope, is not statistically significant.

located above the horizonal line, and are thus high-productivity sub-sectors. Therefore, the shift of productive resources toward these manufacturing sub-sectors (shift bubbles to northeast quadrant), driven by the growth and diversification of these sub-sectors, would ultimately lift aggregate productivity in the South African economy and drive economic growth. There is thus a policy imperative to advancing the industries that comprise the MER sector.

2.2 The Economic Importance of the MER sectors: The Sector's Relative Position within the South African Economy

The MER sector is key a component of South Africa's manufacturing sector and its relative importance has grown over time. In Table 1 we observe that the MER sector accounted for approximately 7.7 percent of the South Africa's gross value-added (GVA) in 1995, this rose to 8.2 percent in 2008, and declined to 7.2 percent in 2017. Thus, in the context of deindustrialisation, which started in the 1980s, we see that the MER sector experienced a marginal decline in its relative contribution to aggregate GVA in the post-apartheid period. The rest of the manufacturing sector experienced a much larger decline in relative contribution to the aggregate GVA over the corresponding period – 9.4 percent in 1995 to 6.4 percent in 2017. As a result, the MER sector's share of total manufacturing GVA increased from 45 percent in 1995 to 53 percent in 2017.

A similar pattern is evident with respect to the MER sectors relative contribution to employment and exports. Again, while both the MER sector and the rest of the manufacturing sector experienced a relative decline in their contribution to total employment, the decline was smaller in the case of the MER sector. Thus, in 2017, the MER sector accounts for approximately 3.8 percent of total employment in South Africa, and 35 percent of total manufacturing employment. With respect to merchandise exports, the MER sector also experienced a smaller decline relative to the rest of the manufacturing sector. Accordingly, the MER sector accounts for 30.2 percent of total merchandise exports in 2017, and approximately half of all manufacturing exports.

Consistent with the MER sector's rising relative contribution to South Africa's overall manufacturing sector, we observe that the MER sector has outperformed the rest of the manufacturing sector in the post-apartheid period. With respect to GVA, the MER sector experienced an average annual growth rate (AAGR) of 2.4 percent over the period 1995 to 2017. The rest of the manufacturing sector experienced slower average annual growth of 1 percent. In relation to the rest of the economy's GVA performance, the MER sector's average annual growth rate was 90.1 percent of that achieved by the economy on aggerate – the MER sector thus underperformed relative to the economy on aggerate while outperforming the rest of the manufacturing sector. A similar pattern is evident with respect to employment where the MER sector experienced double the average annual employment growth achieved by the rest of the manufacturing sector. However, employment growth in the MER sector was only half of that achieved by the South African economy on aggregate.

Given the composition of high-productivity manufacturing industries within the MER sector and the substantial relative contribution of sector to the South African economy, there is a policy imperative to advancing the industries that comprise the MER sector. The next sub-section discusses the policy importance of the MER sector.

Table 1: MER sector's relative economic performance and contribution to the South African economy

	Levels			Shares			Change	AAGR	Ratio
	1995	2008	2017	1995	2008	2017	1995-2017		
GVA		Rm							
Primary sector	277 437	307 864	336 965	0,126	0,087	0,083	-0,043	0,008	0,316
Non-MER sector manufacturing	207 250	257 069	260 255	0,094	0,072	0,064	-0,030	0,010	0,371
MER sector manufacturing	169 051	292 196	292 756	0,077	0,082	0,072	-0,004	0,024	0,901
Rest of secondary sector	151 048	247 271	257 351	0,068	0,070	0,063	-0,005	0,023	0,874
Tertiary sector	1 403 254	2 447 348	2 912 094	0,636	0,689	0,717	0,082	0,032	1,202
Total	2 208 040	3 551 748	4 059 422					0,027	
Employment		(000s)							
Primary sector	1 024	1 105	1 267	0,122	0,079	0,077	-0,044	0,010	0,317
Non-MER sector manufacturing	951	1 117	1 142	0,113	0,080	0,070	-0,043	0,008	0,272
MER sector manufacturing	441	859	627	0,052	0,062	0,038	-0,014	0,016	0,527
Rest of secondary sector	551	1 241	1 525	0,065	0,089	0,093	0,028	0,047	1,544
Tertiary sector	5 456	9 649	11 822	0,648	0,691	0,722	0,074	0,036	1,165
Total	8 422	13 971	16 385					0,031	
Merchandise Exports		US$m							
Primary sector	8 267	36 647	41 896	0,347	0,353	0,402	0,055	0,073	1,104
Non-MER sector manufacturing	8 047	29 364	30 803	0,338	0,283	0,296	-0,042	0,060	0,907
MER sector manufacturing	7 494	37 725	31 405	0,315	0,364	0,302	-0,013	0,064	0,970
Total	23 808	103 736	104 104					0,066	

Source: Gross value added data adapted from Statistics SA Report PO441 (Statistics South Africa, 2022); Employment data adapted from Kerr et al. (2019): Export data from The Growth Lab at Harvard University (2019).

Notes: The ratio of sectoral AAGR to aggregate AAGR is presented in column 10. A ratio above unity indicates that the sector outperformed the economy as a whole.

2.3 The Policy Importance of the MER Sector

The MER Sector, and the manufacturing sector in general, features prominently within several of the South African government's economic policy narratives. The National Skills Development Plan (NSDP) serves as the key policy informing skills development, and was crafted within the policy context of the National Development Plan (NDP), which provides a framework aimed at achieving several socioeconomic targets by 2030 (Department of Higher Education and Training [DHET], 2019). To achieve these targets, these documents put forward several measures that frequently emphasize the importance of growing the labour-intensive elements of the manufacturing sector, driving export growth and diversification, and exploiting comparative advantage. For instance, the NDP states that "*export growth will… play a major role in boosting growth and employment*" (National Planning Commission [NPC], 2012: 119) and that the country's export portfolio ought to "*be more diverse to enable… further industrialisation"* and "*reduce the strong link to commodity cycles and the associated volatility*" (NPC, 2012: 120). Reducing such mineral resource dependence and enabling industrialisation entails a structural shift toward a non-commodity-based manufacturing export strategy. Diversifying the country's export base is stressed in the NDP's second phase (2018-2023), adding that doing so "*should include building the capacities required*" (NPC, 2012: 157). Hence, the policy framework acknowledges the need to advance industrial capabilities.

Industrialisation – to which the MER Sector is central – is prominent in the government's contemporary policy debate. This emphasis is not unfounded, given that (i) the typical structural transformation path from middle- to high-income status which countries have historically experienced has entailed the development of a vibrant manufacturing sector (Herrendorf, Rogerson & Valentinyi, 2014), and (ii) at least over the last few decades the South African economy has experienced premature de-industrialisation and become a largely services-based economy (Bhorat, Rooney & Steenkamp, 2018). In his inaugural State of the Nation (SONA) address in 2018, President Ramaphosa emphasized industrialisation as a key mechanism to revive economic growth. One year later in his 2019 SONA address, he stressed that South Africa ought to become a "*manufacturing hub*", an emphasis which has persisted in all SONA addresses since: in 2020, through referencing new industrial opportunities in the green economy; in 2021, through expressing support for a sizeable increase in local production as one of the government's COVID-19 Economic Reconstruction and Recovery Plan's (ERRP) priority interventions; and in 2022, by again referencing the ERRP as "*an important pillar… to revitalise our manufacturing base and create globally competitive export industries*."

The latest iteration of the Department of Trade, Industry and Competition's (DTIC) Industrial Policy Action Plan (IPAP) (2018/19-2020/21) serves as a cornerstone of industrial policy in South Africa. With a strong emphasis on manufacturing, the plan aims to enhance "*the productive capabilities of the economy*" by producing more complex goods with greater efficiency, and thereby driving the process of industrialisation. The MER sector features prominently in the various sectoral policy focus areas in the IPAP. These include but are not limited to the *Competitiveness Improvement Initiative* and *Black Supplier Development Programme* in the Automotive chamber, *the National Foundry Technology Network* and *Designation and Localisation Action Plan* in the Metal chamber, and the *Skills Development, Testing and Innovation Cluster* in the Plastics and New Tyres chambers. These initiatives are indicative of active South African industrial policy within the MER sector space.

The government's policy vision for industrialisation is also reflected in both the Black Industrialist Policy (BIP), and the development of sectoral master plans over the past few years. Produced by the DTIC in extensive collaboration with industry and union stakeholders as a core component of the DTIC's *Re-Imagining Industrial Strategy* formed in 2019, these plans stemmed from growing dissatisfaction with the modest impact of existing industrial policy combined with a change in government administration. These plans present a multipronged approach to industrial development through government partnerships with the private sector. In brief, they seek to identify sector-specific visions, constraints, opportunities, and sets of key actions to reignite and grow key industries over the short and medium term. To date, plans have been published for two MER sub-sectors: the *Steel and Metal Fabrication Master Plan 1.0* and the *Automotive Industry Master Plan to 2035*. At the time of writing, a draft of the *Plastics Master Plan* is in the public domain and is being finalised. The government's focus on manufacturing is not limited to the aforementioned policy documents. This includes, but is not limited to, the 2013 White Paper for Post-School Education and Training (WP-PSET), the New Growth Path (NGP), the 2015-2020 National Youth Policy (NYP), and the Youth Employment Accord.

The MER sector is an integral component of the South African manufacturing sector. It comprises a collection of high productivity industries in which future expansion is primed to bring about high levels of economic and employment growth. The prominence of MER sector industries in existing economic and industrial policy indicates that the sector's economic relevance and potential is acknowledged among policy makers. Therefore, in the context of deindustrialisation, there is a clear policy imperative to bring about the growth and diversification of the industries within the sector.

The question is: how can one advance this strategically important sector of the economy? The next section, drawing on Allen Whitehead and Bhorat (2020), addresses this question by drawing on the theories of economic complexity and industrial relatedness.

3 Avenues to Build Economic Complexity in the MER Sector

Allen Whitehead and Bhorat (2021) view the deindustrialisation challenge through the lens of economic complexity theory and examine the role of the MER sector in driving the process of reindustrialisation. In this section we refer to the core elements of their research: First, we consider the economic complexity of the MER sector and the sector's potential to be a conduit to building economic complexity – a desirable policy outcome. Second, we assess the MER sector product space, developed by Allen Whitehead and Bhorat (2021), and discuss the sector's potential to feasibly diversify and expand off existing industrial capabilities. Third, we discuss how economic complexity and industrial relatedness theory and metrics are applied to identify industrial diversification opportunities using an endogenous data-centric industrial policy approach.

3.1 The Economic Complexity of the MER Sector: Evidence of a Potential Economic Complexity Premium

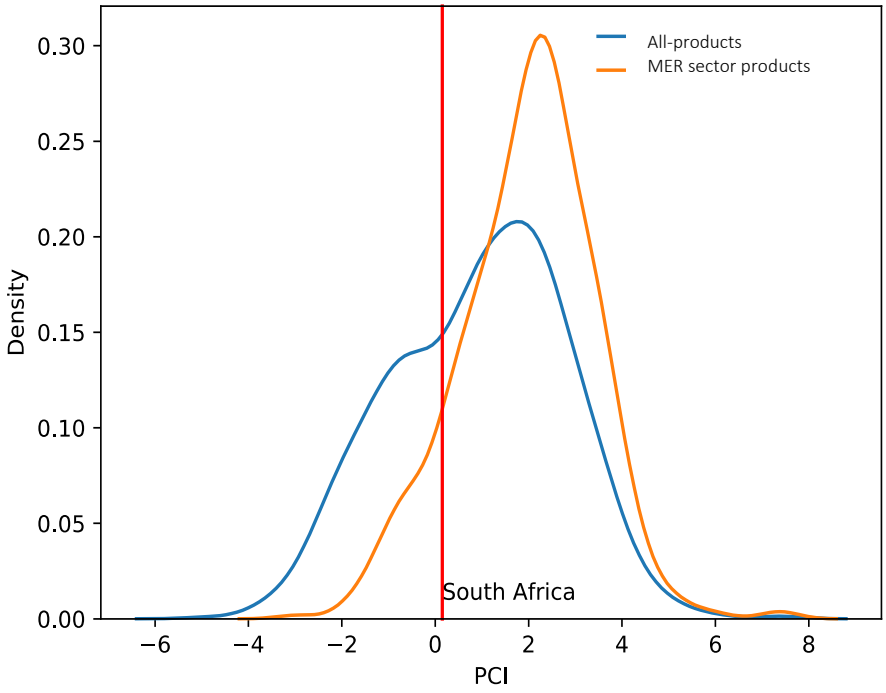
The concept of economic complexity is relatively new in the economic literature.[10] The central idea is that economic actors, such as firms and individuals, in countries, accumulate productive capabilities and knowhow, which enables them to produce a diverse range of sophisticated products, thereby pointing to their economic complexity. The most complex economies produce a diverse range of products, many of which other countries are unable to produce given the specialised nature of capabilities required, whereas the least complex economies produce a small range of ubiquitous products. Countries can increase their complexity through the diversification of their economies toward increasingly complex products that few other countries are able to produce. It has been shown that countries which have experienced industrialisation, or manufacturing-led structural transformation, are more complex (Bhorat, Steenkamp & Rooney, 2017), and are characterised by higher levels of manufacturing sector employment (Bhorat, Kanbur, Rooney & Steenkamp, 2019). These elevated levels of complexity have been linked to desirable outcomes such as higher levels of income and economic development (Hidalgo & Hausmann, 2009; Hausmann et al., 2014).

Considering the economic complexity of the MER sector, two key policy relevant findings emerge from Allen Whitehead and Bhorat (2021): First, after mapping the manufacturing component of the MER sector to product-level international trade data, which is used to construct complexity metrics, they find that MER sector products have, on average, higher product complexity indices (PCI), and are thus more complex, than other traded products.[11] This is evident in Figure 3, which shows the distribution of MER sector products (orange series) and all other products (blue series) in terms of their PCIs. Further, the mean PCI for MER sector products (maximum point of orange series) is greater than South Africa's economic complexity index (red line representing the average PCI of all products that South Africa exports competitively). This suggests that diversification into a greater range of MER sector products has the potential to build economic complexity in the South African economy.

[10] For a detailed discussion on the core themes to emerge in this literature, please refer to Hidalgo (2020).

[11] MER sector products refer to a list of products in the international trade data that is compiled by Allen Whitehead & Bhorat (2021), who mapped the MER sector industry classification table contained within the merSETA Sector Skills Plan (merSETA, 2019), to international trade data nomenclature. The list is a data mapping construct, and is not derived from actual measurement of product-level MER sector exports. Thus, some MER sector products are not produced and exported competitively by South African firms. Other traded products refer to products listed in the international trade data nomenclature that are either primary products, falling within the mining and agricultural sectors, or manufactured products that do not fall within the MER sector industry classification.

Figure 3: Product Complexity Indices (PCI) of MER sector products and all products, 2016



Source: Taken from Allen Whitehead and Bhorat (2021)
Note: 1. red line represents the economic complexity index for South Africa of 0.151 in 2016.

Second, Allen Whitehead and Bhorat (2021) show that South Africa, like other middle-income economies, typically manufacture the less complex sets of MER sector products, and thus there is potential for future economic complexity-building diversification. In fact, they show that the mean product complexity of the MER sector products that South Africa does export competitively, is half of what it could be should South African firms start to competitively produce and export the full range of potential MER sector products.[12] Thus, there exists an economic complexity premium available to South Africa's MER sector should it diversify into this full range of products that fall within the industries that comprise the sector.

From an economic complexity standpoint, MER sector products represent a *desirable* set of products to diversify into. The next sub-section speaks to the notion of whether there are *feasible* diversification pathways toward these complex sets of products.

3.2 The MER Sector Product Space: Positioned to Leverage off Existing Industrial Capabilities

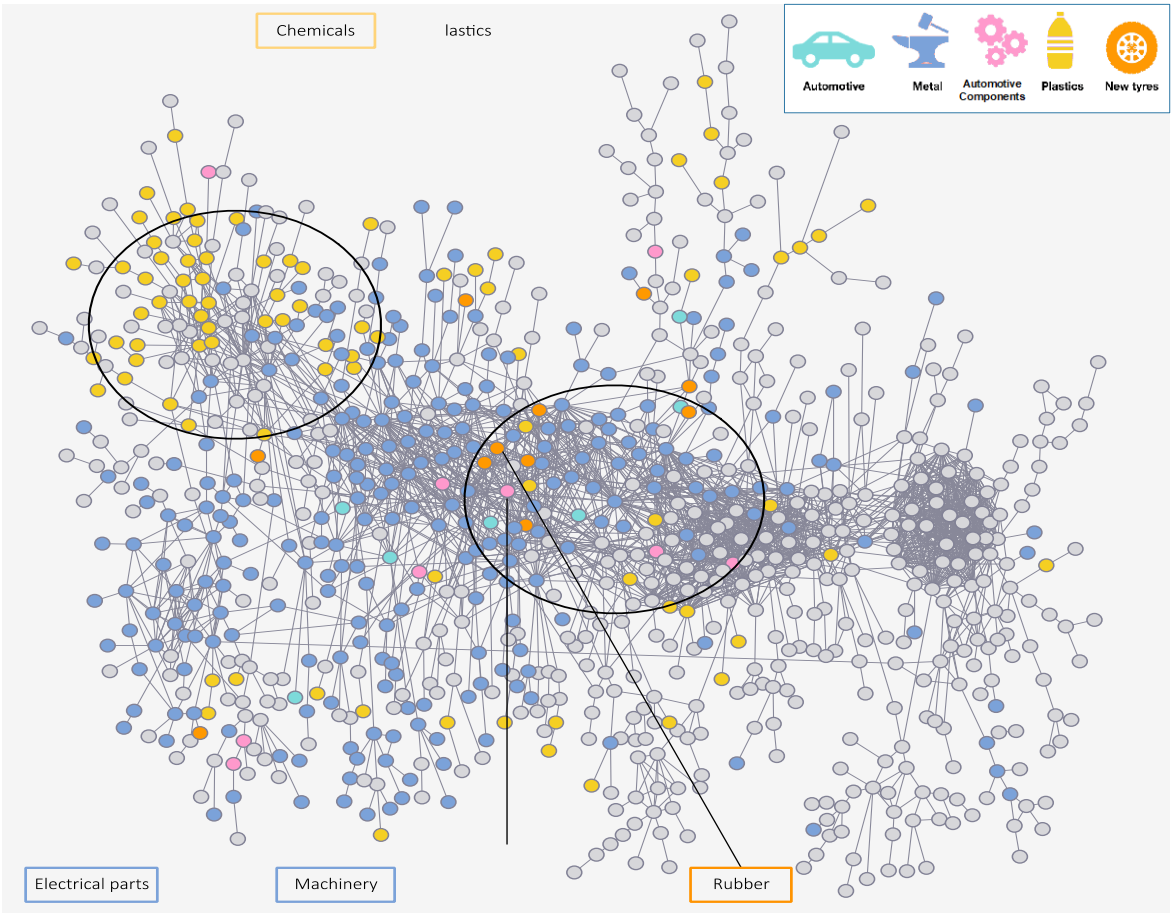
To build economic complexity, countries need to accumulate productive capabilities, which in turn make it feasible to diversify toward more complex products. The manner in which countries accumulate productive capabilities and diversify can be explained using the notion of industrial relatedness. A country's ability to diversify into a new product depends on the overlap of productive capabilities required to produce the new product and those embodied in current

[12] Allen-Whitehead and Bhorat (2021) map the Standard Industrial Classification (SIC) codes for the MER sector to product-level Harmonised System codes for traded products. This allows one to generate a list of products, specified at the HS 4-digit level, that fall within each of the SIC industry codes that comprise the MER sector. This list represents a universe of MER sector products. These MER sector products can be further split into those that South Africa currently produces and exports competitively (measured as having a revealed comparative advantage index greater and equal to unity), and those that it could potentially produce and export competitively (measured as having a revealed comparative advantage index less than unity).

production activities – i.e. the relatedness between existing activities and the new activity. The industrial relatedness literature shows that relatedness predicts the products that a country will enter or exit in the future, and thus suggests that structural transformation is a path dependent process (Hidalgo et al., 2007; Neffke & Henning, 2013).

The notion of relatedness is visually represented using Hidalgo et al.'s (2007) *product space*. The structure of the product space is very important because it provides insight into how easily a country is able to shift to new products and build economic complexity, thereby undergoing a process of structural transformation. Figure 4 presents the global product space based on the representations used by Hausmann et al. (2014). Each node (circle) in the product space represents a product, with the edges (connecting lines) indicating how closely related a pair of products are. If these connecting lines are shorter then products are closely related and require similar capabilities to produce, thus making it easier for a country to diversify their product offering from the product that it currently produces to the proximate product that it doesn't produce. Further, we highlight MER sector product nodes, by chamber, within the products space.

Figure 4: Product space with MER sector chambers highlighted, 2016

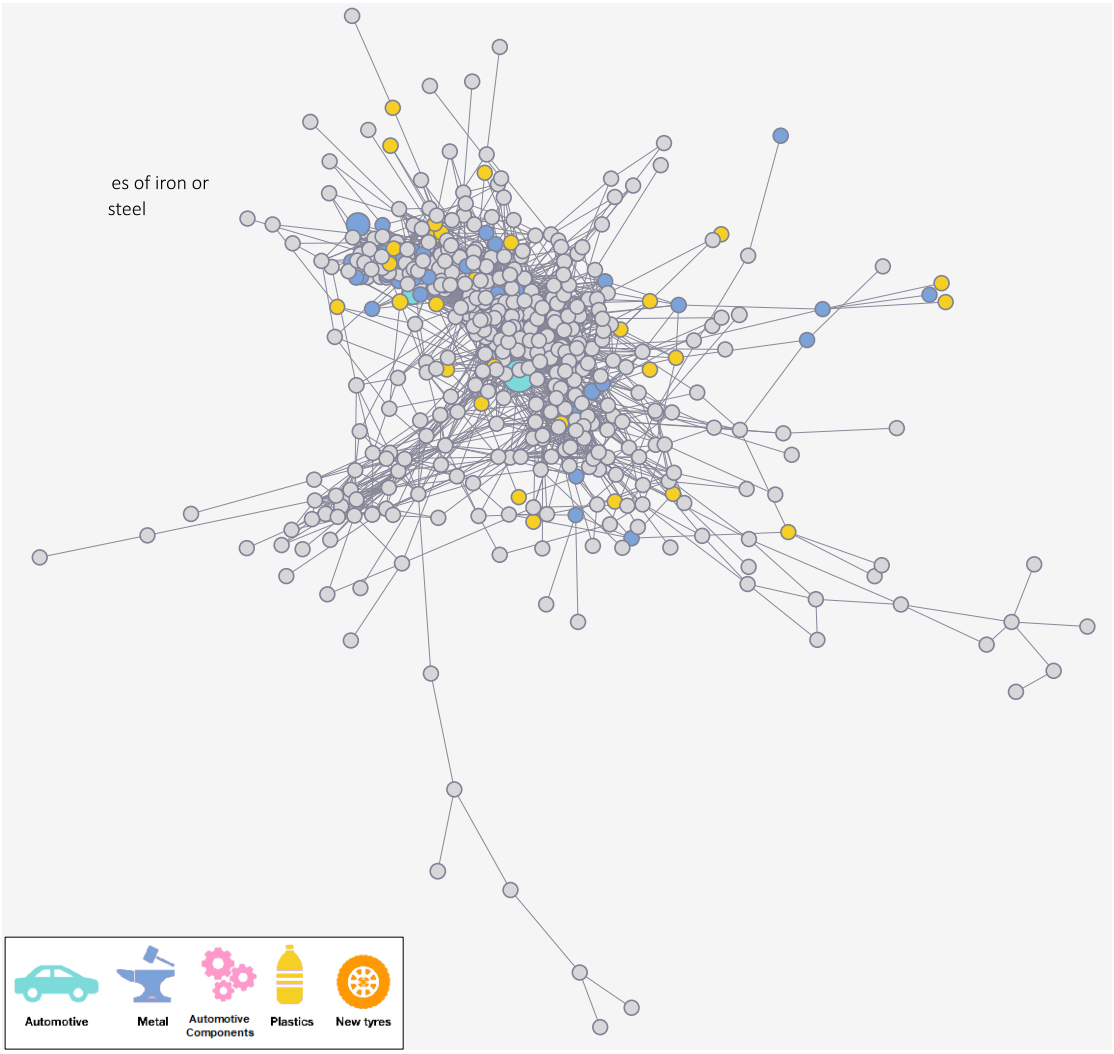


Source: author's own calculations based on The Growth Lab at Harvard University (2019).
Note: 1. MER sector chambers are represented by the following colours: automotive manufacturing (light blue); metal and engineering (dark blue); automotive component manufacturing (pink); plastics (yellow); and new tyre manufacturing (orange). 2. The product space illustration is generated using Python package product-space (CID, 2017).

Observing the location of MER sector products within the product space provides the following insights regarding the structure of the MER sector: First, the clustering of manufacturing products, particularly metal and machinery products (blue nodes) and automotive products (turquoise and pink nodes), in the core of the product space points to the relatively complex nature of products within the sector. There is also a dense clustering of complex chemical and plastic products (yellow nodes) and electrical products (blue nodes) to the left of the product space. Second, the core of the product space is highly connected and dense, which suggests that there is a great deal of overlap in requisite productive capabilities and know-how across the products within these clusters. A key implication emerging from this is that once a country has an industrial foothold in some of these complex manufacturing products in the connected core of the product space, subsequent diversification is relatively easier, as countries are able to combine existing industrial capabilities with a relatively few newly acquired capabilities to enable subsequent diversification.

Allen Whitehead and Bhorat (2021) focus the product space analysis to the MER sector and develop the MER sector product space. They them superimpose the productive structure of South Africa's MER sector into the space. The MER sector product space for South Africa is shown in Figure 5. While a more in depth analysis is provided in Allen Whitehead and Bhorat (2021), one critical point emerges from the visualisation: The MER sector has several occupied nodes in the connected core of the MER sector product space. These include several metal and machinery products (blue nodes, such as, centrifuges; structures of iron or steel; stainless steel products), automotive products (turquoise and pinks nodes, such as, cars; motor vehicles for transporting goods; containers for multimodal transportation), and plastic products (yellow nodes, such as, polymers of propylene). The centrality of these occupied nodes indicates that the MER sector is well positioned to leverage off existing industrial capabilities, which suggests that there are *feasible* industrial diversification opportunities available to MER sector firms in South Africa.

Figure 5: The MER sector product space for South Africa, 2016



Source: author's own calculations based on The Growth Lab at Harvard University (2019).
Note: 1. The product space illustration is generated using Python package product-space (CID, 2017).

3.3 Identifying Industrial Diversification Opportunities for the MER Sector

Bringing together these two ideas – economic complexity and industrial relatedness – we follow the smart specialisation literature and identify a set of product-level industrial diversification opportunities – namely, MER sector *frontier products* – that provide a pathway to the reindustrialisation of the South African economy.[13]

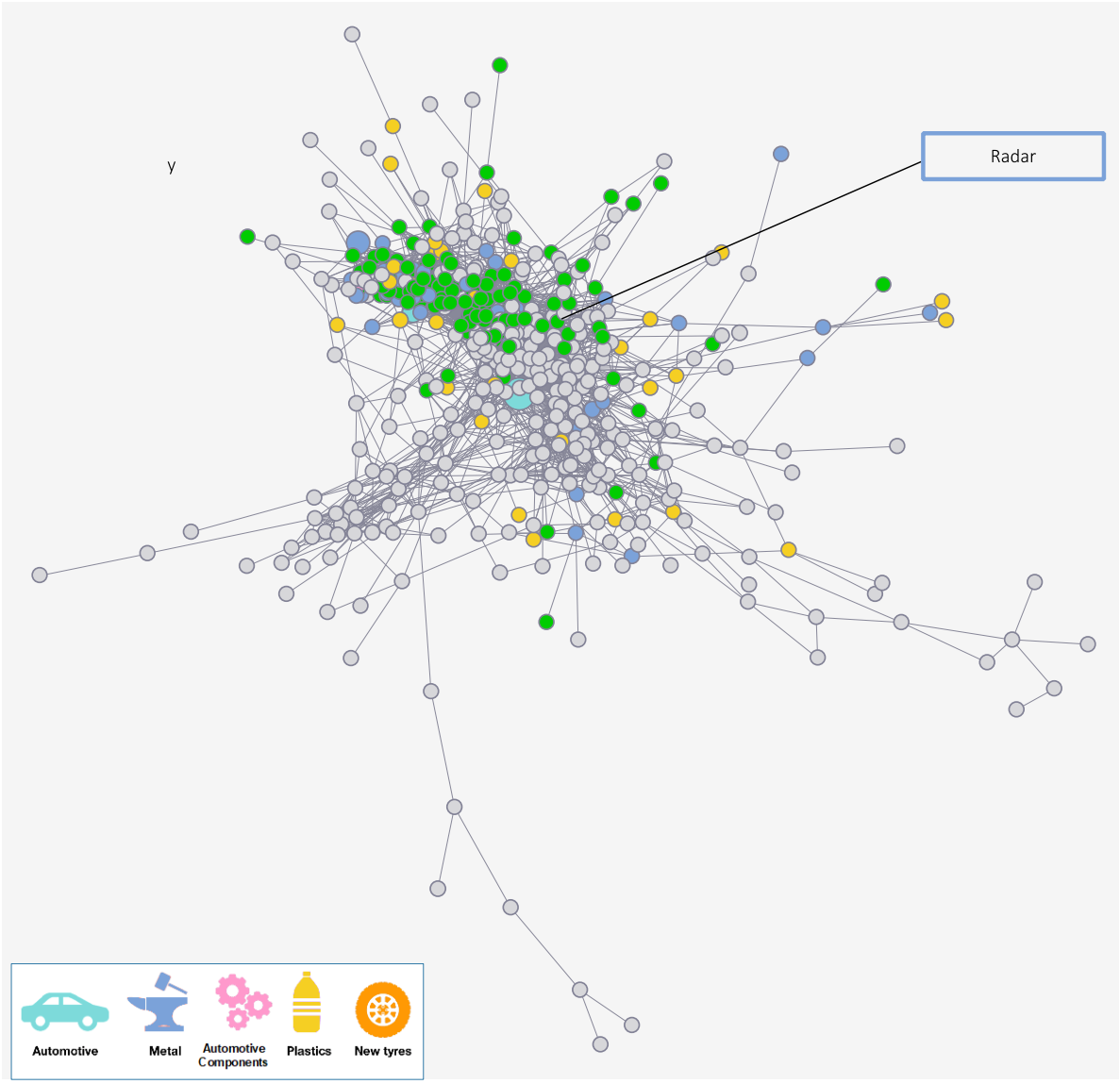
We use network criteria to identify the product-level industrial diversification opportunities in the MER sector. Following Hausmann and Chauvin (2015) and Bhorat et al. (2019), the main criteria are as follows: Firstly, frontier products should be *desirable* and thus build economic complexity. Put differently, these products should be more complex than the country's current export basket. Second, the diversification into these products should be *feasible*. Put

[13] For a general review of the application of these methods in the smart specialisation literature see Hidalgo (2020), and for a specific application of smart specialisation in EU industrial policy, see Balland, Boschma, Crespo & Rigby (2018).

differently, frontier products should be 'nearby' or related in terms of the requisite capabilities and those embodied in the current productive structure. And third, this diversification should take place in the core of the product space ensuring potential for future diversification.

Using the above approach, Allen Whitehead and Bhorat (2021) generate a list of industrial diversification opportunities in the MER sector. In Figure 6, we superimpose these frontier products into the MER sector product space. This provides a visual representation of the potential effects that diversification into these products could have on the productive structure of the MER sector.

Figure 6: The MER sector product space for South Africa with top ten MER sector frontier products, 2016



Source: author's own calculations based on The Growth Lab at Harvard University (2019).
Note: 1. The product space illustration is generated using Python package product-space (CID, 2017).

Unsurprisingly, given the criteria used to identify frontier products, the majority of the MER sector frontier products are in the core of the MER sector product space, as well as being

nearby South Africa's competitively exported products. Therefore, diversification will not only grow economy-wide complexity, but also the complexity of the MER sector. A full list of these frontier products can be found in Appendix Table A 1.

In sum, South Africa has a clear industrial diversification pathway that involves shifting production toward more complex products that are feasible given current industrial capabilities. However, diversification towards such products can potentially be limited by capability constraints. In the next section, informed by a quantitative firm survey, we detail capability constraints present in the MER sector that may hinder the ability of firms in the sector from expanding and diversifying frontier product markets.

4 Constraints to Building Economic Complexity in the MER Sector

In this section, we draw on Allen Whitehead, Bhorat, Hill, Köhler and Steenkamp (2022a) (Report 3), and discuss the constraints that hinder firms in the MER sector from realising the industrial diversification opportunities referred to in Section 3. We start by framing the discussion on constraints by, firstly, detailing the main constraints identified in the MER Sector Enterprise Survey, in terms of their incidence and severity. Secondly, we position these constraints within a framework that distinguishes between exogenous and endogenous constraints. The section then discusses the main exogeneous constraints identified in the MER Sector Enterprise Survey. We then look at skills constraints – an endogenous constraint – from the both the demand- and supply-side perspectives.

4.1 Constraints Facing MER Sector Establishments: Framing the Discussion

To gain a better understanding of the capabilities and constraints faced by manufacturing establishments, we ran a quantitative survey of MER sector establishments between 16 August 2021 and 30 April 2022. Our focus is specifically on establishments, which are defined as a physical location where business operations are carried out. This definition implies that an individual firm or enterprise could be made up of one or more establishments. This survey focussed on interrogating the capabilities and constraints faced by MER sector firms and followed a stratified sampling process in order to ensure the final results could be generalised to the manufacturing component of the MER sector.[14] In short, the quantitative survey was an establishment-focussed survey that sampled a total of 254 establishments engaged in manufacturing activity in the MER sector. While there were concerns with small sample sizes and low response rates, we believe that the final results obtained from this survey are broadly generalisable to the MER sector as a whole. We opted to collect establishment-level data since constraints and capabilities may be heterogeneous across establishments within a single enterprise, thus making it more appropriate to gather information at a more granular level.

In our quantitative survey, we asked respondent establishments to indicate the constraints they felt were hindering their ability to expand and diversify their production processes. In addition, we asked establishments to differentiate between the *incidence* of a constraint – i.e., whether or not they experienced the constraint themselves – and the *severity* of the constraint – i.e.,

[14] For further details on the survey methodology, the interested reader is referred to Allen Whitehead et al. (2022a) and the accompanying methodological appendix, Allen Whitehead et al. (2022b).

how strongly they experienced the constraint. These two concepts are measured slightly differently: incidence will indicate the proportion of establishments in the MER sector that report facing the specified constraint, while the severity of a constraint is measured on a scale from 0 to 4, where a score of 0 indicates that the constraint is no obstacle to production, while a score of 4 indicates that the constraint is a severe or debilitating constraint to production.

We begin, in Table 2, by presenting the incidence of constraints, and how the incidence of constraints differs across chambers. The values in the table indicate the proportion, between 0 and 1, of MER sector firms that reported facing a given constraint. These proportions are colour-coded on a scale from green (0 percent of firms indicated facing such a constraint) to red (100 percent of firms indicated facing such a constraint). Put simply, where a constraint is faced by more firms across the MER sector, cells will tend towards red, while those constraints that were not reported by many establishments in the MER sector will be shaded green.

Overall, the results presented in Table 2 indicate that there are a number of constraints that are cross-cutting concerns for most of the MER sector. In particular, infrastructure, financial, and skill constraints indicate high incidence in most, if not all, MER sector chambers. Cross-referencing these results with those presented by Allen Whitehead and Bhorat (2021), it is of particular concern to note that the chambers that provide the greatest opportunity for complexity jumps through their frontier products – i.e., Automotive Components, New Tyre, and Metals – are also the chambers where the incidence of a number of these constraints is highest. This suggests that these constraints to production are potentially stymieing potential diversification into high-complexity products that, in turn, is holding back overall development of the South African economy.

Table 2: Incidence of constraints across MER-sector chambers

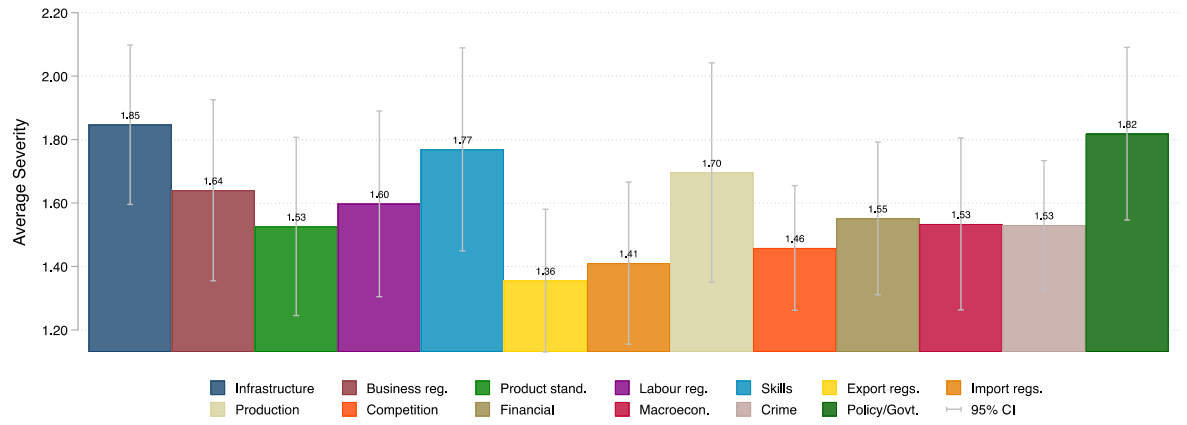
Chamber	Frontier Products (e.g.)	Constraints												
		Infrastructure	Business Regulations	Product Standardisation	Labour regulations	Skills	Export regulations	Import regulations	Production	Competition	Financial	Macroeconomic	Crime	Policy uncertainty, government
Auto *(n=18)*	Motor vehicles for the transport of >10 persons; Special purpose motor vehicles	0.700	0.285	0.265	0.220	0.309	0.145	0.145	0.285	0.297	0.265	0.215	0.239	0.170
Metal *(n=160)*	Radars; Firearms; Alloy Steel in Primary Form; Agricultural Machinery; Parts for Machines and Appliances; etc.	0.666	0.393	0.330	0.431	0.435	0.281	0.241	0.371	0.417	0.592	0.364	0.421	0.351
Auto Components *(n=22)*	Parts suitable for use with spark-ignition engines; Parts of motor vehicles and tractors; Vehicle bodies; etc.	0.661	0.433	0.406	0.406	0.596	0.387	0.290	0.298	0.544	0.761	0.317	0.568	0.317
New Tyre *(n=8)*	Vulcanized rubber plates; Used pneumatic tyres of rubber; New pneumatic tyres of rubber	0.791	0.556	0.497	0.556	0.556	0.497	0.556	0.556	0.556	0.791	0.556	0.556	0.556
Plastics *(n=46)*	Polymers of styrene; Other articles of plastic; Sulphonitric acids; Non-radioactive isotopes; etc.	0.641	0.479	0.345	0.367	0.379	0.353	0.348	0.353	0.508	0.503	0.360	0.394	0.374

Source: MER Sector Enterprise Survey (Development Policy Research Unit, 2022). Authors' own calculations.
Notes: 1. Table presents proportion of establishments classifying a constraint as applicable to them. 2. All estimates weighted using sampling weights and corrected for complex survey design. 3. Colour coding of estimates is done according to proportion reporting a given constraint. Colour scale runs from green (0 percent of establishments report facing the constraint) to red (100 percent of establishments report facing the constraint). 4. Sample sizes provided in parentheses underneath chamber name. 5. Frontier product examples taken from Allen Whitehead and Bhorat (2021).

However, as mentioned above, there are two measures of constraint incidence from the quantitative survey: incidence and severity. While the incidence on constraints is a good indication of how widespread a problem is, the severity of the constraint gives very useful insight into how much of a problem these constraints truly pose to manufacturing entities. In Figure 7, below, we present the average severity score across all constraints for the MER sector as a whole.

We note that the average constraint severity ranges from 1.36 to 1.85 out of 4, indicating that the majority of constraints are moderate obstacles to expanding production processes. That being said, the most severe constraints reported by establishments are partially aligned with the most widespread constraints: Specifically, infrastructure is the most severe constraint reported by respondent establishments, followed by policy uncertainty, and skill constraints. While a more detailed discussion of constraint severity is presented in Allen Whitehead et al. (2022a), we note some of the key takeaways in this discussion.

Figure 7: Average constraint severity score for expanding current product portfolio



Source: MER Sector Enterprise Survey (Development Policy Research Unit, 2022). Authors' own calculations.
Notes: 1. This figure presents the average severity score for each constraint, as measured out of 4. Individual scores interpreted as: Scores are interpreted as follows: 1 – "Minor obstacle"; 2 – "Moderate obstacle"; 3 – "Major obstacle"; and 4 – "Severe obstacle". 2. All estimates weighted using sampling weights and corrected for complex survey design. 3. Estimates calculated only over those individuals who reported a constraint as applicable to them – i.e. sample excludes establishments indicating a constraint was "No obstacle" to their operations.

First, we note that in general, constraint incidence and severity generally does not differ between frontier establishments – those currently producing frontier products – non-frontier establishments. Secondly, we note that disaggregating results by establishment size results in a dichotomy between SMMEs and large establishments: Specifically, while large establishments are more likely to report experiencing a specific constraint (incidence), SMMEs report experiencing these constraints much more acutely (i.e., with higher severity scores). In particular, SMMEs report being particularly acutely affected by constraints related to production constraints, business regulations, and policy uncertainty, with a severity score approximately 50 percent higher than that reported by larger firms in each case. Credit and skill constraints are also more severely experienced by SMMEs, with severity scores of approximately 30 percent higher than those reported by their larger counterparts.

While knowing what constraints establishments face is useful, we emphasise that identification is only half of the story in this case. Specifically, identifying the constraints should be followed

by policies and actions that address the constraints identified as problems. One of the key considerations for addressing constraints lies in understanding who the relevant actor is that should be intervening to overcome constraints faced by establishments. To this end, we believe the constraints listed by firms can broadly be divided into two categories: **exogenous constraints**, which are those constraints over which establishments and merSETA have little to no influence; and **endogenous constraints**, which are those constraints over which establishments and merSETA have substantially more influence.[15]

Exogenous constraints, such as infrastructure challenges with electricity provision, or challenges with labour regulations, are generally not something that establishments are able to solve themselves. While there may be workarounds, such as investing in private generation capacity, we argue that exogenous constraints are those that require strong government intervention in order to solve in the long-term. On the other hand, endogenous constraints encompass those constraints, such as skill constraints, that establishments are generally able to address themselves, or along with intervention from an organisation such as merSETA. For example, skill constraints might be something that firms can overcome either through the provision of on-the-job training, or by consulting with merSETA to build relationships with education and training institutions in order to develop more industry-relevant curricula.

The remainder of this section is divided into two sections that broadly follow these two categories: exogenous and endogenous constraints. In each case, we present the findings of our quantitative survey, which we believe is broadly representative of the manufacturing component of the MER sector. However, we also supplement these findings with the results from a qualitative follow-up interview with a selected subsample of establishments and higher education institutions (HEIs). This qualitative interview process does not provide representative data on establishments in the relevant population, but instead aims to provide further flavour and detail on information provided as part of the representative quantitative survey. Thus, while we report information from our qualitative interviews, we stress that these results should be considered more as a case study. This further implies that the views presented by respondents in the qualitative surveys are not representative of the broader MER sector, but may still provide interesting insights into what issues could be at the front of policymakers' minds as they attempt to design policy to support firms and create an enabling environment for future economic development in the MER sector.

4.2 Exogenous Constraints

4.2.1 Infrastructure Constraints

Concerns surrounding infrastructure are the most widespread of all constraints facing establishments in the MER sector, according to our quantitative survey. On average, 2 of every 3 MER sector establishments reported facing constraints to infrastructure in some form, and establishments noted that infrastructure constraints were the most severe constraint they

[15] We note that although these categories of constraints are presented as a dichotomy, it is not so simple in practice. In reality, we recognize that actually, constraints likely lie on a continuum ranging from completely exogenous to completely endogenous, and that there is likely to be an element of internal and external influence over most constraints. However, in this case, we suggest the dichotomous classification of constraints as a framework for directing individual agents to address the constraints they are best-placed to address, even if this will require cooperation from other actors along the way.

faced. Specifically, 1 in every 4 frontier establishments indicated that the infrastructure constraints they faced were major or severe obstacles to their ability to diversify their production processes. Interestingly, while the incidence of infrastructure constraints among frontier establishments was fairly constant across establishment size, larger establishments reported lower severity of the constraint (1.86 out of 4 for SMMEs compared to 1.45 out of 4 for large establishments), indicating that infrastructure constraints are disproportionately felt by SMMEs. This finding is backed by recent research by Fortunato (2022), who contends that the electricity crisis is the dominant supply-side issue behind the deindustrialisation of the South African economy.

All respondents in the follow-up interviews reported the provision of electricity, and more specifically loadshedding, as a constraint to their operations. Several respondents noted that they could mitigate the negative impacts of load-shedding to a degree through the purchase and use of generators. However, in some instances the use of heavy machinery could not be supported. Further, it was noted that the curtailing of productive activities extended beyond the load-shedding period. Most of the follow-up interview respondents stated that the downtime in the factory was extended beyond the loadshedding period due to: machinery needing to be cleared of any raw materials; and machinery needing to go through a lengthy rebooting process before becoming operational again. Interestingly, a couple of respondents stated that if they had sufficient advanced notice of loadshedding periods, then they could structure their production plan to account for this downtime. Instead, respondents noted that they are forced to send workers home or close the factory completely.

Another topic of concern raised by interviewed respondents was logistics management. The first concern was the supply of raw materials and parts for machinery, with a secondary concern being the provision of finished goods. Two weaknesses were identified: the inefficiencies of the Durban Port and the reliability of rail transport. Another issue, particularly important for manufacturers of large machinery, is the transportation of final goods along national freeways and across provincial borders. Respondents noted that the cost of the permits for transportation were high and the application process lengthy. Further, one respondent noted that despite having all the requisite permits, their truck drivers were still having problems dealing with police authorities.

4.2.2 Labour Regulatory Constraints

On average, labour regulatory constraints, which included aspects such as labour laws (e.g., BCEA conditions, LRA conditions) and union disputes, were reported as a constraint for approximately 40 percent of MER sector establishments based on results from our quantitative survey. Incidence of this constraint varied across chambers, however, with only 22 percent of firms in the Automotive chamber reporting that they faced such constraints, while 55 percent of firms in the New Tyre chamber reported the same. On average, labour regulations were reported to have a severity of approximately 1.6 out of 4, indicating a slightly below moderate constraint to MER sector establishments. Frontier establishments reported slightly more severe constraints from labour regulation (at a score of 1.71 out of 4 compared to 1.46 out of 4). Similar to infrastructure constraints, SMMEs were disproportionately impacted by labour regulatory constraints, with SMMEs experiencing more severe constraints than large establishments (scores of 1.81 and 1.33 out of 4, respectively), even though larger establishments reported labour regulatory constraints slightly more frequently than SMMEs.

We note, however, that since large firms, by definition, hire more labour, the likelihood of experiencing labour regulatory constraints is higher for such firms.

Interviewed respondents noted challenges dealing with unions but with varying experiences. Several respondents reflected on strike action haven taken place pre-COVID, with many employees being too intimidated to come to work despite not wanting to engage in strike action. Those firms that had a large cohort of unionised members have taken steps to prevent strike action for the next few years by opening these conversations with shop stewards and negotiating benefits and salaries. This type of proactive activity pre-empts disruptions resulting from trade union negotiations. Another respondent noted a declining influence of unions. They cited in-house research into union activities, which found that union membership had dropped in recent years as individuals that were resigning were typically union members, whereas union membership was less prevalent among incoming employees.

4.2.3 Policy Uncertainty, Corruption and Crime

Policy uncertainty was noted by respondent firms in our quantitative survey to be the second-most severe of all the constraints facing the MER sector, with an average severity score of 1.82 out of 4. Interestingly, though, only approximately 1 in 3 firms actually indicated that policy uncertainty was a constraint to them. This result seems particularly driven by establishments in the Metals chamber, which actually noted policy uncertainty as the most severe constraint they faced across all categories. Areas of concern raised by establishments regarding policy uncertainty include political instability, corruption, and inefficiencies in government processes. Once again, SMMEs reported facing disproportionately more severe constraints due to policy uncertainty than their larger counterparts, with an average severity score of 1.98 out of 4 compared to 1.33 out of 4, respectively.

In follow-up interviews, respondents indicated inefficiencies in local government as a key policy concern. Examples of complaints included broken storm water drains, potholes, and a general lack of maintenance in the manufacturing locality. In contrast, two respondents noted that they have an open and positive relationship with local government and have benefited in terms of service delivery. One respondent mentioned crime as a constraint and thus had to incur substantial security expenditure – thus increasing the cost of doing business – to protect their premises.

4.2.4 Export Regulatory Constraints

According to quantitative findings, approximately 1 in 3 MER sector establishments indicated that they faced export regulatory constraints. However, this should be considered in conjunction with the fact that only approximately 37 percent of all MER sector firms actually export their products. Specifically, we find that 33 percent of exporters face challenges with export regulations, while 27 percent of non-exporters face the same. This raises interesting policy considerations since this may indicate that there are constraints facing non-exporting firms that preclude them from entering the international market as a whole, and that action should be taken in order to support these firms. On average, the severity of export regulatory constraints was reported to be the lowest amongst all constraints, at a score of only 1.36 out of 4, which was disproportionately influenced by SMMEs once again facing more severe

constraints than their larger counterparts. However, we note once again that large firms were more likely to report facing an export regulatory constraint. This finding could be the result of selection, however: establishments that have opted to operate on the global market will likely be larger than those who don't, and thus, larger firms – who are more likely to export – are thus, by definition, more likely to face constraints from export regulations.

Most of the respondents in the follow-up interviews stated that they were not engaged in export activity. A key reason cited, was that they were not interested in exploring foreign markets given the high fixed costs associated with entering foreign markets. For those firms that required certification that enables access to foreign markets and/or global value chains, it was noted that this process is cumbersome and costly. A respondents that supplied parts to international OEMs, discussed the rigorous set of requirements from different regions and companies to meet their quality standards.

4.2.5 Business Regulatory Constraints

Approximately 40 percent of establishments in our quantitative survey indicated that business regulations were a constraint to their operations, and this figure was found to fairly consistent across chambers in the MER sector. The severity of the constraint faced by establishments averaged to approximately 1.64 out of 4, however, it should be noted that nearly 1 in 3 (28 percent) of establishments facing these constraints considered them to be major or severe obstacles to their operations. Business regulatory constraints form one of the largest discrepancies between SMMEs and large establishments, since the average severity of the constraint faced by SMMEs is approximately 1.5 times greater than that faced by large firms (1.93 out of 4 compared to 1.29 out of 4 for SMMEs and larger firms, respectively). The most commonly cited business regulatory constraints from sampled establishments related to Broad-Based Black Economic Empowerment (BBBEE) legislation and criteria; administrative costs and burdens faced by establishments; and adherence to tax regulations.

POPIA compliance and BBBEE administration was generally identified as being time-consuming, with one follow-up interview respondent stating that older staff were resistant to updates to their contracts to become POPIA compliant. Environmental levies were raised by a respondent, noting that it was frustrating to pay these amounts yet see no positive impact. One would expect that the administration of environmental levies will become more relevant as the country consolidates the various pieces of legislation required to implement such a programme. Most firms identified challenges relating to BBBEE legislation. These included: difficulty in allocating funds for training and education in a way that was equitable; deciding on individuals to promote; finding the right partners that are interested in their type of manufacturing activities; and struggling with local procurement from non-BBBEE compliant suppliers. In addition, firms struggled to tender for government programmes as they did not have the requisite BBBEE status, with many firms mentioning corruption in the tender process.

4.3 Endogenous Constraints – Skills Constraints

Following from our description of the various exogenous constraints faced by MER Sector establishments above, we now describe the endogenous skills-related constraints. We first provide an overview of demand-side skills constraints – that is, skills-related constraints faced by firms – by drawing on our MER Sector Enterprise Survey data analysis of both skills gaps and

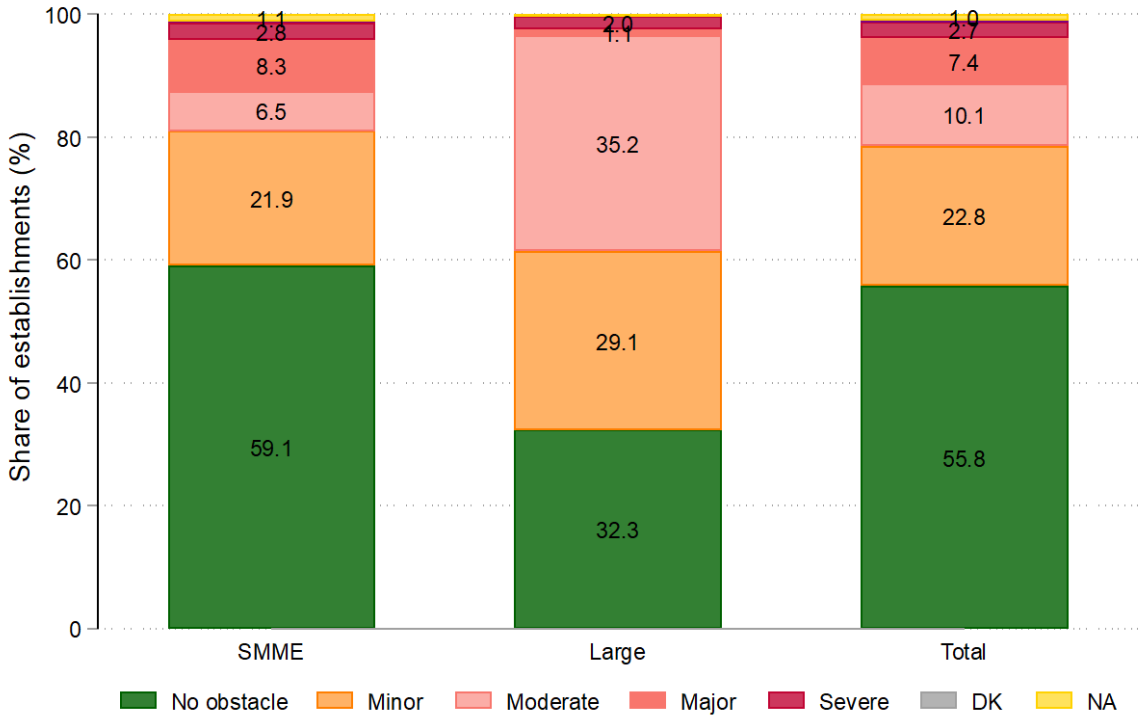
shortages combined with our follow-up firm interviews. Thereafter, we focus on constraints on the supply-side – that is, skills-related constraints faced by skills providers – by discussing our findings from the qualitative higher education and training institution (HEI) interviews, discussed in more detail below. We additionally draw on key findings from Allen Whitehead, Bhorat, Hill, Köhler and Steenkamp (2021) (Report 2), which looks at how 4IR technologies may potentially impact of skills demand in the MER sector in the future.

4.3.1 Skills Constraints on the Demand-Side

A lack of skills serves as one of the most pressing constraints faced by MER Sector establishments. As shown in Table 2 and Figure 8, just over two in every five (43 percent) establishments experience such a constraint to any extent for their current production activities. A lack of skills serves as one of the most severe constraints faced by those establishments who experience it at all, regardless of chamber, as shown in Figure 8, and earlier in Figure 7. Amongst those that do, however, half consider it to be a minor constraint. This suggests that although establishments in the MER Sector require a better supply of appropriately skilled workers, many believe this obstacle can be feasibly overcome in some way. By size, we observe the incidence of skills constraints to be more prevalent among large establishments – two-thirds (67%) of large establishments report it as a constraint in comparison to 40 percent of SMMEs. However, we also observe that SMMEs are more likely to experience it more acutely – 11.1 percent of SMMEs report skills constraints as major or severe, while the corresponding share for large establishments is 3.1 percent.

The relatively widespread incidence and severity of skills as a production constraint is somewhat surprising given the education profile of workers in the sector. The majority of MER sector employees have at least a matric qualification or equivalent. By establishment size, however, larger establishments have more qualified workers relative to SMMEs, despite exhibiting largely similar occupational compositions. This may be attributable to size-specific differences in abilities to recruit workers or upskill workers who are already employed. Skills development interventions targeting SMMEs would need to take this lower base level of education into account. Importantly, the dominant reason for skills constraints, as reported by establishments, appears to be a lack of required technical skills, as opposed to a relevant qualification. The vast majority (87 percent) of establishments who reported skills as a major or severe constraint indicated this reason, as opposed to half who indicated a lack of correctly qualified workers as a reason. This finding holds regardless of establishment size, and strongly suggests that many individuals entering the MER Sector labour market may be qualified, but still not adequately prepared for the work they are required to do.

Figure 8: Distribution of the degree of skills constraint of the current workforce, by establishment size



Source: MER Sector Enterprise Survey (Development Policy Research Unit, 2022). Authors' own calculations.
Notes: 1. This figure presents, by chamber and establishment size, the distribution of the degree to which establishments report the skills and education of its available workforce are a constraint to the growth of the production and sale of its current product portfolio. 2. All estimates are weighted using sampling weights. 3. DK = Don't know; NA = Not applicable.

This lack of technical skills is consistent with a phenomenon identified by all respondents in the follow-up interviews – the `brain drain'. This term refers to the loss of knowledge and know-how as experienced staff members are retiring from the industry and there is a lack of these technical skills in the emerging cohort of workers. Two interviewees stated that they could not motivate young people to gain the passion and knowledge required to succeed in the sector. Attrition amongst the youngest cohort of workers was noted, with the manufacturing sector being deemed as paying less and having less favourable working hours and conditions compared to sectors such as business services. Several respondents suggested that this hurdle could be overcome by the government, in conjunction with merSETA, dedicating funds to upskilling those employees that are genuinely interested in training. One respondent made the point that it would be more efficient for the private sector and government entities to work together to come up with a targeted strategy to increase knowledge transfer and lessen the impact of knowledge loss as more experienced staff retire. Another respondent took a very proactive approach to dealing with this 'brain drain' challenge by identifying when an individual would be retiring and identifying a replacement, perhaps a year in advance, so that the two can work together to ensure that knowledge and know-how is passed down within the company hierarchy. The respondent added that sometimes people that go on retirement may stay on in a consultancy role to provide support.

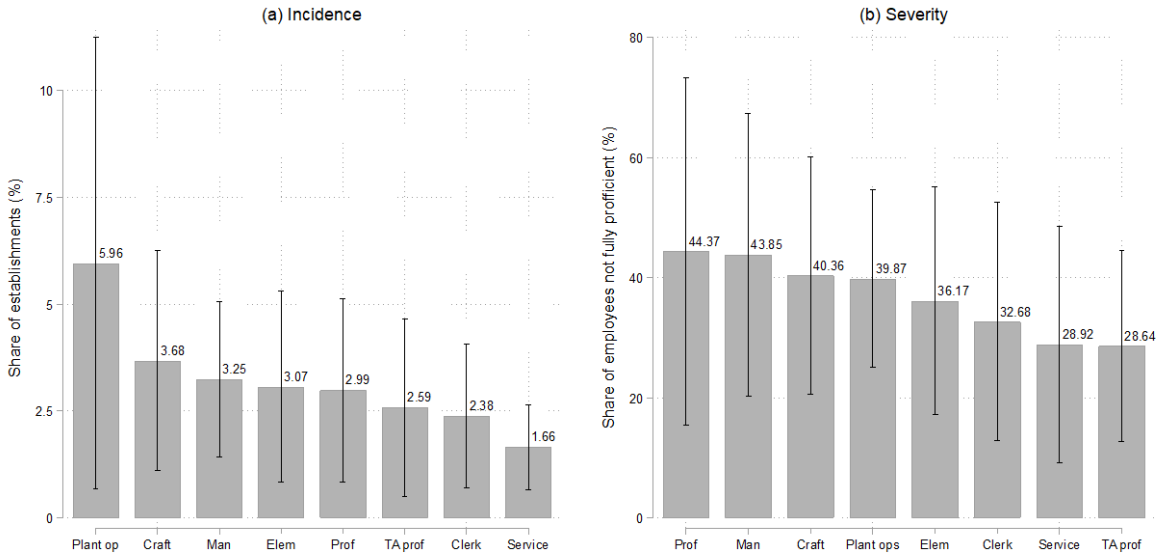
4.3.1.1 Skills Gaps

One of the channels through which skills constraints emerge in firms, is in the form of skills gaps. Skill gaps refer to an establishment's share of workers who are not fully proficient, and can arise for numerous reasons, such as establishments not being able to find suitably skilled applicants or because of evolving skill requirements. We estimate an aggregate MER Sector skills gap of approximately 10 percent – in other words, 10 percent of establishments have some non-zero share of their workforce that are not fully proficient. This is equivalent to approximately 22 000 workers in 500 establishments, or just under 5 percent of total employment in the sector. On average, the size of this skill gap is 43 employees. Persistent skill gaps can hinder the establishment's ability to function effectively and harm its productivity, profitability, and ability to innovate. Indeed, nearly two-thirds (64.5%) of establishments with skill gaps believe that the existence of these gaps have negatively impacted on their performance. Skill gaps are not equally distributed. Notably, they are concentrated in SMMEs, who represent most of the establishments with skills gaps (86 percent). This then provides some guidance for the targeting of skills development programmes to mitigate the presence and magnitude of such gaps.

All respondents in our follow-up interviews stated that their firm offers training opportunities to incumbent workers that show a willingness to further their education. It was noted across respondents that the workers that took up these opportunities were often those that displayed qualities such as, ambition, and a positive attitude. Training varied from basic courses in firefighting and health and safety, to additional formal certifications in areas, such as welding and boiler making. In all cases employees were incentivised to better their qualifications through promotions and pay raises. The downside of these training efforts was that skill gaps occur when they are unable to train their existing workers in time to fulfil new tenders, so they are required to hire new contract workers, which in turn limits promotion opportunities and has adverse impacts on productivity. Most respondents reported that their firm does a combination of in-house and on-the-job training as they prefer to train new hires on their machinery and to be well-positioned to work in their factory, thereby reducing the time and cost of training. Interestingly, one respondent mentioned that their firm only uses one training provider for ease of record-keeping when they are required to report back to merSETA.

We find that while most establishments do not report any skill gaps, the size of the gaps are quite severe among those that do. Referring to panel a) of Figure 9, we observe that the skill gap incidence is relatively low – ranging between just 2 and 6 percent of establishments across occupation groupings. The most common occupation groupings for which establishments have skill gaps, is plant and machine operators and assemblers and craft and related trade workers, who together represent almost two-thirds of workers in the sector, and this is consistent across establishment size. While the incidence of skill gaps is relatively low, the severity of these gaps – defined as the average share of employees who are not fully proficient for a given occupation group among establishments who report a skill gap for that occupation group – is more pronounced. Of establishments reporting a skills gap, depending on occupation grouping, between 29 and 44 percent of workers are reported as having a skills gap.

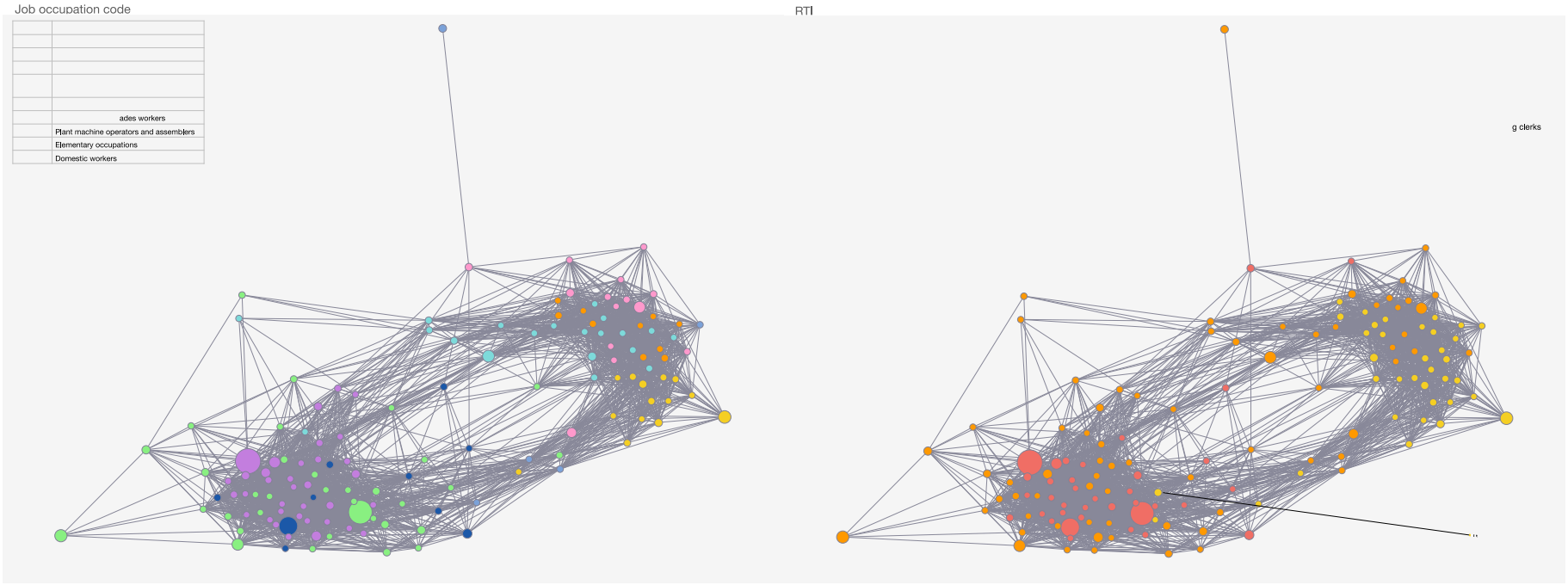
Figure 9: Incidence and severity of skill gaps, by main occupation



Authors' own calculations. Source: MER Sector Enterprise Survey (Development Policy Research Unit, 2022).
Notes: 1. This figure presents estimates of the distribution and severity of skill gaps by main occupation. Magnitude of skill gaps calculated as the share of establishments who report any skill gap (defined as any non-zero share of their workforce for a given occupation that is not fully proficient, i.e. someone who is unable to do the job to the required level). 2. Severity of skills gaps calculated as, among establishments who report a skill gap for a given occupation, the average share of employees who are regarded as not fully proficient. 3. All estimates are weighted using sampling weights and account for the complex survey design. 4. Capped spikes represent 95% confidence intervals.

Concerningly, in our analysis of automation risk in the sector (Allan Whitehead et al., 2021), we observed that, plant and machine operators and assemblers and craft and related trade workers, were amongst those who exhibited the highest risk of automation-induced employment displacement (or displacement resulting from uptake of 4IR technologies in general). As shown in the left panel of Figure 10, which presents the 'dumbell-shaped' occupational structure of the MER sector using a network analytics approach, a clear dichotomy exists between the types of tasks conducted in production jobs, clustered on the lower left-hand side, (including craft and related trades workers and plant and machine operators and assemblers), and non-production jobs, clustered on the upper right-hand side (including senior officials, managers, and clerks), within the MER sector labour market. Concerningly, the right panel shows that automation risk is not randomly distributed across occupations, but instead concentrated in the cluster of production jobs, which are markedly more routine in nature. Given that this cluster represents the majority of workers in the MER Sector, this analysis suggests that a substantial share of workers in the sector are at risk of displacement induced by 4IR technologies, accompanied by an increase in relative demand for the minority of workers in high-skill non-production occupations.

Figure 10: The MER Sector Occupation Space, by occupation group and Routine Task Intensity



Source: Authors' calculations from PALMS v3.3 (Kerr, Lam & Wittenberg, 2019) and O*NET (2020).
Notes: 1. The 4-digit occupation, represented by a node in the map, falls within a 1-digit occupation grouping based on the mode value of 1-digit occupation categories within a 3-digit occupation. 2. Occupations with a value of the RTI equal to or lower than the 25th percentile of the RTI distribution are classified as "non-routine" or 'low risk', and shaded yellow. 3. Occupations with an RTI between the 25th and 75th percentile (exclusive) of the RTI distribution, are classified as "intermediate" or 'medium risk', and shaded orange. 4. Occupations with an RTI above the 75th percentile of the RTI distribution are classified as "routine" or 'high risk', and shaded red.

A discrepancy between the qualification an establishment requires for a given occupation and the qualification typically held by their relevant employees serves as an alternative measure of a skill gap. In our analysis, we find that just 4 percent of MER Sector establishments report a discrepancy (that is, those whose qualification is less than what is required), which suggests that establishments in the sector are largely able to find suitably qualified workers. Taken together with the larger, proficiency-defined skill gap estimate of 10 percent, this implies that there are a number of workers in the sector who are not fully proficient despite having the required qualification for their occupation. This speaks to a disconnect between the skills that education and training institutions are supplying and those that industry are demanding.

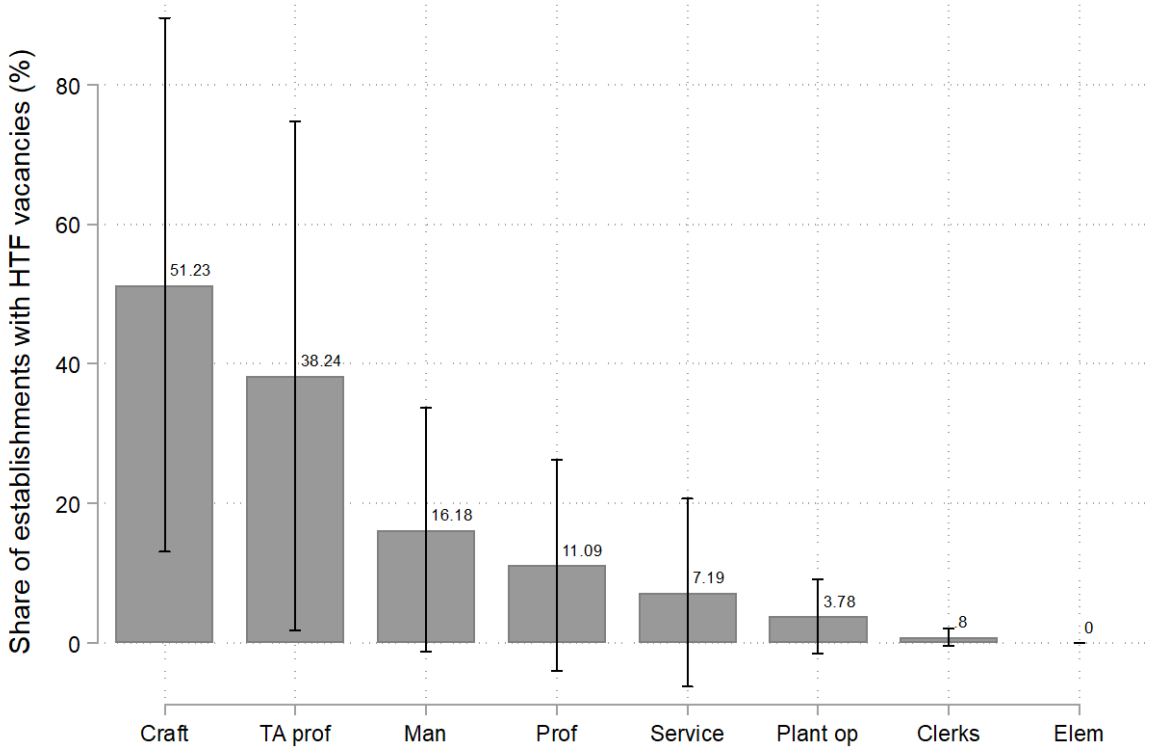
4.3.1.2 Skills shortages

While skills gaps place emphasis on skills that are lacking internally within establishments, skills shortages – defined as the presence of vacancies within an establishment – shift the focus to the demand for skills and the ability of the labour market to meet this demand. In our analysis of the MER Sector Enterprise Survey data, we estimate an aggregate MER Sector skills shortage rate of 12 percent. This is equivalent to approximately 1 500 vacancies in 616 establishments across the sector. Most establishments with a skills shortage report that it had a negative impact on their performance. Although large establishments are relatively more likely to have skills shortages, they are more pervasive in SMMEs. In other words, in absolute terms most establishments with skills shortages are SMMEs, but in relative terms a higher share of large establishments have skills shortages.

Most vacancies (80%) in the sector are considered as being hard-to-fill (HTF). Although HTF vacancies are evident across all main occupation groups (apart from elementary occupations), certain occupations face a higher skills shortage risk than others. As shown in Figure 11, over half (51.2%) of establishments who have HTF vacancies report these vacancies being for workers in the craft and related trades occupation, which specifically includes boilermakers, welders, millwrights, fitter and turners, and toolmakers. We find several reasons for the existence of HTF vacancies, but notably, for every occupation group we find that a lack qualifications and technical skills served as dominant reasons, but to varying degrees. In some cases, such as for service and sales workers, managers, and technicians and associate professionals, other reasons appear more important, such as a lack of interest. This suggests that although skills development indeed plays an integral role in mitigating vacancies, other factors curtailing the labour market's ability to supply skills demanded by industry also need to be addressed.

In the follow-up interviews, most respondents noted that they struggle with filling vacancies for more specialised roles that are often unique to their industry, or even their firm. Though no individual occupations were listed, the difficulties encountered by firms outside of the main metros in filling these vacancies was more pronounced. All respondents highlighted the importance of soft skills, such as a willingness to work and professionalism as characteristics that make a potential new hire stand out from their competition. One respondent stated that their hiring process includes aptitude testing and regular check-ins to ensure that a new hire is a good fit for their firm. Many firms have elected to train new hires inhouse with supplementary training from industry specialists. In this way they are able to mould these individuals to fit into the gaps created by these HTF vacancies.

Figure 11: Incidence of hard-to-fill (HTF) vacancies, by occupation



Source: MER Sector Enterprise Survey (Development Policy Research Unit, 2022). Authors' own calculations.
Notes: 1. This figure presents, for all establishments who reported having any hard-to-fill (HTF) vacancies, estimates of the incidence of HTF vacancies by main occupation. 2. All estimates are weighted using sampling weights and account for the complex survey design. 3. Capped spikes represent 95% confidence intervals.

4.3.2 Skills Constraints on the Supply-Side

To analyse skills constraints on the supply-side, we supplement our analysis of the MER Sector Enterprise Survey with structured qualitative interviews, that we conducted on a sample of representatives from several relevant private and public higher education and training institutions (HEIs), including public universities, TVET colleges, and private training providers. Ultimately, through these interviews, we aimed to gain insight into the constraints faced by HEIs in equipping individuals with the skills required for the HTF vacancy occupations identified in the quantitative firm survey.[16] Sample selection entailed first identifying firms in the quantitative survey that currently manufacture, or aim to manufacture, frontier products through cross-referencing product codes with frontier products identified in Allen Whitehead and Bhorat (2021), and then identifying the HTF vacancy occupations reported by this subset of firms using the job descriptions provided. We then collected a list of relevant HEIs from industry representatives who provide programmes related to these occupations, and then randomly selected HEIs from this list to interview. For each HEI, we interviewed a representative who was familiar with the curriculum and administration of the relevant programmes. As shown in Table 3, we conducted the interviews during October 2022 with five willing HEI representatives pertaining to 13 unique HTF occupations which are represented in all five chambers in the MER Sector.

[16] HTF vacancies serve as one measure of an inadequate supply of skills.

Table 3: Qualitative interview sample of higher education and training institutions and relevant hard-to-fill (HTF) occupations

Institution	Type	Relevant HTF occupation
Nelson Mandela University	Public university	Series Buyer Technicians CNC technologists CAD/CAM technicians Safety manager
Majuba TVET College	Public college	Millwright Copper welder Fitter and turner Electrician Machine operator Boilermaker
Technotrain	Private training provider	Millwright Copper welder Fitter and turner Electrician Machine operator Boilermaker
Plastics SA	Private training provider	Quality inspector
Production Technologies Association of South Africa	Private training provider	Toolmaker

These interviews consisted of three components, structured to follow the flow of learners into and out of the institution, and can be described as follows: (i) constraints related to the admission of learners into the institution; (ii) constraints related to the curriculum design and resources for its administration; and (iii) constraints related to the transition of graduates from the institution into the labour market. We outline our primary findings with respect to these components separately in the sub-sections to follow. Before doing so it is important to emphasise that, given the sampling method, these results do not intend to be representative of the population of HEIs in South Africa, but instead seek to provide rich descriptions of the experiences of the varied skills providers linked to the MER Sector.

4.3.2.1 Constraints to admission of learners

Among this sample of HEIs, it does not appear that institutions are constrained in their ability to attract learners. The representatives we interviewed reported that they did not to attract learners to participate in their programmes. This may in part be attributable to the large variety of promotion measures that these institutions have in place. Whereas the public institutions reported making use of career fares, school-based information-sharing sessions, and online and print media advertisements, the private institutions reported active communication with industry stakeholders to consider their needs, firm-based information-sharing sessions, as well as online and print media advertisements targeted to specific audiences.

Considering the eligibility of applicants, most representatives emphasised that they want their institutions to be as accessible as possible, and hence try to not, in the words of one respondent, "*set the bar too high*" in terms of academic eligibility criteria. The criteria of course eligibility varies between different programmes and institutions, but some institutions stressed

the importance of providing additional support to learners as they progress through their programme(s). For example, the public university representative discussed how their institution additionally offers alternative qualifications, such as diplomas, certificates, and extended programmes, which have less demanding eligibility requirements, to cater for applicants with poor secondary-level academic records, and argued that by doing so improves their future labour market prospects. They additionally discussed the importance of the guidance provided by recruited academic advisors and mentors who tend to be senior learners. On the other hand, the representatives of two private skills providers reflected on a discrepancy between applicants' education levels and their programme requirements. One discussed how, with respect to applicants of colour, most have a matric qualification but are older individuals and hence tend to have received a significantly lower-quality matric education due to the discriminatory education policies in place during the apartheid era. In other words, many applicants were eligible in terms of education quantity but not quality. The other discussed their institution's issue with the contemporary National Qualifications Framework's (NQF) equivalence of matric and N3 certificates as NQF level 4 qualifications. They stressed that this causes many learners with matric certificates to be eligible to apply and obtain N4 to N6 certificates without, however, gaining the foundational competency provided by the trade-related N2 qualification which is also a requirement for various programmes and trade-related tests. These experiences of both these institutions are suggestive of an inconsistency in the qualifications framework which may hinder the learning and career pathways of prospective workers in the sector.

The dominant constraint related to admissions, particularly for private providers, concerned access to funding. While the public institution representatives reported how the vast majority of their learners were publicly-funded by the National Students Financial Aid Scheme (NSFAS), the private institution representatives reported that they are not able to access public funding schemes or provide funding themselves. Because of this, they reported that most of their learners are either funded by the firms that they work for, if they're employed, or they are self-funded. This is not surprising given that NSFAS is not available for part-time learners and employed learners. One private institution representative expressed frustration regarding their inaccessibility to public subsidies despite their institution's supply of training programmes for critical skills which, in their view, no public institutions offer. "*If [merSETA] really are serious about skills development, start by seeing which industry bodies are doing that training that public institutions aren't, and allow them to have some kind of subsidy."* They argued that because employers tend to rely on SETA funding when sending their workers for training, but could not access this funding when considering the private institution, this lack of recognition of private industry institutions as training providers severely restricted their ability to contribute to skills development. The representative explained how this then makes it difficult for their institution to convince employers to train their workers, despite the latter being able to partially mitigate the training costs through mandatory SETA grants (if eligible) and tax rebates. "*If companies were awarded money towards the right programs, then they would send learners for training*." None of the public institution representatives reported such a constraint. This experience suggests that policymakers ought to consider reviewing the public funding framework to ensure resources are accessible for both public and private critical skills providers. A review of the SETA's discretionary grants policy for professional, vocational,

technical, and academic learning (PIVOTAL) and non-PIVOTAL programmes may be one such avenue to consider.

4.3.2.2 Constraints to curriculum administration

Most institution representatives reported that their training staff and physical resources were adequate for program administration. However, the public university representative discussed how their programmes may be constrained by not all teaching staff having industry experience, as opposed to just a qualification and academic experience. On the other hand, one private institution representative discussed how their institution lacks adequate physical resources like machinery, and explained how access to funding may mitigate this physical resource constraint as opposed to relying on industry donations.

Considering curriculum design and administration, the representatives from all public and private institutions reported that their curricula are designed through similar means. All reported that international standards, regular board meetings to discuss programme content and outcomes, and consultations with industry experts and other stakeholders are included in the process. Most programmes first entail a theoretical component, practical component, and workplace exposure component. However, one public and one private institution representatives expressed concern that the effectiveness of their programmes may be constrained by an inadequate workplace exposure component. The public university representative discussed how not all programmes have a compulsory experiential component, which they argued hinders learners' labour market prospects, while for those that do, they may be too short in duration and occur too late in the relevant programme. They concluded then that by graduation, learners then are not adequately prepared for the labour market. Similarly, the private institution representative expressed that although workplace exposure is compulsory in their programmes, they struggle with accessing relevant and willing firms to place their learners in.

Several institution representatives expressed frustration and confusion concerning the transition to the new Quality Council for Trades and Occupations (QCTO) standards framework. The representatives discussed how they struggle to get adequate responses to their queries, conditional on getting any response at all. "*The lack of knowledge amongst those who are supposed to guide us is shocking"* one stated, after asking why a "*system overhaul every 10 years*" was required as opposed to incremental improvements over time. These experiences suggest that policymakers ought to consider addressing their lines of communication with skills providers to ensure all are adequately prepared for the transition to the new system.

4.3.2.3 Constraints to labour market entry of graduates

Most institutions have initiatives in place to help learners transition into the labour market upon completion of their programmes, and believe these initiatives are important. The public university representative discussed how they have a unit dedicated to job placements, internships, and experiential training, and regularly engage in career fares, interview coaching, and employability workshops to improve graduates' labour market prospects. "*We tell students if you come study, you will have a greater chance of getting a job. So, we must put in effort to actually ensure that students realize this outcome*. *Graduation should not mark the end of our relationship with them.*" One private institution representative discussed their formal database

they keep to matching graduates with potential employers. The public college representative had also reported such a database, but explained that it does not serve to keep track of learners but it is an outcome they are striving towards. In addition to maintaining a matching database, another private provider explained that they also assist learners with resume preparation.

Some remarks made by the representatives suggest that, in some instances, graduates may not be adequately prepared for the labour market and would instead need to continue upskilling. One private institution representative discussed how the majority of their applicants already have a post-secondary education through attending a university or TVET college, however they believe that because such a qualification does not adequately prepare them for the labour market, they seek to obtain a qualification through their institution to improve their labour market prospects. This experience is in line with our skills gap-related finding from our quantitative MER Sector Enterprise Survey; that is, many individuals entering the MER Sector labour market may be qualified but still not adequately prepared for the work they are required to do. This again suggests that a disconnect may exist between the skills that certain education and training institutions are supplying and those that industry are demanding.

5 Policy Discussion and Considerations

The MER sector is an integral component of the South African manufacturing sector. Drawing on economic complexity theory, and work by Allen Whitehead and Bhorat (2021), we know that expanding and diversifying the MER sector has the potential to build economic complexity and ultimately drive economic growth. We develop an endogenous data-centric industrial policy approach to identifying the product-level industrial diversification opportunities in the MER sector – or frontier products. In this section, using a unique policy calculus, we start by showing the potential economic outcomes that may emerge should these industrial pathways be realised. However, we know that the sector faces a number of capability constraints, and we thus conclude the section by providing a set of policy considerations informed by our analysis of these constraints.

5.1 Potential Policy Outcomes – A Policy Calculus

The work conducted by Allen Whitehead and Bhorat (2021) identified the frontier product industrial diversification opportunities that the MER sector could diversify toward in order to build complexity and create an enabling environment for future economic development in the South African manufacturing sector. This research presented a list of 113 frontier products that spanned across the constituent chambers in the MER sector, and which could provide a lens for policymakers to direct policy interventions in the future.

As alluded to in Section 3.3, a key factor for identifying these frontier products was that the products needed to be (a) more complex than the current MER sector productive structure (i.e. 'desirable'), (b) close enough to the current productive structure (i.e. 'feasible'), and (c) provide future opportunities for diversification. Given this definition of a frontier product, diversification into these frontier products will necessarily lead to growing economic complexity and future opportunities for diversification. It has been shown that these metrics are positively correlated with economic development (Hausmann et al., 2014), which means

that diversification into frontier products will encourage future economic development in the South African MER sector.

However, given South Africa's economic positioning as a country with high unemployment, high inequality, and a services-focussed economy resulting from premature deindustrialisation, it is not clear whether "economic development" is necessarily progressive in terms of job creation or inequality alleviation. To this end, we opt to extend the analysis to consider how certain indicator measures for certain key development metrics will be affected when diversification into frontier products is achieved. Specifically, we focus on measures of inequality, labour intensity, and global demand.

Our measure for inequality is the product Gini coefficient, which is constructed following the method put forward by Hartmann et al. (2020). They make use of data from the Estimated Household Income Inequality (EHII) dataset to calculate the level of income inequality associated with products by considering the weighted average of income inequality levels for countries that produce a given product. Ultimately, this results in the Product Gini Index (PGI), which provides a measure of how inclusive a particular product is regarding income inequality metrics.[17] The average PGI for all products produced with comparative advantage by a given country is known as its XGini – a measure of inequality associated with a country's export basket.

To measure labour intensity, we follow the method put forward by Shirotori, Tumurchudur and Cadot (2010), and more recently Estman et al (2022), to develop a Revealed Capital Intensity (RCI) index for each product present in the trade data. For our purposes, we opt to invert the RCI measure in order to achieve a Revealed Labour Intensity (RLI) measure, since labour intensity is much more salient to the South African context of high unemployment and job creation. Similarly, to the XGini above, the average RLI for all products a country produces with comparative advantage gives the XRLI – a measure of labour intensity of a country's export basket.

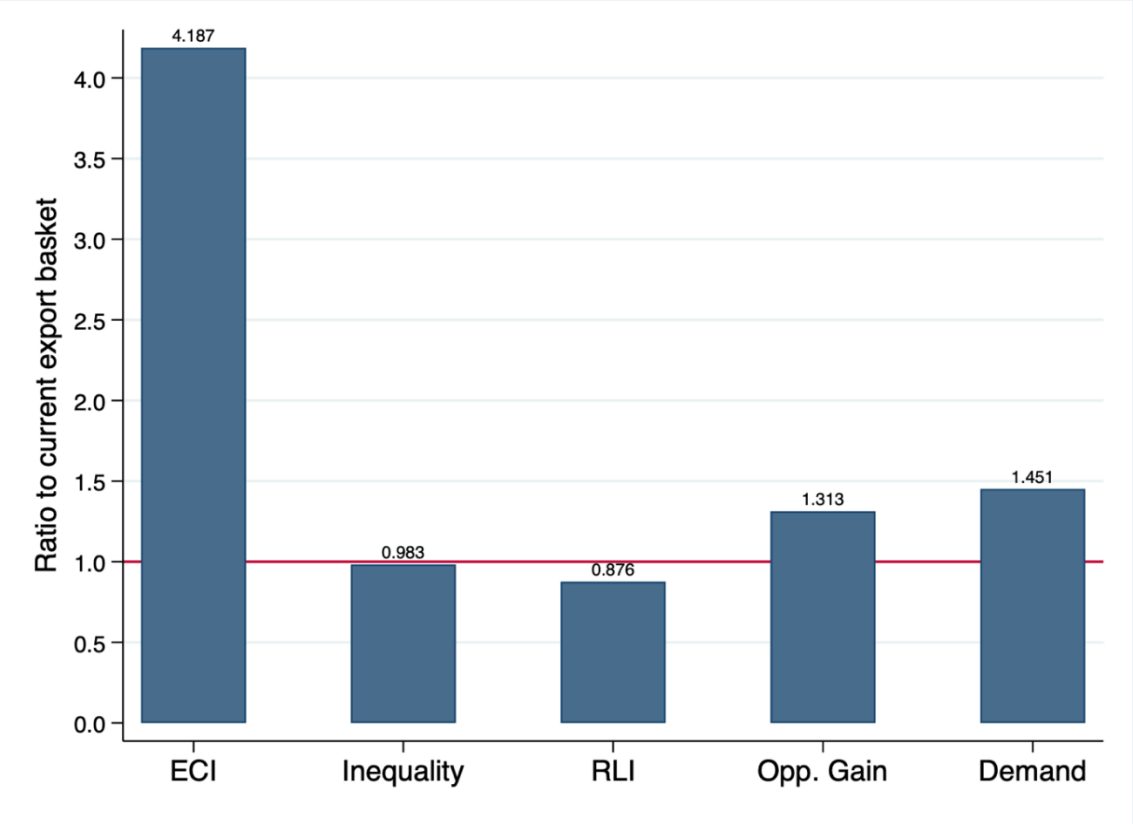
Finally, we calculate the growth in average export share for each product between 2010 and 2016 using the same trade data used to calculate the economic complexity measures discussed in Section 3. We use export growth for the period 2010 to 2016 in order to align with the analysis conducted by Allen Whitehead and Bhorat (2021) where 2016 was the most recent trade data available at time of writing. We further curtail the period to only run from 2010 in order to ensure that we observe export trends that emerge after the Global Financial Crisis of 2008/2009. If a product exhibits a growing share of the global export basket between 2010 and 2016, we deem it to have growing global demand, and thus it could potentially provide greater opportunities for South African firms to enter competitive global markets in the future. The average growth rate of product markets for all products produced with relative comparative advantage provides a proxy measure for a country's positioning in global product markets, and thus, a proxy measure for how well-positioned a country may be to grow international trade for products in high-demand in the future.

[17] Note that higher PGI values, much like higher Gini values, are interpreted as more unequal, while lower PGI values are interpreted as more equal.

We begin by assuming that the MER sector produces all 113 frontier products identified by Allen Whitehead and Bhorat (2021). Essentially, this entails recoding all frontier products to have revealed comparative advantage in the MER sector productive structure. Based on this, we can compare how economic complexity, inequality, labour intensity, future opportunities for diversification (opportunity gain), and global demand, could potentially evolve as a result of this change in productive structure. The results of this simulation are presented in Figure 12.

Figure 12 presents a set of comparative indices across the five areas of interest mentioned above. In particular, the indices are normalised so that the value of the current index in each area is equal to 1. This provides an opportunity to compare and contrast how diversification could impact each of the relevant indicators.

Figure 12: Multi-dimensional impact of producing all MER sector frontier products competitively



Source: Authors' calculations based on Allen Whitehead & Bhorat (2021) and The Growth Lab at Harvard University (2019)
Notes: 1. The red line at 1 indicates measures for all indices in the current scenario. Bar heights represent the ratio of the relevant index value after achieving relative comparative advantage (RCA) in all MER-sector frontier products relative to the current scenario. 2. The scenario under consideration assumes RCA is achieved in all 113 frontier products identified in Allen Whitehead and Bhorat (2021).

What is initially clear is that the expansion of production to include all new MER sector frontier products will significantly increase economic complexity – by just over 4-fold. Given that frontier products, by definition, increase economic complexity, it is unsurprising that economic complexity has increased, but the extent of the increase is quite stark. We can furthermore see that opportunity gain – the indicator measuring the extent of future diversification opportunities – increases by approximately 30 percent, and that diversifying into these frontier

MER sector products will favourably place the South African MER sector in markets that are growing approximately 1.45 times faster than the markets we currently occupy.

Furthermore, although slight, the indicator measure for inequality decreases through the diversification into these frontier products. This indicates that through producing these MER sector frontier products, South Africa will be able to position itself towards inclusive economic development. Unfortunately, however, the diversification into frontier products for the MER sector will lead to reduced labour intensity. Simply put, this means that the export basket of goods South Africa would produce is more capital-intensive, and that this diversification path may not align with a "jobs first" development agenda. However, given the nature of the manufacturing sector, particularly for highly complex products, it is unsurprising that capital intensity for these products is high. It should also be noted that increased capital intensity does not mean that jobs will be lost, necessarily, but just that the products being produced will require greater capital input than labour input. This may imply slower job growth, but insofar as capital and labour are complementary in the production process, a lower labour intensity could still lead to increased employment in the long run.

The analysis up to now has considered the case of diversification into the full list of 113 frontier MER sector products, however, it is clear that this may not be practical in the short term. Policy interventions are often more narrowly focussed, and it is infeasible to expect that South African firms could suddenly become competitive in the production of 113 products of varying complexity and distance. Specifically, different products may be more feasible or more desirable for policymakers to diversify into, given the constraints facing South African firms, or the current country context in general.

To this end, we are able to make use of a policy calculus to model different scenarios representing policymakers with different preferences. To model various preference scenarios, we make use of a normalised index for each indicator, and weight each component according to the strength of preference associated with the relevant indicator. We rescale all indicators to lie between 0 and 1, so that 0 is undesirable, while 1 is desirable. This is to ensure that the composite weighted index can be directly compared and ranked to choose the top 20 frontier products.

Specifically, we model scenarios where the policymaker (1) cares only about building economic complexity; (2) cares strongly about inclusive growth; (3) cares strongly about labour-intensive growth; and (4) cares only about diversifying into those frontier products closest to the current productive structure. We create the composite indicator for each scenario by weighting each indicator as displayed in Table 4.

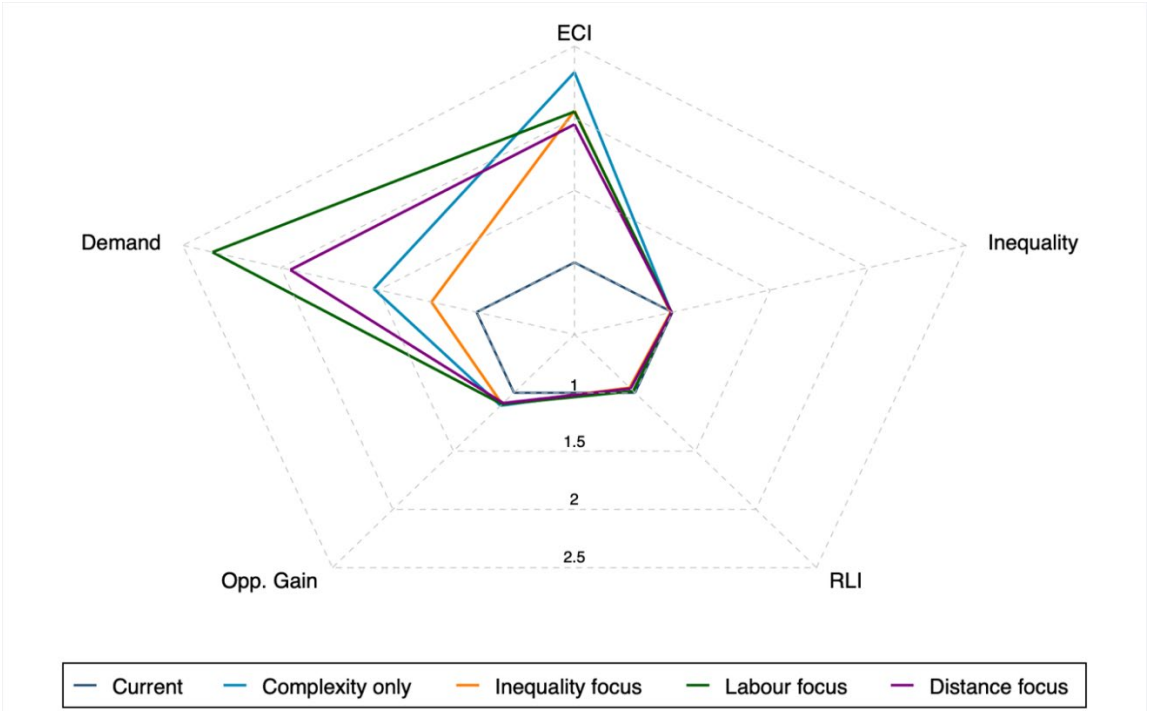
Table 4: Weights used in creation of composite indicator by policy preference scenario

Scenario	Complexity	Inequality	RLI	Opp. Gain	Demand	Distance
(1) Complexity only	1	0	0	0	0	0
(2) Inclusive growth preference	0.0625	0.75	0.0625	0.0625	0.0625	0
(3) Labour-intensive growth preference	0.0625	0.0625	0.75	0.0625	0.0625	0
(4) Distance/feasibility focus	0	0	0	0	0	1

Note: In general, feasibility/distance is not considered for scenarios (1), (2) and (3) since all frontier products under consideration in this stage of the analysis are already deemed to be close enough for feasible jumps to occur. As a result, we do not re-introduce distance as a criterion for our choice of diversification path.

After combining the indicators into a composite index, we rank frontier products according to their desirability under the given preferences. We choose to focus on diversification into the top 20 frontier products according to our ranking.[18] In Figure 13, we present a comparative radar plot of each indicator measure for each of the four described policy preference scenarios described above. Lists of exactly which products fall in the top 20 under each scenario are presented from Table A 2 to Table A 5 in the Appendix.

Figure 13: Scenario analysis for diversifying into top 20 policy-directed frontier products



Source: Authors' calculations based on Allen Whitehead & Bhorat (2021) and The Growth Lab at Harvard University (2019)
Notes: 1. The dark blue regular pentagon at 1 indicates measures for all indices in the current scenario. Irregular pentagons represent the ratio of the relevant index value under the specified scenario relative to the current scenario. 2. Each scenario plotted assumes RCA>1 is attained in the top 20 MER sector frontier products for the given scenario. 3. The centre of the diagram is at 0.5.

[18] The choice of 20 products is essentially arbitrary. This number could be updated depending on policy best practice.

The results presented in Figure 13 show that, relative to the current scenario, all policy preference scenarios lead to large increases in complexity and demand, with more modest increases in opportunity gain. Changes in labour intensity and inequality are negligible, although labour intensity does decrease slightly more in non-labour-centric policies. A key point to note, however, is that a set of policy preferences that target labour-intensive diversification are also best-placed to increase the MER sector's positioning in growing global markets, while still providing the second-highest increase in economic complexity. Thus, from a policy perspective, it would seem that growing economic complexity through a labour-centric lens may well assist South Africa in entering competitive global markets and drive international trade due to increased demand for manufactured products. Frontier products most desirable under this policy preference set include, for example, isotopes and inorganic or organic compounds (HS code 2845); lifting, handling and loading machinery (HS code 8428); and boards, panels, consoles and desks (HS code 8537).

We do note that these are only some of the scenarios that one could present and analyse to determine an optimal policy path, however, we believe that this is a useful data centric approach for analysing the multi-faceted concerns a policymaker may have to juggle in their decision-making process. While all choices come with a trade-off of some kind (for example, choosing a labour-focussed development path will come at the expense of some economic complexity growth in the short- to medium-run), we believe that there is value to be had in making specific choices while being aware of the sacrifices that come with such choices. We have, in this section, presented a method of choosing a policy agenda, however, the next step is to choose and enact policies that would specifically support the agenda in question, as well as overcoming the challenges that establishments may face in order to reallocate resources towards a specific production path. In the next section, we present a discussion on some policy considerations that may be useful for beginning this process of creating an enabling environment for targeted diversification of the MER sector.

5.2 Policy Considerations

In Section 4 we delineate between exogenous constraints – which are those constraints over which establishments and merSETA have little to no influence – and endogenous constraints – those constraints over which establishments and merSETA have a greater degree of influence. The locating of constraints within these two groups provides a framework for organising a set of policy considerations that emerge from the broader research project synthesised in this paper. In this section, we first discuss a set of policy considerations related to exogenous constraints. We then shift focus to endogenous constraints, specifically, skill constraints.

5.2.1 Exogenous Constraints

SMMEs are a significant component of the MER sector and experience constraints more acutely than large firms: Allen Whitehead et al. (2022a) show that SMMEs account for 87 percent of establishments and approximately 40 percent of employment in the MER sector. They also point out that large establishments are, in general, much more likely to report facing a given constraint than SMMEs, however, when SMMEs face a constraint, they face it much more acutely than their larger counterparts. This pattern is consistent across both exogenous and endogenous constraints. These results suggest that policy could be adapted for SMMEs in the MER sector to better support operations and remove barriers for future diversification and

development. This suggests that any policy interventions aimed at overcoming the various constraints facing the sector, should, in some form, take cognisance of the unique challenges facing SMMEs. For example, the streamlining of administrative burdens for SMMEs, since large firms can overcome a lot of these problems by hiring specific individuals to focus on these administrative tasks.

Export regulatory constraints serve to increase the fixed costs of entering export markets and thus reduce the likelihood of MER sector firms driving export-led growth. Industrial growth and diversification in economies with relatively small domestic markets, such is the case with South Africa, can only be achieved through export growth. However, we observe that a substantial share of MER sector establishments face export regulatory constraints. We see that approximately 33 percent of exporters face challenges with export regulations. Interestingly, 27 percent of non-exporters face the same constraints, which suggests that export regulatory constraints may be increasing the fixed cost of entry into export markets. Ultimately, the growth of frontier products and the building of economic complexity in the MER sector requires export growth, and to the extent that export regulations hinder export growth, these regulations hinder this pathway toward reindustrialisation. It is thus important to put in place policy that creates an enabling environment for firms to enter international markets. It is worth noting that the burden is steeper for SMMEs. For example, SMMEs often do not have the human and final resources needed to travel to prospective markets and build business relationships with importers. Thus, trade facilitation measures should be geared toward assisting SMMEs.

Business regulatory constraints raise the costs of doing business. Approximately two in five frontier establishments report facing business regulatory constraints. Of the establishments facing business regulatory constraints, three quarters of them that listed business regulations as a major or severe constraint, did so because administrative costs and burdens were too large. To reduce the cost of doing business in the sector, and South Africa in general, creating more streamlined ways of completing administrative compliance and regulatory requirements and procedures may go a long way toward creating a more enabling environment for firms to grow.

Infrastructure constraints, particularly the reliable provision of electricity, represent the largest set of exogenous constraints facing the MER sector. While infrastructure constraints speak to issues, such as the efficiency of rail transportation, the ability of ports to handle the movement of goods, and the reliable provision of water, electricity remains the most pressing industrial constraint in South Africa. Recent research by Fortunato (2022), contends that the electricity crisis is the dominant supply-side issue behind the deindustrialisation of the South African economy. Ultimately, the limited generation capacity of the South African energy sector imposes a ceiling on the extent to which the South African economy can grow, particularly if that growth is to be driven by relatively energy-intensive industrial growth, say in the MER sector. Again, it is worth noting that the adverse impacts of load-shedding are disproportionately felt by SMMEs who may not have the resources needed to mitigate power interruptions through the procurement of generators and other off-grid power sources.

5.2.2 Endogenous – Skill – Constraints

SMMEs experience skill constraints more acutely than large firms. Skill gaps and skill shortages are more prevalent among this group of establishments. For example, SMMEs represent most of the establishments with skills gaps (86 percent) and skill shortages (80 percent). Thus, policy interventions aimed at addressing the skill constraint needs to place emphasis on this important group of establishments and identify their specific set of needs and circumstances. For example, larger establishments have more qualified workers relative to SMMEs, and thus, skills development interventions targeting SMMEs would need to take this lower base level of education into account.

There is a discontinuity between skills obtained through educational qualifications and skills required to meet industry needs. Allen Whitehead et al. (2022a) show that almost all MER sector workers seem to have the right qualification for their job, as defined by their establishment (96% of establishments). However, the overall estimated skill gap of 10 percent suggests that there are a number of workers who, despite having the required qualification, are not fully proficient for their occupation. The dominant reason for skills constraints, as reported by establishments, appears to be a lack of required technical skills, as opposed to a relevant qualification. The vast majority (87 percent) of establishments who reported skills as a major or severe constraint indicated this reason, as opposed to half who indicated a lack of correctly qualified workers as a reason. Taking these results together, we see that there are more establishments who find a lack of technical skills than those who find a lack of appropriate qualification. The natural corollary of this finding is that workers entering the labour market, may be qualified, but their qualification does not correctly or adequately prepare them for the work they are required to do. Overall, this suggests that establishments are largely able to hire workers with adequate qualifications but still face skill problems, which is indicative of an education system that is misaligned with the skill needs of the sector. Policymakers ought to take such discontinuity into account when formulating skills development initiatives.

The mean MER sector employee – who is an individual with at least a matric level education, working as a plant and machine operator or in a craft and related trade occupation – is also the most at risk of future employment displacement arising from greater uptake of 4IR technologies. Allen Whitehead et al. (2022a) show that 62 percent of MER sector workers fit within the plant and machine operator and craft and related trade occupational groupings. Further, they find that plant and machine operators and craft and related trade workers have a relatively even distribution between those with a matric (49 and 52 percent, respectively) and those with a matric plus diploma or certificate (45 and 42 percent, respectively). Further, skill gaps are disproportionately prevalent among workers within these two occupational groupings. Worryingly, Allan Whitehead et al. (2021) observe that plant and machine operators and assemblers and craft and related trade workers, were amongst those who exhibited the highest risk of automation-induced employment displacement. Thus, skills development interventions targeting skill gaps among plant and machine operators and craft and related trade workers, may provide the most efficient approach to mitigating both current and future adverse labour market prospects.

A key constraint facing training institutions, particularly private training institutions, concerns access to funding. This constraint emerged in the admissions stage of the education pipeline,

where it was contended by private HEIs that because employers tend to rely on SETA funding when sending their workers for training, they could not access this funding when considering the private institution, and this lack of recognition of private industry institutions as training providers severely restricted their ability to contribute to skills development. At the training stage of the education pipeline, it was expressed by a private institution representative that their institution lacks adequate physical resources like machinery for training, and that access to funding may mitigate this physical resource constraint as opposed to merely relying on industry donations. These experiences suggests that there may be scope to review the public funding framework to ensure resources are accessible for both public and private critical skills providers, with the ultimate goal of meeting industry skill needs.

The effectiveness of training programmes may be constrained by an inadequate workplace exposure component. It was noted by HEI respondents that although workplace exposure is compulsory in their programmes, they struggle with accessing relevant and willing firms to place their learners in. As such, there may be scope for the incentivisation of firms to participate in workplace exposure programme linked to HEIs.

6 Conclusion

In this paper, drawing on Bhorat, Hill, Köhler, Monnakgotla and Steenkamp (2020), we show that the MER sector is an integral component of the South African manufacturing sector. It comprises a collection of high productivity industries in which future expansion is primed to bring about high levels of economic and employment growth. The prominence of MER sector industries in existing economic and industrial policy indicates that the sector's economic relevance and potential is acknowledged among policy makers. Therefore, in the context of deindustrialisation, there is a clear policy imperative to bring about the growth and diversification of the industries within the sector.

Allen Whitehead and Bhorat (2021) view the deindustrialisation challenge through the lens of economic complexity and industrial relatedness theory and examine the role of the MER sector in driving the process of reindustrialisation. They show that MER sector products are on average more complex than other traded products and that there exists an economic complexity premium available to South Africa's MER sector should it diversify into the full range of products that fall within the industries that comprise the sector. Thus, from an economic complexity standpoint, MER sector products represent a *desirable* set of products to diversify into. Allen Whitehead and Bhorat (2021) develop the MER sector product space and show that South Africa's MER sector productive structure is such that the sector is well positioned to leverage off existing industrial capabilities This suggests that there are *feasible* industrial diversification opportunities available to MER sector firms in South Africa. Then, drawing on the smart specialisation literature, they apply an endogenous data-centric industrial policy approach to identify a set of product-level industrial diversification opportunities that are both *desirable* and *feasible*. These MER sector *frontier products* provide a pathway to the reindustrialisation of the South African economy.

However, diversification towards such products can potentially be limited by capability constraints. Informed by the MER Sector Enterprise Survey, Allen Whitehead, Bhorat, Hill, Köhler and Steenkamp (2022a) identify and analyse the constraints that hinder firms in the MER

sector from realising these industrial diversification opportunities. They identify exogenous constraints – which are those constraints over which establishments and merSETA have little to no influence – such as infrastructure constraints, business regulatory constraints, labour regulatory constraints, export regulatory constraints, and policy uncertainty, corruption and crime. These constraints are felt more acutely by SMMEs.

Allen Whitehead, Bhorat, Hill, Köhler and Steenkamp (2022a) also identify endogenous constraints – those constraints over which establishments and merSETA have a greater degree of influence – specifically, skill constraints. They show that skill constraints are predominant among SMMEs and the major reason for these skill constraints is a lack of technical skills. This is strongly linked to a misalignment between the skills obtained through educational qualifications and the skills required to meet industry needs. They report a 10 percent skill gap in the MER sector – equivalent to approximately 22 000 workers in 500 establishments. Skill gaps are most prevalent among SMMEs, on the firm side, and plant and machine operators and craft and related trade workers, on the employee side. Allan Whitehead et al. (2021) observe that plant and machine operators and assemblers and craft and related trade workers, were amongst those who exhibited the highest risk of 4IR technology-induced employment displacement. Thus, skills development interventions targeting skill gaps among plant and machine operators and craft and related trade workers, may provide the most efficient approach to mitigating both current and future adverse labour market prospects. The sector is also characterised by a skills shortage rate of 12 percent, which is equivalent to approximately 1 500 vacancies in 616 establishments across the sector. Clearly, skills is a key constraint facing the MER sector.

We also develop a unique policy calculus, which provides a quantitative lens to view the potential economic outcomes that may emerge should the MER sector realise the industrial diversification opportunities identified by Allen Whitehead and Bhorat (2021). The policy calculus details the potential outcomes in terms of complexity metrics such as economic complexity and opportunity gain (movement toward more complex future diversification opportunities). In addition, the calculus takes a broader view and considers metrics controlling for inequality, labour absorption and demand outcomes that may emerge from the realisation of these the industrial diversification opportunities. This policy calculus provides a quantitative tool and framework for thinking about and thus informing industrial policy targeting.

We conclude by discussing several policy considerations that emerge from the broader research project. Ultimately, the realisation of the industrial potential of the MER sector is contingent on overcoming the capability constraints facing the sector and providing an enabling environment for firms within the sector to flourish.

References

Allen Whitehead, C. and Bhorat, H. 2021. Understanding economic complexity: an application to the MER sector. *DPRU Working Paper 202105*. Development Policy Research Unit: Cape Town (South Africa).

Allen Whitehead, C., Bhorat, H., Hill, R., Köhler, T. and Steenkamp, F. 2021. The potential employment implications of the fourth industrial revolution technologies: The case of the Manufacturing, Engineering and Related Services Sector. *DPRU Working Paper 202106*. Development Policy Research Unit: Cape Town (South Africa).

Allen Whitehead, C., Bhorat, H., Hill, R., Köhler, T. and Steenkamp, F. 2022a. Expansion and Diversification in the MER Sector: Results from an Enterprise Survey. *DPRU Working Paper 202203*. Development Policy Research Unit: Cape Town (South Africa).

Allen Whitehead, C., Bhorat, H., Hill, R., Köhler, T. and Steenkamp, F. 2022b. MER Sector Enterprise Survey: Survey Methods. *Appendix DPRU Working Paper 202203*. Development Policy Research Unit: Cape Town (South Africa).

Andreoni, A. and Tregenna, F. 2021. The middle-income trap and premature deindustrialisation in South Africa. In *Structural Transformation in South Africa: The Challenges of Inclusive Industrial Development in a Middle-Income Country*. A. Andreoni, P. Mondliwa, S. Roberts and F. Tregenna, Eds. Oxford University Press.

Balland, P.A., Boschma, R., Crespo, J. and Rigby, D.L. (2019) Smart specialization policy in the European Union: relatedness, knowledge complexity and regional diversification. *Regional Studies*. 53(9): 1252-1268.

Bhorat, H., Cassim, A., and Hirsch, A. 2014. Policy co-ordination and growth traps in a middle-income country setting. *WIDER Working Paper 2014/155*. UNU-WIDER: Helsinki (Finland).

Bhorat, H., Steenkamp, F. and Rooney, R. 2017. Chapter 5: Understanding the determinants of Africa's manufacturing malaise. In Income Inequality Trends in Sub-Saharan Africa. A. Odusola, G.A. Cornia, Bhorat, B. & P. Conceição, Eds. New York: United National Development Programme, Regional Bureau for Africa.

Bhorat, H., Rooney, C., & Steenkamp. F. 2018. Understanding and characterizing the services sector in South Africa: an overview. In Industries without Smokestacks: Industrialisation in Africa Reconsidered. Newfarmer, R., Page, J. & Tarp, F, Eds. Oxford: Oxford University Press.

Bhorat, H., Ewinyu, A., Lilenstein, K., Rooney, C., Steenkamp, F. and Thornton, A. 2019. Economic complexity and employment expansion: The case of South Africa. DPRU: Cape Town.

Bhorat, H., Kanbur, R., Rooney, C. & Steenkamp, F. 2019b. Chapter 8: Sub-Saharan Africa's Manufacturing Sector: Building Economic Complexity. In *The Quality of Growth in Africa*. R. Kanbur, A. Noman & J.E. Stiglitz Eds. Columbia University Press.

Bhorat, H., Hill, R., Köhler, T., Monnakgotla, J. and Steenkamp, F. 2020. Understanding Economic Complexity in the MER Sector Space with the Focus on SMMEs: Situational Analysis.

Bhorat, H., Lilenstein, K., Oosthuizen, M. and Steenkamp, F. 2022. Economic Growth, Rising Inequality, and Deindustrialisation: South Africa's Kuznetsian Tension. In *The Developer's Dilemma: Structural Transformation, Inequality Dynamics, and Inclusive Growth*. A. S. Alisjahbana, K. Sen, A. Sumner, A. A. Yusuf (Eds). Oxford University Press.

Department of Higher Education and Training [DHET], 2019. National Skills Development Plan 2030: An educated, skilled and capable workforce for South Africa. DHET: Pretoria (South Africa).

de Vries, G., Arfelt, L., Drees, D., Godemann, M., Hamilton, C., Jessen-Thiesen, B., Kaya, A. I., Kruse, H., Mensah, E. and Woltjer, P. 2021. The Economic Transformation Database (ETD): Content, Sources, and Methods. *WIDER Technical Note 2/2021*. UNU-WIDER: Helsinki (Finland).

Fortunato, A. 2022. Getting back on the curve: South Africa's manufacturing challenge. *CID Working Paper No. 139*. Centre for International Development: Harvard University(MA)

Hartmann, D., Bezerra, M., Lodolo, B. and Pinheiro, F.L., 2020. International trade, development traps, and the core-periphery structure of income inequality. *EconomiA*. 21(2): 255-278.

Hausmann, R., Hidalgo, C.A., Bustos, S., Coscia, M., Simoes, A. & Yildirim, M.A. 2014. The atlas of economic complexity: mapping paths to prosperity. MIT Press.

Hausmann, R. and Chauvin, J. 2015. Moving to the adjacent possible: Discovering paths for export diversification in Rwanda. *CID Working Paper Series 2015.294*. Harvard University: Cambridge, MA.

Herrendorf, B., Rogerson, R. and Valentinyi, A. 2014. Chapter 6: Growth and structural transformation. In *Handbook of economic growth (Volume 2: 855-941)*. P. Aghion and S.N. Durlauf. Eds.

Hidalgo, C.A., Klinger, B., Barabási, A.L. and Hausmann, R. 2007. The product space conditions the development of nations. *Science*. *317*(5837):482-487.

Hidalgo, C.A. and Hausmann, R. 2009. The building blocks of economic complexity. *Proceedings of the National Academy of Sciences*. 106(26):10570-10575.

Hidalgo, C.A., 2021. Economic complexity theory and applications. *Nature Reviews Physics*. 3(2):92-113

Kerr, A., Lam, D. and Wittenberg, M. 2019. Post-Apartheid Labour Market Series [dataset]. Version 3.3. Cape Town: DataFirst [producer and distributor], 2019.

merSETA. 2019. Sector Skills Plan 2020-2025. Manufacturing, Engineering and Related Services SETA: Johannesburg (South Africa)

National Planning Commission (NPC). 2012. National development plan 2030: Our Future – Make it Work. Pretoria: Department of the Presidency.

Neffke, F. and Henning, M. (2013) Skill relatedness and firm diversification. *Strategic Management Journal*. 34(3): 297-316.

Rodrik, D. 2016. Premature deindustrialisation. *Journal of Economic Growth*. 21(1): 1-33.

Shirotori, M., Tumurchudur, B. and Cadot, O., 2010. Revealed factor intensity indices at the product level. Policy Issues in International Trade and Commodities (Vol. 44). United Nations Conference on Trade and Development.

Statistics South Africa. 2022. Statistical Release PO441 Gross Domestic Product. GDP *P0441 Generation of income account*. Statistics South Africa: Pretoria (South Africa).

The Growth Lab at Harvard University. 2019. International Trade Data (HS 92) [Dataset]. The Growth Lab at Harvard University. Available: https://dataverse.harvard.edu/dataset.xhtml?persistentId=doi:10.7910/DVN/T4CHWJ.

Timmer, M. P., de Vries, G. J., and de Vries, K. 2015. Patterns of Structural Change in Developing Countries. In *Routledge Handbook of Industry and Development*. J. Weiss, & M. Tribe (Eds.) (pp. 65-83). Routledge.

World Bank. 2022. World Development Indicators. World Bank: Washington D.C. (United States)

Appendix

Table A 1: List of MER sector frontier products identified in Allen Whitehead & Bhorat (2021)

Rank	Chamber	Product description	PCI
1	Plastics	Polymers of styrene	2.921
2	Automotive components	Parts suitable for use with spark-ignition engines	2.898
3	Automotive components	Parts of motor vehicles and tractors	2.813
4	Automotive components	Vehicle Bodies	2.739
5	Metals	Other lifting machinery	2.668
6	New tyre	Vulcanized rubber plates	2.650
7	Metals	Radar	2.637
8	Metals	Other firearms	2.631
9	Metals	Other alloy steel in primary form	2.611
10	Metals	Other agricultural machinery	2.598
11	Metals	Other parts for machines and appliances	2.575
12	New tyre	Other articles of vulcanized rubber	2.534
13	Metals	Water gas generators	2.529
14	Metals	Parts for use with electric generators	2.514
15	Metals	Radiators for central heating of iron or steel	2.513
16	Metals	Direction finding compasses	2.459
17	Plastics	Other articles of plastic	2.457
18	Metals	Industrial furnaces	2.444
19	Metals	Other articles of nickel	2.440
20	Metals	Nuclear reactors and related equipment	2.408
21	Metals	Parts of military weapons	2.383
22	Metals	Flat-rolled iron, width < 600mm, clad	2.324
23	Metals	Other engines and motors	2.299
24	Metals	Dairy machinery	2.295
25	Metals	Other articles of iron or steel	2.267
26	Metals	Harvesting or agricultural machinery	2.230
27	Metals	Railway track fixtures	2.225
28	Metals	Tractors	2.173
29	Metals	Electrical boards for protecting electrical circuits	2.131
30	Metals	Military weapons, other than pistols	2.123
31	Metals	Flat-rolled iron, width < 600mm, not clad	2.122
32	Plastics	Other colouring matter	2.121
33	Metals	Machinery for soil preparation or cultivation	2.096
34	Plastics	Sulphonitric acids	2.088
35	Metals	Munitions of war	2.084
36	Metals	Other cast articles of iron or steel	2.063
37	Plastics	Non-radioactive isotopes	2.059
38	Plastics	Other plastic plates, sheets etc.	2.051
39	Metals	Parts of other aircraft	2.034
40	Metals	Work trucks	2.004
41	Automotive components	Trailers and semi-trailers	1.985
42	Metals	Automatic goods-vending machines	1.982
43	Metals	Nickel waste and scrap	1.960
44	Metals	Pulleys and winches	1.937
45	Metals	Refrigerators, freezers	1.934
46	Metals	Tubes, seamless, of iron or steel	1.876
47	Metals	Electric heaters	1.837
48	Metals	Titanium	1.829
49	Metals	Railway cars, not self-propelled	1.829
50	Plastics	Baths, sinks etc.	1.807
51	Plastics	Ethers	1.800
52	Metals	Railway construction material of iron or steel	1.799
53	Metals	Central heating boilers	1.793
54	Metals	Wire etc. used for welding	1.768
55	Metals	Self-propelled bulldozers, excavators and road rollers	1.758
56	Metals	Other articles of zinc	1.757
57	Plastics	Monofilament	1.753

Rank	Chamber	Product description	PCI
58	Metals	Other articles of aluminium	1.700
59	Metals	Medical, dental or veterinary furniture	1.645
60	Metals	Other articles of copper	1.633
61	Plastics	Polymers of vinyl chloride	1.596
62	Plastics	Sodium or potassium hydroxides or peroxides	1.589
63	Plastics	Other plates of plastics, noncellular and not reinforced	1.577
64	Plastics	Carbon	1.531
65	Automotive	Motor vehicles for the transport of > 10 persons	1.514
66	Metals	Hot rolled bars of iron	1.481
67	Metals	Aluminium containers, >300 litters	1.444
68	Metals	Stoppers, caps and lids of metal	1.399
69	Metals	Other metals	1.398
70	Metals	Other floating structures	1.389
71	Metals	Tin waste and scrap	1.359
72	Metals	Aluminium structures (bridges, towers etc)	1.355
73	Metals	Hydraulic turbines, water wheels and regulators	1.354
74	Plastics	Plastic builders' ware	1.354
75	Metals	Other arms (air guns, truncheons, etc.)	1.352
76	Metals	Machinery for preparing tobacco	1.306
77	Automotive	Special purpose motor vehicles	1.230
78	New tyre	Used pneumatic tires of rubber	1.225
79	Plastics	Sulphuric acid, oleum	1.189
80	Metals	Cadmium	1.180
81	Metals	Stainless steel in ingots	1.156
82	New tyre	New pneumatic tires of rubber	1.142
83	Plastics	Sulphur, sublimed or precipitated	1.139
84	Plastics	Other inorganic acids	1.127
85	Metals	Copper wire, uninsulated	1.110
86	Metals	Prefabricated buildings	1.089
87	Metals	Flat-rolled iron, width > 600mm, cold-rolled, not clad	1.020
88	Plastics	Hydrogen peroxide	0.988
89	Plastics	Rosin and resin acids	0.949
90	Metals	Hand-tools for gardening	0.936
91	Metals	Surveying instruments	0.915
92	Metals	Flat rolled iron, width > 600mm, clad	0.913
93	Metals	Nails and similar articles of iron or steel	0.905
94	New tyre	Rubber hygienic or pharmaceutical items	0.900
95	Metals	Tanks etc. > 300 litres, iron or steel	0.863
96	Plastics	Sulfonated, nitrated derivatives of hydrocarbons	0.861
97	Plastics	Silicates	0.845
98	Plastics	Polymers of ethylene	0.797
99	Plastics	Chlorates, bromates, y iodates	0.746
100	Metals	Other vessels	0.733
101	Plastics	Zinc oxide or peroxide	0.733
102	Plastics	Plastic tubes and fittings	0.686
103	Plastics	Oils etc. from high temperature coal tar	0.663
104	Metals	Stoves and similar non-electric appliances of iron or steel	0.654
105	Metals	Ferrous waste and scrap	0.600
106	Metals	Aluminium wire, not insulated	0.392
107	Metals	Tugs and pusher craft	0.330
108	Metals	Other moving, excavating or boring machinery	0.318
109	Plastics	Turpentines	0.288
110	Metals	Other tubes, pipes and hollow profiles of iron or steel	0.283
111	Plastics	Carbonates	0.266
112	Plastics	Packing lids	0.217
113	Metals	Fishing vessels	0.155

Source: Author's own calculations based on The Growth Lab at Harvard University (2019).

Table A 2: Top 20 frontier products under scenario (1): Complexity growth only

Rank	Chamber	HS Code	Product description
1	Metals	8607	Parts of railway locomotives
2	Plastics	3903	Polymers of styrene
3	Motor vehicles	8708	Parts of motor vehicles and tractors
4	Plastics	2915	Saturated acyclic monocarboxylic acids
5	Metals	8428	Other lifting machinery
6	Metals	9303	Other firearms
7	Metals	8436	Other agricultural machinery
8	Metals	9033	Other parts for machines and appliances
9	New tyre	4016	Other articles of vulcanized rubber
10	Metals	8405	Water gas generators
11	Metals	9007	Cinematographic cameras and projectors
12	Metals	8503	Parts for use with electric generators
13	Metals	7322	Radiators for central heating of iron or steel
14	Metals	9014	Direction finding compasses
15	Metals	9018	Medical, surgical, dental or vet instruments
16	Metals	7508	Other articles of nickel
17	Metals	9305	Parts of military weapons
18	Metals	7212	Flat-rolled iron, width < 600mm, clad
19	Metals	8412	Other engines and motors
20	Metals	8434	Dairy machinery

Source: Authors' calculations based on Allen Whitehead and Bhorat (2021) and The Growth Lab at Harvard University (2019)

Table A 3: Top 20 frontier products under scenario (2): Strong preference for inclusive growth

Rank	Chamber	HS Code	Product description
1	Metals	9304	Other arms (air guns, truncheons, etc.)
2	Metals	8428	Other lifting machinery
3	Metals	8436	Other agricultural machinery
4	Metals	8607	Parts of railway locomotives
5	Metals	8412	Other engines and motors
6	Metals	8503	Parts for use with electric generators
7	Metals	7218	Stainless steel in ingots
8	Metals	8476	Automatic goods-vending machines
9	Metals	7326	Other articles of iron or steel
10	Motor vehicles	8708	Parts of motor vehicles and tractors
11	Metals	8403	Central heating boilers
12	Metals	8434	Dairy machinery
13	Metals	9402	Medical, dental or veterinary furniture
14	Metals	8432	Machinery for soil preparation or cultivation
15	Metals	8425	Pulleys and winches
16	Metals	8433	Harvesting or agricultural machinery
17	Metals	7211	Flat-rolled iron, width < 600mm, not clad
18	Plastics	3206	Other coloring matter
19	Metals	8530	Electric signal and traffic controls
20	Metals	7212	Flat-rolled iron, width < 600mm, clad

Source: Authors' calculations based on Allen Whitehead and Bhorat (2021) and The Growth Lab at Harvard University (2019)

Table A 4: Top 20 frontier products under scenario (3): Strong preference for labour-intensive growth

Rank	Chamber	HS Code	Product description
1	Plastics	2807	Sulfiric acid, oleum
2	Metals	9301	Military weapons, other than pistols
3	Plastics	2839	Silicates
4	New tyre	4012	Used pneumatic tires of rubber
5	Plastics	2845	Non-radioactive isotopes
6	Metals	7419	Other articles of copper
7	Metals	8607	Parts of railway locomotives
8	Metals	8107	Cadmium
9	Metals	9304	Other arms (air guns, truncheons, etc.)
10	Motor vehicles	8708	Parts of motor vehicles and tractors
11	Metals	8428	Other lifting machinery
12	New tyre	4016	Other articles of vulcanized rubber
13	Metals	8436	Other agricultural machinery
14	Metals	9018	Medical, surgical, dental or vet instruments
15	Metals	8412	Other engines and motors
16	Metals	8503	Parts for use with electric generators
17	Metals	9007	Cinematographic cameras and projectors
18	Metals	8108	Titanium
19	Metals	8537	Electrical boards for protecting electrical circuits
20	Metals	8433	Harvesting or agricultural machinery

Source: Authors' calculations based on Allen Whitehead and Bhorat (2021) and The Growth Lab at Harvard University (2019)

Table A 5: Top 20 frontier products under scenario (4): Distance/feasibility focus

Rank	Chamber	HS Code	Product description
1	Plastics	2840	Borates; peroxoborates
2	Plastics	2902	Cyclic hydrocarbons
3	Metals	9018	Medical, surgical, dental or vet instruments
4	Metals	8805	Aircraft launching gear
5	Metals	9007	Cinematographic cameras and projectors
6	Plastics	2915	Saturated acyclic monocarboxylic acids
7	Metals	8607	Parts of railway locomotives
8	Plastics	2848	Phosphides
9	Metals	8545	Carbon articles for eletrical purposes
10	Plastics	2909	Ethers
11	Metals	9402	Medical, dental or veterinary furniture
12	Metals	8516	Electric heaters
13	Metals	7614	Aluminum wire, not insulated
14	Metals	9304	Other arms (air guns, truncheons, etc.)
15	Plastics	2904	Sulfonated, nitrated derivatives of hydrocarbons
16	Metals	8503	Parts for use with electric generators
17	New tyre	4016	Other articles of vulcanized rubber
18	Metals	8108	Titanium
19	Metals	8902	Fishing vessels
20	Metals	7212	Flat-rolled iron, width < 600mm, clad

Source: Authors' calculations based on Allen Whitehead and Bhorat (2021) and The Growth Lab at Harvard University (2019)

Development Policy Research Unit
University of Cape Town
Private Bag, Rondebosch 7701
Cape Town, South Africa
Tel: +27 21 650 5701
www.dpru.uct.ac.za