Economic Complexity and Employment Expansion:
The Case of South Africa

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1   Introduction

Economic complexity refers to the magnitude of productive knowledge or capabilities embedded in society (Hausmann, Hidalgo, Bustos et al., 2011).[1] Capabilities are akin to specialised bytes of knowledge distributed across individuals in society. The level of productive knowledge is not that contained within any individual, but rather that contained across the many individuals comprising society. When brought together through organisations and markets, these individual bits of knowledge bring into effect economic diversity. Economic diversity is reflected in a diversity of increasingly complex products (and services)[2]. The more productive knowledge a country has, the greater the diversity of products it can produce by combining these bits of knowledge, and thus the more complex it is.

Cross-country levels of economic complexity, and hence productive knowledge, are positively correlated with economic development (Hidalgo, Hausmann & Dasgupta, 2009). Shifts to higher levels of economic development are enabled through the process of structural transformation. Thus, building economic complexity, or accumulating productive knowledge, is associated with the process of structural transformation – shifts from low productivity activities toward high productivity activities. This is akin to the shift from less complex products toward more complex products (Hausmann, Hidalgo, Bustos et al., 2011).

However, this process of expanding the amount of productive knowledge and diversifying into new more complex activities is complicated by the 'chicken and egg' problem (Hausmann, Hidalgo, Bustos et al., 2011). Products, or industries more broadly, will not exist if the requisite capabilities are not present. However, the accumulation of these bits of knowledge is unlikely if the industries that require them do not exist. As such, it is easier for a country to diversify into related products: products where the required capabilities partly overlap with the country's existing capabilities. This is observed empirically where countries move from products that they already produce, to new products that are 'proximate' or 'related' in terms of the productive knowledge that they require (Hidalgo, Klinger, Barabási & Hausmann, 2007).

It is within this framework of understanding economic development, using the methodological tools from the Atlas of Economic Complexity, that we attempt to address the following objectives[3]: First, detail the level of economic complexity of the South African economy, and locate its relative level of complexity within the regional and global space. Second, examine the extent to which the South African economy has undergone complexity-led structural transformation. Third, identify avenues for South Africa to diversify toward an increasingly complex productive structure. And furthermore, examine whether these avenues have the potential to generate economic opportunities for women and youth.

The paper is structured as follows: Section 2 provides an overview of the performance of South Africa's post-apartheid economy. In order to provide a reference point from which to compare the targeted products (sectors) generated using complexity analytics, Section 3 reviews South African industrial policy, specifically the Industrial Policy Action Plan (IPAP). Section 4 does the following: First, South Africa's level of economic complexity is presented. South Africa's economic complexity in relation to regional groupings and other African economies is also examined. Second, the *product space* approach is used to examine South Africa's existing productive structure, as well the extent to which

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[1] The terms capabilities and productive knowledge are used interchangeably.

[2] The economic complexity analytics applied by Hausmann, Hidalgo, Bustos et al. (2011) is unable to take into account services, since disaggregated data on services across countries and time is sparse, of poor quality and not comparable across countries. The broader project under which this paper falls, acknowledges the increasing importance of service-orientated economic activities in economic development, and as such, a separate report focusing on the services economy in Africa is included within this project.

[3] Resources relating to the Atlas of Economic Complexity can be found on the Observatory of Economic Complexity website: http://atlas.media.mit.edu/en/.

it has undergone structural transformation in the post-apartheid period. Section 5 uses complexity analytics to identify potential channels for future diversification. The approach is unique in the sense that the avenues for diversification are identified at the granular product level.

In Section 6 we consider five industrial sectors that house a number of the frontier products, namely, agro-processing, transport, metals, machinery and equipment, and stone and glass. For each of these sectors, we describe the employment potential of the relevant frontier product, the diversification options that arise from manufacturing the product, and the constraints that hinder the realisation of the diversification path toward the frontier product. This is informed by firm and industry association interviews. Section 7 discusses employment trends for industries housing frontier products, by discussing whether growth in the industry will encourage higher levels of employment or not. This discussion focusses on the employment potential for women and youth. Section 8 of the paper identifies key themes that should inform policy considerations concerning diversification into the frontier products. Section 9 concludes.

2   South Africa's Growth Path: 1995 – 2016

After a tumultuous decade in the 1980s, both politically and economically, South Africa experienced a relatively prosperous post-1994 period, with the onset of democratic rule and the country's re-entry into the global economy. The optimism was not misplaced, with South Africa experiencing 55 quarters of uninterrupted GDP growth between 1995 Q1 and 2008 Q3 – one of the longest periods of sustained economic growth in South Africa's history (Bhorat & Oosthuizen, 2015).[4] This sustained period of economic growth is depicted in Figure 1, which shows the evolution of South Africa's real GDP per capita (left-hand y-axis), and real GDP per capita growth rate (right-hand y-axis) between 1995 and 2016.

Figure 1: Real GDP per capita and Real GDP per capita growth, 1995 - 2016
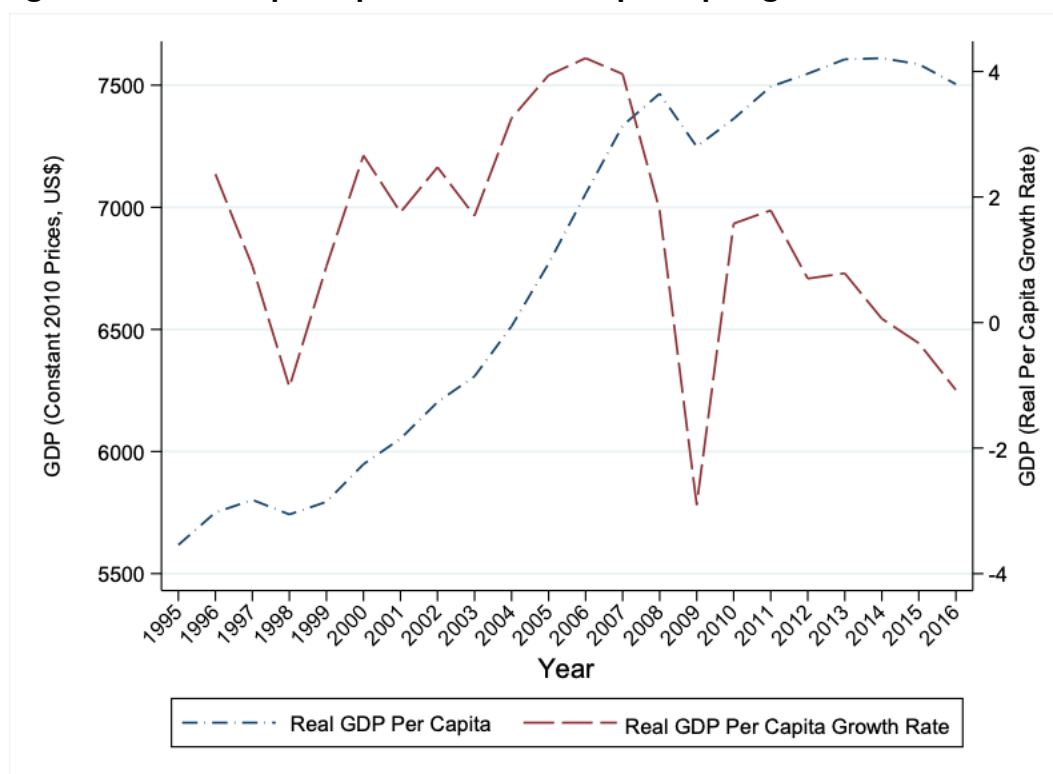
Source: World Development Indicators (2017), own calculations.

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[4] This is not reflected in Figure 1, which presents GDP per capita growth.

There are three distinct periods evident in Figure 1: Firstly, the period 1995 to 1999 is characterised by volatility, and thus a weak average annual growth rate of 0.78 percent. It is worth noting that in 1998, average income per capita declined compared to the previous year. This is largely a result of the East Asian financial crisis. Secondly, the post-2000 period enjoyed relatively strong and sustained growth, with per capita income increasing by 3 percent per annum between 2000 and 2007. Growth was particularly strong between 2004 and 2007, with the average annual growth rate exceeding 3 percent over this period. This period of growth is largely a result of the 2000s' commodity super cycle. Thirdly, with the onset of the global financial crisis in the final quarter of 2008, per capita income growth turned negative for the first time since 1998, decreasing by 2.9 percent from the previous year. Post-2009, growth has been subdued, with negative growth rates recorded in 2015 and 2016.

In absolute terms, real GDP per capita increased from $5 617 in 1995 to $7 504 in 2016 – an increase of $1 887 over 21 years, or equivalently, $90 per year. Growth in per capita income has been largely positive over this period apart from 1997-1998 (East Asian financial crisis), 2008-2009 (financial recession) and between 2015-2016 (post great recession). Real income has, however, stagnated between 2011 and 2016. In summary, the South African economy has experienced steady, albeit modest, real economic growth since the demise of apartheid.

However, this growth, and certainly in the aftermath of the 2008/2009 financial crisis, has been inadequate at generating sufficient employment opportunities for a growing labour force. The result is a perennially high unemployment rate. Bhorat, Cassim and Hirsch (2014) estimated employment elasticities for nine sectors in South Africa between 1997 and 2012, and found that six – or two-thirds – had an employment elasticity of below unity. In other words, employment growth was below that of GDP growth. Sectors that were least responsive to GDP growth were manufacturing (0.22), agriculture (0.37), and transport (0.42).

To provide context to South Africa's high unemployment rate, we compare it to other upper middle-income emerging economies in Figure 2 below.

Figure 2: Emerging Economy Unemployment Rates, 2016
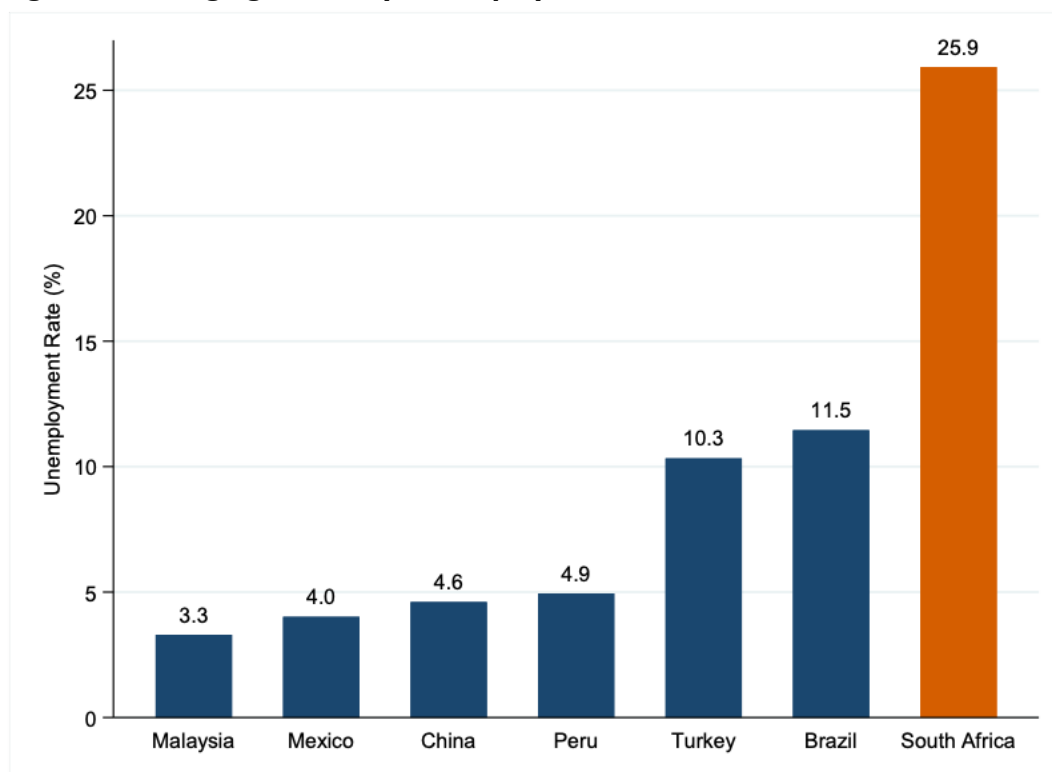
In comparison with other upper middle-income countries, South Africa's unemployment rate is extraordinarily high. Brazil's unemployment rate, which is the second highest in our sample, is less than half that of South Africa's. Furthermore, four of the seven countries considered yield single-digit unemployment rates. However, unlike these economies, South Africa does not have a large informal sector, and is thus unable to absorb the large number of low-skilled workers in the economy.

The unemployment challenge is that much greater when one considers the broad unemployment rate. The broad unemployment rate takes into account discouraged jobseekers, which in the South African case, is fairly pervasive. For example, the legacy of apartheid legislation means that many black workers are located far from cities, and as a result, job search is prohibitively costly. Figure 3 shows the narrow and broad unemployment rates, as well as the narrow rates for females and the youth, for the period 1995 to 2016.[5] The broad unemployment rate has consistently exceeded the 30 percent level throughout the period. For the past six years, it has stabilised at 35 to 36 percent levels, which is around 10 percentage points higher than the narrow unemployment rate. As such, a substantial share of the labour force is willing and able to work, but have become discouraged from searching for job opportunities.

Figure 3: Unemployment Rate – 1995-2016
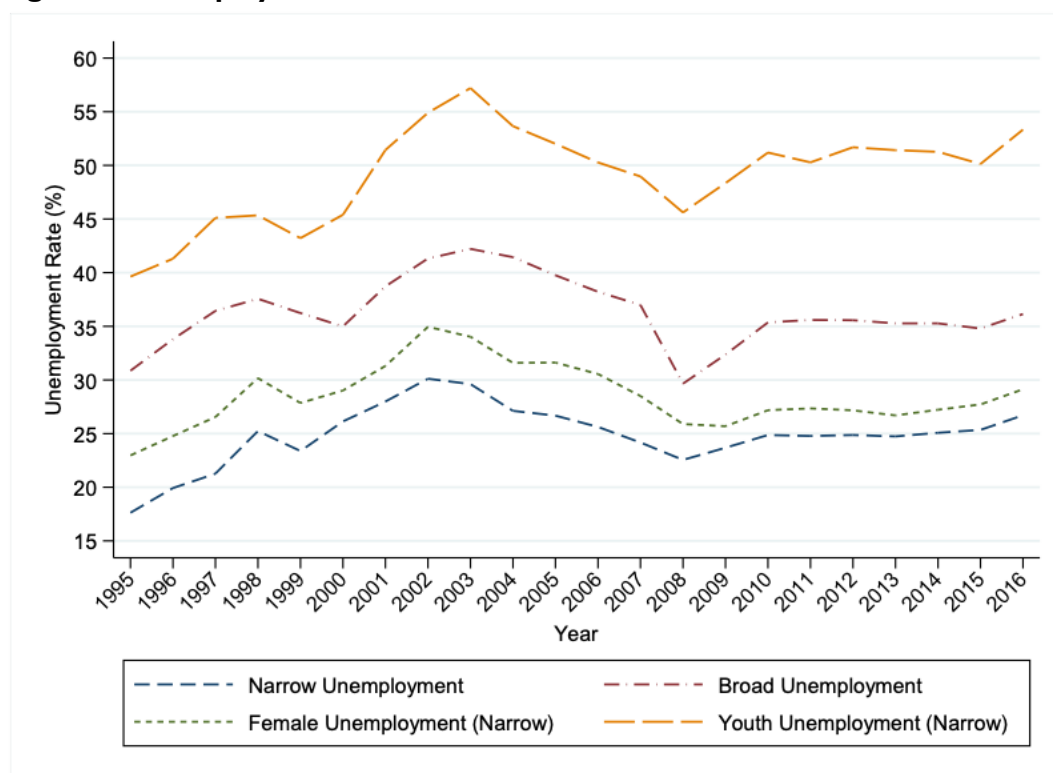
Source: OHS (1995-1999), LFS (2000-2007), QLFS (2008 – 2016), own calculations.
Notes: 1. Unemployment rates for 2000-2007 reflect an average of the bi-annual LFS. 2. Unemployment rates for 2008-2016 reflect an average of Quarterly Labour Force Surveys.

Both female and youth unemployment rates are higher than the aggregate unemployment rate. The female unemployment rate exceeds the aggregate rate by approximately 2 to 3 percentage points, and this gap has remained fixed over time. The picture for youth is far bleaker, with unemployment rates exceeding 50 percent since 2010 – effectively double the narrow aggregate unemployment rate.

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[5] "Youth" is defined as individuals aged between 15 and 24 years.

One of the major factors explaining high youth unemployment rates, is the lack of skills required for the job market. Indeed, approximately only 40 percent of students who begin Grade 2 eventually pass the Grade 12 school-leaving examination (Equal Education, 2017). In turn, of those 40 percent who successfully pass Grade 12, 18 percent register at university, with about half them dropping out of university before completing their studies (Nkosi, 2015). This leaves a large pool of youth who are not in education, thus significantly and negatively impacting on the probability of them obtaining employment or post-secondary training.

In Figure 4, we compare the share of youth Not in Education, Employment or Training (NEET) in South Africa, to countries of a similar economic profile. As with the unemployment rate, South Africa clearly has the biggest proportion of youth who are NEET, although the differences are not as pronounced as with the unemployment rate. Evidently, there is a large reservoir of untapped potential; youth, who with the right opportunities and training, could make a significant contribution towards enhanced productivity and economic growth in the South African economy.

Figure 4: Share of Youth Not in Education, Employment or Training, 2015
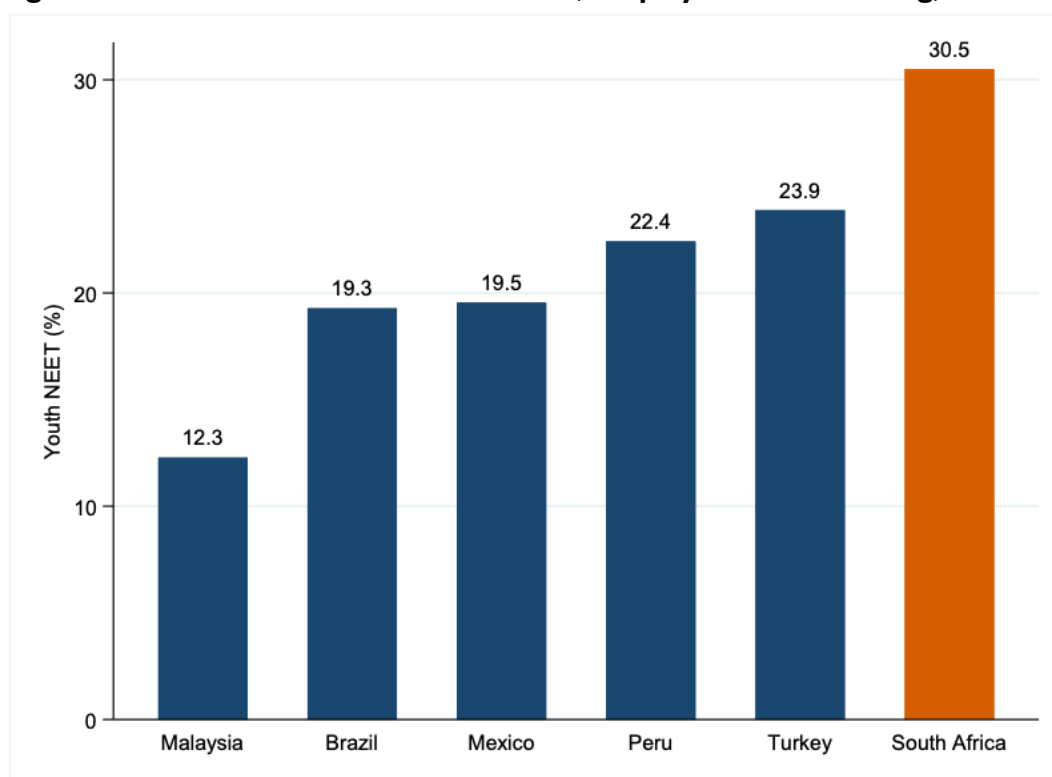
Source: ILO database, own calculations.
Note: The share of youth NEETs was unavailable for China.

The increase in unemployment despite steady economic growth is indicative of a growth path that is not labour absorbing. Both Bhorat and Hodge (1999) and Edwards (2001) have shown that there has been a structural shift in the South African economy towards more capital-intensive sectors.

Following the methodology outlined by McMillan et al. (2014), we examine the extent of structural transformation in South Africa between 1995 and 2016. Figure 5 shows the correlation between the natural log of relative productivity, and the change in employment by industry.[6] The size of the bubble represents the sector's share of employment in 2016. The linear regression line indicates whether the structural transformation is growth-inducing (positively sloped) or not (negatively sloped). Ideally, one

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[6] Productivity is calculated by dividing a sector's GDP by the number of individuals employed in that sector. Relative productivity is calculated by dividing the sector's productivity by the productivity of the entire economy.

would want to see declining employment shares in low-productivity industries (bottom left quadrant) and rising employment in high productivity industries (top right quadrant).

Although the slope is positive, the estimated coefficient is insignificant (p-value: 0.72), indicating that there is no evidence of growth-inducing structural transformation. Labour resources have thus shifted from low productivity agriculture to other low productivity sectors such as CSP services, domestic work, wholesale and retail trade, and construction. To a lesser extent though, there has also been some shift to the high productivity sectors in transport and financial services.

This structural transformation pattern contrasts with the East Asian model, which would depict manufacturing in the top right quadrant – i.e. a shift in labour resources toward high productivity manufacturing industries. In South Africa's case, the opposite has occurred, with manufacturing in the top left quadrant, suggesting a shift of labour away from this high productivity industry.

The main reason for this negative employment growth is due to an increased use of capital in the manufacturing sector (Edwards, 2001). In turn, this has changed the skills profile of the manufacturing sector from one which was dominated by low-skilled elementary workers, to highly-skilled workers (Edwards, 2001). As low-skilled workers are far more numerous than highly-skilled workers in South Africa, this shift resulted in substantial job losses occurring.

Figure 5: Correlation between Sectoral Productivity and Change in Employment in South Africa (1995-2016)
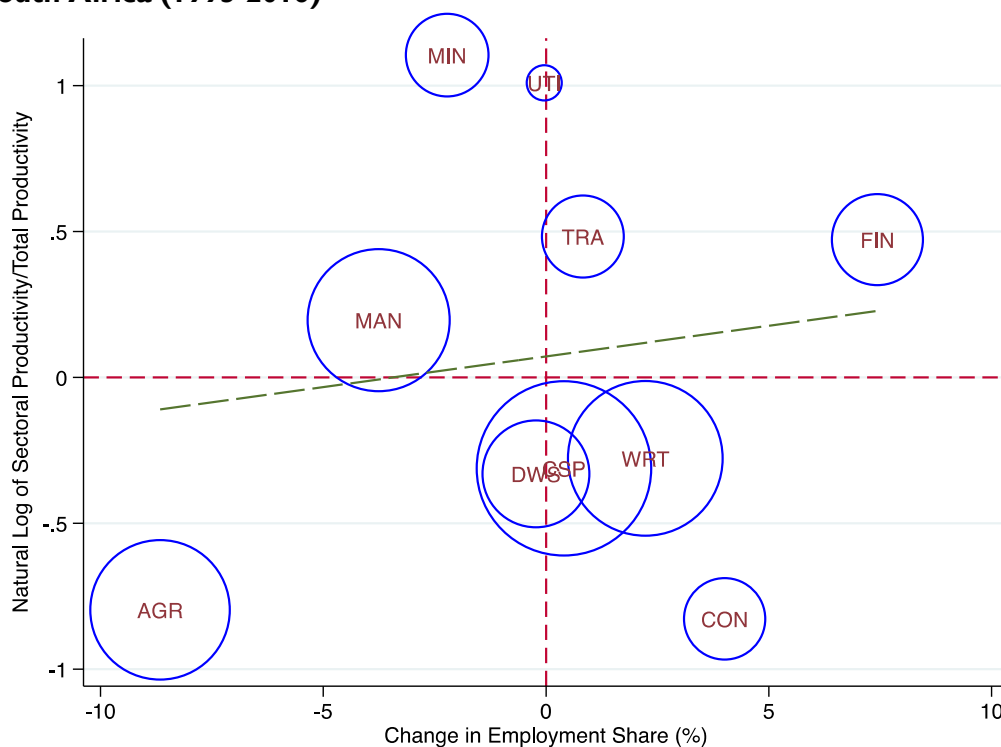
Source: Own calculations using SARB (2017).
Notes: 1. Size of circle indicates employment share in 2016. 2. $\beta = 0.02$ ($T - stat: 0.37, p - value: 0.72$) 3. AGR = Agriculture; MIN = Mining; MAN = Manufacturing; UTI = Utilities; CON = Construction; WRT = Wholesale & Retail Trade Services; TRA = Transport Services; BUS = Business Services; CSP = Community, Social and Personal Services; DWS = Domestic Worker Services.

The upshot of the above form of structural transformation, is that the South African economy is becoming increasingly reliant on those sectors represented in the services economy. Broadly speaking, the services sector experienced the highest employment growth, followed by the secondary sector, and finally the primary sector. Bhorat, Steenkamp and Rooney (2016) raise a few concerns with this growth path. Firstly, in the wholesale and retail sector, many individuals are in the low-productivity,

informal sector, making it difficult to conceive how this sector can facilitate growth. Secondly, while financial services is a high-productivity sector, much of the employment growth has come from an increase in demand for Temporary Employment Service workers, who are typically low-skilled (Bhorat, Cassim & Yu, 2016).[7] Thirdly, despite the generation of high productivity jobs in the financial services sector, the skill intensity of the sector acts as an impediment to large scale structural transformation given South Africa's large endowment of unskilled labour.

Arguably, the manufacturing sector remains key to growth-inducing structural transformation, and ultimately addressing South Africa's unemployment challenge. The evidence in Figure 5 suggests that South Africa has not followed a manufacturing-led growth path. Key to addressing this lack of manufacturing-led structural transformation – and the consequent lack of jobs, especially for women and the youth – is identifying and developing targeted industries within the manufacturing sector. As a start, we consider South Africa's current industrial policy, and the industries targeted by the current policy thinking. In so doing, we provide a reference from which to compare and critique the products and industries identified using the *economic complexity* framework.

3 South Africa's Industrial Policy

The implementation and development of a formal industrial policy in South Africa has accelerated since 2007, when the South African Cabinet approved the National Industrial Policy Framework (NIPF) (Zalk, 2014). The annually released Industrial Policy Action Plan (IPAP) is the implementation blueprint of the NIPF, and highlights specific focus areas and sectors for promotion and development. In designing the latest iteration of the IPAP (2017/18 – 2019/20), a number of key international and local issues were highlighted. These issues, to varying degrees, mitigate the effect that industrial policy can have on economic growth and development. In this section, we outline these issues and then discuss the key themes from the IPAP. Finally, we provide a summary of the key sectors identified in the IPAP, for the purposes of this paper. This list of targeted sectors evident in formal policy, serves as a comparator to the list generated using the complexity analytics, thereby allowing for a critique of existing policy.

3.1 Global and Local Issues Facing South Africa

The IPAP identifies three key constraints to industrial growth, emanating from international economic conditions. Firstly, the negative aftershocks stemming from the financial crisis of 2008/2009 have not fully dissipated, resulting in stagnant growth and an over-supply of goods, especially commodities (DTI, 2017). As a result, commodity prices remain below their pre-recession peak level. Secondly, in the USA and Western Europe, there is a growing backlash against globalisation (DTI, 2017). This backlash was symbolised by the United Kingdom's vote to leave the European Union, and the election of Donald Trump as the President of the USA. France, Austria, Italy, Greece and Scandinavian countries are also witnessing a surge in support for parties that advocate for more protectionist economic policies. Finally, there have been renewed fears about large job losses as a result of rapid technological advances in robotics, artificial intelligence and machine learning (DTI, 2017). The concern is that these advancements will not only affect low-skilled jobs, but semi- and highly-skilled jobs too. In a country with already high levels of unemployment, these disruptive technologies could lead to political instability if policies are not put in place to minimise the negative employment effects of these technologies.

Domestically, there are five main challenges that hamper the effectiveness of industrial policy. Firstly, despite service-led growth, South Africa remains resource dependent (DTI, 2017). In particular, mining is responsible for 16 percent of all foreign direct investment in South Africa and approximately a third

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[7] Temporary Employment Service workers are classified under the 'Business not elsewhere classified' sub-category, which falls under the broad financial services sector.

of export revenues (FSE, 2018). Furthermore, the strong economic growth experienced by South Africa between 2001 and 2008 was primarily as a result of the commodity price boom (DTI, 2017).

Secondly, the DTI is concerned with the growing prominence of the financial services sector (DTI, 2017). This sector has been growing at twice the rate of the 'productive sectors' – i.e. manufacturing – and has also attracted a significant proportion of investment (DTI, 2017). In particular, there has been an increase in portfolio investments from abroad, which are generally volatile and can create instability. Portfolio flows are quite different from FDI, which is long-term in nature and involves investment in physical infrastructure (CDE, 2013).

Thirdly, the industry concentration in the manufacturing sector is high (DTI, 2017). For example, Fedderke and Szalontai (2009) found that in 24 manufacturing subsectors, 5 percent of firms accounted for 50 percent of the output. In addition, they found that greater concentration is associated with lower employment and investment.

Fourthly, there are a variety of issues relating to infrastructure. The cost of electricity for industrial users – of which the manufacturing industry is a heavy user – increased by 291 percent between 2006/07 and 2015/16 (Department of Energy, 2016). Although the road, rail and port infrastructure is the best in Africa, South Africa's infrastructure competitiveness ranking has been slipping (Doke, 2015). This is largely as a result of an infrastructure backlog of R1.5 trillion, leading to inefficiencies within the transport sector, and subsequent rise in costs (Doke, 2015).

Lastly, the government has failed to create an environment that is conducive to business (DTI, 2017). South Africa's ranking in the World Bank's Doing Business Index, which measures the ease of starting and operating a business, has steadily declined from 32nd in 2008, to 74th in 2016.

In closing, South Africa faces various external and internal challenges that will constrain the effectiveness of industrial policy to guide the structural transformation of the South African economy. In the next section, we examine the key themes of the IPAP, taking into account the context described above.

3.2 Key Themes in the Industrial Action Policy Plan (IPAP)

As a central theme, the IPAP addresses the issue of slow growth and demand in the South African economy. The IPAP aims to stimulate growth and demand in more than one way. Firstly, the policy aims to strengthen domestic demand through the localisation of public procurement, and by encouraging private sector localisation and local supplier development. Secondly, the IPAP promises to accelerate and highlight the national Buy Back SA Campaign launched by the DTI in 2013. The campaign aims to encourage South African companies and consumers to buy locally produced goods rather than cheaper imports, in order to support the local economy and create jobs. Thirdly, the policy highlights efforts to stimulate internationally generated growth by supporting existing exporters and developing new export-ready firms. The IPAP also promotes beneficiation, which aims to harness the country's resource endowment as a global competitive advantage, transforming primary materials such as minerals into more value-added finished products for export. Finally, the IPAP proposes expanding technology-intensive exports, particularly in the electrical-technical and whites goods (e.g. televisions, refrigerators, etc.)

While the IPAP promotes export growth, it also highlights the threat that international trade presents in the form of illegal dumping of cheap imports into the country. For example, one case found that dumping of stainless steel sinks from China and Malaysia resulted in damage to South Africa's stainless steel sink industry (International Trade Administration Commission, 2009). As a result, the IPAP highlights the illegal economy as a focus area, directing the efforts of the security cluster and the National Regulator for Compulsory Specifications to lock out illegal and sub-standard imports.

Another dominant theme in the IPAP relates to one of the economy's greatest challenges – a persistently high unemployment rate. In light of the unemployment challenge, several of the IPAP key themes are directly focused on using industrial policy as a possible solution. In particular, the IPAP highlights the growth of labour-intensive industries, particularly across the value chains that link the country's primary and secondary sectors. This goal of labour-intensive industrialisation is also a guiding principle for the identification of specific sectors that the IPAP promotes, namely: agro-processing, CTLF (clothing, textiles, leather and footwear), and component manufacturing.

The IPAP not only highlights employment growth in general, but also focuses specifically on employment amongst the economically marginalised. The apartheid era left the South African economy with major and persistent challenges – it is one of the most unequal societies in the world with a significantly high proportion of households living in poverty. Race and gender are important determinants of inequality and poverty in South Africa, where females and non-Whites are the most economically marginalised groups (Bhorat & van der Westhuizen, 2012). Therefore, a key focal point of the IPAP is to scale up the efforts to secure shared and inclusive growth, where wealth, economic management, and ownership, are transformed from their currently unequal state. According to the IPAP, the realisation of these goals can be achieved through the creation of decent jobs in labour intensive sectors, and through providing commercial support measures to the 'Black Industrialist' programme.

The IPAP identifies manufacturing as a labour-intensive sector that can provide secure wage employment to individuals of various skill types. According to the Global Manufacturing Competitiveness Index, although South Africa is ranked in the top 30, its ranking has been deteriorating over recent years (Deloitte, 2016). In order for this industry to develop, specifically as a driver for job creation, the IPAP identifies a need to build a less concentrated and more competitive manufacturing sector by removing barriers to entry for entrants. The 'Manufacturing Competitiveness Enhancement Programme' and the 'Furniture Competitiveness Programme', are examples of actions taken by the Department of Trade and Industry to reach this goal.[8]

The IPAP also identifies reducing bureaucracy as an important tool for ensuring increased competitiveness. As previously discussed, South Africa's Doing Business Index ranking has decreased significantly over the past nine years. This suggests that the regulatory environment may present challenges for businesses, a factor that can limit productive investment in the economy. Therefore, the IPAP highlights the need for a well-regulated and integrated investment framework to increase the economy's productive capital inflows. To support this goal and make the economy more investor friendly, the DTI launched the Invest South Africa One Stop Shop in May 2017. Besides this focus on the regulatory environment, the IPAP also identifies a need to build a stronger system of industrial finance and incentives to support and secure increased investment in the productive sectors of the economy.

The IPAP highlights the effects of technology on the economy in two ways. Firstly, if effectively harnessed, advances in technology have the potential to support and stimulate economic performance and competitiveness among firms in the economy (for example, see Soto-Acosta, Popa & Palacios-Marqués, 2016). Additionally, the IPAP examines the optimisation of technology transfer and diffusion across South African firms, as well as the commercialisation of locally developed research and design. This is exemplified in the creation of the Department of Science and Technology's "Technology Localisation Implementation Unit". Secondly, the IPAP highlights the impending effects of the "Fourth Industrial Revolution" – the global movement towards highly complex technological capabilities in the form of artificial intelligence, robotics, and big data. These advances in industrial technology could be highly disruptive to the South African economy, given their potential to change standard industrial

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[8] The key objective of the 'Manufacturing Competitiveness Enhancement Programme' is to assist manufacturing companies with working capital. The key objective of the "Furniture Competitiveness Programme' is to position the South African furniture industry as a producer of niche, high value products.

processes in the manufacturing and services sectors. Of key concern is a shift to greater automation and capital-intensity, at the expense of employment, thereby threatening to exacerbate already high unemployment levels. Thus, the IPAP highlights the importance of understanding these emergent technologies, as well as adapting South Africa's productive and services sectors to these changes and limiting job losses resulting from them.

Another focus of the IPAP is to promote South Africa's gas industry. This sector is one of the priorities of the IPAP because of its potential to have significant economic and employment effects, to balance the country's energy-mix, and because of its low carbon-intensity. Various initiatives are already in place to promote gas industrialisation, for example: the development of Liquid Gas Petroleum and Liquid Natural Gas; gas-to-power requests for proposals; and the expansion of the Sasol pipeline. Furthermore, the Gas Industrialisation Unit was launched by the DTI in 2016 to spearhead South Africa's gas industrialisation implementation strategy. Besides this focus on gas, the IPAP also highlights the promotion of green technology in all sectors of the economy. The policy aims to prioritise energy-efficient production and carbon mitigation to allow for sustainable adaptation in all South African industries.

Lastly, it is essential that South Africa's various industrial policy documents are aligned and complementary. Kaplan (2013) compares the IPAP, the National Development Plan (NDP) and the New Growth Path (NGP) in order to identify areas of agreement and conflict. The report finds that while the documents broadly identify employment creation as a key objective of economic policy, major disagreements arise regarding the sectors and activities proposed to create employment opportunities, as well as their identification of the constraints to South Africa's economic development. A key theme of the IPAP is therefore programme alignment, with a focus on streamlining relevant inter-departmental policies and programmes in order to reduce implementation bottlenecks and ensure that all departments work together to support the industrialisation effort.

3.3 Target Sectors in the IPAP

In light of the key issues and themes identified in the IPAP, the DTI targeted 14 sectors for growth. These are outlined in Table 1 below, including the associated programmes / initiatives. It is worth noting that as it stands, the IPAP does not describe a manufacturing strategy. Rather, the focus is on downstream activities in certain sectors, which can be captured as a form of manufacturing.

Table 1: IPAP Target Sectors

Sector	Programmes/Initiatives
Automotives	• Competitiveness Improvement • Autos Master Plan
Clothing, textiles, leather and footwear	• CTCP Impact Monitoring • Beneficiation: Clusters and Hubs
Metal fabrication, capital and rail transport equipment	• Designation / localisation • Company-level enhancement • Jewellery Industry Support Programme
Agro-processing	• Agro-processing Framework • Niche Opportunity Programme • Food Retailer Procurement Strategy / Charter • Priority Product Identification for Large Scale Localisation
Forestry, timber, paper, pulp and furniture	• Furniture competitiveness • Furniture market access development • Regional development programme in forestry value chain • SA paper recycling programme
Plastics	• Designation / localisation • Plastic components cluster

Sector	Programmes/Initiatives
	• Trade Policy Measures • Recycling
Chemicals, pharmaceuticals and cosmetics	• Chemicals and Bio-Chemicals Development Plan • Biopharmaceuticals Innovation Forum • Preferential Measures for Locally Manufactured Medicines • Medical Devices Supplier Development Programme • Advanced Bio-Manufacturing Hub • Aerosol Manufacturing Development Programme • Natural Ingredients Export Development Strategy
Primary minerals beneficiation	• Maximising the Industrial Potential of Southern African gas resources • Energy Storage Development • Fuel Cell Industry Development • Expansion of PGM Beneficiation Industries • Steel Sector Supply-Side Interventions • Monitor and Evaluate Reciprocal Commitments by Steel Industry Stakeholders • Establish Mining R&D Hub at CSIR
Green industries	• Policy Roadmap for Climate-Compatible Industrial Development • Strategic National Smart Grid Vision for the South African Electricity Industry
Business Process Services	• Implement the new BPS Incentive • Talent Development for the BPS Sector
Water and sanitation	• Water Industrialisation Development Plan • Desalination in Manufacturing • Next Generation Sanitation Cluster Development • Advanced Wastewater Technologies in Manufacturing
Marine manufacturing and associated services	• Designation and Localisation Programme • Components Supplier Development Programme • Skills Development Programme for Increase Competitiveness • Tariff Measures to Encourage Domestic Component Manufacturing
Aerospace and defence	• Technology Enhancement for High Value Manufacturing in Aerospace Industry
Electro-technical and white goods industries	• Local Procurement of Vaccine Refrigerators • Supplier Development Programme for White Goods Industry • Localisation of Products Largely Procured by National Department of Public Works

Source: DTI (2017)

Out of the 14 sectors, 13 are located within the manufacturing sector, with the exception of Business Process Services. This aligns with the emphasis on labour-intensive growth in the IPAP. However, as described in Section 2, manufacturing has not been driving structural transformation in South Africa, which brings into question whether this emphasis is misplaced.

As can be seen from Table 1, however, industrial policy has an aggregated approach towards the growth of industries. For example, the IPAP discusses developing the agro-processing industry without detailing which crops would be best suited for agro-processing. Our approach, which will be explained in greater detail in the following section, will be more granular. Returning to the agro-processing

example, our methodology might find that potatoes or groundnuts would be the best choices for growing the agro-processing industry in the future.

A second shortcoming of the IPAP, is the methodology for choosing the targeted sectors is not clearly explained. As previously discussed, the sectors seem to have been chosen with the biggest potential for future growth and employment creation as the primary criteria. However, there is little explanation in the IPAP on how the DTI identified these sectors as having high growth and employment potential. In contrast, our methodology will clearly elucidate how we identified the products with the most growth potential. In the conclusion, we will compare the results of the two approaches and identify similarities and differences.

Thirdly, although the IPAP speaks about employment creation, it does not specifically speak about female or youth employment. These two groups experience higher unemployment rates than the overall employment rate, and therefore should be a priority focus. Our framework will account for these two groups by examining the proportion of females and youth employed in industries which have the greatest growth potential.

This will aid policymakers in designing well-targeted policies, which will facilitate a more inclusive, sustainable growth path for South Africa.

4   The Accumulation of Productive Capabilities: An Alternative Approach to Understanding Structural Transformation

Building economic complexity, or accumulating productive knowledge, is associated with the process of structural transformation – the shift from low productivity (or low complexity) activities toward high productivity (or high complexity) activities (Hausmann et al., 2011). In this section, we consider South Africa's level of economic complexity, particularly, in relation to that of other regions. Using the *product space*, we examine the extent to which South Africa has undergone structural transformation, and hence shifted toward more complex productive activities in the post-apartheid period. It is important to note that within this section, we provide the methodological basis for measuring economic complexity and analysing structural transformation using the *product space*.

4.1 The Economic Complexity of the South African Economy

4.1.1 The Notion of Economic Complexity

The authors of the Atlas of Economic Complexity (Hausmann et al., 2014) provide an alternative approach to thinking about how countries undergo structural transformation and thereby develop and grow. Economic Complexity represents a shift away from aggregates when thinking about growth and development. Rather, in order to understand the process of development, there is a shift toward exploiting the richness and complexity of an economy in reality. There is a move away from thinking about growth only in terms of the accumulation of factors of production. Rather, economic growth and development can be thought of as being about the accumulation of productive capabilities or productive know-how within complex networks of interactions among productive agents. Growth is not about producing more of the same. Instead, it's about producing a diversity of products (and services) that do not (yet) exist, using techniques that do not (yet) exist.

Growth is about increasing productivity. Higher productivity is achieved through productive agents (for example an entrepreneur) being able to access networks of productive know-how or capabilities. Hidalgo, Hausmann and Dasgupta (2009) describe these productive capabilities as non-tradable networks of collective know-how, such as logistics networks, finance networks, supply networks, and knowledge networks. For example, a commercial farmer is more productive if she is able to access networks that distribute seed and fertiliser, financial networks that facilitate investment in machinery and equipment, domestic and international product markets, and the like. Individual capabilities or

productive know-how is not as important as societal capabilities. Therefore, development is about the accumulation of know-how across society, which is expressed in the production of a greater diversity of increasingly complex products.[9]

Since there is no direct means of measuring the amount of productive know-how embedded within a country, the CID develop an indirect measure that is derived from international trade data. This measure is called the economic complexity index (ECI).

In order to measure the productive capabilities of a country, Hidalgo, Hausmann and Dasgupta (2009) use international trade data to examine what products countries make, and from this, infer their productive capabilities.[10] Two components inform the construction of ECI: Firstly, countries with individuals and firms that possess more productive capabilities produce a greater diversity of products. Secondly, products that require large amounts of productive capabilities are only produced in the few countries where this knowledge is available. Therefore, the more diverse a country's export basket and the less ubiquitous the products that comprise this basket, the more productive capabilities embedded in its economy.

Figure 6 provides an hypothetical example on how the dual measures of diversity and ubiquity are used in the measurement of the ECI (and, analogously, the product complexity index (PCI)). The diversity measure suggests that the most complex country is Holland (5 products), followed by Argentina (3 products) and then Ghana (1 product). More productive knowledge, and hence economic complexity, is inferred from greater product diversity. By further taking into account the average ubiquity of the products that each country produces, the ordering of economic complexity is substantiated further.[11] For example, Holland produces the two least ubiquitous products, x-ray machines and pharmaceuticals, suggesting in part some form of specialised capabilities in the production and export of these goods. In contrast, Ghana produces only one product, frozen fish, and that product is the most ubiquitous product. Ghana has the productive capabilities to produce just this product, and this product is also produced by the other two countries, which further suggests that these productive capabilities are common and basic. Therefore, using diversity and ubiquity, one is able to measure that Holland is the most complex of the three countries, while Ghana is the least complex.

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[9] This stands in contrast to most trade theories that posit countries accumulating factors of production that allow them to specialise in a set of products determined by their relative comparative advantage.

[10] Complexity analytics use international trade data since this enables one to compare a wide cross-section of countries over long periods of time using a consistent set of product categories. Although the analytics use export data, Hausmann, Hidalgo, Bustos et al. (2011) contend that exports are a fairly good reflection of a country's productive structure.

[11] The average ubiquity of the productive structure of Holland (9/5), Argentina (7/3) and Ghana (3/1) is 1.8, 2.3 and 3, respectively. A lower average ubiquity for a country points to greater economic complexity because fewer other countries, on average, are able to make what it makes. From this, one can infer that it possesses unique and specialized capabilities that enable it to produce less ubiquitous products.

Figure 6: Example of Country-Product Network used in Method of Reflections

Diversity	Countries	Products	Ubiquity

$K_{c,0} = 5$ Holland   X-ray machines $K_{p,0} = 1$

Pharmaceuticals $K_{p,0} = 1$

$K_{c,0} = 3$ Argentina   Creams $K_{p,0} = 2$

Cheese $K_{p,0} = 2$

$K_{c,0} = 1$ Ghana   Frozen fish $K_{p,0} = 3$
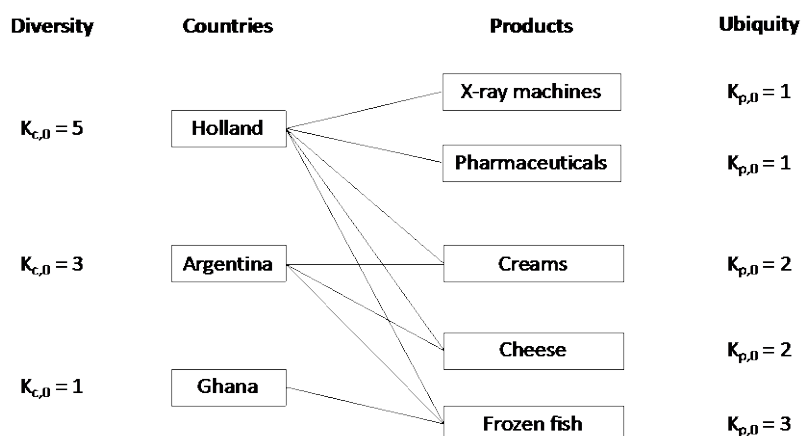
Analogously from the product side, x-ray machines and pharmaceuticals are the least ubiquitous products. Since only one country, Holland, is able to produce them, it suggests that the productive knowledge needed to produce them is scarce and specialised. Hence, these products are the most complex in Figure 6. This conclusion is further substantiated by the fact that the only country able to produce these products is the most diverse country – Holland. For similar reasoning, frozen fish is the least complex product. All three countries produce this product and thus it is the most ubiquitous of the five products. Furthermore, the least diverse country, Ghana, is also able to produce this product.

Using information on ubiquity to further substantiate or correct information on diversity is evident in Figure 7. The horizontal axis shows the export diversity of countries in 2014, while the vertical axis shows the average ubiquity of the products comprising each country's export basket.[12] If one were to only consider diversity when measuring economic complexity, then Pakistan (PAK) and Switzerland (CHE), both having a diversity measure of approximately 200 products, would be equally complex. However, after considering the average ubiquity of the products comprising each of these countries' export structures, it is evident that, on average, the products that Switzerland is able to export are exported by fewer countries (16). Those exported by Pakistan are, on average, exported by many more countries (25). This suggests that the productive capabilities present in the Swiss economy are less common and more specialised, while those in the Pakistani economy are more common and less specialised.

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[12] Note that a product at the HS4 level is considered to be exported by country c if its revealed comparative advantage is equal to unity or greater.

Figure 7: Diversity in relation to average ubiquity

Source: Own calculation using data from The Economic Complexity Observatory (Simoes & Hidalgo, 2011) and CID (2018)

Therefore, one can improve the estimate of the productive knowledge of a country that is inferred from its diversity by looking at the ubiquity of the products that it makes. This estimate can be further refined by looking at the diversity of the countries that make these products, and the ubiquity of the products that these countries make. This can be done an infinite number of times using a mathematical process known as the Method of Reflections. This process converges after a few iterations and generates the quantitative measures for complexity for countries (ECI) and, analogously, products (PCI).

Drawing on Hidalgo, Hausmann and Dasgupta (2009), a formal explanation on the measurement of economic complexity is provided in Box 1.

Box 1: Technical Explanation for the Measurement of Economic Complexity

Using bilateral trade data, M_{cp} is the element of a matrix M, which is 1 if country c produces product p, and 0 otherwise. Diversity and ubiquity are measured by summing over the rows or columns of the matrix. Formally this is defined as:

$$Diversity = k_{c,0} = \sum_p M_{cp} \tag{1}$$

$$Ubiquity = k_{p,0} = \sum_c M_{cp} \tag{2}$$

To generate a more accurate measure of the number of productive capabilities embedded within a country, or required by a product, one needs to correct the information that diversity and ubiquity carry by using each one to correct for the other. For countries, this requires one to calculate the average ubiquity of the products that it exports, the average diversity of the countries that make those products that it exports, and so forth. For products, this requires one to calculate the average density of the countries that make them, and the average ubiquity of the other products that these countries make. This can be expressed as follows:

$$k_{c,N} = \frac{1}{k_{c,0}} \sum_p M_{cp} . k_{p,N-1} \tag{3}$$

$$k_{p,N} = \frac{1}{k_{p,0}} \sum_c M_{cp} . k_{c,N-1} \tag{4}$$

This mathematical process converges after a few iterations, and generates measures of complexity for countries, ECI; and measures of complexity for products, PCI. Formally, this is presented by manipulating equations (3) and (4) to arrive at:

$$k_{c,N} = \sum_{c'} \tilde{M}_{cc'} k_{c',N-2} \tag{5}$$

This corresponds to the eigenvector capturing the largest eigenvalue in the system. Eigenvalues represent the measure of economic complexity. More formally, this is represented as:

$$ECI = \frac{\vec{K} - <\vec{K}>}{stdev(\vec{K})} \tag{6}$$

In the equation, $<>$ and $stdev$ represent average and standard deviation, respectively. $\vec{K}$ represents the eigenvector of $\tilde{M}_{cc'}$ associated with the second largest eigenvalue[13]. This procedure allows for the generation of the measures: ECI, which measures the productive capabilities specific to each country; and PCI, which measures the productive capabilities needed to produce a product.

Source: Hausmann et al. (2014) and Hidalgo, Hausmann & Dasgupta (2009)

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[13] The eigenvector associated with the second-largest eigenvalue is used because the largest eigenvalue satisfying equation (5) is always a vector of ones, and this is not informative. Hence, by using the second-largest eigenvalue, an informative measure of complexity can be constructed.

4.1.2 South Africa's Relative Economic Complexity

Hausmann et al. (2014) show that ECI is closely linked to a country's level of development and is predictive of its future economic growth. It is thus interesting to locate South Africa within the global complexity space. In Figure 8, we plot economic complexity and the natural log of GDP per capita, and differentiate across countries by World Bank income grouping. It is evident that economic complexity is correlated with level of development. High-income countries tend to have more complex economies. The opposite is also true. Deviations from the regression line, for a given level of complexity, provide further insights. For example, South Africa (ZAF), Brazil (BRA), Argentina (ARG), Columbia (COL), Saudi Arabia (SAU) and the United Arab Emirates (ARE) all have similar levels of economic complexity. Nevertheless, the latter two Middle Eastern countries have substantially higher levels of income, which is related to their natural resource abundance, particularly, an abundance of petroleum oil.

Figure 8: Economic Complexity and GDP, 2014
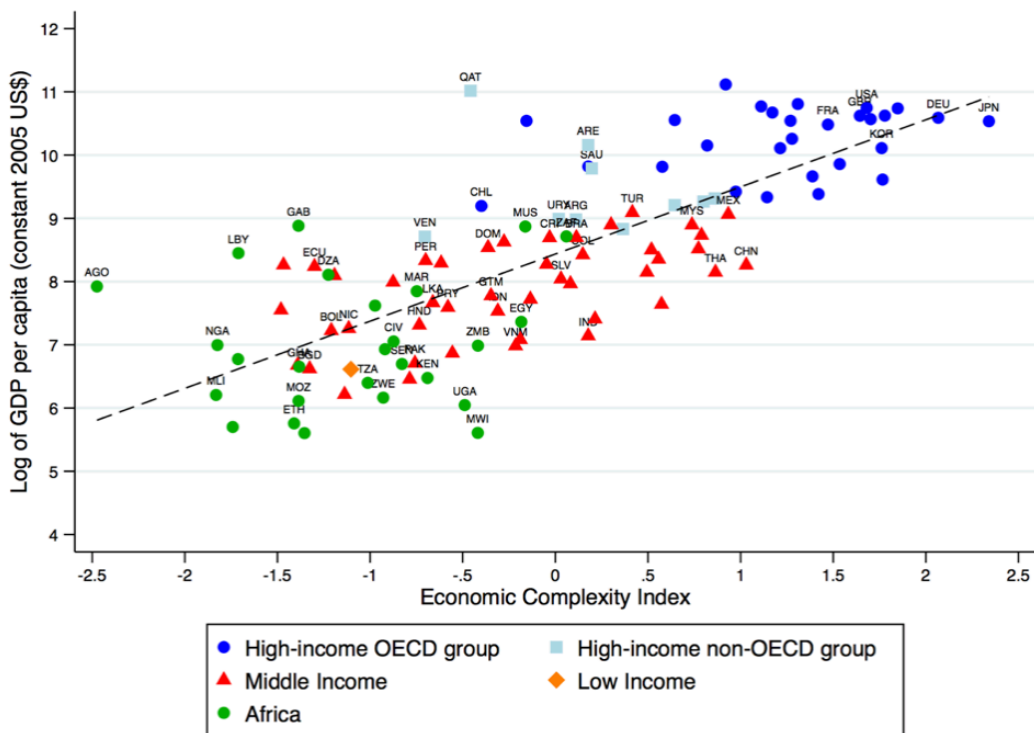
Source: Own calculation using data from The Economic Complexity Observatory (Simoes & Hidalgo, 2011) and CID (2018)
Notes: 1. ZAF is the ISO 3-digit country code for South Africa.

South Africa is a middle-income country and its GDP per capita is slightly higher than average. South Africa's economic complexity is also situated at the centre of the group at 0.06. South Africa is relatively more complex than almost all African countries, while being one of the more complex developing country economies. In Figure 9, we present South Africa's ECI relative to other African countries and regional groupings. The South African economy (0.06) is more complex than every other African economy other than Tunisia (0.16). Therefore, South Africa's productive capabilities are above the regional aggregates for Sub-Saharan Africa (-1.10) and North Africa (-0.74). The South African ECI is higher than the developing world regional aggregates for South Asia (-0.64), South America (-0.45), Central America (-0.31), and Middle East (-0.08). However, South Africa's relative complexity is lower than regional aggregates comprising more developed countries, such as Eastern Europe (0.19), East Asia & Pacific (0.19), North America (1.16), and Europe (1.31).
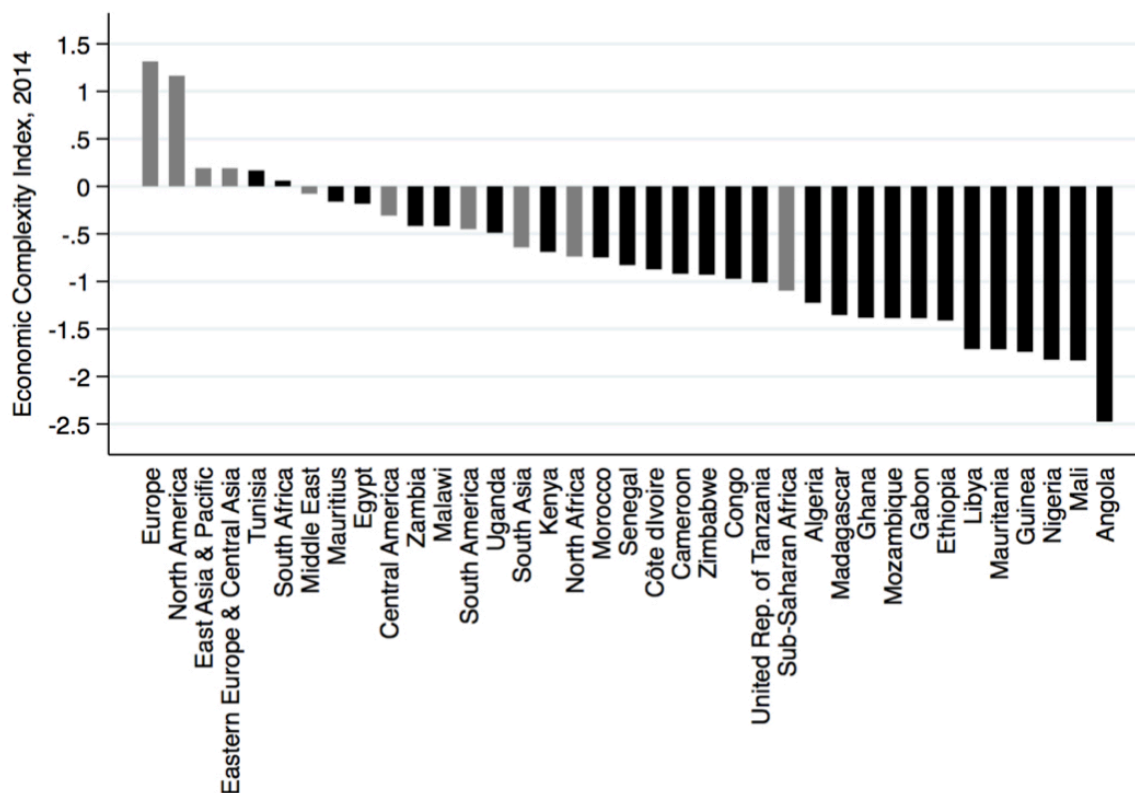
Figure 9: South Africa's Relative Economic Complexity, 2014

Source: Own calculation using data from The Economic Complexity Observatory (Simoes & Hidalgo, 2011) and CID (2018)
Notes: 1. Bars for regional aggregates a shaded in grey, whereby aggregate is a simple mean of the ECI for countries comprising each region.

4.1.3 Economic Complexity and Manufacturing

We now consider whether there is a link between the economic complexity of an economy and its ability to produce a diverse range of manufacturing products. Following, Bhorat, Steenkamp and Rooney (2016), Figure 10 plots the economic complexity index, and the number of manufactured products a country exports with a revealed comparative advantage of unity or more.[14] A number of points emerge: Firstly, it is clear that countries with more product knowledge, indicated by a higher ECI, tend to produce a greater diversity of manufactured products. Secondly, there is substantial variation among the high-income group, where some high-income countries export a similar number of manufactured products to low-income countries. These are typically non-OECD oil-based economies (e.g. Saudi-Arabia (SAU); United Arab Emirates (ARE); and Qatar (QAT)). Thirdly, there is also substantial variation among the middle-income group, with China having the greatest manufacturing diversity of all countries in the sample. South Africa placed at the mean (the mean number of manufactured products is 126 and South Africa has 128), and there a number of middle-income countries producing similar numbers of manufacturing products to low-income countries.

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[14] Following Hausmann et al. (2014), in order to code a country as exporting a product, we determine whether it has a revealed comparative advantage in that product. As such, we try to focus on major exporters of a product and remove all insignificant instances where a country may marginally export a product.

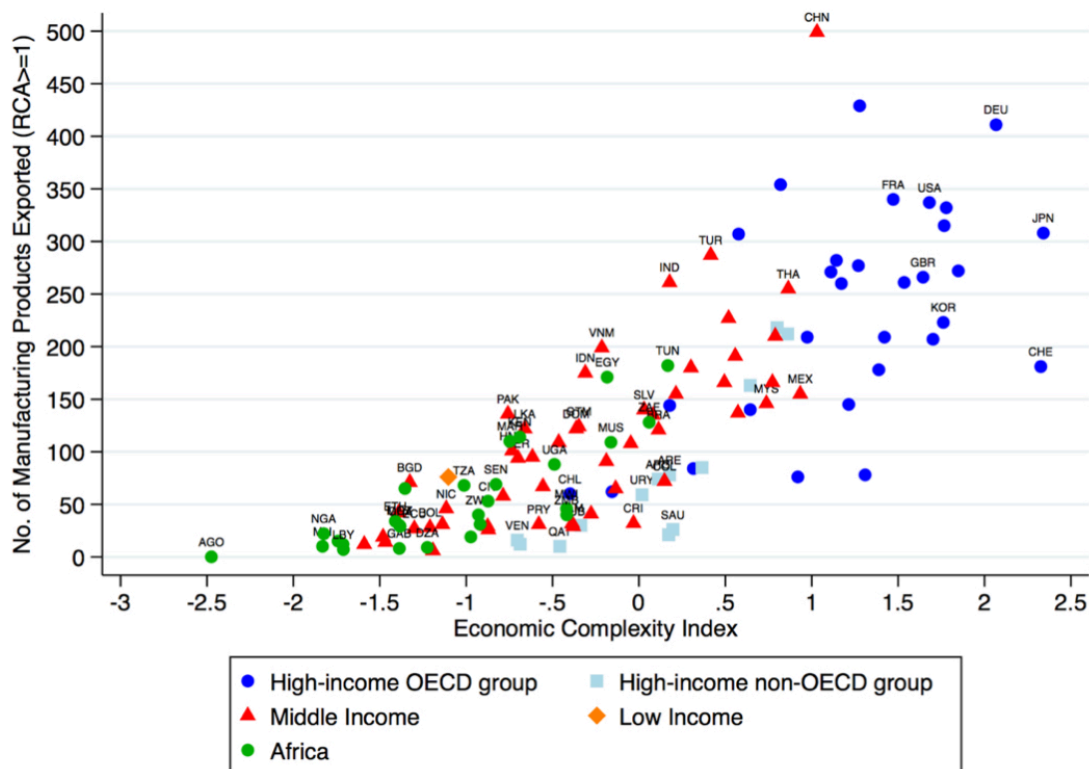**Figure 10: Economic Complexity and Number of Manufactured Products (RCA>=1), 2014**

Source: Own calculation using data from The Economic Complexity Observatory (Simoes & Hidalgo, 2011) and CID (2018)
Notes: 1. ZAF is the ISO 3-digit country code for South Africa. 2. Trade data is analysed at the HS 4-digit level. 3. A HS product line is coded as a 1 if a country has a RCA greater or equal to unity.

In this section, despite some heterogeneity, two important points emerge: Firstly, countries that are more complex (i.e. have more productive knowledge) are more developed. Secondly, countries that are more complex produce a greater diversity of manufactured products, which are typically characterised by higher levels of product complexity. This does suggest that the accumulation of productive knowledge allows countries to produce a greater diversity of increasingly complex products. These increasingly complex products tend to be manufactured products. In the next section, we use another tool from the Atlas of Economic Complexity – the *product space* – to examine the evolution of South Africa's productive structure in more detail.

4.2 Structural Transformation: Locating the South African Economy within the Product Space

4.2.1 The Notion of the Product Space

Drawing on Hausmann et al. (2014) one can posit that structural transformation is the process whereby countries accumulate productive capabilities and diversify toward increasingly complex products, thereby becoming more complex. Analyses in the previous section, and that found in Hidalgo, Hausman and Dasgupta (2009), show that higher levels of complexity are correlated with higher levels of development. Therefore, in order to develop and grow in economic complexity, countries need to accumulate new productive capabilities.

However, the accumulation of new productive capabilities, and hence the ability to produce more complex products, is complicated by what Hausmann et al. (2014) term the 'chicken and egg problem'.

A country cannot produce products that require productive capabilities that it does not have. At the same time, there is no incentive to accumulate productive capabilities if the industries that demand them do not exist. This is especially true if the productive capabilities required by a new product are significantly divergent from those already embodied in a country's current productive structure.

The question remains: how do countries accumulate new productive capabilities and produce the new products that require such capabilities? In research by Hidalgo, Klinger, Barabáse and Hausmann (2007) and Hausmann et al. (2014), it is argued that new capabilities are more easily accumulated if they are combined with others that already exist. This implies that countries will move from industries that already exist, to others that require a similar set of capabilities. It is easier to shift from shirts to blouses, than from shirts to jet engines, because the productive capabilities embedded in shirts is similar or proximate to those of blouses, but dissimilar to those of jet engines.

As mentioned above, we do not observe capabilities – and thus measuring the similarity in capability requirements for different pairs of products, is no simple task. Hidalgo et al. (2007) generate an indirect measure that infers the similarity between capabilities required by a pair of products by looking at the probability that they are co-exported.[15] The probability that a pair of products are co-exported, carries information on the similarity in productive capabilities embedded in both products. This is based on the assumption that if two products share most of the requisite capabilities, the countries that export the one will also export the other. Relatedly, if the two products do not share many capabilities, then they are less likely to be co-exported. This logic allows one to measure the proximity between all pairs of products, thereby creating a network of proximities between products that form the structure of the product space. This is discussed in more detail in Box 2.

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[15] A pair of products, such as shirts and blouses, are co-exported if two or more countries export both these products.

Box 2: Generating the Product Space

In order to create the product space, Hidalgo et al. (2007) use product-level trade data at the 4-digit level of the Harmonised System (HS) (1241 product groups) and the Standard Industrial Trade Classification (SITC) (1033 product groups). The product space is comprised of nodes, and links connecting the nodes. The nodes represent products, and the links represent the proximity between the two connected products – shorter and thicker lines indicate high proximity. The size of the node can be adjusted to represent the share of that product in a country's total trade.

A country is deemed to export a product if the revealed comparative advantage (RCA) measure for the country-product combination is greater than or equal to unity. This restricts country exports to substantial exports, and eliminates marginal exports. The RCA is calculated as follows:

$$RCA_{cp} = \frac{X_{cp}}{\sum_c X_{cp}} \Big/ \frac{\sum_p X_{cp}}{\sum_{c,p} X_{cp}} \qquad (7)$$

The RCA captures the share of product p in country c's total exports relative to the share of product p in total world exports. Using the RCA as an indication of a country being a substantial exporter of a product, the proximity between a pair of products, p and j, is defined as such:

$$\phi_{pj} = min\{P(RCA_p|RCA_j), P(RCA_j|RCA_p)\} \qquad (8)$$

where $P(RCA_p|RCA_j)$ is the conditional probability of exporting product p given that a country already exports product j. The minimum between both conditional probabilities is used to define proximity. Using network analytics, this allows for the creation of a product-to-product network called the proximity matrix, which is used to generate the underlying structure of the product space. Hausmann et al. (2014) adjust the visual representation of the product space network, using a variety of network analytic tools, in order to generate a more economically meaningful visualisation.[16]

The links between products define the structure of the product space and hence the connectedness and distance between products. If two products are close together it indicates that they have similar productive capability requirements. This implies that if a country produces one of the two products, it is relatively easier to shift production to the other. Conversely, it is much harder to jump to products that are more distant from a country's current productive structure. The structure of the product space implies that the process of accumulating productive knowledge and shifting to new products is not haphazard, but rather path dependent. Therefore, products that a country currently produces influence the products that it is able to produce in the future.

The colour of each node represents product communities. These are groups of products that are connected to one another more strongly, because they tend to be co-exported more frequently than products existing outside of their community. This implies that products within a community require similar sets of productive capabilities.

Source: Hidalgo et al. (2007) and Hausmann et al. (2014).

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[16] More details on the manner in which the product space network is constructed can be found in the Supporting Online Material attached to Hidalgo et al. (2007).

The product space suggests that the process of accumulating productive capabilities and shifting to new products is path-dependent. In other words, a country's current productive structure influences its future productive structure, and hence the process of structural transformation does not take place within a vacuum.

An important aspect of the product space is the presence of a core and periphery. The core is comprised of relatively more proximate and connected products (typically manufactured products), while the periphery is comprised of relatively less proximate and connected products (typically primary products). This has implications for the process of structural transformation and the ability to shift into more complex manufactured products. If a country's productive structure is represented by a number of highly connected products within the core of the product space, then its ability to diversify into new products is made easier by the fact that there are many nearby products that require similar productive capabilities to that which it currently has. Conversely, if a country's productive structure is less connected and more peripheral, then its ability to diversify into products in the core of the product space is limited because its productive capabilities are 'far' from that which it requires in order to diversify.

The next sub-section considers South Africa's product space, which provides insight into the extent to which it has undergone structural transformation, and the potential for future manufacturing-led structural transformation.

4.2.2 South Africa's Product Space

South Africa's evolving productive structure, as evidenced in the *product space* visualisations in Figure 11 (below) and Figure 12 (below), suggests that the country has not undergone any substantial structural transformation in the post-apartheid period. Evidence of complexity-led structural transformation would be supported by an increased occupation of nodes within the core of the *product space*. Comparing Figure 11 to Figure 12 shows that this, for the most part, has not happened. Although there is some diversification into machinery and chemicals products, South Africa's productive structure remains commodity based.

To reiterate, South Africa's productive structure, as represented by the *product space* graphs, remains peripheral and rooted in commodities. Looking at Figure 11 (PS for 1995), it is evident that these commodities include mineral products such as platinum, coal, gold, diamonds and other minerals[17]. The productive structure also comprises a number of agricultural commodities, such as raw sugarcane, wheat, and corn (see yellow nodes). In addition, there are a number of horticulture[18] and processed agricultural products[19]. In addition, manufacturing activities are typically resource-based. These productive activities include the production of paper and pulp products[20], metal products[21], and leather products[22]. These commodity exports and commodity-based exports, although adjusting in relative shares over time, have remained important components of South Africa's export structure

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[17] Mineral products are represented by the dark and light brown nodes and include products such as Iron ore and concentrates; Manganese iron ore agglomerates; Precious metal ores; Chromium ore; Cobalt ore; Niobium and tantalum ores; and Titanium ores (all located on the periphery of the product space).

[18] These products are represented by yellow nodes and include products such as Oranges; Apricots; Peaches; Cherries and plums; Grapes; Dried fruit; and Citrus fruit.

[19] These products are represented by yellow nodes and include sea food such as Fish fillets; Frozen fish fillets; and Molluscs, and other processed agricultural products such as Jams, jellies and marmalades; Fruit juices; Fruit and nuts; Wine; Waters, flavoured or sweetened; and Ginger, Saffron and other spices.

[20] These products are represented by yellow nodes and include products such as Fiberboard and wood; Fuel wood; Wood carpentry for construction; and Chemical woodpulp.

[21] These products are represented by red nodes and include products such as Refined copper and copper alloys; Ferroalloys; Copper bars, rods and profiles; Flat-rolled iron; Hot rolled bars of iron; Wire of iron and non-alloy steel; Angles or iron or non-alloy steel; Pig iron; Stainless steel ingots; Nickel mattes; Cobalt; and Unwrought aluminium.

[22] These products are represented by yellow nodes and include products such as Bovine leather further prepared; and Raw skins of sheep and lamb.

over the period 1995 to 2015. This is evidenced by the *product space* for 2015 looking relatively similar to the *product space* in 1995.

Figure 11: South Africa's Product Space in 1995
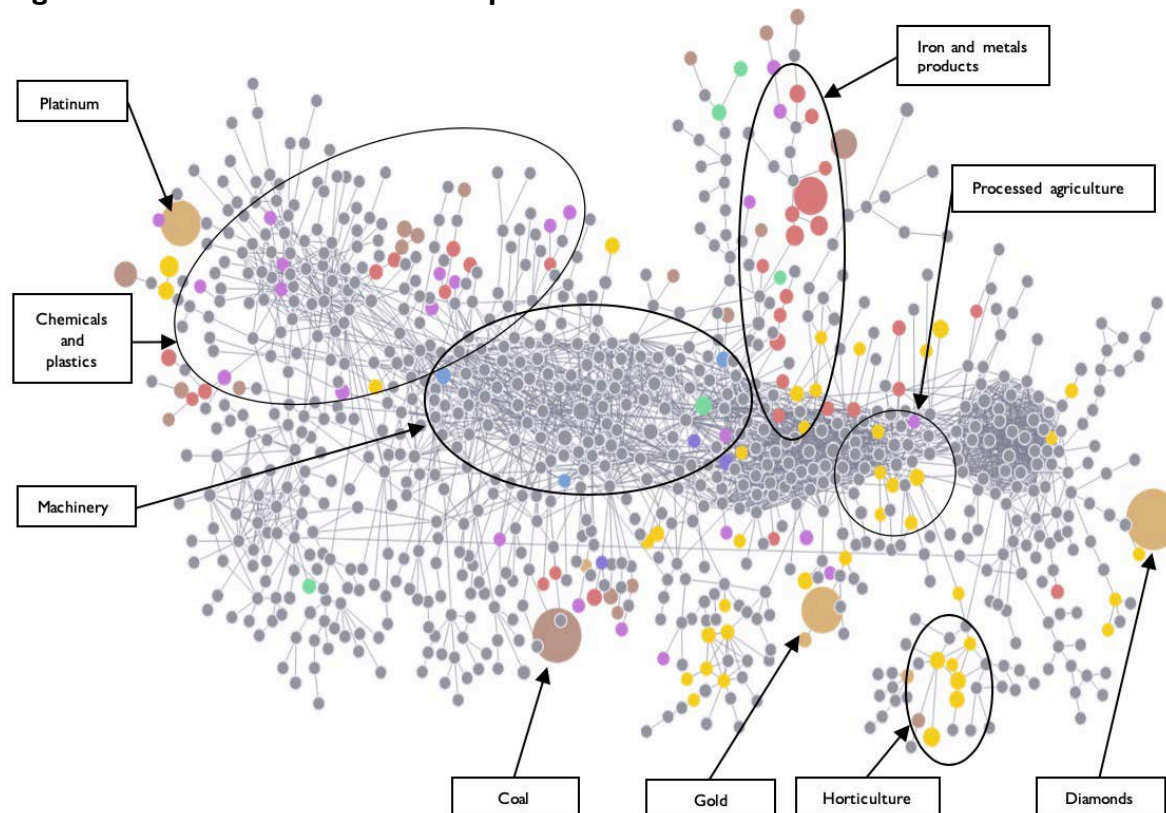
Source: CID (2018)
Notes: Product groupings or clusters are represented by the following colours: Textiles & Furniture (light green); Vegetables, Foodstuffs & Wood (yellow); Stone & Glass (light brown); Minerals (dark brown); Metals (red); Chemicals & Plastics (light purple); Transport Vehicles (dark purple); Machinery (blue); Electronics (turquoise); and Other (dark blue).

However, there is some evidence of diversification into more complex manufactured products. There has been growth and diversification within the machinery industry over the period. In 1995, machinery exports, in which South Africa had a revealed comparative advantage, consisted of Centrifuges, Agricultural machinery, and Machinery for working earth, stone and other minerals (Mining machinery) – blue nodes. In addition, there were also a number of transport vehicle related exports, such as Pleasure or sports boats, Railway cars (not self-propelled), and Containers for multimodal transportation – dark purple nodes. In 2015, machinery exports intensified, especially in the case of Centrifuges, and diversified into a variety of other machinery[23] and transport products[24]. In particular, there has been substantial growth in the production of cars within the automotive industry, driven by industrial incentives under the Motor Industry Development Plan (MIDP), and more recently, the Automotive Production & Development Programme (APDP). The chemicals industry has also shown

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[23] These products are represented by blue nodes and include products such as Water gas generators; Machinery for processing grain; Gas, liquid and electricity meters; and Machinery for working earth, stone and other minerals.
[24] These products are represented by dark purple nodes and include products such as Cars; Motor vehicles for transporting goods; Rail locomotives; and Tanks and other armoured fighting vehicles. Exports of Pleasure or sports boats; and Containers for multimodal transportation, remained.

signs of diversification. In 1995, South Africa had a revealed comparative advantage in 23 chemical products[25]. This expanded to 29 chemical products[26] in 2015.

Figure 12: South Africa's Product Space in 2015

Source: CID (2018)
Notes: Product groupings or clusters are represented by the following colours: Textiles & Furniture (light green); Vegetables, Foodstuffs & Wood (yellow); Stone & Glass (light brown); Minerals (dark brown); Metals (red); Chemicals & Plastics (light purple); Transport Vehicles (dark purple); Machinery (blue); Electronics (turquoise); and Other (dark blue).
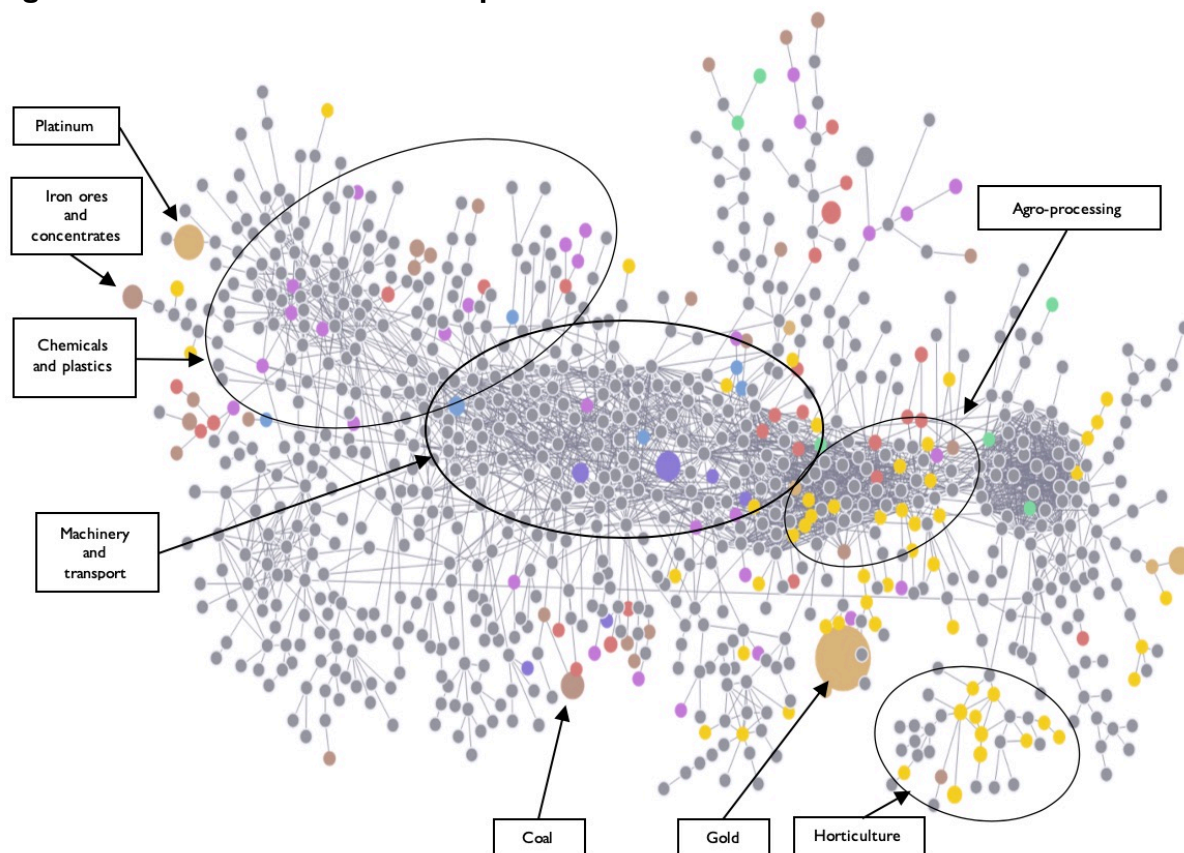
Nevertheless, despite a degree of diversification in the machinery and chemical industries, the South African productive structure remains concentrated in commodities, and thus peripheral. The inability of South Africa to undergo complexity-led structural transformation in the post-apartheid period is reflected in the measures shown in Table 2. Table 2 shows South Africa's export diversity[27], economic complexity index, economic complexity ranking, and opportunity value index for the years 1995 and 2014. For further context, the same set of measures for other emerging economies is included.

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[25] These products are represented by light purple nodes, and include Cobalt oxides & hydroxides; Phosphatic fertilisers; Radioactive chemical elements; Phenols & phenol-alcohols; Ketones & quinones; Polymers of propylene; Carbides; Carbon; Insecticides, rodenticides & pesticides; Hydrazine & Hydroxylamine; Hydrogen & other non-metals; Artificial graphite; Sulfates; Nitrites & Nitrates; Detonators; Mixed fertilisers; Soap; Candles; Phosphates; Phosphoric acid; and Organic composite solvents & thinners.

[26] These products are represented by light purple nodes and include Phenols & phenol-alcohols; Ketones & quinones; Catalytic preparations; Unsaturated acyclic monocarboxylic acids; Insecticides, rodenticides & pesticides; Polymers of propylene; Carbides; Hydrazine & Hydroxylamine; Radioactive chemical elements; Nitrogenous fertilisers; Acyclic hydrocarbons; Hydrogen & other non-metals; Artificial graphite; Sulfates; Nitrites & Nitrates; Toiletries; Polishes & creams; Essential oils; Detonators; Acyclic alcohols; Phosphates; Phosphoric acid; Soap; Dental Hygiene products; Enzymes; Organic composite solvents & thinners; and Salts of oxometallic acids.

[27] A product is defined as exported if the revealed comparative advantage for that product is equal to or greater than unity. Products defined at the 4-digit level.

A number of points emerge: First, the diversity of South Africa's export portfolio has declined over the period, from 244 to 211 products. This is depicted by less occupied nodes in the *product space*. In contrast, countries such as China, Turkey, Poland, Thailand and Vietnam experienced substantial growth in diversity. Second, South Africa's decline in product diversity is reflected in a decline in economic complexity. It is worth noting that the countries that experienced declining diversity do not automatically experience declining complexity. For example, while Brazil, South Africa and Chile experienced drops in diversity matched by drops in economic complexity, Columbia and Indonesia experienced drops in diversity matched by growing economic complexity. Arguably, while experiencing a net decline in diversity, the latter countries shifted from less complex products (more ubiquitous) to more complex products (less ubiquitous). Third, South Africa's declining economic complexity over the period is matched by its declining complexity relative to other emerging economies over the period.

A fourth point that warrants further discussion, is South Africa's declining opportunity value index. The 'opportunity value index' is a measure capturing the value of the unexploited product diversification opportunities available to a country. A country's location within the *product space* has implications on the opportunities available to it in terms of diversification. If a country is mainly producing and exporting peripheral products, then its occupied nodes are located next to fewer, less connected, and less complex products. Conversely, if a country is mainly producing and exporting core products, then its occupied nodes are located next to many, highly connected, relatively more complex products. A peripheral *product space* is characterised by fewer diversification opportunities and hence a lower opportunity value index, whereas a core *product space* is characterised by more diversification opportunities and hence a higher opportunity value index. South Africa's declining opportunity value index suggests an increasingly peripheral productive structure and declining diversification opportunities. This has adverse implications on future structural transformation.[28]

Table 2: Complexity measures – South Africa in relation to other emerging markets

	Diversity			Economic complexity index			Economic complexity rank			Opportunity value index		
	1995	2014	Δ	1995	2014	Δ	1995	2014	Δ	1995	2014	Δ
Poland	341	401	60	0,80	1,14	0,34	26	25	1	2,12	1,41	-0,70
Brazil	254	194	-60	0,62	0,11	-0,50	30	51	-21	1,61	1,04	-0,57
Malaysia	187	200	13	0,37	0,74	0,36	44	26	18	0,87	1,01	0,14
South Africa	244	211	-33	0,50	0,06	-0,44	47	57	-10	1,28	1,18	-0,10
China	424	565	141	0,31	1,03	0,72	50	21	29	3,93	1,90	-2,04
Thailand	280	325	45	-0,04	0,86	0,91	52	24	28	1,82	1,90	0,07
Turkey	278	386	108	0,13	0,42	0,29	62	43	19	1,64	3,23	1,59
Columbia	151	109	-42	-0,02	0,15	0,17	66	62	4	0,25	-0,05	-0,30
India	332	360	28	0,16	0,18	0,02	67	47	20	2,78	3,62	0,84
Chile	143	126	-17	-0,12	-0,40	-0,28	73	70	3	-0,02	-0,24	-0,22
Indonesia	260	248	-12	-0,51	-0,31	0,20	87	53	34	1,80	1,80	0,00
Vietnam	164	259	95	-1,20	-0,21	0,99	114	59	55	0,01	1,81	1,80

Source: Own calculation using data from The Economic Complexity Observatory (Simoes & Hidalgo, 2011)

As mentioned in the previous sub-section, structural transformation is a path-dependent process, and diversification into 'core' manufactured products is more difficult from a peripheral productive structure (i.e. a low opportunity value index). This is due to the productive knowledge or know-how

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[28] In a recent paper, Bhorat, Steenkamp and Rooney (2016) show that a country's manufacturing performance, in terms of export diversification, is positively related to its opportunity value index. This indicates that countries with connected 'core' product spaces, are better able to diversify into manufacturing products.

embedded in peripheral commodity-centred products being distant from that needed in order to produce more complex products. Therefore, one could argue that it is the peripheral nature of the South African productive structure that has hindered its ability to undergo complexity-driven structural transformation in the post-apartheid period.

4.2.3 Product Space Analytics

Using product space analytics, one can examine why South Africa has struggled to undergo manufacturing-led structural transformation. As discussed in the previous section, the peripheral and disconnected nature of South Africa's productive structure has hindered its shift to more complex and connected manufacturing products. The products that South Africa produces and exports, which are predominantly located in the periphery of the product space, are distant from the more complex manufacturing products in the core of the product space.

A measure that picks up this distance, in terms of productive capabilities between what a country currently produces and what it doesn't, is the density measure. Hausmann and Klinger (2007) use this measure to examine whether the probability of a country exporting a product with comparative advantage in the future, is dependent on how proximate that product is to other products that it currently exports. The density measure is a country-product level measure capturing the degree to which a country's current export basket surrounds a particular product under consideration. Intuitively, a peripheral productive structure will be more distant from the more connected products in the denser core of the product space, and thus shifting to these products is that much harder. The measure is defined in greater detail in Box 3.

Box 3: Measuring Density in the Product Space

In order to generate the density measure, one needs the pairwise proximity measures for all products comprising the product space, and to then relate these to each country's export structure. The derived density measure is a country-product level measure. Density is the sum of proximities from product j to all products that are currently exported with comparative advantage, divided by the sum of proximities of all products. Formally, the measure is represented as follows:

$$density_{j,c,t} = \left(\frac{\sum_p x_{c,p,t} \phi_{p,j,t}}{\sum_p \phi_{p,j,t}} \right) \qquad (9)$$

Density is the sum of all paths leading to a product from products in which the country is present, scaled by the total number of paths to that product. The value of density varies between 0 and 1, with higher values indicating that a country exports many of the products connected to a particular product. The inverse of density is defined as distance.

Source: Hausmann & Klinger (2007; 2008)

Using the product space measures, one can also depict the products that South Africa exports significantly (RCA>1), and those that it does not export significantly, or not at all (RCA<1 or RCA=0), within the product complexity-distance space.[29] In Figure 13, RCA (shaded in blue) and non-RCA (shaded in grey) products are positioned within the product complexity-distance space. The size of the bubble represents the products' share of total South African exports. A number of points emerge: Firstly, it is evident that South Africa has a revealed comparative advantage in commodities, particularly, Coal, Manganese, Iron ore, Gold, Ferro-alloy, Citrus, and Platinum. Secondly, these commodities are, on average, characterised by lower levels of complexity. Thirdly, products in which South Africa does not have a revealed comparative advantage are, on average, relatively more distant and complex. Fourthly, there is evidence of substantial exports in relatively complex manufactured

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[29] Distance is simply the inverse of density.

products such as Delivery Trucks and Centrifuges.[30] Therefore, in order to build complexity, entry into new industries would require entry into relatively more distant and complex products.

Figure 13: South African Export Portfolio - RCA and non-RCA Products
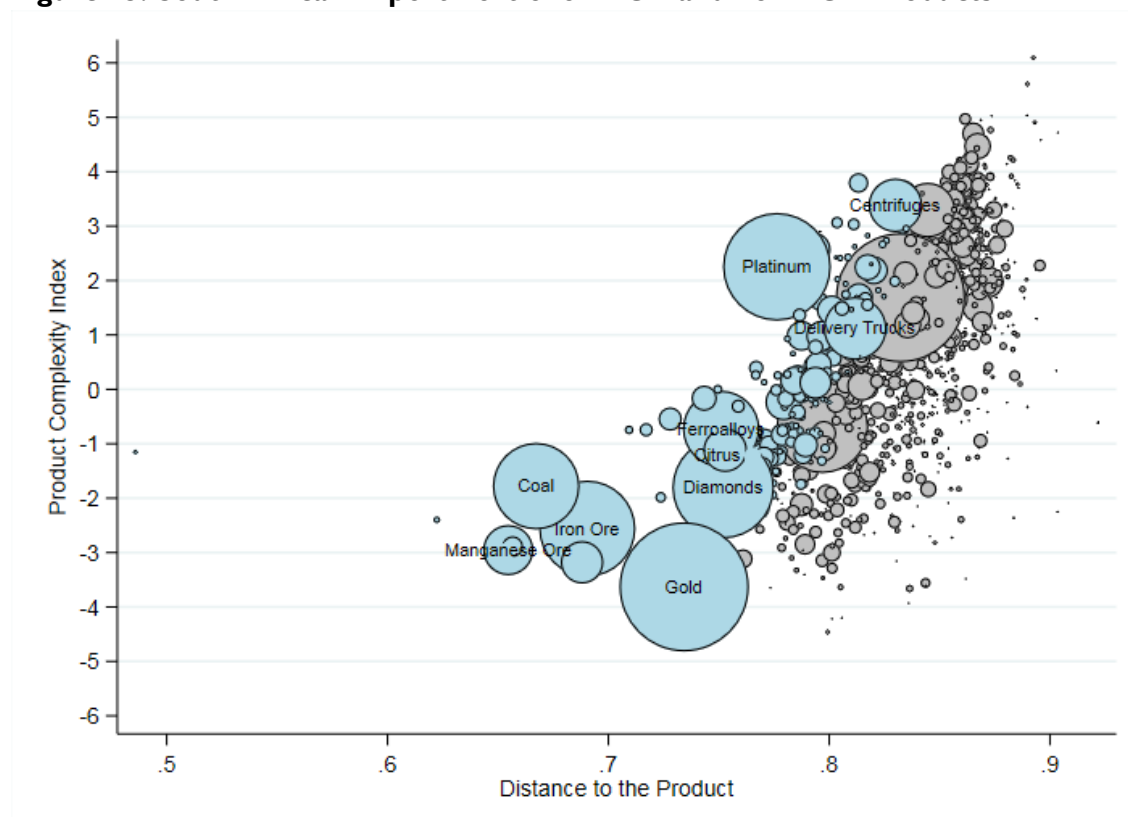
Source: Own calculation using data from The Economic Complexity Observatory (Simoes & Hidalgo, 2011) & CID (2018)
Notes: 1. Distance is the inverse of density. Thus lower density value implies higher distance value. 2. Products shaded blue are products that South Africa exports with a RCA greater or equal to unity. Products shaded in grey are products that South Africa does not export, or exports with an RCA less than unity.

One can use product space analytics to determine what may be influencing South Africa's limited manufacturing-led structural transformation over the post-1994 period. Using these analytics one can determine whether its poor positioning within the product space (i.e. the productive capabilities embedded in South Africa's productive structure are distant from those needed in order to diversify in more complex manufacturing products) or whether there is a South Africa-specific explanation. We do this by following Hausmann & Klinger (2007; 2008).

Following Hausmann & Klinger (2007; 2008), we regress the probability of comparative advantage for country c in product p in period $t + 1$, on the country's density around that product (ln Density$_{c,p,t}$), while controlling for the country's level of development (ln GDP per capita$_{c,t}$), whether it had a revealed comparative advantage for that product (RCA$_{c,p,t}$), its level of economic complexity (ECI$_{c,t}$), the complexity of the product in question (PCI$_{c,p,t}$), and whether the country has a revealed comparative advantage in the industry grouping within which the product falls (RCA$_{c,HS,t}$), all measured in period t. Formally, this regression is presented as follows:

$$X_{p,c,t+1} = \alpha + \beta_1 RCA_{c,p,t} + \beta_2 lnDensity_{c,p,t} + \beta_2 lnGDP\ pc_{c,t} + \beta_3 ECI_{c,t} + \beta_4 PCI_{p,t} \\ + \beta_5 RCA_{c,HS,t} + \gamma_c + \gamma_p + \gamma_t + \varepsilon_{c,p,t} \tag{10}$$

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[30] It is worth noting that the large grey bubble refers to motor vehicles (RCA=0.93).

The regression is estimated using a 5-year panel for the period 1995 to 2014.[31] Product-level trade data at the 4-digit level of the Harmonised System 1988 revision (1240 products) is used for a sample of 120 countries.[32] The regressions presented in Table 3 are linear probability models estimated using ordinary least squares (OLS). Estimation (1) includes product, country and time fixed effects, while estimation (2) includes product-year and country-year fixed effects.

Table 3: The Atlas Determinants of Structural Transformation, 1995-2014

	(1)	(2)
$RCA_{c,p,t}$	0.608***	0.588***
	[0.009]	[0.010]
Ln Density$_{c,p,t}$	0.556***	0.821***
	[0.033]	[0.059]
Ln GDP per capita$_{c,t}$	0.018	
	[0.013]	
$ECI_{c,t}$	-0.009	
	[0.006]	
$PCI_{c,p,t}$	0.010***	
	[0.002]	
$RCA_{c,HS,t}$	0.007***	0.006***
	[0.001]	[0.001]
South Africa	-0.057***	
	[0.020]	
Constant	-0.172*	
	[0.103]	
Observations	587,402	587,402
R-squared	0.522	0.531
Product FE	YES	NO
Year FE	YES	NO
Country FE	YES	NO
Product-year FE	NO	YES
Country-year FE	NO	YES

Source: Own calculation using data from The Economic Complexity Observatory (Simoes & Hidalgo, 2011).
Notes:1. Robust standard errors in brackets. 2. *** p<0.01, ** p<0.05, * p<0.1. 3. Standard errors are clustered at the country level. 4. Country, product and time fixed effects included in model (1), and product-year and country-year fixed effects included in model (2).

As in Hausmann & Klinger (2008), there is a positive and statistically significant relationship between density and the probability of exporting a new product, thus suggesting that density is a key determinant of future structural transformation. Therefore, where a country is located within the product space matters. This result is consistent across both estimations. Interestingly, if a country has a revealed comparative advantage in the industry in which a specific product falls, the probability of exporting that product in the next period is higher. This is important from a policy perspective because it suggests that by enabling firms within an industry to gain a foothold within the broader international market, those firms, or firms within the industry, are more likely to be successful in shifting activities to related products within the industry. The coefficient estimates for the remaining variables are consistent with the results found in Hausmann and Klinger (2006, 2007, 2008).

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[31] For example, the dependent variable in 2000 is regressed on the explanatory variables for 1995 in each of the time dimensions of the panel.
[32] These countries are used in the construction of the Atlas of Economic Complexity – see Section 7 of Hausmann et al. (2014) for discussion on choice of these countries.

In estimation (1) we control for country fixed effects by including country dummies into the regression. Hausmann and Klinger (2008) point out that statistically significant coefficient estimates on the country dummies indicate unexpectedly rapid or slow structural transformation if the sign of the estimate is positive or negative, respectively. The implication being that factors other than a country's position within the product space are important in explaining the pace of structural transformation. For an earlier period of analysis, 1985-2000, Hausmann and Klinger (2008) show that the South African country dummy is not statistically significant, thus suggesting no tendency toward slow or fast structural transformation once having controlled for its location within the product space.

However, in our estimates for a more recent and longer period, 1995 to 2014, we find a statistically significant coefficient estimate for the South African country dummy. Following the logic of Hausmann and Klinger (2008), this suggests that South Africa's pace of structural transformation over the period was unexpectedly slow. Furthermore, it suggests that the ease at which its existing productive capabilities can be mobilised and adapted to new products does not fully explain its pace of structural transformation. One can posit a few other country-specific factors that may have influenced the pace of structural transformation: For example, firstly, it could be argued that the global commodity boom during the early 2000s may have helped maintain the commodity-dependent structural *status quo*. Secondly, one could argue that the post-Great recession period has been marked by political instability and in some sense policy paralysis, which have not created an enabling economic environment. Third, South Africa is geographically remote and thus entering global manufacturing value chains is constrained by costs to market. Fourth, it is possible that the long-run effects of a poor schooling system have constrained firms in terms of access to a stable supply of skilled labour.

The *product space* analytics provide a product-level depiction of South Africa's inability to undergo complexity-led structural transformation in the post-apartheid period. From a manufacturing perspective, apart from some growth and diversification in machinery and chemicals, there has been an overall decline. This has impacted negatively on the South African economy's ability to generate employment for a growing labour force, particularly for women and youth. Using complexity analytics, the next section identifies avenues for South Africa to diversify toward an increasingly complex productive structure, and thereby generate employment opportunities for women and youth.

5 Building Economic Complexity in South Africa: Identifying Paths for Future Structural Transformation

In this section, we use the tools of the economic complexity framework to identify new products that South Africa can shift production toward. It is important that these products are more complex than the products that comprise South Africa's current export structure, thereby enabling South Africa to grow its economic complexity. In order to ensure feasibility, it is also important that these products are sufficiently proximate to South Africa's current productive structure. Put differently, the capabilities required in order to shift to these new and more complex products are similar to the capabilities embodied in South Africa's current productive structure.

5.1 Identifying a New Product Space

Using complexity analytics, we proceed to answer the following question: What products can South Africa diversify toward? To do this, we aim to pinpoint products that Hausmann and Chauvin (2015) term "frontier products". Frontier products need to be, firstly, more complex than South Africa's current export mix; secondly, feasible given South Africa's current productive knowledge; and thirdly, provide potential for further diversification. Using complexity analytics terminology, these three features imply a high product complexity index (PCI), a low distance index, and a positive opportunity gain index. In Figure 14, we depict how these three measures are employed in generating the list of

frontier products. Since there are trade-offs between these three features, we employ the methodology from Hausmann and Chauvin (2015) to identify South Africa's frontier products.[33]

We follow five steps: Firstly, using product-level export data, South African exports are divided according to revealed comparative advantage.[34] Of the products that South Africa does not have a revealed comparative advantage in (i.e. non-RCA products[35]), those with a PCI below South Africa's mean PCI of the products that it exports, are eliminated. This ensures that diversification into the remaining products will increase the complexity of South Africa's export basket. For example, in Figure 14, Motor vehicle parts (dashed black circle), which is identified as a frontier product below, has a PCI of 3.29.

Secondly, we order non-RCA products by increasing distance (inverse measure of density) and eliminate products that are higher than the median distance of this sample of non-RCA products. In other words, out of the sample already identified as more complex, half of these products are retained. These products are the next closest to South Africa's existing export structure in terms of capabilities.[36] For example in Figure 14, Motor Vehicles (solid black dot), a product that South Africa exports with an RCA greater and equal to unity, is connected and located 'close' to Motor vehicle parts, hence a low distance index.

Thirdly, we eliminate any products with a zero or negative opportunity gain index since such products represent low potential for future expansion and diversification. The opportunity gain index quantifies the contribution of a new non-RCA product in terms of its connectedness to more complex products. Intuitively, this means that the capabilities embedded in this product are proximate to the required capabilities of a number of other more complex products. For example, in Figure 14, there are 25 unoccupied nodes connected to Motor vehicle parts (dashed red lines), which corresponds with a high opportunity gain index.

Fourthly, we deviate from Hausmann and Chauvin (2015), and eliminate products that have not shown positive global trade growth over the period 1995-2015. This process is useful for two reasons: Firstly, we eliminate products that are relics of old trade patterns associated with the 1993 Revision of the HS nomenclature. Secondly, we eliminate products that are experiencing declining importance in global trade, and thus not offering future growth potential.

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[33] For example, it is typically the case that complex products are also the least proximate to a country's current export structure.

[34] South African export data, for the period 2014, is analysed at the 4-digit level of the Harmonised System 1992 revision (Approximately 1200 product categories).

[35] Non-RCA products include products that South Africa does not export (commonly referred to as 'zeros' in the gravity equation literature – see Helpman, Melitz & Rubenstein, 2008), as well as products that South Africa exports, but not with a revealed comparative advantage.

[36] Hausmann and Chauvin (2015) explain that there is no standard cut-off for what a feasible distance is, and to overcome this, they select the median as it simply divides the bundle in half.

Figure 14: Graphical representation of method used to identify frontier products
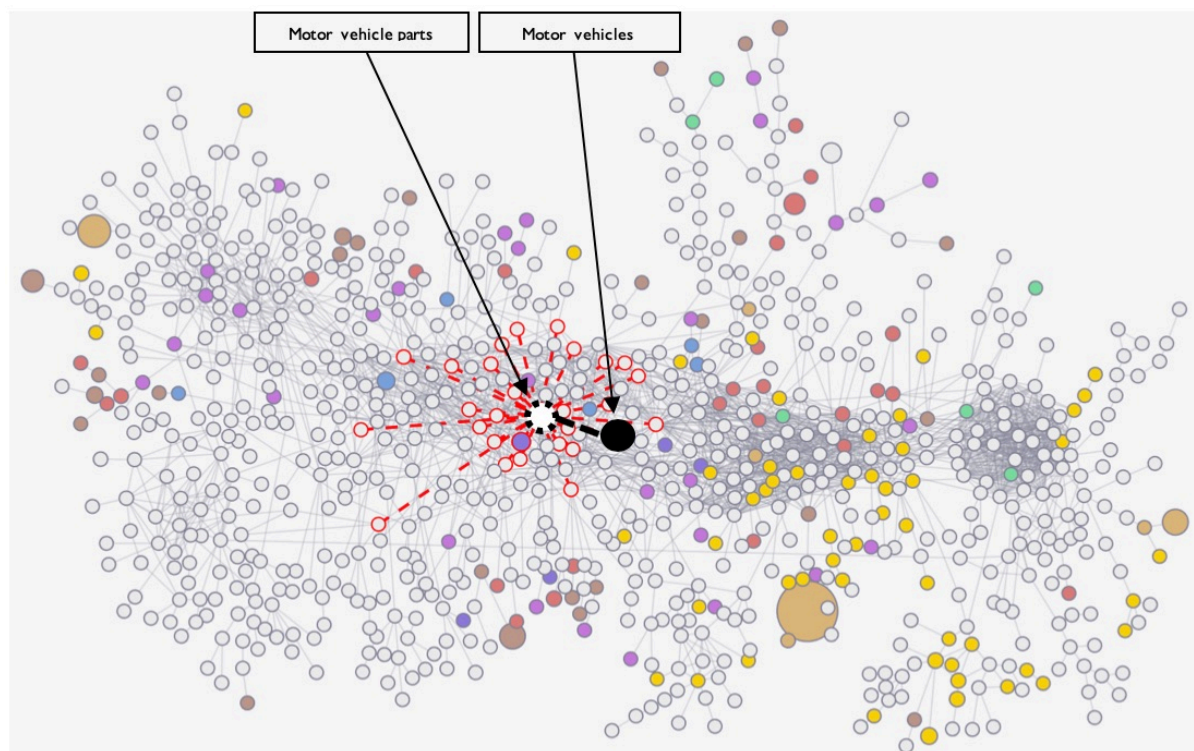
Notes: Product groupings or clusters are represented by the following colours: Textiles & Furniture (light green); Vegetables, Foodstuffs & Wood (yellow); Stone & Glass (light brown); Minerals (dark brown); Metals (red); Chemicals & Plastics (light purple); Transport Vehicles (dark purple); Machinery (blue); Electronics (turquoise); and Other (dark blue).

This process leaves us with 164 frontier products. We complete our methodology by combining the three complexity analysis measures listed in steps one to three (PCI, distance, and opportunity gain), and generate a weighted index that allows us to rank the frontier products. From this we settle on a list of the top 20 frontier products. We follow Hausmann, Cunningham, Matovu, Osire and Wyett (2014) who use this strategy. The next sections provide more detail on this process.

5.2 Finding the Frontier Products

Distance and PCI are the two main complexity variables that are traded-off against one another when identifying the frontier products. Therefore, we plot the sample of non-RCA products within the product complexity-distance space, as evident in Figure 15. The graph is divided into quadrants according to the median distance of South Africa's non-RCA products (dotted line), and the average PCI of the products that South Africa exports (solid line). The frontier products are located in the upper left-hand quadrant. These are products that, if produced, are expected to increase the complexity of South Africa's export structure, yet are feasible given current capabilities.

Figure 15: South Africa's Non-RCA Products Located within the Product Complexity-Distance Space, 2014
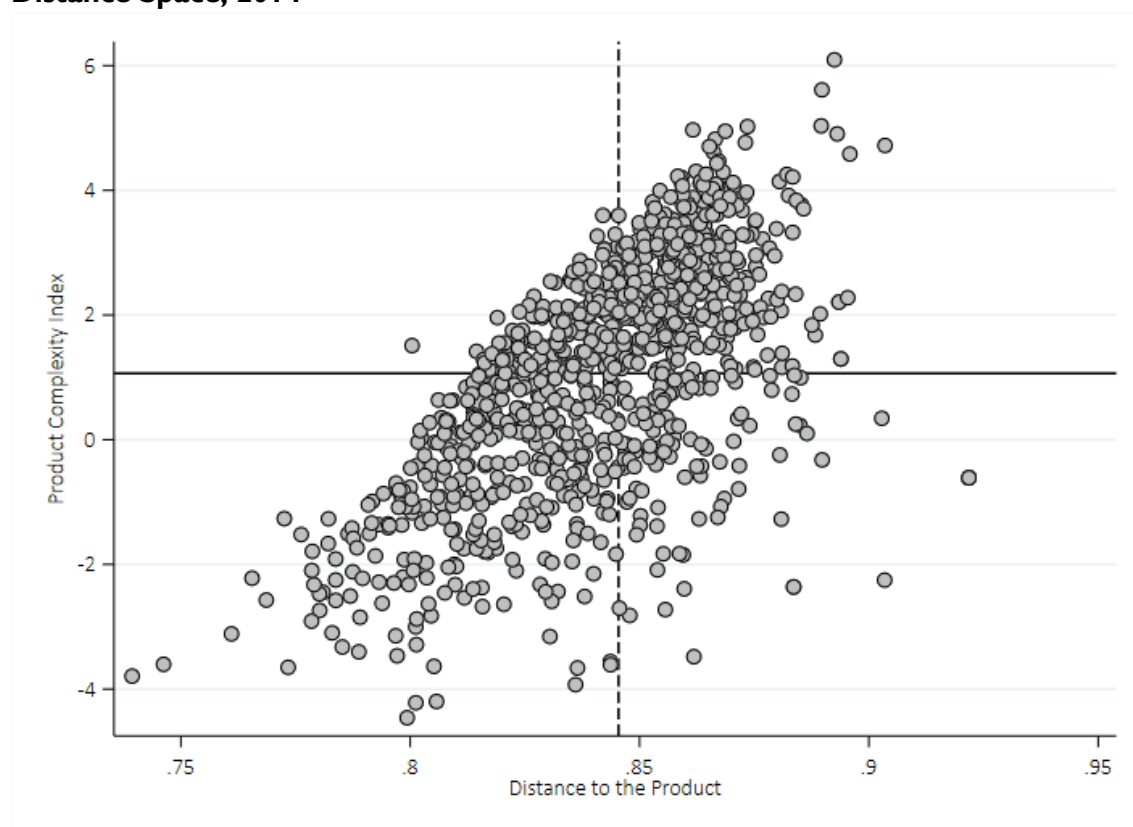
Source: Own calculations using data from The Economic Complexity Observatory (Simoes & Hidalgo, 2011)

In Figure 16 and Figure 17 we take a closer look at the agriculture and manufacturing frontier products, respectively (i.e. the products in the top left quadrant). Drawing on Regmi et al. (2005), in Figure 16, frontier products falling under agriculture are differentiated according to degree of processing (i.e. bulk, horticulture, semi-processed, and processed). It is evident that frontier products for agriculture are mainly processed or semi-processed. This suggests that greater complexity can be achieved by adding value to South Africa's current agricultural output via increased processing before export. Typically, as per capita income levels rise, countries start consuming greater volumes of processed food (Fukase & Martin, 2016). Given rising income levels across the Sub-Saharan African region, agri-processing offers growth potential in this regional market. South Africa has a relatively well-developed agriculture sector and is thus well positioned to take advantage of growth across the continent.

Figure 16: South Africa's Frontier Agricultural Products, 2014
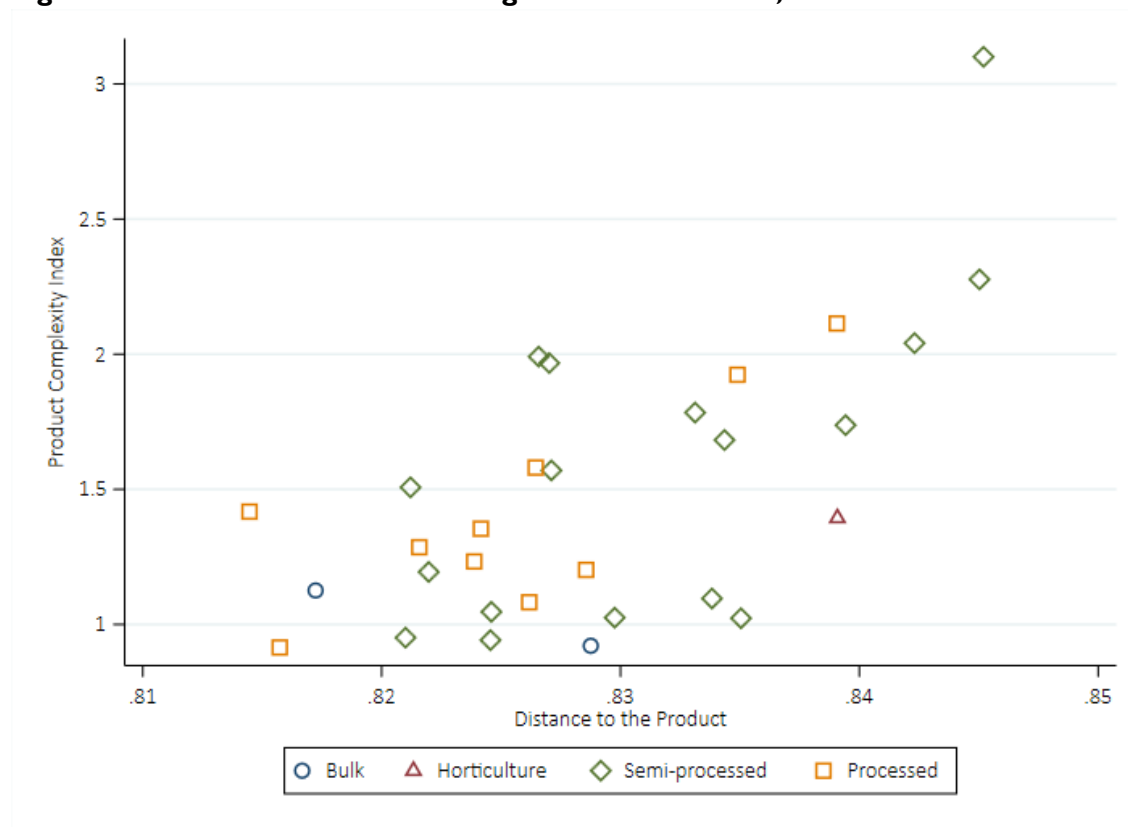
Source: Own calculations using data from The Economic Complexity Observatory (Simoes & Hidalgo, 2011)

In Figure 17, manufacturing frontier products are differentiated according to product communities. In terms of product community grouping amongst the frontier products, there is no clear pattern. A wide variety of manufactured goods are spread rather evenly across the plot area, and across product community groupings. The set of manufacturing frontier products are thus diverse, which suggests that were South Africa to target these products, its export structure would diversify. Such an approach is favourable from a developmental perspective, because increased diversification of a country's productive and exports structure is associated with higher levels of economic development (Imbs & Wacziarg, 2003; Cadot, Carrère & Strauss-Kahn, 2011).

Looking at specific product groupings, a number of points emerge: Firstly, textiles are an interesting comparator to machinery and electrical products. Both these groups are clustering at a similar distance (mainly rightwards of a distance of 0.83). However, machinery and electrical goods tend to have higher complexity indices. Therefore, with the purpose of growing complexity, machinery and electrical goods would perhaps be a more strategic choice than textiles. Secondly, quite a few nodes for the chemical and allied industries community fall very nearby in terms of distance. This suggests relatively easier adoption. Chemicals and allied industries products have useful linkages to the agro-processing sector, meaning there are synergies to be exploited between the frontier products for agriculture and manufacturing.

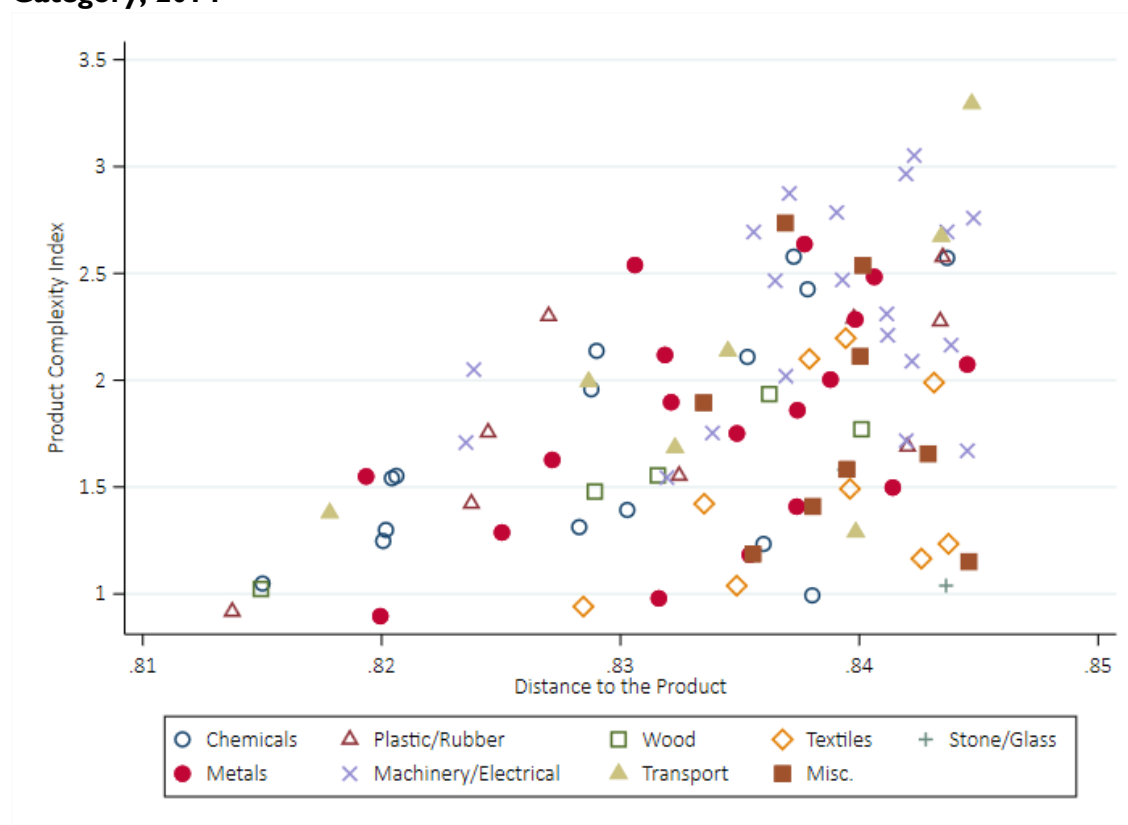**Figure 17: South Africa's Frontier Manufacturing Products by Product Community Category, 2014**

Source: Own calculations using data from The Economic Complexity Observatory (Simoes & Hidalgo, 2011)

5.3 Choosing amongst Frontier Products: Weights

As previously mentioned, 164 frontier products have been identified using the approach discussed above. In order to differentiate amongst these and identify the top 20 products that can be targeted using industrial policy, we rank the products according to three different weights. Each weight is a combination of product complexity, distance and opportunity gain indices. This strategy is introduced by Hausmann et al. (2014) who create two different weights in order to differentiate between what they describe as "more jobs versus better jobs". The 'Parsimonious Transformation' weight values labour-intensive industries and favours industries that are highly feasible, that is, those that are closer in terms of distance (i.e. "more jobs"). The 'Strategic Bets' weight acknowledges that more strategic sectors may be further away in terms of distance, and hence emphasises complexity and opportunity gain (i.e. "better jobs").

We adopt the weighting of the parsimonious and strategic weights of Hausmann et al. (2014). For robustness purposes, we also include a version of the weight where each variable is equally weighted. Variables are adjusted in order to vary in the same direction. Higher values of complexity and opportunity gain indicate better prospects; whereas lower values of distance indicate the same. We therefore invert distance so that higher values also indicate better prospects. This is to ensure sound interpretation of the weight. We scale each variable to vary between zero and one. We do this so that once the variables are weighted, all three of the weights vary within the same interval. This makes it easier to compare across weights. Table 3 below presents the weighting system.

Table 4: Three Weighting Systems for analysis of the South African Case

	Distance	Complexity	Opportunity Gain
Equal	0.33	0.33	0.33
Parsimonious	0.6	0.2	0.2
Strategic	0.2	0.4	0.4

When comparing the top twenty products that emerge from applying the three weighting systems, there is significant overlap. The top twenty are highly robust to weight choice. This provides confidence that in choosing these products we are selecting the correct ones. Aside from rank order, there is agreement between all three weights on the inclusion of 18 products in the top twenty.[37] The analysis that follows is based on the equal weight system. Since the three weights agree to such a high level, there is no need to replicate results for all three.

Table 5 lists the top twenty products for South Africa according to the equal weighting system for all frontier products. We also note the product community to which they belong. It is evident that 40 percent of the frontier products fall within the machinery community, whilst a fifth fall within the chemicals and plastics community.

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[37] The parsimonious weight disagrees with the other two weighting systems for the last two products. This is shown in Appendix Table 1, which shows the list of the top twenty products that emerge when using each of the weighting systems.

Table 5: The Top Twenty Products According to the Equal Weight

ALL	Com.	Description
Stone Wool	STON	Slag, rock wool, mineral fibre and similar mineral wools
Vehicle Parts	TRAN	Part and accessories (e.g. bumpers, safety seat belts, gear boxes, drive-axles, exhaust pipes, radiators, suspension system)
Pig and Poultry Fat	VEGP	Pig fat (including lard) and poultry fat
Lifting Machinery	MACH	Lifting, handling, loading or unloading machinery (e.g. lifts, escalators, conveyors, hoists, elevators)
Traffic Signals	MACH	Signalling, safety or traffic control equipment; for railways, tramways, roads, inland waterways, parking facilities, port installations, airfields
Aldehydes	CHEM	Aldehydes, whether or not with other oxygen function; cyclic polymers of aldehydes; paraformaldehyde
Other Engines	MACH	Engines and motors (e.g. reaction engines, hydraulic power engines, pneumatic power engines)
Rubber Sheets	PLAS	Plates, sheets, strip, rods and profile shapes, of vulcanised rubber other than hard rubber
Engine Parts	MACH	Parts for engines (spark-ignition reciprocating or rotary internal combustion piston engines, diesel or semi-diesel engines)
Vinyl Chloride Polymers	CHEM	Polymers of vinyl chloride or of other halogenated olefins, in primary forms
Large Flat-Rolled Iron	MET	Iron or non-alloy steel; flat-rolled products, width less than 600mm, not clad, plated or coated
Nitrile Compounds	CHEM	Nitrile-function compounds
Refractory Cements	CHEM	Refractory cements, mortars, concretes and similar compositions
Fire Extinguishers Preparations	CHEM	Preparations and charges for fire extinguishers; charged fire-extinguishing
Other Agricultural Machinery	MACH	Agricultural, horticultural, forestry, poultry-keeping, bee-keeping machinery; poultry incubators and brooders
Dairy Machinery	MACH	Milking machines and dairy machinery
Iron Radiators	MET	Radiators for central heating, not electrically heated and parts thereof, of iron or steel; air heaters
Harvesting Machinery	MACH	Harvesting and threshing machinery, straw and fodder balers, grass or hay mowers; machines for cleaning, sorting or grading eggs, fruit or other agricultural produce
Large Construction Vehicles	MACH	Bulldozers, graders, levellers, scrapers, angledozers, mechanical shovels, excavators, shovel loaders, tamping machines and road rollers, self-propelled
Prints	MISC	Engraving, prints and lithographs

Source: Own calculations using data from The Economic Complexity Observatory (Simoes & Hidalgo, 2011).
Notes: Com. refers to product communities. The shortened words denote: CHEM = Chemicals & Plastics; MACH = Machinery; MET = Metals; STON = Stone & Glass; TRAN = Transport Vehicles; VEGP = Vegetables, Foodstuffs & Wood; MISC = miscellaneous

Taking the twenty frontier products, we superimpose them onto South Africa's 2015 *product space*, and observe how its productive structure, visualised using the *product space*, could potentially evolve. This is depicted in Figure 18. Diversification toward these products would involve a clear shift to the core of the *product space*, particularly toward products in the machinery, transport, chemicals and plastics, and metals clusters. Two implications arise from shifting to the core of the product space: Firstly, it involves a shift to more complex products (higher PCI index), which implies growth in productive knowledge and hence higher economic complexity. Secondly, it involves a shift to more connected products (higher opportunity gain index), which implies the opening up of more future diversification opportunities.

A further two points emerge regarding the relatedness of the frontier products: First, these products are related to South Africa's current productive structure. This is not all that surprising since the methodology is designed to do this. We observe that a number of the products are related to the

primary sector activities that dominate South Africa's export structure. For example, dairy machinery, harvesting machinery, and other agricultural machinery all relate to South Africa's relatively robust commercial agriculture sector. Similarly, large construction vehicles and lifting machinery are related to South Africa's mining sector, and vehicle parts are related to its automotive sector.

Second, it appears that the frontier products are related to one another. A number of the frontier products are likely to feature as inputs into the production of other frontier products. For example, pig and poultry fat is used in the production of sausages. Similarly, vinyl chloride polymers (plastic) and rubber sheets are used as inputs into motor vehicle parts. Engines and engine parts are used as inputs into the production of construction vehicles and agricultural machinery. As such, we observe, at least initially, a complementarity across the list of frontier products.[38] A key implication of this, certainly in a policy sense, is that frontier products are an interconnected network of related products that can be targeted in a broad holistic manner.[39]

In this next section, we discuss the results from the firm and industry interviews. One of the key outcomes of this section is to identify what can be done to facilitate the evolution of South Africa's productive structure toward these frontier products.

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[38] The firm and industry interviews detailed in the section below corroborate this assertion.
[39] For example, developing engines and engine parts feeds into the machinery and automotive industries.

Figure 18: South Africa's Potential Product Space
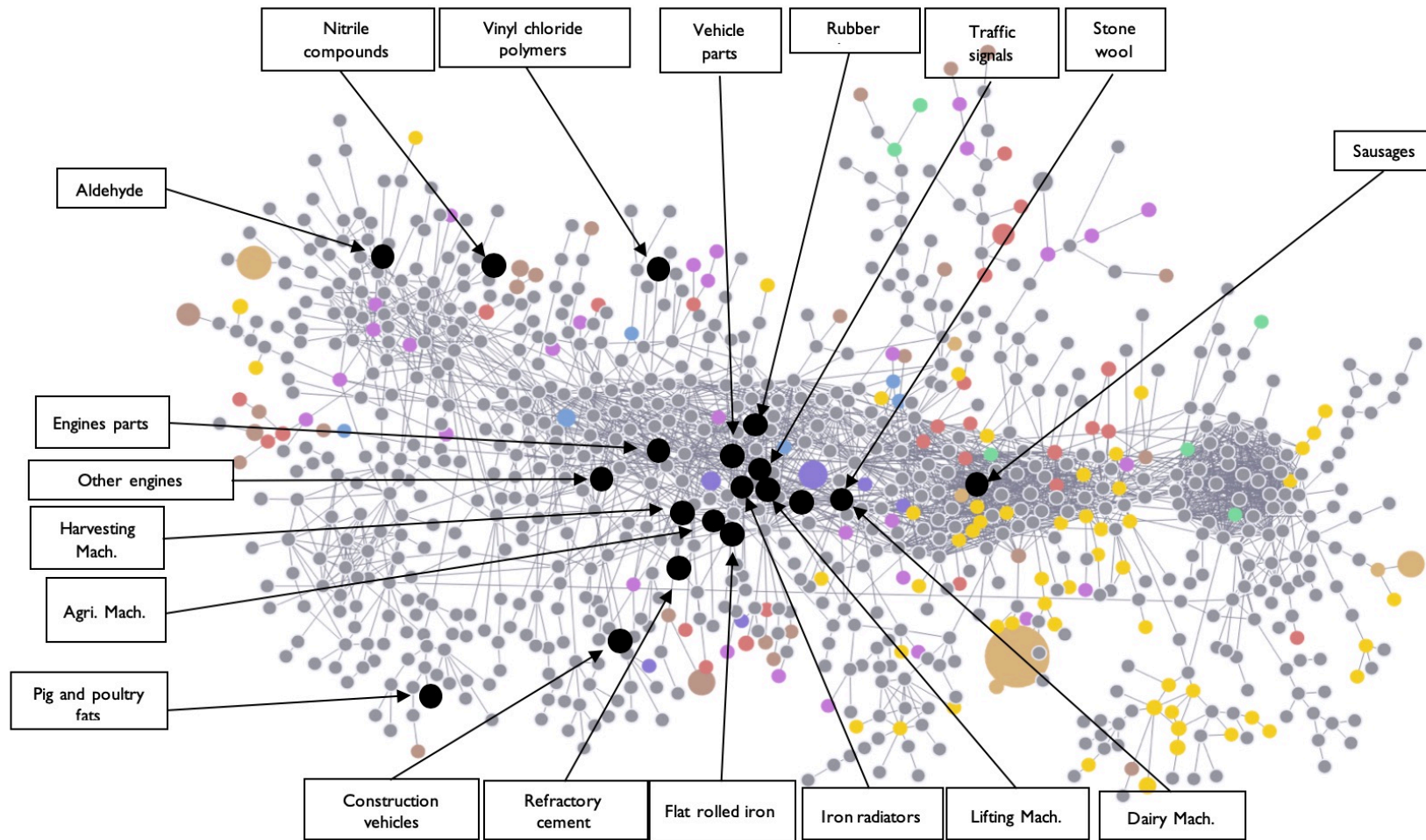
Source: CID (2018)

Notes: Product groupings or clusters are represented by the following colours: Textiles & Furniture (light green); Vegetables, Foodstuffs & Wood (yellow); Stone & Glass (light brown); Minerals (dark brown); Metals (red); Chemicals & Plastics (light purple); Transport Vehicles (dark purple); Machinery (blue); Electronics (turquoise); and Other (dark blue)

6   Unlocking Growth through Diversification

This section starts by detailing the firm identification and data collection strategy that informs the analysis of the top 20 products identified in the previous section. The proceeding sub-sections are structured according to the industrial communities or groupings in which the products reside. Within each of these sub-sections, the following is discussed: First, an overview of the broader industry in which the product resides. Second, a detailing of the diversification paths emerging from each product and thus an expansion of the product space. Third, a discussion on the employment propensity, particularly with respect to women and youth, associated with the product. Fourth, a discussion on the capabilities required to diversify into the product, and thereby grow complexity in the economy as a whole.

Firm Identification / Data Collection Strategy

A stratified three-stage purposive sample design with a criterion strategy was employed in sampling firms to be included in the survey. The first two stages involved desktop work, whereby in the first stage, the 164 South African frontier products were identified, and in the second stage, this list was condensed to include only the top 20 frontier products. In the third stage (which is the focus of this section), interviews were undertaken with key informants (comprised of industry bodies and industry experts) and firms.

The stratified three-stage purposive sampling with a criterion strategy is a common sampling approach in social sciences. Our choice of this method is driven by the need to identify firms dealing with specific products that could only be identified in a systematic manner. Stratification of products enables us to offer the possibility of product comparison (Miles & Huberman, 1994), while also providing enough information on the relevant industry to capture major variations in firm behaviour, outlooks and experiences (Patton, 1990). This method of sampling increases the likelihood of arriving at findings that are "both rich in content and inclusive in scope" (Kemper et al., 2003). Additionally, using a predetermined criterion to qualify a firm ensured that some level of quality assurance was maintained (Patton, 1990; Miles & Huberman, 1994). In our case, we purposefully selected firms that were sizable players in the industry; exporters; registered with an industry body; and located in at least one of the three major cities in South Africa.

Further, by using open-ended questions in our interviews, we are able to build a nuanced story of the product space in South Africa. Both our key informant and firm questionnaires consisted of mainly open-ended questions. This was a deliberate choice as part of an attempt to collect as much information from the respondents as possible, with the objective of synthesising it into a comprehensive picture of the South African product space. The use of open-ended questions, as Piore (2006) argues, is instrumental in the identification of patterns which can provide a richer context within which to revise industrial policy – an invaluable benefit of qualitative research.

Our choice for this sampling approach was also driven by the following considerations: First, it is a cost- and time-effective sampling method. The potential number of firms engaging in the production of the 20 identified frontier products is likely to be high. As a result, we would not be able to interview all of them, and therefore chose to limit our sample to a selection of firms located in Johannesburg, Cape Town and Durban. As these are located in South Africa's largest provinces in terms of their overall contribution to GDP, we deemed limiting the study to these cities justified. Second, we had to ensure that the firms selected could supply us with as much information as was required at the sector level, and for the project overall. Consequently, the selected firm did not need to be a representative of the industry; they simply had to have operational and sectoral knowledge of the product or industry. The selected industry body and firms however, had to meet the following set of characteristics:
 i.   An industry association had to meet at least one or all of the following considerations: Firstly, it was the largest, in terms of the share of the firms it represented in that industry. Secondly, it was the main association that focused on increasing access to export markets. Finally, it was

the association that had been present in the sector for the longest period, and could therefore provide an overview of historical changes to the sector.

ii. In the case of individual researchers, academics and other industry experts, we included those who were working in or who had previously researched the sector's dynamics.

iii. For a firm to qualify it was, either currently or historically, involved in the manufacture or production of the listed product for local use or exportation.

The initial sample of industry associations and firms offered referrals to other firms or people of interest to the study. Furthermore, based on the level of detail and nature of responses from interviewed firms, we supplemented our findings with desktop research where appropriate. Firm interview responses were deemed valid if they offered new insights and were, at least, consistent with the industry bodies' responses. This assisted in ensuring that we were not presented with contradictory views that were uninterpretable as findings for the broader study.

This sampling approach is not without limitations, however. The major limitation posed by purposively selecting the firms, is selection bias. This is most likely to occur due to firms identified for interviews opting out of the interview due to characteristics unobservable to us. The potential for selection bias poses concerns on the generalisability of our findings, however, we attempted to mitigate this bias in various ways: Firstly, in our reporting, we restrict our analysis to firms dealing in one product which means a narrower comparison of homogeneous firms, which in turn helps to contain any potential effects of selection bias, as discussed in Collier and Mahoney (1996). In order to ensure that the presented results are at least somewhat robust, at least two firms dealing with the production of each of the 20 frontier products were included. This would provide us, as researchers, with a way to compare findings across firms and avoid basing policy recommendations on claims by a single firm which may not represent the views of the wider industry.

Even after taking all of these points into consideration, it needs to be stressed that the resultant sample of firms is not representative of the entire population of firms in the relevant industry, and thus the results should be interpreted with caution. Although attempts have been made to mitigate the biases that arise in the results, they cannot be eliminated completely. That is not to say that the results presented in the following subsections are without value, though: Respondents provided valuable insight into their industries, which can be used as a springboard for researchers and policymakers to identify which sectors and products merit further, more rigorous investigation.

6.1 Agro-processing Sector – Pig and poultry fat (HS 1501)[40]

The agro-processing sector is one of the better performing manufacturing sectors in the South African economy.[41] Over the period 2008 to 2014, production, exports and employment have grown by 3.2, 5.2 and 2.6 percent per annum, respectively (Statistics SA, 2008; 2014a; 2014b). The sector's share of manufacturing production and manufacturing employment have grown by 3.3 and 5.1 percent, respectively. In terms of the share of total manufacturing production and employment, agro-processing is the second largest sector in 2014. The sector's share of total exports and total manufacturing exports has also risen between 2008 and 2014. Despite this, agro-processing is not as big an exporter as other sectors, such as metals and chemicals. This is reflected in the share of total manufacturing exports – 7.2 percent in 2014 – being relatively minor. Exports per worker is also below the average for manufacturing. This stands in contrast to agro-processing's relative position with respect to employment and production. It would thus seem that the sector is focused on the domestic economy, rather than exports. However, processed food products are generally considered a normal good,

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[40] Of the 150 frontier products, there are other products related to the pork production, such as, Pig meat (0203), Animal Fat (0209) and Sausages (1601).

[41] The agro-processing sector aligns with Division 30 of the SIC coding system used by Statistics South Africa. This includes the manufacture of food and beverage products.

which may suggest that with growing income levels in other African countries, South African manufacturers may be well placed to exploit this potential source of demand in the future.

In this section we focus on a processed agricultural product, namely pig fat, which is a sub-component of the identified frontier product, *Pig and poultry fat (HS 1501)*. The product classification in the trade data refers to pig fat or lard, which is typically used in the production of downstream emulsified products, such as sausages (another frontier product), ham, polony and salami. To gain an understanding of the potential of this product as an avenue for export diversification and growth, one needs to consider it in light of the broader pork value chain, especially since, due to the high level of inter-relatedness present in the pork industry, the development of the frontier product in itself requires the development of all aspects of the pork value chain.

Primary producers in the South African pork sector operate so-called "farrow-to-finish" units, which incorporate the breeding, weaning and finishing aspects of pig rearing. Once the pigs have been raised to the appropriate weight, they are moved to abattoirs for slaughter. Hereafter, 45 percent of the meat is sold for the fresh meat market and 55 percent is sold for the processed market. Fresh meat is moved to retailers via wholesalers, or in some cases, cutting and packaging is undertaken at abattoir level and thus shifted directly to retailers. Value addition is undertaken by the processing sector, which is capital- and scale-intensive. High capital investment acts as a barrier to entry and thus the sector is highly concentrated, with 80 percent of the market accounted for by two firms. This fresh and processed meat is then absorbed mostly into the domestic markets, as South African demand for pork products generally outstrips production.

6.1.1 Employment Potential for Women and Youth

Although orientated toward male workers, the agro-processing sector provides more opportunities for women relative to other manufacturing sectors. This is reflected in the female to male employment ratio for the sector (0.53) exceeding the average for manufacturing (0.45) (Statistics South Africa, 2014b). However, employment growth over the period 2008 to 2014 has been orientated toward males, with employment growth for male workers expanding at 3.5 percent per annum, versus 1.2 percent for females. This is reflected in a declining female to male employment ratio for the sector. A similar pattern is evident in the sub-industry most closely linked to the frontier product, namely, *Production, processing and preserving of meat and meat products*. With respect to the employment of youth, the broader industry has a youth-to-non-youth ratio of 0.07 in 2014, thus indicating the dearth of young employees in the industry.

At the primary producer level, operations are capital-intensive and the global trend is for increased capital-intensity. For example, a 10,000 sow farm employs between 30 and 40 workers. It was noted in the interviews that being competitive in global markets requires scale economies, and that this is achieved through increased capital intensity in production and the uptake of the latest industry technologies. In comparison to major global pork producers, South African production is relatively labour-intensive. Employment in primary production is male-dominated and characterised by an aging workforce. The respondents noted that their industry faces difficulties in attracting youth into farming. A further point of interest is the fact that South African pig farms may require workers with broader skill-sets than their international competitors. Due to South African pig farms being "farrow-to-finish" operations instead of focussing on only one aspect of pig breeding, workers will require diversified skills if they are expected to operate across all processes in primary production.

Although still capital-intensive, abattoir and processing activities are less so than those in primary production. One respondent, involved in the slaughter and processing of pork, noted that male and female workers comprised 40 and 60 percent of its workforce, respectively. This suggests that there is a higher propensity of generating jobs for women in pork processing than at any other point in the value chain. The respondent further noted that 22 percent of employees are under the age of 30.

Additionally, the firm claims from the Employment Tax Incentive (ETI) for these employees, perhaps indicating that pork processing also exhibits higher propensities for generating youth employment.

6.1.2 Paths for Future Diversification

There are two elements to export diversification: first, the type of product exported, and second, the chosen destination market. With respect to pork products, interviews with firms and industry experts revealed that both these elements have potential.

Globally, the most consumed meat is pork, accounting for approximately 40 percent of global meat consumption. India, China and Vietnam are high-demand markets, with pork being the primary source of protein in these high populace emerging markets. China is demanding high volumes of pork; in particular, tails and ears. The extent to which South African firms can enter these large markets is contingent on them generating the scale economies needed to meet the large volume demands associated with these markets. Currently, South Africa accounts for approximately 0.2 percent of global pork production, and is thus considered a minor pork producer in the global market, indicating that expansion of productive capabilities is likely necessary to expand into this market (Mugido, 2017).

With respect to the rest of Africa, there is certainly the potential for export growth. This is driven by the notion that rising incomes across the continent are likely to lead to increased meat consumption. One of the firms interviewed noted that it did export fresh meat to Namibia and could possibly export to other neighbouring states. However, the export of fresh meat is constrained by the length of time it takes to transport the product from factory to shop. Fresh meat remains safe for consumption for seven days after slaughter and inefficient border procedures act as a constraint to the export of fresh meat. However, cut and frozen meat can last for 2 years, and thus the export of frozen cuts opens up more distant markets. One firm noted that a major constraint regarding trade in Africa is the lack of formal retailers since meat is often traded in informal markets. This restricts the firm's ability to match itself with meat sellers, and thus enter these markets.

Another potential avenue for diversification is to diversify the products available for export. It was noted by one firm that its strategy moving forward is to diversify into processed pork products. Given that demand is currently skewed towards processed pork products rather than fresh pork, this move may open up opportunities for this firm to access larger markets.

It is important to note that in order to exploit the export potential of pork products, the growth of the pork value chain is vital. It is noted that China and India offer huge export potential. However, the volumes demanded by these markets are large and thus the South African pork value chain needs to expand its scale to meet these high-volume demands. For example, primary producers need to expand production and this needs to be matched by an increase in the number and scale of abattoirs. This would enable the production of increased volumes of pig fat, which is then fed into the production of processed pork products. Being globally competitive in export markets requires scale economies, and thus the entire value chain needs to increase in scale. However, there are several constraints (or lack of capabilities) to this growth of the pork value chain.

6.1.3 Identifying the Capabilities and Constraints for Future Diversification

In a broad sense, growth in the pork industry is contingent on entering large export markets, such as those in China and India, and ensuring that there is sufficient evidence available to firms that access to these markets is secure. If there is no guarantee that diversification into these export markets can occur, then firms will not be willing to take on capital procurement ventures that will allow the growth of the entire pork value chain. This can be achieved, for example, through careful regulation of trade protocols as they relate to the exporting of pork products from South Africa. As a result, it is important to consider all aspects of the pork industry when identifying the constraints and capabilities

associated with this diversification. This subsection presents a discussion of these capabilities and constraints in the context of the processing of pig fats and related pork products.

At the primary production level, the following capabilities are key: Firstly, to compete globally, the industry needs to invest heavily in research and development. Modern pig production is highly scientific and involves genetic product development. Although South Africa has good genetic material for breeding, according to the respondents, it has fallen behind in R&D activities, which stunts the industry's ability to compete globally. For example, major exporting countries, such as the USA and Netherlands, have entire farms dedicated to R&D. R&D activities enable producers to develop productive methods that maximise productive efficiency.

Secondly, it is vital that the costs of feed, which comprise between 70 and 80 percent of the variable costs of pig production, are both minimised and stabilised. At a macro level, a stable macroeconomic environment would minimise the volatility of the exchange rate, and thus stabilise the price of maize and proteins, which comprise 65 and 15 percent of the cost of pig feed, respectively. Although maize is sourced domestically, it is priced according to the Chicago Market, and is thus subject to exchange rate fluctuations. With respect to proteins, despite being a net exporter of soya beans, the domestic crushing capacity of soya beans is underdeveloped and insufficient, meaning that farmers have to import proteins to create pig feed. This results in volatile and potentially inflated feed prices. By developing the capability to crush soya beans, the cost of this input can be reduced, thereby allowing primary producers to grow their margins and expand scale.

Scale and capital intensity of production are key to competing in the global market. Scale and capital intensity are also important in the production-orientated components of the value chain: primary production, abattoir, and processing. All three of these components require substantial capital investment. For example, pigs are sensitive to their environment, and thus to optimise growing conditions, specialised housing with advanced climate control is needed. The imported equipment and technology is expensive and thus presents a significant barrier to entry into pig production. For example, Davids et al. (2014) state that the estimated capital outlay is R60 000 per sow. An economically viable farm consists of at least 300 sows, which equates to an R18 million capital outlay. The presence of efficient capital markets facilitates the process of capital investment, which enables producers to expand the scale of production and move down the average cost curve. The presence of well-functioning capital markets that have an intimate knowledge of modern agriculture is a key capability needed to facilitate a shift to increased economies of scale within the industry.

Another key capability that affects the various production-orientated components of the value chain, is bio-security. It is well accepted that the health status of the pig industry is vital to its survival and growth. Davids et al. (2014) note that while there are 485 abattoirs in South Africa, only 150 slaughter pigs, and only 5 of these comply with the standards and regulations needed to be accredited for exporting. The limited availability of abattoirs that are export-compliant acts a key constraint to entering new markets. In response to this, the South African Pig Producers Organisation (SAPPO), in conjunction with key players in the pig industry (producers, abattoirs, processors, retailers, and pig veterinarians), has taken biosecurity and consumerism into consideration and developed quality assurance and traceability standards for the South African Pig Industry – known as *Pork 360*. *Pork 360* aligns the industry to international best practice, and accreditation allows for participation in the industry. A key example of adoption of international best practice is compliance with the compartment system. This involves farmers separating their livestock into units that do not encounter one another, and coding the meat that comes from each unit. The idea is that if one unit is contaminated with a disease, the other units are safe from the spread of the virus, and the contaminated meat can be traced.

A related capability required to ensure bio-security is the supply of skilled and experienced veterinary experts. Compliance and accreditation with *Pork 360* requires producers to employ or hire

an accredited veterinary consultant who, in turn, regularly visits, advises, and evaluates the farm and production processes.

Institutions that regulate the industry, and the presence of veterinary experts, not only ensure bio-security, but also enable the negotiation of trade protocols. For two countries to trade meat products with one another, there needs to be a trade protocol. For this to happen, veterinary authorities need to be in place to regulate health and safety in the industry. There needs to be agreement that the industry in each country meets certain requirements in terms of health and safety. These negotiations can take upwards of five years, and thus continuity and stability within the bureaucracy is important. Ultimately, the growth of the industry, and expansion into export markets, needs to be accompanied by the strengthening of the institutions that ensure bio-security.

Ultimately, then, if the pork industry is to expand in scale, then it needs to grow beyond the domestic market and enter into export markets. However, there is no incentive to increase scale unless trade protocols have been negotiated with respective export markets. This would suggest that of immediate (short- to medium-term) importance, is the strengthening of the regulatory authorities ensuring bio-security across the value chain. This needs to happen in conjunction with the negotiation of the trade protocols with high demand export markets. As production is scaled up, the incentive to develop other key capabilities would be motivated. These more long-term capabilities include: increased investment in R&D, increased supply of veterinary experts, and the development of soya bean crushing capacity. However, it is worth noting that in many cases, the development of each of these capabilities is contingent on the development of the others.

6.2 Transport Sector – Vehicle parts (HS 8708)

Within the transport sector, Vehicle parts (HS 8708) is identified as a frontier product. [42] The transport sector forms a value-chain that spans the manufacturing and retail sectors. The manufacturing element, comprised of vehicle assembly and component production, starts with the Original Equipment Manufacturers (OEMs), which are focused on motor vehicle assembly. [43] The OEMs feed into three tiers of component suppliers, which is the element of the value chain specific to the identified frontier product. Tier one suppliers manufacture car components such as engines, leather trims, dashboards, and catalytic converters. Tier two and three suppliers produce the sub-components used by tier one suppliers, such as pistons for engines, and tracks for seats. The retail component is comprised of franchised and non-franchised service centres, workshops and body shops that sell directly to final consumers.

At the outset it is worth stating that the focus is on identifying policy interventions that will drive growth in the tier two and three elements of the value chain. However, it is our view that these interventions should complement existing policy, and ultimately aim to facilitate growth of the entire value chain. [44] Further, it is also important to view this value chain in the context of it linking with the global value chain for automotive products, which provides a unique set of challenges and opportunities.

The transport sector is a key manufacturing sector in the South African economy, with vehicle assembly and component production jointly accounting for over 33 percent of South Africa's manufacturing output in 2016 (South Africa Automotive Export Manual, 2017). Over a similar period,

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[42] From the onset, it must be stated that vehicle parts are not a single homogenous product, but are rather made up of various components necessary for the assembly of motor vehicles.

[43] OEMs located in South Africa include BMW, Nissan, Ford (The Gauteng Cluster), General Motors, Volkswagen, Mercedez-Benz (The Eastern Cape Cluster), Toyota, and Motus.

[44] In terms of industrial policy, the automotive sector is a priority sector, with the flagship policy being the Motor Industry Development Programme (MIDP) that was in place between 1995 and 2012, and currently the Automotive Production Development Programme (APDP), which is in place until 2020.

exports from this sector accounted for R171 billion, representing approximately 15 percent of total South African exports. Component production comprises a smaller subsection of total transport manufacturing production (30%) and exports (5.4%).

Overall production of motor vehicle parts declined by 9.6 percent annually in South Africa between 2008 and 2014 (Statistics South Africa, 2008; 2014a). Despite this decline in production, exports grew at an average annual rate of 2.6 percent per annum, and the value of exports per worker rose (Statistics South Africa, 2008; 2014a). Coupled with a 12.3 percent annual decline in employment, and a rise in the value of production per worker, this supports the finding that worker productivity increased over this horizon.

6.2.1 Employment Potential for Women and Youth

Ultimately, the growth of the entire value-chain, from assembly to retail, is expected to offer substantial employment growth potential. However, it was expressed by respondents that the tier two and three elements of the value chain provide the greatest potential for employment growth. It was noted that in relation to OEMs and tier one component suppliers, tier two and tier three firms, are typically smaller, have lower start-up costs, and are less capital-intensive.[45] The increased labour intensity of these component suppliers suggests that growth of these firms and entry of new firms is likely to yield relatively strong employment gains.

Due to the physical nature of the work and the increasing demand for skilled labour, the component manufacturing element of the broader sector remains male-dominated with an older age profile.[46] Firstly, with respect to age, the ratio of youth aged 15 to 24 to non-youth in the sector is 0.09 in 2014, down from 0.12 in 2008. Despite the data pointing to declining youth representation, respondents noted that there are increasingly more young people in the sub-sector. It was noted that this is may be due to the increasing role of technology in component manufacturing, which implies that new entrants into the sector need to be computer literate. Younger workers are more likely to have computer literacy skills relative to older workers.

Secondly, with respect to gender, the orientation of the sector toward male employees is evident in the female-to-male employment ratio of 0.37 in 2014 (Statistics South Africa, 2008; 2014b). In other words, 37 female employees for every hundred male employees. This is, however, a slight improvement in female representation relative to the ratio of 0.29 in 2008. This improved representation, albeit slight, may be due to a combination of relatively high sector wages, and production becoming less manual.

Data from Statistics South Africa (2008; 2014b) point to declining employment levels in vehicle component manufacturing for the period 2008 to 2014. This decline in employment levels is coupled with an overall decline in output from this sector, however, it should be noted that employment levels decreased more rapidly than output levels, suggesting that the decrease in employment is not solely due to reduced production. Given that mechanisation of production processes is relatively common in the current economic climate, this may have been a cause for the decrease in employment in this industry. However, when asked about the impact of mechanisation and the potential impacts of the fourth industrial revolution, respondents indicated that while mechanisation has expanded across the sector, there has been no visible impact on employment levels[47]. Respondents noted that this is

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[45] However, there are exceptions, with large firms, such as Sasol and Arcelor Mittal, being tier two and three component suppliers.
[46] When asked, the respondents indicated that there is nothing in the sector or the various job requirements that make the sector less suitable for younger or women workers.
[47] It is important at this point to recall that these interviews are not representative of the industry as a whole. As a result, although the interviewed firms reported little to no change in overall employment, this is not to say that this trend is evident in the rest of the industry.

perhaps partly due to the high levels of labour supply prevalent in South Africa, which naturally skew the factor-mix towards labour.

However, respondents report that as the role of technology in the sector has risen, the basic skills types demanded have also shifted, resulting in current entrants being required to have a complete secondary school certificate, with preference for individuals who have studied maths and science. This may limit opportunities for youth employment in the South African context, due to the low school completion rates for South African youth. It was, however, noted by respondents that, subject to workers having this minimum level of education, entry into the industry is relatively easy, and there is substantial scope for progress at basic occupation levels.

6.2.2 Paths for Future Diversification

Interview findings, drawn from industry experts and firm respondents, indicate that the opportunities for growth are present at the second and third tier of component suppliers, and that targeting this level of the value chain would yield various economy-wide benefits. These economy-wide benefits include: first, the creation of employment opportunities for individuals of different skills levels. Second, increasing the bulk of firms that supply critical components to vehicle assemblers will increase the local content of exported vehicles, which increases the sector's sustainability.[48] Lastly, component suppliers also supply other non-automotive sectors, which would result in competitive prices for a variety of products.

Black, Barnes and Monaco (2018) note that component exports have grown significantly from an estimated R3.3 billion in 1995 to R49.6 billion in 2015. Despite these growing trends, recent work into the development of component suppliers concludes that export expansion has not been led by traditional component suppliers, but rather by foreign owned firms that are integrated with global OEMs (Black, Barnes & Monaco, 2018). As a result, the overall investments within the sector have remained light, and the sector is further characterised by low levels of integration into the rest of the domestic industry (Black, Barnes & Monaco, 2018).

Another challenge facing the local automotive industry is the growing production or assembly of large commodity products that comprise a declining share of automotive value addition. According to Black, Barnes and Monaco (2018), between 48 and 76 percent of local content is derived from low value-added components that arise from the choice to focus on "metal pressings and plastic moulded products, as opposed to electronics, powertrain, telematics, and advanced safety products". This suggests that it is desirable for the sub-sector to diversify into more complex higher value-add components and drive up local content.

Further, few of the tier two and three component suppliers currently possess the capabilities to expand. For such firms to harness the envisioned potential within the sector, they would require additional support such as access to capital to procure the right type of tooling equipment, machinery and technology to meet market demand. These constraints are expounded upon in the next sub-section.

6.2.3 Identifying the Capabilities and Constraints for Future Diversification

Based on interviews with firm respondents and industry experts a number of capabilities and constraints emerged.

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[48] The Thai government in 1974, set an initial low local content target that was reassigned in 1980 to various components based on the government's assessment of their developmental importance, rather than their commercial value. Once set targets were met, or surpassed, the government shifted the support to offer tax and import duty exemptions. As a result, the sector has become increasingly export-oriented, and the number of supplier firms has grown as well. It is estimated that there are approximately 650 first-tier suppliers and over 1600 second- and third-tier suppliers in Thailand.

A key constraint impacting the ability of tier two and three firms to attract sufficiently skilled labour, is the substantial wage differential between what workers earn in OEM and tier one firms relative to what workers earn in tier two and three firms. Wage setting in OEMs and tier one component suppliers is highly regulated with bargaining agreements being finalised and applicable over three-year periods. Conversely, wage setting within the tier two and three sub-sector is less stringently regulated and wages are in turn lower. These wage differentials are further exacerbated by the increasing push by the OEMS for component suppliers to lower costs. The extent to which lower wages hinder tier two and three firms from attracting suitably skilled labour adversely impacts on their ability to meet the productive requirements of tier one firms and OEMs, thereby hindering access into the automotive value chain.

A further issue limiting the growth of these local component suppliers is intrinsically tied to the scale of domestic production. More specifically, the proliferation of vehicle models manufactured by domestic OEMs places a demand on component suppliers to manufacture a diverse range of components at relatively low volumes (Black, 2011; Black, Barnes & Monaco, 2018). This diversity pushes up production costs, such as tooling costs, and limits the firms' ability to drive up scale and thus reduce average costs. As a volume-based industry that depends on high levels of technology, growth is dependent on consistently lowering production costs.

Further growth within this level of the supply chain is further limited by the fact that the automotive industry requires long lead times to supply OEMs as contracts are negotiated far in advance. Potential suppliers therefore need to be flexible in terms of their production capacity and their skills to adjust to the change in demand. However, this additional flexibility has had the effect of increasing overall production costs.

A key skills constraint facing component suppliers is the lack of systems integration experts. Systems integration experts design and program the automation of production lines and the integration of robotics systems. Respondents noted that there is only one local firm with the capability to do this, as their two competitors filed for bankruptcy and left the market.

There are also a number of constraints that drive up the cost of doing business across the entire value chain. These include: first, the current use of "dirty fuels" forces firms to operate separate production lines for vehicles sold in domestic and international markets.[49] This drives up production costs. Second, the declining performance of the rail sector forces firms to transport manufactured vehicles via road, which is costlier. Additionally, respondents indicated that while port costs had reduced over time, they remain high relative to global competitors. Third, the tyre levies imposed by the Department of Transport serves to drive up production costs.

In summary, the diversification of the motor vehicle parts industry is concentrated amongst tier two and tier three manufacturers. In order to fully realise the potential for growth and diversification in this sector, South African policy should focus on developing the inputs into the production process: Firstly, the upskilling of workers in tier two and three manufacturing firms is crucial in order to stay abreast of technological advancements in the sector, and operate more sophisticated, flexible tooling equipment which allows a single firm to diversify their production and decrease average costs. Policy that focusses on decreasing the wage penalty associated with working for a tier two or three manufacturer may go some way towards addressing this lack of skilled labour. Secondly, integration into global value chains and global OEMs would assist local manufacturers in their attempts to increase

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[49] Following the enactment of the Cleaner Fuel legislation, oil refineries are compelled to shift from Euro level II fuels to Euro V, which are deemed to be the high-quality fuel grades sold in Europe and other similar markets. The resulting fuel is also cleaner as it has lower impurities and emits lower carbon and other hazardous gases. Automotive companies also argue that cleaner fuel is required for modern, fuel-efficient cars. Source: http://www.engineeringnews.co.za/article/mid-2017-clean-fuels-compliance-deadline-off-the-table-2014-05-06 (Accessed: 19 June 2018).

exports, and hence, production. As has been mentioned above, the process of diversification must be considered within the context of the global value chain, and in the case of motor vehicle parts, this requires local manufacturers to engage and attempt to integrate with global suppliers and OEMs in order to access the opportunities for expansion which are currently inaccessible to them.

6.3 Metals Sector

Two frontier products fall within the metals sector: Large Flat-Rolled Iron (HS 7211) and Iron Radiators (HS 7322). Iron is a major input into the production of steel, and thus this section discusses the dynamics of both the iron and steel sectors, which fit within the iron and steel chain. The value chain is divided broadly into upstream and downstream industries, each of which with their own unique function. Upstream industries incorporate the exploration and extraction of iron ore through mining. This then feeds into firms involved in two elements of beneficiation: first, mining beneficiation, which is the process of converting mined ore into useful products that steel producers can use. Second, metallurgical beneficiation and shaping, which involves the process of converting iron into steel. Steel producers then supply downstream industries, which include firms involved in the conversion and fabrication of steel products. These downstream industries feature in the discussions on the automotive sector and the machinery and equipment sector.

Production in the metals sector has declined at an average rate of 3.4 percent per annum for the period 2008 to 2014 (Statistics South Africa, 2008; 2014a). However, it is worth highlighting that the collected data coincides with the global financial crisis and the ensuing period when commodity prices declined globally. Exports within the sector also declined, but at a lower annualised rate of 1.5 percent, indicating that global demand for South African products did not diminish greatly. Coupled with the decreased production levels, it seems that South African manufacturers opted to prioritise the international market over the domestic one, perhaps because of greater profitability associated with export markets.

The South African iron ore industry supplies the domestic market's full demand for iron ore. Residual volumes are exported to destinations such as China, India, Japan, South Korea, Europe and the Middle East. [50] The South African iron ore industry is globally competitive, arising from the significant volume of high-quality iron ore mined locally. However, international competitors have cost advantages such as being situated closer to final markets resulting in lower transportation and port handling costs. Being larger, they also produce at scale, which further lowers their production costs.

When considering the steel industry, on the other hand, South Africa has various manufacturers, namely: ArcelorMittal South Africa (AMSA), Evraz Highveld Steel, Scaw Metals, CISCO, and Cape Gate. AMSA is Africa's largest steel producer with an annual production capacity of 6.1 million tonnes of liquid steel, corresponding to approximately 5.2 million tonnes of saleable steel products (Anglo American Kumba Iron Ore, 2011). Due to AMSA's size and cost base, the performance of the steel producer is, to a large extent, tied to the overall economic performance of the national economy, particularly, infrastructure investment (ArcelorMittal South Africa, 2017).

6.3.1 Employment Potential for Women and Youth

AMSA estimates that three jobs are created for every 1 000 tonnes of steel that are produced. Hence, there is a direct correlation between increasing the domestic demand for steel and creating employment (ArcelorMittal South Africa, 2017). However, overall production in the metals sector has decreased between 2008 and 2014 at an annualised rate of 3.4 percent. This contraction in production,

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[50] The Chamber of Mines (2017) estimates that in 2016, 91 percent of total domestic iron ore production was exported. In 2016 for instance, Kumba produced 41.5Mt and exported 39.1Mt – relating to 94 percent of total production.

however, has been accompanied by a relatively small rise in employment, driven by a growing share of female employees within the sector.

Despite this growth in female representation, the share of male employees far exceeds that of female employees, with approximately six male employees being employed for every single female worker (Statistics South Africa, 2008; 2014b). Unfortunately, even though the number of women employed in this sector has increased in absolute terms, there has been little change in the ratio of male to female employees over time. Thus, while there is room to grow women's employment in the metals sector, this potential is not being fulfilled at present.

At the iron and steel production level, the share of women employed has been gradually increasing. This follows the employment equity targets set by the Department of Mineral Resources to increase the share of black and female individuals in both mining and non-mining positions. Further downstream, we observed that few women apply for positions, or where they do apply, few are employed. This is typically a function of the perceived physical requirements of the job.

The age profile of the sector favours older workers, with a significantly higher ratio of them compared to youth. This is especially the case when we define youth as those individuals aged between 15 and 24. Compared to this group, we observe that 10 non-youth workers are hired for every single worker in this age group (Statistics South Africa, 2008; 2014b). This ratio improves when we categorise youth as aged between 15 and 34. In this instance, for every 100 non-youth employees, there are 63 youth. This is broadly in line with manufacturing as a whole, and indicates that there is a high prevalence of individuals between 25 and 34 years of age employed in this sector.

Skills at the iron smelter and steel producer level are generally high, with entry-level jobs requiring individuals to have Matric and, in some instances, to have completed Mathematics and Science as subjects. Much like in the transport sector, the requirement that new entrants into the sector should have a high school completion certificate may limit the potential for youth employment. This is supported by the ratio of youth (15 to 34-year-old classification) to non-youth employees having decreased from 0.77 in 2008 to 0.64 in 2014 (Statistics South Africa, 2008; 2014b). However, many larger firms train artisans internally. These artisans are then either recruited directly by the firm, or else they are provided with a qualification they can use to find a job in another firm. This artisan-training programme is perhaps a way of encouraging youth employment in a sector that seems to be struggling to keep their workforce young.

6.3.2 Paths for Future Diversification

More than 85 percent of South African steel is consumed in industry sectors for which steel's share of product value is less than 5 percent – only packaging and machinery and equipment are designated as high steel-intensity sectors. The main steel-consuming sectors – mining, construction and manufacturing – have realised a contraction in their growth, which has resulted in low aggregate domestic demand for steel. This lack of domestic demand affects many key players – for example, Kumba supplies AMSA with 6.2mt of iron ore annually at mining gate prices, in order to increase competitiveness. However, due to subdued domestic demand for steel products AMSA have historically only been claiming half of this amount.

Therefore, a possible avenue for growth in the steel sector would include incentivising the growth of steel-dependent sectors, such as developing the manufacture of machinery and equipment, which this paper has identified as a potential source of growth and employment. The theory behind economic complexity argues that because there are interdependencies between industries, one should focus on growing a cluster of related industries in order to supplement growth and development in the economy as a whole, rather than focussing on one isolated product. Thus, focussing on the related machinery and equipment manufacturing sectors in conjunction with the metals sector may be the most sustainable source of growth for the metals industry in South Africa.

This diversification into the production of products for related industries is also practically being considered by firms. The interviewed iron producer indicated that with the right level of financing, they would diversify into the production of pins and bushes for the mining sector. This expansion would enable them to create between 100 and 500 jobs depending on the scale of investment undertaken. Interviewed respondents also indicated that the rest of the African continent could be a market for local iron ore and final steel products, although supplying this market faces some unique challenges, namely: poor infrastructure and low purchasing power of these nations.

6.3.3 Identifying the Capabilities and Constraints for Future Diversification

The South African steel producing industry has witnessed significant concentration as the major producers merged with various international companies. A direct consequence of these global trends is that South Africa's major steel manufacturing firms since the early 2000s had their operations directed to serve the global corporations profit objective, which often is at odds with the country's industrialisation or developmental objective (Rustomjee et al., 2018). It is thus important to identify and pursue policy objectives specific to South Africa in order to encourage growth and development within the local metals sector.

Relatedly, the sector, particularly the mining component, is currently operating against a backdrop of mounting regulatory and policy uncertainty. This growing uncertainty directly affects the market capitalisation of listed companies and discourages long-term investment in the sector. Following an intervention by the office of the President, the Chamber of Mines, and the Department of Mineral Resources, agreed to postpone the commencement of the review application to afford all parties an opportunity to revisit the Mining Charter and provide necessary feedback (Anglo American Kumba Iron, 2018).

At the extraction and mining beneficiation level of the value chain it is expressed that logistics costs (namely railways, ports and ships) are a key constraint to lowering production costs. The rail costs alone are estimated to be 30 percent of total operational costs.[51] This implies that increasing efficiencies at the relevant state-owned entities will directly increase the profitability of iron-ore producers. For example, the iron ore industry has the potential to increase their output in the medium- to long-term, if the necessary bulk logistic services (such as rail and port infrastructure) are updated, provided consistently, and priced competitively. This would enable them to service domestic and international buyers rapidly, and to offer competitive unit prices.

Producers of iron products indicated that the capability most required for their overall growth, is the development of local foundries, and making them more competitive. The foundry segment of the value chain provides a vital link between the upstream iron and steel producers and the downstream end users such as OEMs and machinery manufacturers. From interviews with various firms, we understand that local foundries are faced with declining demand for their products. This is mainly due to inconsistency in the quality of products, and because they are not competitive in terms of price. Downstream producers are therefore forced to increasingly depend on imports for all kinds of components – even those that local foundries previously had established capabilities to produce. As imports become the norm, South African foundries will find it harder to access and supply the value chain (Rustomjee et al., 2018). Furthermore, as firms that depend on various foundry components are forced to procure necessary inputs at a costly price (either through imports or paying a premium for high quality locally produced components), this affects the overall profitability of sectors such as manufacturing of machinery and equipment that have strong linkages with foundries. Hence, improving the productivity of local foundries will have significant knock-on effects on potentially competitive sectors of the economy, such as machine manufacturing.

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[51] This figure was provided by one of the respondents we spoke to.

A key factor reducing the profitability and thus viability of foundries is the pricing of electricity, which is a substantial component of these firms' cost structure. Rustomjee et al. (2018) contend that while large firms, such as AMSA, are able to get electricity directly from Eskom at a developmental price, smaller firms, such as foundries, source their electricity via municipalities. Municipalities have an incentive to accumulate revenues from the sale of electricity and thus charge higher prices than what is paid when sourcing electricity directly from Eskom. Assuming the importance of foundries in the broader industrial development strategy, the pricing of electricity to these producers at a 'developmental' level may be desirable.

It may also be profitable to invest in emerging technologies that might reduce South African steel producers' dependence on expensive imported coking coal in a bid to lower overall operating costs, which are a significant barrier to the industry at present. This should also be accompanied with the development of skills for various machine operators. This becomes increasingly important as the role of technology increases across the manufacturing processes. Rustomjee et al. (2018) propose increasing efficiencies in the foundry sector by investing in automation through investment in new technologies.

Given the high skills requirements of workers, it is important for policies that aim to develop the metals sector to also focus on the development of human capital. When asked how to achieve this within the metals sector, interviewed respondents provided two suggestions. Firstly, to identify high school students with potential and then match them to the right type of training given their abilities. While the necessary capabilities are accumulated locally, it might be necessary to train these individuals overseas in locations such as Germany, Canada and America, where machines are manufactured, to ensure that individuals are trained in the most cutting-edge technology. Through the finalised firm interviews, respondents indicated the following as critical skills within the sector: industrial engineers, planning, and modelling. Secondly, while training is on-going, it might be beneficial to engage in skill-transfers by attracting individuals with the right skills to come and work in South Africa for a short period in local industries, with the objective of upgrading local worker skills.

Mechanisation and technology are increasingly being rolled out within the mining sector – and the iron and steel producers are no exception. This has had various benefits, namely, productivity gains, lowering labour costs, and reducing deaths or safety incidences. However, these gains are inversely related with the level of employment, as some individuals that are currently employed will lose their jobs following the widespread use of technology. When asked whether South Africa has the capabilities to produce the technology or machinery locally, firms replied that the necessary skills are currently lacking locally. As a result, they prefer to act as fast followers and copy global trends and technology, adapting them to the South African context. Employees are then trained on how to use the new technology and machinery.

6.4 Machinery & Equipment Sector

The machinery and equipment sector has been in decline between 2008 and 2014, with decreases in production and exports of 0.8 and 6.1 percent per annum, respectively (Statistics South Africa, 2008; 2014a; 2014b; CID, 2018). This was accompanied by declines in employment.[52] However, there has been a rising ratio of exports per worker, which means that declining production may have been driven largely by drops in local demand. Declining local demand is consistent with findings in Rustomjee et al. (2018), who argue that increased import penetration has adversely impacted on the machinery and equipment sector. It is also worth noting that despite falls in production, production per worker rose over the period. This is consistent with employment declining at a faster rate than production.

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[52] It is worth noting that over the period 1994 to 2016, employment in the machinery and equipment manufacturing sector has risen, although with a marginal decline and flattening over the period 2008 to 2016 (Rustomjee, et al. 2018)

The declining levels of production, exports and employment reflect the declining presence of the machinery sector as a whole. The sector comprises 4.8 percent of manufacturing production (down from 7.7 percent in 2008), 8.4 percent of manufacturing employment (down from 12.3 percent), and 8.4 percent of manufacturing exports (down from 9.2 percent) (Statistics South Africa, 2008; 2014a; 2014b).

Reflecting the existence of relevant productive capabilities needed to manufacture machinery and related equipment, a number of the frontier products fall within this sector. These include: Other Engines (HS 8412), Harvesting Machinery (HS 8433), Large Construction Vehicles (HS 8429), Other Agricultural Machinery (HS 8436), Dairy Machinery (HS 8434), and Lifting Machinery (HS 8428). In the discussion to follow, we focus on the broader categories these products fall within, namely: agricultural, mining and construction machinery.

6.4.1 Employment Potential for Women and Youth

As in metals, employment in this sector is skewed toward older males. The ratio of women to men in this sector is 0.25 in 2014 (i.e. one female for every four males), which sits below the average for manufacturing (0.45) (StatsSA, 2014a). The prevalence of male relative to female employees in the manufacture of agricultural and construction machinery is even more apparent, with the ratio of female to male being 0.2 in 2014 (Statistics South Africa, 2008; 2014b). There is evidence of a marginal (at best) shift in the workforce toward greater female representation: The ratio of women to men for machinery and equipment manufacturing has shifted from 0.23 to 0.25 over the period 2008 to 2014 (Statistics South Africa, 2008; 2014b). In the case of agricultural and construction machinery, the ratio has shifted from 0.14 to 0.2 over the same period.

These findings correspond with what was observed on the factory floor, when the interviews were conducted.[53] There are women working on the production line, but they are far less represented than their male colleagues. When enquiring about the low levels of female representation, a number of reasons were provided, including cultural norms amongst workers, as well as the physical nature of the job required. However, there are a multiplicity of tasks along the production line that do not require brute force, and thus the physical requirements of the job do not fully explain the low level of female representation. Furthermore, it seems that awareness of potential careers in the manufacturing sector is not widespread among women: firms noted that they do not receive as many job applications from women as from men. However, it is also possible that women are reluctant to enter into male-dominated working environments since they may be perceived to be hostile or unwelcoming. This was more of an issue for smaller firms than bigger firms, which seemed to be able to attract more female applicants, and thereby employ more women.

Youth to non-youth ratios are all below unity, whether for youth between 15 and 24 years of age or for youth between 15 and 34 years of age.[54] The ratio is less pronounced when the definition of youth is extended to include those older than 24 and younger than 35 – 0.55 youth for every non-youth worker compared to 0.05 in 2014 (Statistics South Africa, 2014). However, these numbers have decreased from 0.15 for 15- to 24-year olds, and 0.91 for 15- to 34-year-olds since 2008, indicating a severe decrease in youth employment in the machinery sector.

Firm interviews revealed a cautionary approach to hiring youth, which supports this trend of decreasing youth employment in the sector. Firms indicated that youth hires are higher-risk hires since younger workers tend to be unstable and characterised by shorter employment spells relative to older

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[53] For example, one firm producing agricultural machinery stated that 24 of its 350 production workers (7 percent) are women.
[54] A ratio of employment of youth relative to non-youth that is less than unity indicates that there are less youth employees relative to non-youth employees.

workers. Furthermore, because of the high sectoral minimum wage imposed on hires, firms seek stable longer-term employees so as to maximise any investment made in the employee through skills development programmes. Due to their shorter employment spells, youth do not provide the experience and stability which firms desire, and as such, they are hired less than their older counterparts.

The firm interviews did not provide favourable evidence for the effectiveness of the Employment Tax Incentive (ETI). For the smaller firms, there was a lack of awareness of the incentive scheme. It was further stated that irrespective of the incentive scheme, the high minimum wage associated with the sector incentivises firms to employ workers with characteristics typically not evident in youth. For these firms, an older, stable employee outweighs any gain in terms of the incentive scheme. For the larger firms, it seems that they would hire these youth regardless of the incentive scheme. They take advantage of the incentives with respect to placing young employees in apprenticeship training and engineering students doing a year of work experience – i.e. individuals that they would have hired, irrespective of the ETI.

6.4.2 Paths for Future Diversification

It is evident in the interviews that the firms constantly advance and modify existing products, in order to better service the customers' needs and keep up with global trends, also known as implementing micro-improvements on the production line. The respondents producing agricultural machinery noted that their field service technicians working from service branches located proximate to farming localities facilitated this modification process. By establishing strong working relationships with farmers, they are able to update and modify machinery according to the needs of the client.

When questioned about diversification into new products, the respondents noted that product development is a key feature of the business strategy, but that any new opportunity investigated must be closely linked with their current core competencies and capabilities. They further noted that the needs and demands of the customer play a key role in driving product diversification. For example, a firm that produces and exports articulated dump trucks (ADTs) has had to continually develop larger ADTs, such as their 50 and 60 ton models, as clients have demanded bigger trucks. This same firm noted that they have considered diversifying into underground mining machinery, fire trucks, trains and locomotives, and interestingly, blades for wind power producers. All these products involve the fabrication of metal products that move, and as such are closely linked to the current capabilities present in the firm.

Given the discussions with firms, it is also important to note that while there are various avenues open for future diversification, certain products are not viable in the South African context. For example, there are no South African firms with the requisite capabilities needed to produce dairy machinery.[55] Dairy machinery is imported from countries such as the Netherlands and Germany. Even if a local firm acquired these capabilities and aimed to enter this market, it would face significant barriers to entry. For instance, global brands such as DeLaval have established reputations and have thus gained the trust of farmers. A dairy farmer's entire income is reliant on supplying high quality milk to the market. It is thus vitally important that they can rely on the machinery that they use in their production process. Stated simply by a dairy farmer, it is not worth taking the risk on a product that they do not know and trust.

Another avenue for diversification noted by the respondents was the scope for developing technology that complements the machinery. For example, planting and seeding machines have computers, which distribute fertiliser according to the soil characteristics of different areas of a farm. The computer adjusts the rate of flow, so that the volume of fertiliser aligns with the needs of each soil type on the

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[55] Although it was noted by one respondent that some firms may be able to produce certain parts locally.

farm. Such technology, and the technical expertise linked to these services, is becoming increasingly important as commercial producers continually look to increase efficiencies.

The final element of market diversification relates to the entry into new geographical markets. In particular, Africa as a regional market is seen as one with potential, especially given the prominence of agriculture, the relatively low levels of mechanisation (UNIDO, 2008), and market proximity. It is worth noting that geographical diversification is not restricted to African markets. One respondent has been successful in exporting seeding and planting machinery to wheat producers in West Australia. Another respondent has invested in an assembly plant in Germany, which allows it to access markets proximate to Germany.

It was noted by all respondents that while the African regional market is a potential source of growth, doing business in Africa is hard. In particular, respondents reported that the financial risk was high, with non-payment being a key issue faced when doing business on the continent. Interestingly, a key strategy employed by these firms is the same employed when entering new markets within South Africa. The firm either establishes its own dealership and service centre in the locality, or links with a reputable third party. In this way, the firm is better able to manage the financial risk, and it benefits from being in close proximity to the farmer, thereby enjoying a close working relationship.

6.4.3 Identifying the Capabilities for Future Diversification

South African trade and industrial policy can be viewed as a capability in its conception, but a constraint in its implementation. For example, the Mineral and Petroleum Resources Development Act (MPRDA) provides an example of policy that is strong in driving industrialisation, yet weak in implementation. The MPRDA contains instruments that allow the Minister to attach beneficiation commitments to mineral extraction rights. However, Rustomjee et al. (2018) note that the Department of Mineral Resources (DMR) is yet to implement this beneficiation policy instrument.

Policy reflects a general acknowledgement that the iron and steel value chain is a key path toward industrialisation, and that jobs that are generated through such processes. Therefore, it is evident that policy makers are looking to drive industrialisation, particularly via advancement of the iron and steel value chain. These policies have the potential to provide an environment for the industries comprising the chain to grow, however, implementation is a key factor constraining the process.

Current trade policy is aimed at driving growth in upstream activities, often at the expense of downstream activities, particularly the manufacture of machinery and equipment. Most notably, the recently imposed tariffs on steel protect a single dominant firm at the expense of a large number of machinery and equipment manufacturers. In the machinery industry itself tariffs pose large barriers to local manufacturers: One of the interviewed firms manufactures large construction vehicles that require large heavy duty tyres. Despite these tyres not being manufactured domestically, there is a 15 percent duty on tyre imports[56], which when combined with steel tariffs, makes it 27 percent more expensive than its competitors, before even starting the manufacturing process. As such, there is certainly a case for a more nuanced approach to trade policy.

It was also noted by firms that despite policy allowing for firms to claim rebates on these steel and tyre tariffs, subject to exporting the final product, this process is difficult. For example, to reclaim the tariff on a batch of steel used in the production of a piece of machinery, that piece of steel needs to be followed and recorded throughout its movement across the value chain. Once exported, the rebate, if proven, can be claimed. If the broader industrial strategy is aimed at targeting export growth,

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[56] The domestic tyre industry in South Africa does not manufacture large heavy-duty tyres needed for construction vehicles since it is focused on producing tyres for the automotive sector. It was noted by one of the firms that tyres represent the single largest cost input in the production of their construction vehicles (articulated dump trucks).

which it is, then there is a case for rationalising the rebate process in consultation with industry role players to make it more practically actionable.

A further constraint relates to the facilitation of entry into new export markets, particularly African markets.[57] For manufacturing firms to expand their scale of production, exporting is vital since domestic market demand is insufficient. It was noted by all respondents that while this market is a potential source of growth, doing business in Africa is hard. In particular, respondents reported that the financial risk was high, with non-payment being a key issue faced when doing business on the continent. Furthermore, the process of establishing business relationships with buyers in another country is costly in terms of time and resources. This is particularly problematic in the case of small-to medium-size firms. Thirdly, access to export finance is vital for firms looking to compete in global markets. Rustomjee et al. (2018) emphasise the need to establish an export-import bank that would enable more favourable financing solutions for firms looking to trade.[58] Access to export finance is particularly important in the case of entrants – e.g. financing for firms when payment of orders is delayed. There is thus a role for trade facilitation policy interventions.

A key capability present in firms in the machinery cluster relates to their close association with primary sector activities. A common theme across the firms interviewed is that the founder of the firm emerged from the agricultural sector and shifted to machinery or equipment production in order to meet a primary sector need. For example, the founder of a firm manufacturing seeders and planters is a former wheat farmer who designed machines that are suited to harder African soil. This has given the firm a competitive advantage when entering the West Australian wheat market, where the soil is of similar nature. Global leaders in this type of machinery, offer machines designed for soft European soil and thus cannot match the capabilities of the South African machine that is more robust and hardy.

This evidence of machinery firms emerging from primary sector activities does provide a basis for designing policy that uses primary sector activities as a catalyst for more advanced manufacturing activity. This method has seen success in Scandinavia: Blomström and Kokko (2007) argue that Scandinavian countries increased the technology- and knowledge-intensity of the resource industries, which facilitated the shift to more advanced manufacturing industries. For example, policy incentivised the development of universities and institutes that supplied skills and research input to resource-based industries.

Recently, there has been a reduction in R&D and innovation activities in the machinery and equipment cluster (Rustomjee et al, 2018)[59]. R&D is vital for firms, and the industry more broadly, to drive productivity growth and develop competitive advantage over international competitors. R&D is vital as firms need to keep abreast of the scientific advances in agricultural production, and as such, machinery needs to advance to support this. However, it was noted that farmers are conservative by nature and are not easily convinced to try new innovations. For example, wheat and maize farmers have just five weeks every year to do all their seeding and planting, and thus their entire crop and livelihood is contingent on the success of this process. As such, they will only use machinery that they trust. This impacts agricultural machinery manufacturers by creating barriers to entry insofar as farmers are not willing to purchase machinery until it has been proven that it is both reliable and increases productivity. It is thus hard for new entrants to gain foothold in the market as farmers are likely to rather go with the brands they know, which are generally international.

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[57] For example, the National Development Plan (NDP) aims for a greater proportion of exports to be directed to emerging markets (NPC, 2011:93). The New Growth Path (NGP) looks to widen the market for South African exports into the region and other fast-growing markets (Economic Development Department, 2011: 21).

[58] For example, the provision of buyer's credit, pre- and post-shipment credit, and investment finance.

[59] For example, Rustomjee et al. (2018) note that the Chamber of Mines Research Organisation (COMRO), which has been a key driver of innovation in the mining industry, has drastically reduced its research capacity. The newly established Mandela Mining Precinct, falling under the CSIR, is set to fill the R&D void left by COMRO. However, this initiative has struggled to gain traction.

These constraints to R&D can be addressed by facilitating the integration of research and development across academic institutions, public sector research institutes (such as the CSIR), and the private sector. One of the key elements of the Scandinavian experience was the integration of R&D activities across these role players, thereby developing technology- and knowledge-intensive resource-based industries. For example, a possible practical intervention noted by one of the firms is the provision of testing grounds for agricultural machinery. This would enable firms to test their machinery and thereby provide evidence of the machinery's effectiveness to farmers.[60]

Earlier discussion alludes to the importance of the integration of service centre branches into the manufacturing firms' overall business model. It allows firms to: diversify their income stream through service provision, establish working relationships with new and existing clients, and enter new markets (both domestic and international). It was noted by firms that a key capability that enables the successful integration of this service element into the overall business model is the implementation of an appropriate accounting system.[61] A good accounting system allows the firm to monitor and manage the various components of the business. For example, one firm noted that once they established a single accounting system across the entire firm, they were better able to monitor the performance of the service centres. This meant they were able to set sales targets for these units of the business, and thus establish incentive mechanisms to drive productivity.

Thus, in order to facilitate growth in the South African machinery industry, focus should be levied on trade policies to assist firms in their pursuits to decrease production costs and expand their reach to international markets. Firms have strong links to primary sector activity, and as such are able to carefully develop products that are suitable for the specific constraints and challenges faced by these primary sectors. However, in order to facilitate this, it is important to provide a medium for firms to engage in scientific research in order to establish themselves as reliable brands and, as a result, capture a larger part of the market.

6.5 Stone and Glass

In South Africa, the stone and glass industry is comprised of products made from glass and minerals, such as cement, bricks, and ceramics, which are primarily used in the construction industry (TIPS, 2017). Overall, the stone and glass industry is a relatively small part of South Africa's manufacturing industry. In 2014, employment in the industry was 59 792 individuals, or 5 percent of total manufacturing employment in South Africa (Stats SA, 2014). Production was R48 597 million, or 3 percent of overall manufacturing production. The share of stone and glass exports in overall manufacturing exports is even lower, at 1 percent. This indicates that this sector has not yet become a key player in the South African market.

As is the case with many of the other manufacturing industries in South Africa, the stone and glass industry has seen a decline in production and employment over recent years. Between 2008 and 2014, production declined by 0.8 percent per annum, while employment declined by 3 497 workers, also averaging 0.8 percent per annum (Statistics South Africa, 2008; 2014a; CID, 2018). However, the share of the stone and glass industry in overall manufacturing production and employment remained unchanged over the period. On the other hand, exports increased by $163 million between 2008 and 2014, although the share of stone and glass in manufacturing exports also remained unchanged over the period.

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[60] One of the larger firms has its own testing site for its construction machinery. However, smaller firms may not have the resources and the space to develop their own testing sites. If the state is looking to enable the growth of small to medium firms, then this offers a policy opportunity.
[61] This is particularly important in the case where a firm establishes its own service centre branch as opposed to entering into an agreement with a third-party dealership.

We find that 9 of our 160 frontier products are classified under the stone and glass industry. These products include stone wool, asphalt, cement and insulating glass. Of these, both stone wool and refractory cement are in our list of Top 20 frontier products.[62] Stone wool features consistently in our list of Top 20 frontier products, despite any changes in weighting or methodology used to construct the list.[63] Top exporters of stone wool include Germany, the USA, China and Japan, while top importers include Germany, the USA, France and China. Stone wool's high opportunity gain index points to it being highly connected in the product space, with links to machinery and chemical products as well as various other stone and glass products. As a result, the remainder of this section focusses mainly on stone wool as an avenue for diversifying the South African product space.

6.5.1 Employment Potential for Women and Youth

As is generally the case in the manufacturing industry, the manufacture of stone and glass products is a male-dominated industry. In 2014, the industry employed 12 000 women, making up just 21 percent of overall employment (Statistics South Africa, 2008; 2014b). The female to male ratio has also decreased between 2008 and 2014, from 0.31 to 0.26 (compared to a relatively constant average of 0.47 and 0.45 for manufacturing as a whole in 2008 and 2014, respectively). Even though employment as a whole has decreased in the stone and glass sector, women have been particularly affected, with their decrease in employment averaging 2.6 percent per annum, compared to men's 0.3 percent per annum decline.

The ratio of youth aged 15 to 24 to non-youth in the cluster is 0.09 in 2014. In other words, there are 9 youth for every hundred non-youth employees in the sector. However, when the definition of youth is expanded to include those aged 15 to 34, this ratio increases to 0.60, or sixty youth for every hundred non-youth employees in the sector. This is in comparison to the overall youth to non-youth employee ratio of 0.09 (narrow definition), and 0.63 (broad definition) in manufacturing as a whole. This means that while very young workers may struggle to gain access to the industry, their access is on par with youth access in manufacturing as a whole. However, between 2008 and 2014, the youth to non-youth ratio has decreased substantially irrespective of the definition of youth – from 0.16 to 0.09 for youth between 15 and 24, and from 0.89 to 0.6 for youth between 15 and 34. This suggests a growing trend of manufacturing firms hiring fewer youth, and as such, it would seem that the prospects for youth employment in the sector are deteriorating over time.

6.5.2 Paths for Future Diversification

Opportunities exist in the manufacturing of high-tech construction technologies in which South African manufacturers currently have little or no experience. An example of this is aerogel, which is an ultralight material used in a variety of applications, including thermal insulation. While previously there were international companies manufacturing these products in South Africa, many have withdrawn due to the stagnant economy, thus creating a gap in the market. There is potential for South African firms to fill this gap, provided they have the capabilities to do so. However, South African manufacturers currently do not have access to these products, or the information necessary to manufacture them. There are also opportunities for diversification into polyurethane products. These are used – often in the form of polyurethane foam – in the manufacture of products such as automobile seats, houses, wheels, automotive parts, electronic components, adhesives and furniture.[64]

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[62] Please note that stone wool is equivalent to rock wool, with the latter being a brand of stone wool. The generic name is stone wool.
[63] See Appendix Table 1 for list of Top 20 frontier products using different weighting choices.
[64] The strong potential linkages with the automotive sector reiterate the interconnectedness of these industries. This also suggests that firms within this industry can link to the automotive industry and become tier 2 and tier 3 suppliers, which are typically the more employment-intensive producers in the automotive value chain.

The key constraint holding back manufacturers in this industry is the declining capacity of the South African Bureau of Standards (SABS).[65] The SABS has limited capacity and outdated equipment, leading to extensive delays and poor testing quality. While some product standards are voluntary, those surrounding fire are compulsory. This means that products like stone wool must pass certification in order to be used in the construction of buildings listed under the A20 regulation.

A major setback has been the suspension of services allowing for partial testing of products at SABS. Partial testing can involve testing only one component of a product, or be limited to a reduced number of the full set of tests prescribed to meet a particular product standard. For example, a manufacturer may want to test one parameter of a product during the initial design phase to ensure compliance with the necessary product standards early on. The suspension of partial testing may therefore have severe financial implications for a manufacturer, who either has to do a full product test at every phase of development, or risk continuing with the production of a product that has not been proven to pass the various standards at earlier stages of the design process. This cost is especially prohibitive for small firms.

Due to the excessive delay in the full product testing services that are available at SABS, stone wool is often imported rather than purchased locally. For example, the government has recently been in the process of upgrading various power stations. Due to the nature of the building, only non-combustible materials are allowed to be used in this upgrade. While this should have been a major boon to stone wool manufacturers, South African stone wool was refused due to quality concerns, which could not be negated due to inefficiency at the Bureau.

In addition, South African manufacturers of construction material who are able to secure certification of their products currently export to the SADC region, which uses the same set of standards and regulations as those used in South Africa. Therefore, increasing the efficiency at the product testing phase will substantially increase local demand for stone wool, as well as affect the ability of manufacturers to export the product.

7 Employment Considerations

Diversification into the frontier products will enable South Africa to build economic complexity. However, given high levels of unemployment, to what extent does building economic complexity align with the broader economic imperative of generating jobs? This section attempts to address this issue. First, we consider the linkages between growing economic complexity and creating jobs. We then attempt to decipher the employment potential of the frontier products. Finally, we consider whether diversification into the frontier products has the potential to create jobs for women and youth, as well as the possible factors constraining this from happening.

7.1 Building Complexity, Interconnectedness and Growing Employment

One approach to determining the extent to which growth of a product is likely to generate jobs, is to consider the capital intensity of production associated with that product. Products produced using more capital-intensive production processes have lower employment multipliers than products produced using more labour-intensive production processes. As such, diversification into labour-intensive products is likely to lead to greater job creation. In Figure 19, we plot the relationship

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[65] SABS is a statutory body that was established as the national institution for the promotion and maintenance of standardisation and quality in connection with commodities and the rendering of services.

between the complexity associated with a product, and its revealed capital intensity.[66] This allows one to unpack the potential employment effects associated with increasingly complex products.

Building economic complexity requires diversification into increasingly complex products. However, Figure 19 indicates that rising product complexity is associated with increased capital-intensity in production. Figure 19 plots the product complexity index against the revealed capital intensity index for each product in the trade data (top panel), as well as the for the frontier products identified in Section 5 (bottom panel).[67,68] There is a strong positive relationship between the revealed capital intensity of a product and its complexity, which implies a negative relationship between complexity and labour intensity. This positive relationship between revealed capital intensity and complexity also holds for frontier products, although to a slightly lesser degree.

There appears to be a trade-off between building complexity and generating jobs, which points to a tension between the dual goals of growing exports and creating jobs in South Africa. By shifting to more complex products, a country is shifting to products that use more capital per unit of labour, which suggests lower employment multipliers. Focusing on the lower panel of Figure 19, one observes that the slope of the lowess curve is flatter in the case of the frontier products relative to all products. This suggests that the trade-off between building complexity and creating jobs is less pronounced in the case of the frontier products.

However, it is worth noting that shifting to more complex products does not preclude employment creation. Bhorat, Kanbur, Rooney and Steenkamp (2017) compare the evolution of the manufacturing sectors in East and South Asia relative to Sub-Saharan Africa for the period 1995 to 2013. They show how East and South Asian countries have shifted production toward more complex manufacturing products over the period, while still generating employment opportunities.[69] The sheer scale of the manufacturing sector in these countries provides a significant source of employment.

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[66] A challenge when trying to link employment effects to complexity at the product-level, is the absence of data on capital-to-labour ratios at this level of disaggregation. This data limitation is even more apparent when taking a cross-country perspective. As such, we use the revealed factor intensity indices developed by Shirotori, Tumurchudur and Cadot (2010). The revealed capital intensity index is a product-level measure of the capital intensity associated with a product. The revealed capital intensity measure is taken from the UNCTAD Revealed Factor Intensity Database. Available at :http://www.unctad.info/en/Trade-Analysis-Branch/Data-And-Statistics/Other-Databases/.

[67] A product is defined at the Harmonised System 4-digit level. It is worth noting that the revealed factor intensity indices are defined at the 6-digit level, and we thus generate a mean index for all the 6-digit products falling within a 4-digit product category.

[68] The revealed capital intensity index is an indirect measure of the value of capital per unit of labour.

[69] These countries offer a clear picture of how an economy evolves from less complex toward more complex productive activities, and thus undergo structural transformation.

Figure 19: Product Complexity and Capital Intensity in 2007 for All Products and Frontier Products
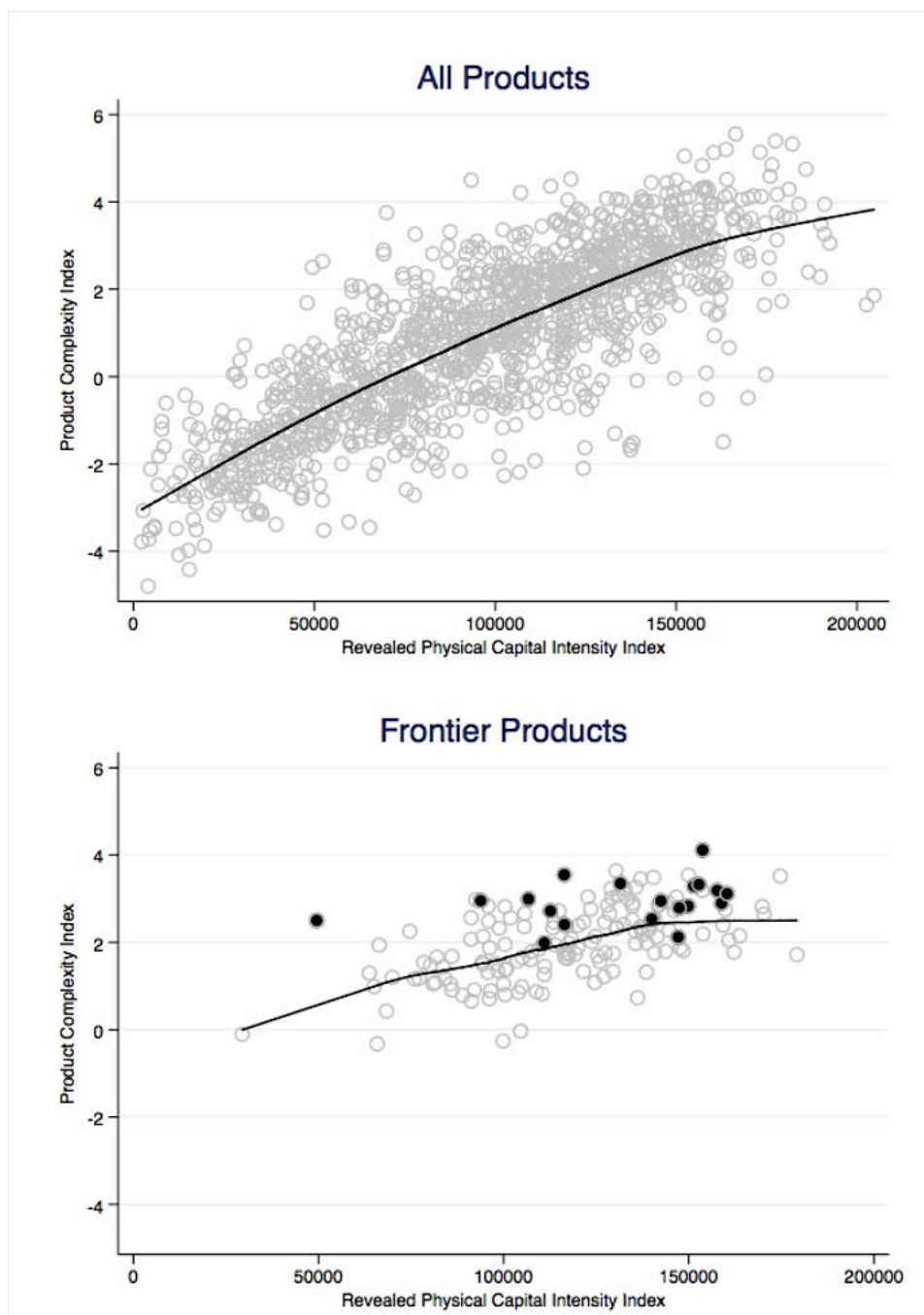
Source: Own calculations using data from The Economic Complexity Observatory (Simoes & Hidalgo, 2011).
Notes: Trend line is a locally weighted smoothing regression (bandwidth 0.8).

Furthermore, it is evident in the lower panel of Figure 19 that there is a degree of heterogeneity in the level of capital intensity for a given level of complexity. This suggests that it is possible to choose between diversifying into products with similar levels of complexity yet diverging levels of capital intensity. For example, both *Pig and Poultry Fat* and *Large Flat Rolled Iron* have product complexity indices of 2.5, while the former and latter have revealed capital intensity indices of $49 518 and $140 044 per unit of labour, respectively. This suggests that a more labour-intensive agro-processing path can be prioritised.

From a policy perspective, it is important to think about the process of diversification into frontier products within the broader economic complexity framework. Building economic complexity is about developing an increasingly complex network off interconnected products. This is evident in the diverse set of industries in which the frontier products fall – chemicals, plastics, metals, machinery, automotives, agro-processing, etc. These industries all vary in capital intensity. Focussing solely on developing the least capital-intensive of these products ignores the interconnectedness of these products. For example, chemical products are typically produced using highly capital-intensive production techniques. Yet, the chemicals industry is closely linked to other less capital-intensive industries, such as agro-processing. Therefore, this interconnectedness implies that the development of one, which is capital-intensive, complements the development of the other, which is less capital-intensive.

Hence, we note that building complexity is predicted to raise growth outcomes, albeit in capital-intensive industries, and this is ultimately linked to higher levels of employment in the long-run.

7.2 Employment potential

In this section, we further unpack the employment potential associated with the frontier products. To complement the product-level revealed factor intensity data described in the previous section, this section uses industry-level data taken from Statistics South Africa's Manufacturing Large Sample Survey. The aggregated industry-level data is mapped as closely as possible to the disaggregated product-level data for the frontier products. We then look at employment, production and capital expenditure trends in each of the categories mapped to the frontier products.

To get an indication of the employment potential associated with the frontier products, we measure the extent to which employment relates to production and capital expenditure.[70] In Figure 20, we present the percentage change in production for each of the categories linked to the frontier products against the percentage change in employment. The period of analysis is defined as the period 2008 to 2014. The size of each bubble represents the share of employment associated with the category linked to the frontier product for 2014. Similarly, Figure 21 shows the percentage change in capital expenditure for each of the categories linked to the frontier products against the percentage change in employment.

Drawing on the trends in employment and production over the period 2008 to 2014, Agro-processing (both broadly and for the sub-sector of meat products) and Plastics show the greatest potential for employment creation. These three categories are positioned in the top-right quadrant of Figure 20, where both the percentage change in production and employment are positive for the period 2008 to 2014. Importantly, Agro-processing is a sector that is growing off a substantial employment base – comprising 19.3 percent of employment in manufacturing in 2014. Despite experiencing declining production levels, both Metal Products and Construction Machinery experience employment growth over the period (bottom-right quadrant). Arguably, growing production could facilitate future employment growth in these industries.

Some of the categories have been shedding jobs over the period, and thus exhibit less employment potential. Chemicals, Machinery and Equipment, and Agricultural Machinery have grown production levels while shedding jobs. This suggests that substantial increases in production are required in order

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[70] It is worth noting that these trends in employment, production and capital expenditure are limited in the extent to which they inform one of the employment potential associated with a frontier product. First, the industry and the product do not line up perfectly, and thus, there is a degree of measurement error. Second, the data pertains to the period 2008 to 2014, which does not allow one to generate long-term employment elasticities by category. Exogenous economic shocks may influence the linkage between employment, production and capital expenditure during this relatively short period. Despite these limitations, these data are the only available data at such level of aggregation for the manufacturing industry, and we analyse them taking cognisance of their limitations.

to generate employment growth in these industries. It may also be the case that these industries are investing in labour-saving technologies – the evidence in Figure 21 supports this claim. In the case of Rubber Products, Glass and Stone Products, Vehicle Parts, and Transportation Equipment, both production and employment levels have declined over the period. This is particularly worrying in the case of the automotive component of Transportation Equipment, since it is subsidised under the Automotive Production and Development Programme (APDP). In the context of high levels of unemployment, the loss of jobs in a subsidised sector is of concern. It is also concerning that three relatively large employers in the manufacturing sector – Chemicals, Machinery and Equipment, and Transport Equipment – are experiencing declining employment shares.
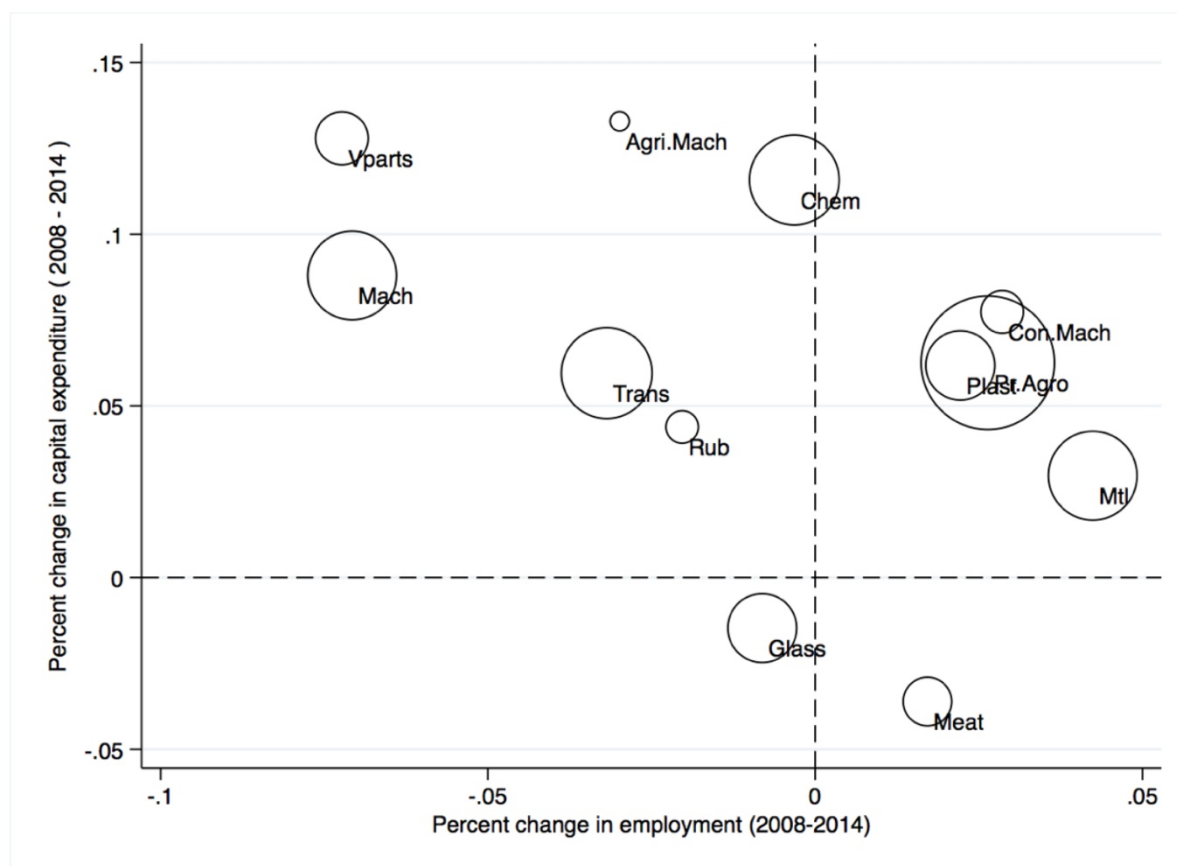
Figure 20: Percentage Change in Production and Employment by category, 2008-2014
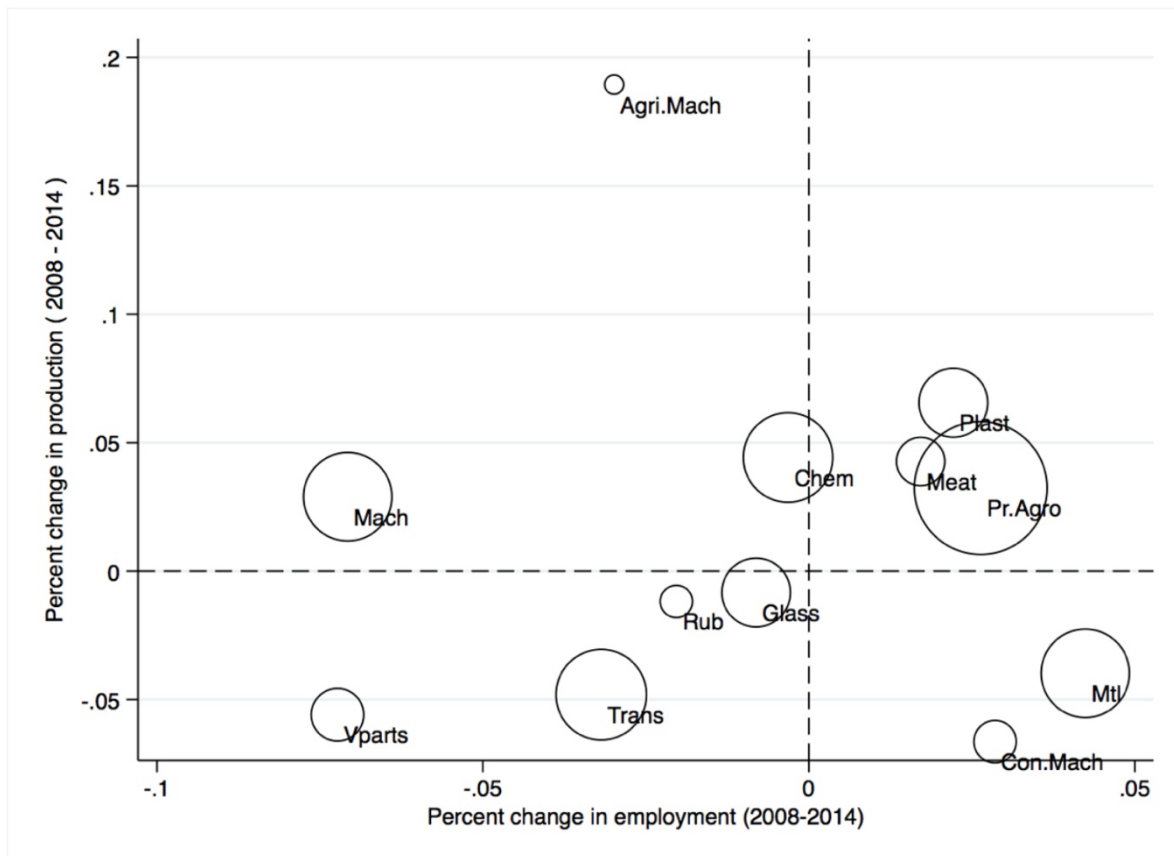
Source: Production and Employment data taken from Statistics South Africa Report No. 30-02-03 (2008) (Statistics South Africa, 2008). Production data taken from Statistics South Africa Report no. 30-02-04 (Statistics South Africa, 2014a). Employment data take from Statistics South Africa Report no. 30-02-03 (Statistics South Africa, 2014b).
Notes: Pr. Agro = Processed Agriculture; Meat = Meat Products; Trans = Transport Equipment; Vparts = Vehicle Parts; Mtl = Metal Parts; Mach = Machinery & Equipment; Con. Mach = Construction Machinery; Agri. Mach = Agricultural Machinery; Glass = Glass Products; Plast = Plastic Products; Rub = Rubber Products; and Chem = Chemical Products.

Drawing on the trends in employment and capital expenditure over the period 2008 to 2014, reveals a number of points: Firstly, Plastics and Agro-processing represent industries that are investing in capital and growing employment (top right quadrant of Figure 21). Construction Machinery is another industry where both capital investment and employment have grown. These industries, and the products that comprise these industries, offer employment potential. Secondly, there are a number of industries where investment in capital has risen while employment levels have declined (top-left quadrant). These include large employers in Chemicals, Machinery and Equipment, and Transport Equipment. Investment in capital in conjunction with declining employment levels points to investment in labour-saving technologies. Again, it is of concern that the subsidised automotive industry, while investing in capital, is experiencing declining employment levels.

Figure 21: Percentage Change in Capital Expenditure and Employment by category, 2008-2014

Source: Production and Employment data taken from Statistics South Africa Report No. 30-02-03 (2008) (Statistics South Africa, 2008). Production data taken from Statistics South Africa Report no. 30-02-04 (Statistics South Africa, 2014a). Employment data take from Statistics South Africa Report no. 30-02-03 (Statistics South Africa, 2014b).
Notes: Pr. Agro = Processed Agriculture; Meat = Meat Products; Trans = Transport Equipment; Vparts = Vehicle Parts; Mtl = Metal Parts; Mach = Machinery & Equipment; Con. Mach = Construction Machinery; Agri. Mach = Agricultural Machinery; Glass = Glass Products; Plast = Plastic Products; Rub = Rubber Products; and Chem = Chemical Products.

Based on the analysis in this sub-section, the Plastics and Agro-processing industries exhibit the greatest employment potential. The next sub-sections consider the potential for employment of youth and women in the industries within which the frontier products reside.

7.3 Potential for Employing Women and Youth

7.3.1 Employment of women

While employment in manufacturing remains male dominated (approx. one female for every two males), there is a degree of heterogeneity across the manufacturing industries that comprise the broader sector. Certain industries employ a relatively higher share of women. These include plastics (0.46), chemicals (0.45), and agro-processing (0.53).[71,72] The higher relative propensity to employ women in these industries suggests that the frontier products falling within these industries offer the greatest potential to generate manufacturing jobs for women.

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[71] Ratio of female-to-male employees in brackets.
[72] There are other manufacturing industries for which the female-to-male employment ratio is relatively high. These include, Textiles, clothing, leather and footwear (2.03), Wood, wood products, paper, publishing and printing (0.48), Electrical machinery and apparatus (0.42), and Furniture, other manufacturing and recycling (0.42). However, none of the Top 20 frontier products fall within these broader manufacturing industries.

However, the female-to-male employment ratios for plastics, chemicals and agro-processing have all declined over the period. This is reflected in Figure 22, which shows the percentage point change in female employment by categories aligned to the frontier products, for the period 2008 to 2014. Plastics, chemicals and agro-processing have all experienced percentage point declines in the share of female employees. It is worth noting that the number of women employed in both agro-processing and plastics has risen over this period, albeit at a lesser rate than the growth in male employees. The number of women employed in chemicals has declined over the period.

Figure 22: Percentage Point Change in Female Employment: 2008 to 2014
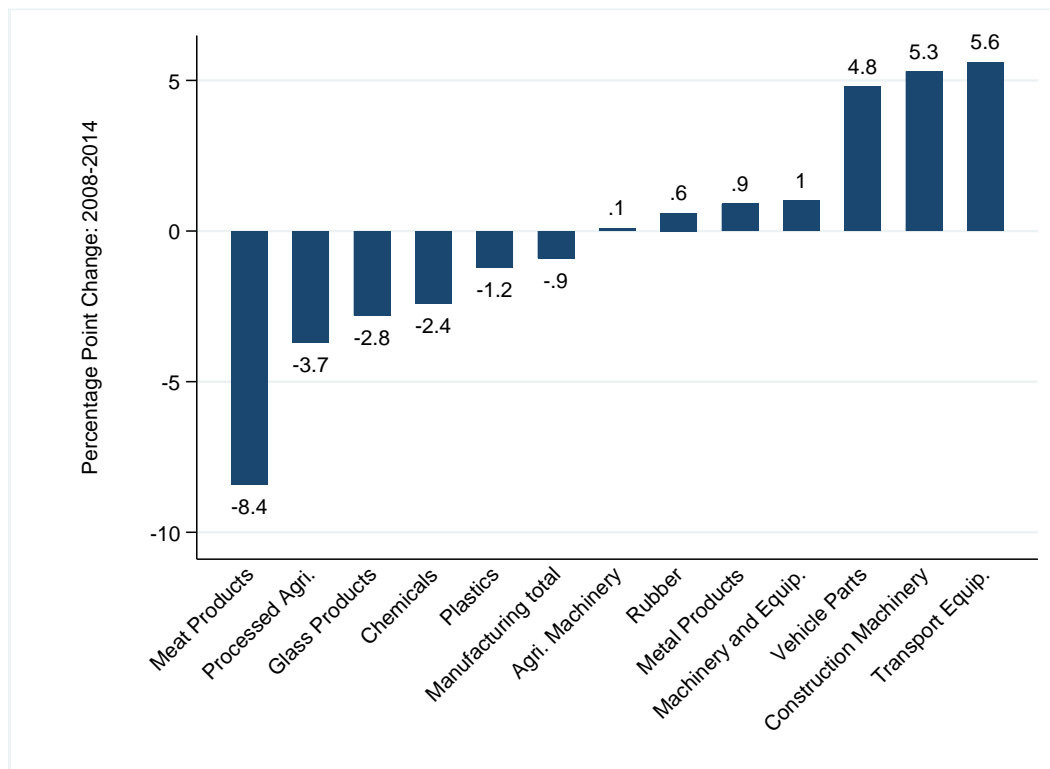
The male dominated industries falling within the iron and steel value chain, and the transport cluster, have increased their relative share of women in the workforce. This is evident in Figure 22, where agricultural machinery, metal products, machinery and equipment, vehicle parts, construction machinery, and transport equipment, have shown percentage point increases in the share of women in their respective workforces. However, this is growth off a low base where, on average, there is one female employee for every five male employees.

Based on the firm and industry expert interviews, there are a number of factors that offer a degree of explanation for the relatively low propensity of the manufacturing sector to employ women. These include: First, there is the notion that tasks along the manufacturing line are physical in nature. It is argued that, relative to men, women are less well equipped to undertake these physical tasks. This is certainly more apparent in industries such as metals and machinery, where heavy objects are shifted along the production line. In industries such as plastics, chemicals and agro-processing, this constraint does not feature as strongly. Second, there are social stigmas that make employers reluctant to place women along the production line. These include: older men not willing to take orders from a younger woman, and potential inappropriate behaviour by men toward women. Third, in some cases, manufacturing plants are not equipped to employ women (e.g. no female restrooms). Fourth, it is

possible that there is an awareness issue playing out. The interviewed firms noted that they did not receive as many employment applications from women and posited that young female applicants are not aware of the possibility of a career in manufacturing.

7.3.2 Employment of Youth

Given the high unemployment rate among youth in South Africa, it is no surprise that the broader manufacturing workforce is characterised as 'old'. On average in manufacturing, there are nine youth (aged between 15 and 24) for every 100 non-youth (aged between 25 and 65). This ratio does not vary considerably across the various industries within the manufacturing sector. In 2014, the rubber industry had the greatest share of youth in its workforce (13 percent), while the chemicals industry had the lowest share of youth in its workforce (5 percent). Industries, such as chemicals, with higher skill requirements (especially tertiary qualifications), are less likely to employ youth. The youth thus struggle to find employment in manufacturing.

Not only are employment shares of youth in manufacturing low, but they also declined over the period 2008 to 2014. In 2008, 12 percent of the manufacturing workforce was aged between 15 and 24. This declined to 9 percent in 2014. It is evident in Figure 23 that most of the industry categories linked to frontier products exhibit declining youth employment shares. Only rubber, meat products, and machinery and equipment, experienced rising youth employment shares.

Figure 23: Percentage Point Change in Youth Employment, 2008-2014
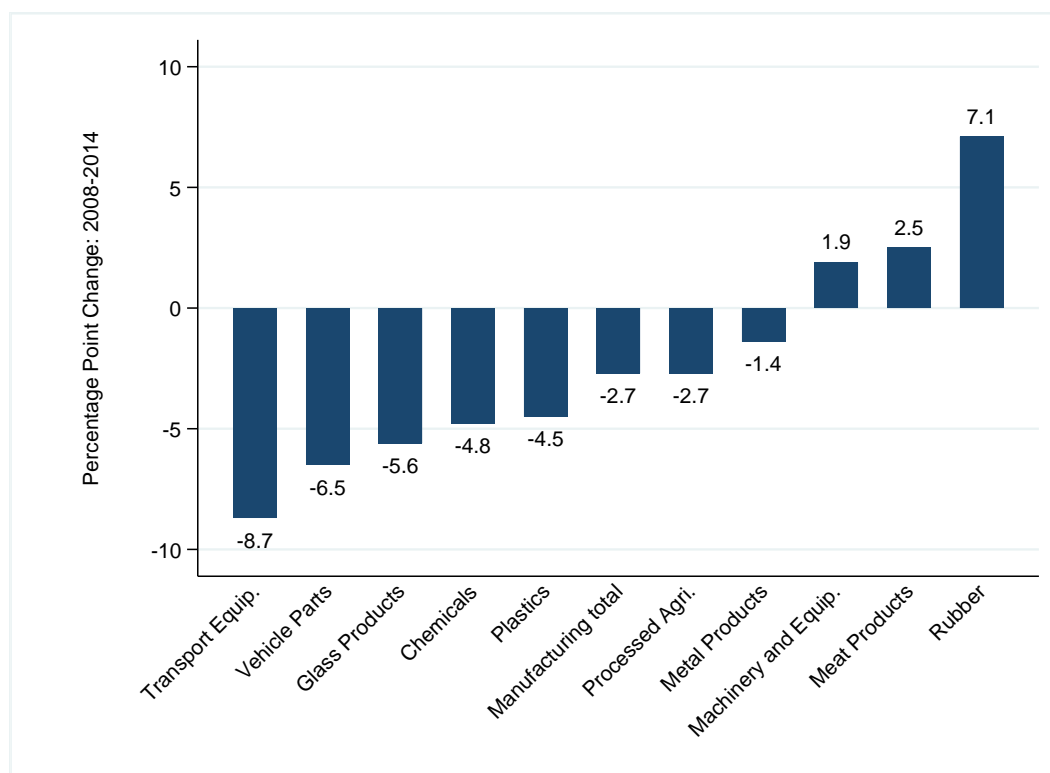
Source: Production and Employment data taken from Statistics South Africa Report No. 30-02-03 (2008) (Statistics South Africa, 2008). Production data taken from Statistics South Africa Report no. 30-02-04 (Statistics South Africa, 2014a). Employment data take from Statistics South Africa Report no. 30-02-03 (Statistics South Africa, 2014b).

Based on the firm and industry expert interviews, there are a number of factors that offer a degree of explanation for the relatively low propensity of the manufacturing sector to employ youth. These include: Firstly, respondents expressed negative perceptions regarding the work ethic and attitude of young workers. Such perceptions adversely impact on youth labour market outcomes. Youth were

often described as "flighty", and thus firms expressed resistance toward employing youth and investing in their skills.

Secondly, there are sector specific factors that impact on the propensity of firms to employ youth. For example, firms in the metals and machinery sector, which fall under the minimum wage regulations of the MEIBC, noted that the high minimum wage for entry level workers acted as a disincentive to employ youth. Due to the high minimum wage, investing in a new worker is costly and the firm needs to be careful about who they employ. They thus look for someone in a stable life stage with experience – factors not typically found in youth.

Thirdly, and relatedly, skills play a role in the hiring of youth; but this is sector-specific. In many of the industries, such as machinery and plastics, floor level workers require a complete secondary education with mathematics. It was noted by respondents that there is a reasonable supply of individuals with this level of education. However, there are sector-specific tertiary qualifications of a technical nature that are often in short supply. For example, a respondent producing plastic and rubber products noted difficulty in finding individuals with technical qualifications linked to understanding and working with plastics and rubber. The chemicals industry is an example of an industry where the skills requirements are so high that often youth between the ages of 15 and 24 are not qualified to work for firms in the industry.[73]

7.3.3 Summary

As observed above, manufacturing sectors have varying propensities to employ women and youth. Assuming that there is a path dependency in employment by gender and age, then the employment of youth and women across these manufacturing sectors will simply increase in line with these ratios. From a policy perspective, one could then target products that fall within industries that have the highest propensity to hire women and youth. Another approach is to implement policy that seeks to alter these ratios over time. Certainly, the evidence suggests that there are certain factors endogenous to firms that can alter their propensity to hire women and youth. These include: dealing with social stigmas relating to the hire of women on the manufacturing line, and enforcing the provision of appropriate facilities for women in manufacturing plants. There are also factors exogenous to firms that can alter their propensity to hire women and youth. These include: advances in technology that reduce the physicality of certain manufacturing tasks, increasing awareness among learners of careers in manufacturing, and prioritising the provision of key technical skills to the youth.

8   Policy Considerations

The firm and industry expert interviews provide key insights into the capabilities present and lacking across the various manufacturing industries. In order to diversify into frontier products and thereby build economic complexity, there is scope for policy makers to develop policy that would allow the generation of the capabilities needed to facilitate diversification. In this section, we identify these capabilities.

8.1 R&D and Technical Expertise

Investment in R&D and the supply of technical expertise was an important theme that emerged from the firm and industry expert interviews. A key element to generating the productive know-how and capabilities needed to diversify into increasingly complex frontier products, is active investment in R&D. Sustained economic growth is best achieved via strong export growth. Exporters are better able to compete in global markets if they are able to innovate and remain at the technological frontier.

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[73] Interestingly, when youth is defined between the ages of 15 and 34, then the chemicals industry has one of the highest shares of youth in its workforce.

R&D is key to ensuring this. Relatedly, the technical expertise and skills needed to use the innovations and technology generated through the R&D process is also key. The importance of R&D, and technical expertise and skills, is evident in relation to a number of the frontier products and their respective industries.

With respect to pig and poultry fat, and the broader pig value chain, R&D activity is essential to generate and maintain international competitiveness. Modern pig production is highly scientific and involves genetic product development. Major exporting countries, such as the USA and Netherlands, have entire farms dedicated to R&D. The technological advances emerging from the research on these farms is then used to drive productivity growth across the entire industry. A complementary investment to that of R&D, is investment in associated expertise in genetics and breeding. Continued R&D is driven by individuals with the relevant expertise, and thus investment in human capital is key. Therefore, linkages with tertiary institutions that have a strong research focus is important for the creation of knowledge-intensive industry.

R&D is also important in driving the competitiveness of the machinery industry, particularly that pertaining to agriculture, mining, and construction machinery. As discussed earlier, agricultural machinery needs to advance in line with the latest developments in agronomy, and relatedly, the latest technology used to advance the productive use of the machinery. In combination with investment in R&D, investment in technical expertise specific to these industries is important. For example, the training of agronomists, agricultural and mechanical engineers, agricultural extension workers, plant breeders, and technicians. As such, linkages between industry and research institutions is critical for ensuring the development of a knowledge-intensive industry.

The technical expertise needed to design and programme production lines using automated machinery and robotics is going to become increasingly important. While firms may have access to the capital needed to invest in automation and robotics, they do not necessarily have the capabilities needed to incorporate this machinery into their production line. Investment in the training and development of individuals who can design and programme robotics and automation is important. The development of appropriate curricula needed to train experts in this field is an initiative that could provide the capabilities needed by firms to shift to greater automation.

Looking at R&D from a policy perspective, we can say the following: first, R&D is critical to the accumulation of productive knowledge and capabilities, which allow economies to produce a variety of increasingly complex products. Thus, there is a policy imperative to invest in R&D. Second, while private sector entities invest in R&D specific to their function and profit motive, the public sector has a strategic role in driving investment in R&D. In particular, it can play an active role in directing R&D expenditure toward targeted industries. The analysis in this paper provides an empirical basis for such targeting. Third, the public sector can play an active role in facilitating the integration of R&D activities across academic institutions, public sector research institutes, and the private sector. One of the key elements of the Scandinavian experience was the integration of R&D activities across these role players, thereby developing technology- and knowledge-intensive industries. Fourth, investment in R&D needs to be accompanied by human capital investment that complements the innovations and advances in technology. Finally, such investment, at least from a public sector perspective, is a medium- to long-term intervention

8.2 Product Certification and Standards

Another theme that emerged from the firm and industry expert interviews is the public sector's regulatory capabilities, particularly pertaining to its ability to certify and validate product quality and standards. The issue of institutional strength and state capacity emerged with respect to a number of the frontier products.

The agricultural industry is particularly reliant on the capacity of state institutions to guarantee product quality and safety. As discussed earlier, this is particularly evident in the case of pork related products, such as the emulsified products made from pig fat. Bio-security is a key element to ensuring the growth of the pork value chain. As discussed earlier, the negotiation of trade protocols that allow for access into new export markets is heavily dependent on the industry's ability to ensure health and safety across the entire value chain. While the industry has developed quality assurance and traceability standards under the authority of *Pork 360*, the supply of skilled and experienced veterinary experts, used to enforce and regulate these standards, is limited. This limited capacity, in terms of veterinary experts at state institutions such as the Department of Forestry and Fisheries, constrains the industry's ability to gain access to new export markets and thus expand scale of production and grow.

Stone wool provides another example of the constraining effects of limited state regulatory capacity. Of particular relevance is the South African Bureau of Standards (SABS). The SABS has limited capacity and outdated equipment, leading to extensive delays and poor testing quality. Products such as stone wool must pass certification in order to be used in the construction of buildings listed under the A20 regulations. Due to the excessive delays in the full product testing services that are available at SABS, stone wool is often imported rather than purchased locally. The suspension of services allowing for partial testing of products at SABS has also increased the cost of innovation and product development.

Another instance of constrained state capacity relates to policy that aims to stimulate industrialisation through localisation of public sector procurement, specifically in relation to the machinery and equipment industry. The PPPFA allows the dti, in consultation with the National Treasury, to stipulate local content requirements. The public procurement process requires verification of local content. One of the reasons for the ineffectiveness of this localisation policy, as listed by Rustomjee et al. (2018), relates to the South African Bureau of Standards (SABS) not having the funds and resources to undertake verification. In some cases, verification is outsourced at a significantly higher cost.

From a policy perspective, the discussion above points to the need to grow state capacity and expertise. This would need to occur across a variety of state entities – e.g. SABS, DAFF – that meet the needs of a variety of industries. Such efforts would allow firms across various industries to access both domestic demand in terms of public sector procurement, and international demand in terms of being able to access new export markets. Building state capacity is a medium- to long-term policy objective.

8.3 Exchange Rate Stability

Exchange rate stability is a macroeconomic factor that impacts on the profitability of manufacturing firms. Exchange rate depreciation lowers the cost of exported products and thus improves the competitiveness of exporters. Correspondingly, exchange rate depreciation increases the cost of imports. This may impact negatively on exporters if a large share of the inputs that comprise the exported final product are imported. The converse is also true in the case of an appreciation of the exchange rate. The importance of the exchange rate is especially evident in 'two-way traders' or firms that both import and export. Edwards, Sanfilippo and Sundaram (2016) note how 'two-way traders' are, on average, the largest firms in terms of employment, the most productive, pay the highest wages, and are the most skill-intensive. These firms are the most successful firms in their respective industries, and thus, from a policy perspective, are strategically important.

Firms noted that, for the most part, the level of the exchange rate can be adjusted for. However, the key concern is exchange rate volatility. Firms that both import and export draw up trade contracts with foreign suppliers and buyers, respectively. The volatility of the exchange rate acts as an additional cost of trade, and thus impacts on the profitability of the firm.

From a policy perspective, it is very hard, and costly, for a small open economy, such as South Africa, to artificially manipulate its exchange rate. The economy is subject to exogenous exchange rate shocks

for which policy makers have little control over. Nevertheless, a stable, investor-friendly political-economic environment may limit self-inflicted exchange rate shocks.

8.4 Trade and Industrial Policy

The interviews revealed three themes in relation to trade and industrial policy: Firstly, the misalignment of trade and industrial policy. Secondly, the extent to which the state lacks the capacity to effectively implement existing policies. And thirdly, the importance of trade facilitation as a tool for generating export growth. These three themes are discussed below.

8.4.1 Trade and Industrial Policy: Misalignment and Challenges

A theme emerging from the interviews relates to the alignment of policy. In some cases, policy is at odds with the economic landscape and thus inhibits – rather than enables – firms from growing. A number of examples emerge in relation to the frontier products and the respective industries under which they fall.

The state's focus on the upstream steel industry, at the expense of the downstream machinery and equipment industry, is an example of policy misalignment. While the development of a sustainable steel industry has merit, it should not come at the expense of a machinery and equipment industry that is characterised by higher levels of complexity and potentially greater employment opportunities. This is particularly problematic in the context of an industry where the largest supplier, AMSA, is struggling financially and operating below capacity. Furthermore, this is the case despite the imposition of various protective import tariffs on long and flat steel products.

If the state is to persist with a focus on steel production, then at the very least, there should be recognition of the need for a more nuanced approach to trade policy. A policy approach acknowledging the importance of manufacturing machinery, particularly mining, construction and agricultural machinery, would consider the following: First, the tariffs on products for which domestic producers do not have the capabilities to produce, should be reduced substantially; preferably duty-free. These products would typically be the low- and high-technology products that are inputs into the production of machinery (e.g. advanced engines and transmissions). Second, in cases where the broad category of inputs (such as tyres) are domestically produced, but a specific product within this broader grouping is not domestically produced (such as large heavy-duty tyres), then the tariff schedule should take this into account. Third, tariffs should rather be imposed on domestically produced machinery, thereby protecting the final product as opposed to the inputs into the final product.

A further point worth mentioning is the strong linkages between primary sector activities in mining and agriculture, and the manufacturing of machinery and equipment used in these primary sector activities. Evidence of machinery firms emerging from primary sector activities, does provide a basis for designing policy that uses primary sector activities as a catalyst for more advanced manufacturing activity. Arguably, this is the Scandinavian model, where advanced manufacturing industries emerged from primary sector activities, particularly in agriculture. Blomström and Kokko (2007) argue that Scandinavian countries increased the technology- and knowledge-intensity of the resource industries, which facilitated the shift to more advanced manufacturing industries. For example, policy incentivised the development of universities and institutes that supplied skills and research input to resource-based industries. This thus motivates for a holistic set of policies that not only recognise the importance of growing complex manufacturing activity, but also growing related primary sector activities.

8.4.2 Trade and Industrial Policy: Implementation and State Capacity

South African trade and industrial policy can be viewed as a capability in its conception, but in a number of cases as a constraint in its implementation. In a number of the industries within which the frontier products fall, there are examples of poor policy implementation.

Policy reflects a general acknowledgement that the iron and steel value chain is a key path toward industrialisation, and thus there are a number of interventions that seek to grow the industries that fit within this value chain. However, as discussed earlier, the effectiveness of a number of these policy interventions is constrained by poor implementation. This poor implementation pertains to the beneficiation instrument falling under the Mineral and Petroleum Resources Development Act (MPRDA), the Price Preference System that seeks to enable foundries access to good quality scrap metal at discounted prices, and the Preferential Procurement Policy Framework Act (PPPFA) that aims to drive industrialisation through the localisation of public sector procurement.

The DTI has a number of incentive programmes designed to stimulate industrial development.[74] In the interviews, firms were asked whether they make use of these incentive programmes. The responses revealed low uptake of incentives.[75] Some firms noted that they have tried to access the incentives but found the process onerous. This is especially problematic for small to medium firms where management is constrained for time, and the opportunity cost of going through the process of applying for the incentive is too high.

Another issue relating to policy implementation concerns the Employment Tax Incentive (ETI), which is a programme that provides a subsidy to firms that hire youth. Although not representative, a disturbing number of firms noted having no knowledge of the incentive or having come across it by accident. The ETI is relatively easy to access since it is linked to a firm's filing of its company income tax form. A lack of awareness of said policy in concerning since it is designed to generate employment opportunities for the youth, who have a high propensity to being unemployed and struggle to find employment in manufacturing. Improved awareness campaigns could encourage better take-up of the incentive.

Therefore, while there are a variety of policies designed to drive industrialisation, in a number of cases, the implementation of these policies is constrained by state capacity.

8.4.3 Trade and Industrial Policy: Trade Facilitation

For firms looking to expand their scale of operation and grow, export markets are key to enabling this expansion. Domestic demand on its own is insufficient, and thus the successful entry and sustained presence in export markets is key to growth. This growth materialises at a macro-level, where an export-orientated growth path is key to sustained economic growth and employment creation. With this in mind, the role of the state in facilitating entry into export markets is an important growth enabler. Entry into new export markets is acknowledged as a policy priority.[76] A common theme that emerged across the interviews was the difficulties that firms faced when trying to enter export markets.

While being peripheral in relation to the broader global market, South African firms are well positioned to access African markets. However, a number of factors that constrain the ability of firms to enter export markets emerged from the interviews: Firstly, the process of establishing business relationships with buyers in another country is costly in terms of time and resources. This is particularly problematic in the case of small- to medium-size firms, where senior management resources are needed on site. Secondly, doing business in Africa is especially challenging – for example, there is a high risk of non-payment. The business model typically employed by agricultural machinery firms, where they establish

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[74] For example, see http://www.dti.gov.za/industrial_development/industrial_incentives.jsp?year=&subthemeid=25.
[75] We acknowledge that the interviews are by no means representative. However, the negative response was quite apparent and is worth noting, as it does point to a weakness in policy implementation.
[76] The National Development Plan (NDP) aims for a greater proportion of exports be directed to emerging markets (NPC, 2011:93). The New Growth Path (NGP) looks to widen the market for South African exports into the region and other fast-growing markets (Economic Development Department, 2011: 21).

sales and service centres in close proximity to the customer, is a useful approach for negating the difficulties of doing business in African countries. However, such an approach requires financing. Thirdly, access to export finance is vital for firms looking to compete in global markets (Rustomjee et al., 2018).

Aligning with stringent global standards is another constraint facing firms looking to access global value chains, especially in relation to tier 2 and tier 3 firms in the automotive sector. For example, these firms are prevented from supplying OEMs if they do not meet global accounting standards or international quality and safety assurance standards, such as the ISO Standards.[77] Forming working relationships with global firms drives firms to higher levels of efficiency and productivity in order to meet the requirements of the global firm.

The state can play an active role in facilitating access to new markets, be it entry into export markets or linking to global supply chains. A number of interventions emerge: First, while the state does organise trade delegations that seek to link South African firms to foreign buyers, the implementation of such initiatives requires improvement.[78] Second, the state can play a role in facilitating the process of firms aligning with global standards. This is especially important in the case of tier 2 and tier 3 suppliers to the automotive industry. Third, as noted in Rustomjee et al. (2018), the state can establish an export-import bank that would enable more favourable financing solutions for firms looking to trade. Such an approach can be expanded to assist firms looking to enter markets using a foreign direct investment approach.

8.5 High Cost of Doing Business

The interviews also revealed that in some instances, the costs of doing business in South Africa adversely affect firm performance.

Across most of the surveyed sectors, we observe that businesses must comply with regulatory requirements across a variety of government departments and levels of government. This raises costs of doing business for most sectors, both in terms of time spent complying, and the financial cost. In the 2018 World Bank Doing Business Survey, South Africa is ranked 82nd out of 190 surveyed countries. When we consider one of the sub-elements – starting a business – South Africa is ranked 132nd, as it takes, on average, 45 days to start a business. This finding supports those from our interviews. Respondents suggested the establishment of a one-step shop in each province, where firms, both domestic and foreign, could register and start operations. However, centralising this office is only the beginning, as it is important to determine the exact obstructions that hamper the speedy and efficient registration of firms in South Africa. The same World Bank Survey notes that South African firms must complete seven procedures to start a business, implying that rather than the onerous requirements imposed on firms, it might be bureaucracy or a lack of capacity, limiting a speedy resolution of issues faced by firms.

Another element influencing the cost of operations is the disparity in the provision of basic services to households. This results in firms, especially those situated in more rural or less-developed regions, having to directly cover these costs for their workers or community members in these areas of operation. Municipalities are the lowest level of government tasked with providing basic services, such as access to water, electricity, sanitation and sewerage, and fostering development within their region of control (Statistics South Africa, 2017). Despite large improvements in the proportion of households with access to these basic services, it is widely accepted that these headline figures mask great

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[77] For example, see https://www.iso.org/about-us.html.
[78] It was noted by an industry expert that while these trade missions have great potential, they are often poorly organized. For example, in one case, the confirmation for the trip was only finalised a few days before leaving, which meant delegates were uncertain and underprepared.

heterogeneity across provinces, district councils, and between local municipalities.[79] Communities in rural areas typically have access to fewer services (and often services of inferior quality) compared to those living in wealthier areas.

Firms that operate within these rural areas are often forced to incur the cost of providing access to services to employees and associated communities. This is particularly the case within the metal cluster where mines are typically located in rural areas, thus exposing them to higher operational costs to set up housing for workers or incur high transportation costs to bring them to mining sites. It was noted by one firm that manufactures agricultural machinery, that the local community expects it to build a library and provide other basic services. These unexpected high operating costs might influence firms to locate only in urban or peri-urban areas, thus further increasing the inequality in development between rural and urban areas, which further increases the migration between the two areas.

Transport costs can also significantly limit the expansion of export trade (Limao & Venables 2001; Micco & Perez 2001). Chasomeris (2011) notes that high freight costs serve, on the one hand to protect domestic producers from imports, while on the other they provide significant anti-export bias that reduces international competitiveness. Interviewed respondents noted that, despite falling port handing charges, exporters still face significantly high costs. This is further supported by the Port Regulator benchmarking report that observes that container handling costs are significantly more expensive in South Africa relative to global averages (Ports Regulator of South Africa, 2018). In response to this, the Port Regulator of South Africa, in conjuction with the National Ports Authority, the dti, the Department of Transport, and other government agencies, developed the Port Tariff Incentive Programme to better support industrialisation, location and beneficiation through port tariff regulation. Over the next ten years, the regulator seeks to systematically remove any unfair cross subsidies that have distorted overall tariffs, resulting in cost-reflective tariffs.

An additional transport cost adversely impacting firm productivity and profitability is that relating to the provision of rail transportation. While rail infrastructure exists, it is outdated and requires repair and upgrading. Road transport is the primary form of transporation in South Africa, however, it is costly and poorly regulated.

Electricity represents a rising cost of doing business in South Africa, especially in relation to manufacturing processes that require heat, such as production of chemicals, plastics, steel, and machinery. While manufacturers have enjoyed relatively low electricity prices since the 1990s, Eskom has rapidly increased electricity tariffs since 2006. A key issue that has emerged, particularly in relation to manufacturers of machinery, is a dual pricing system. It is observed in Rustomjee et al. (2018) that high voltage users, such as steel manufactures, are supplied directly by Eskom at prices based on cost of supply. In contrast, low voltage users, such as foundries and machinery manufacturers, are supplied by municipalities at relatively higher prices, since the municipalities see the provision of electricity as a revenue stream. Furthermore, firms supplied by municipalities are also more likely to experience unreliable supply, since many municipalities have underinvested in maintenance of infrastructure. Arguably, there is a policy case for providing electricity to manufacturers at cost of supply prices, in order to reduce costs and maintain competitiveness, thereby providing an environment open to job creation.

A further cost to doing business in South Africa that warrants a more nuanced policy approach relates to the implementation of Broad-Based Black Economic Empowerment (BBBEE).[80] The procurement

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[79] Statistics South Africa (2017) estimates that in 2016, 89.8 percent of households used piped water, 63.4 percent used flush toilets connected to either the public sewerage or to a local septic system, 63.9 percent of households received refuse removal services, and finally, that 87.6 percent of households had access to electricity.
[80] BBEEE looks to make the South African economy more inclusive. The main policy thrust relates to direct empowerment (ownership and management control), human resource empowerment (skills development and employment equity), and indirect empowerment (preferential procurement, enterprise development and socio-economic development).

element of the BBBEE calculation can be problematic (Venter, 2018). One firm noted that it does not score well on this section, because it imports high-value components, such as engines, transmissions, large heavy duty tyres, and hydraulic components. Domestic manufacturers do not have the capabilities to produce these components. The firm does not score well with respect to procurement, since the procurement section is value-based, and these high-value components constitute a disproportionate share of procurement spend. One solution is to appoint an intermediate black-owned company – a BBBEE compliant 'middleman' – as an importer of these components, thereby improving the procurement score.

The need for the compliant 'middleman' has become increasingly important since the imposition of new BBBEE legislation, which made a number of previously compliant firms non-compliant. For example, one firm noted that it shifted from a compliant level 4 to a non-compliant level 8, once the new legislation came into force. It was no longer able to supply motor vehicle parts to an OEM (which is not BBBEE compliant) and thus lost this source of revenue. However, a few months later, a compliant 'middleman' placed an order for these parts, which were a perfect match to those they previously supplied to the OEM.

In South Africa, the need for economic transformation is critical and complex. There is also an argument for a more nuanced implementation of relevant policy. In such cases (as in that noted above) the compliant 'middleman' adversely impacts on a firm's international competitiveness, since the firm will incur a commission cost to the BBBEE compliant importing firm. Arguably, there is room for engagement with state role players, such as the dti, in order to take into account of such instances.

8.6 Job Awareness and Culture as Barriers to Women's Advancement in Manufacturing

Although there is cross-industry heterogeneity, for the most part, manufacturing is male-dominated. The female-to-male employee ratio is 0.45 in 2014, down from 0.47 in 2008. In our enquiries regarding the low share of women in the sector, respondents noted, amongst others, three interesting explanations. First, cultural and social barriers impact on firms' willingness to hire women on the production line. Examples include, older men not being willing to be managed by younger women, inappropriate behaviour of male employees directed toward female employees, etc. Second, firms noted that they received relatively fewer applications from women. It is possible that the cultural and social barriers mentioned above drive this second explanation. Nevertheless, these firms expressed a clear desire to hire women, but struggled to find applicants. Third, firms have not equipped manufacturing plants with female restrooms.

From a policy perspective, these issues can be addressed. Cultural and social stigmas can be addressed through education and training at the workplace. Attracting female applicants can be addressed through job awareness programmes. In many cases, a complete secondary education with mathematics would suffice for an entry level job. This would suggest that firms could attract female applicants by targeting local schools. The lack of facilities for women on production plants requires enforcement of existing legalisation regarding the workplace.

8.7 Development of Capabilities in Linked Industries

The interviews also revealed the need for the development of capabilities in industries that supply inputs to firms producing the frontier products.

First, in relation to the pig value chain, the importance of developing domestic soy bean crushing capabilities was emphasised. Protein is a key component of the cost of feed, and given that South Africa is a net exporter of soya beans, the generation of domestic soy bean crushing capabilities is important to reducing input costs to the pig value chain.

Second, manufacturers of iron products indicated that the capability most required for their overall growth is the development of local foundries and making them more competitive. South Africa used to have a strong foundry sector, and thus the productive capabilities are present. Rustomjee et al., (2018) propose increasing efficiencies in the foundry sector by investing in automation through investment in new technologies. This should also be accompanied with the development of skills for various machine operators. This becomes increasingly important as the role of technology increases across the manufacturing processes.

9   Conclusion

In this paper, we have examined South Africa's level of economic complexity and the extent to which it has undergone manufacturing-led structural transformation. Manufacturing performance in the post-1994 period has been weak and the country can be characterised as having undergone deindustrialisation. As such, we have applied complexity analytics to identify manufacturing and agro-processing products – i.e. frontier products – that South African firms can diversify toward, thereby building economic complexity. We then conducted interviews with firms and industry experts in an effort to determine the capabilities needed in order to diversify into these products, and the factors constraining this process. The interviews also served to validate the products identified. The insights gained into these capabilities and constraints provide a basis for formulating policy.

The analysis in this paper provides a blueprint for evidence-based policy design. The approach to identifying the products is empirical in approach and data-intensive. This is then validated by qualitative research that involves the interview of firms and industry experts. It is our belief that such an approach is key to generating useful policy interventions. Of course, the approach is dependent on the availability of high-quality data that is disaggregated to both the product- and firm-level. As such, data collection and sound statistical approach is important.

The design of this project was to look for new avenues from which to diversify, build economic complexity, and generate growth. However, it must be noted that this is not to be done at the expense of existing industries. Certainly, there is a case for expanding existing industries and enabling these industries to enter new markets. The notion of the product space and complexity analytics sees the economy as an interconnected network, and thus the growth of one component of a network can feed into the growth of another. For example, growing the chemicals industry feeds into related industries in metals, textiles, and agriculture. Similarly, downstream processing of agricultural products can feed into the production of products in automotives and machinery, and textiles and chemicals. As a result of this interrelatedness, a country needs to continue producing what is currently being produced and then expand on the productive capabilities in these industries, expanding into more complex related products.

Building complexity is about diversifying a country's production structure. This is evident in the identification of a diverse set of frontier products that are spread across a wide range of industries – chemicals, machinery, metals, plastics, stone and glass, and agro-processing. As such, building complexity is about growing a network of interconnected products and industries. These interconnections are certainly evident with plastics and metals being used to manufacture motor vehicle parts and various machinery; chemicals being used in agro-processing; and the like. The interconnectedness of these products, and hence industries, is important from a policy perspective. Since these products and industries comprise a greater productive network, policy needs to be formulated in such a manner that it facilitates the growth of the network in its entirety. Thus, the challenge is to design a coherent industrial strategy that advances the growth of the productive network and builds economic complexity.

Growing the manufacturing sector and building complexity will generate employment opportunities. The interconnectedness of the products and industries suggests that focus should be placed on growing the productive network as opposed to only targeting industries that are employment-

intensive. The overall growth of the network is set to generate employment in both capital- and labour-intensive industries. Generating jobs in manufacturing for women and youth requires policy formulation that is both general in its application across industries – i.e. awareness of jobs in manufacturing – as well as specific to certain industries – i.e. training cohorts of female chemical engineers.

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Appendix

Appendix Table 1: The Top 20 Products According to Three Different Weighting Systems

Equal Weight	Parsimonious Weight	Strategic Weight
Stone Wool	Stone Wool	Stone Wool
Vehicle Parts	Vehicle Parts	Vehicle Parts
Pig and Poultry Fat	Pig and Poultry Fat	Pig and Poultry Fat
Lifting Machinery	Other Engines	Lifting Machinery
Traffic Signals	Lifting Machinery	Aldehydes
Aldehydes	Traffic Signals	Traffic Signals
Other Engines	Large Flat-Rolled Iron	Other Engines
Rubber Sheets	Aldehydes	Rubber Sheets
Engine Parts	Rubber Sheets	Engine Parts
Vinyl Chloride Polymers	Engine Parts	Vinyl Chloride Polymers
Large Flat-Rolled Iron	Vinyl Chloride Polymers	Nitrile Compounds
Nitrile Compounds	Dairy Machinery	Fire Extinguishers Preparations
Refractory Cements	Other Agricultural Machinery	Large Flat-Rolled Iron
Fire Extinguishers Preparations	Nitrile Compounds	Refractory Cements
Other Agricultural Machinery	Refractory Cements	Other Agricultural Machinery
Dairy Machinery	Iron Radiators	Dairy Machinery
Iron Radiators	Fire Extinguishers Preparations	Iron Radiators
Harvesting Machinery	Harvesting Machinery	Harvesting Machinery
Large Construction Vehicles	Other Plastic Sheetings	Large Construction Vehicles
Prints	Antifreeze	Prints

Source: Own calculations using data from The Economic Complexity Observatory (Simoes & Hidalgo, 2011).