The Business Strategies of South African Textile Firms and Global Trends in 4IR and Sustainability Technologies

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Abstract

New technologies in robotics, artificial intelligence, big data analytics, the internet of things, smart sensors and 3D printing are seen as disruptive technologies that will change manufacturing. This paper argues that the sustainability shift in apparel and textile global supply chains has led to innovations that combine digitalisation and biotechnology in ways that will have bigger disruptive effects on the global apparel and textile industry. It examines the extent to which South African textile firms are adopting 4IR technologies as well as environmental sustainability technologies in their business strategies, drawing on original empirical materials from a survey of a sample of textile firms carried out in August 2022. South Africa's textile and apparel industry stagnated even before trade liberalisation in the mid-1990s and was not competitive at the time of opening to the global economy, because firms had not kept up with technological changes. Only when the South African retailers faced growing competition from international retail corporations in the late 2010s did the industry actors come together and commit to investments to make the local supply chain more competitive. The survey findings show a quite limited adoption of 4IR technologies among textile firms. Firms that produced relatively higher value products had adopted some aspects of 4IR and newer machines. In contrast, firms producing low-value products for retailers focussed on the low-value segment did not as their product type made such technologies unnecessary, and their profit margins were not capable of affording them in the short term. The findings also point to structural constraints within the South African textile and apparel industry and the general domestic economy that limit the adoption of 4IR and sustainability technologies. In concluding, we argue that the South African textile and apparel industry is relatively well placed to capitalise on the window of opportunity to adopt the latest fibre and textile technologies and to engage in research and development in these areas, and that doing so will increase the competitiveness of the industry and position it better to export.

Keywords: South Africa, apparel global value chain, digitalisation, circular economy

JEL codes: L67, L21, L22, L23, L25, L52

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Table of Contents

List of Tables

1. Introduction

New technologies in robotics, artificial intelligence, big data analytics, the internet of things, smart sensors and 3D printing are seen as disruptive technologies that will change manufacturing, as well as the way we live. These technologies build on the computer and internet technological revolution of the late 20th century, but are referred to as the 'Fourth Industrial Revolution', emphasising that they constitute a distinct change characterised by the integration of new automation technologies with big data analytics and increased interconnectivity along the (global) value chain.[1] These technologies hold the prospect of allowing firms to manage their supply, production and delivery relations in real time, increasing flexibility and industrial productivity.

While these new and emerging digital and automation technologies are (and will) change manufacturing processes, it is debatable whether they constitute a new technological revolution or simple extend what academics call the information and communication techno-economic paradigm that began in the 1980s. Furthermore, as Freeman and Perez (1988) have shown, the information and communication techno-economic paradigm was the fifth industrial revolution. On this side of the debate, it is argued that the so-called 4IR technologies increase the speed of connectivity and the degree of automation through digitalisation, but do not constitute a profound change in the technology system that would lead to a new range of products, services, systems and industries. As such, their disruptive effects may be overstated.

Machine learning, robotics and smart sensors can lead to further increases in productivity and the quality of textile production, while the internet of things and big data can lead to better planning and resource management, and thus improve costing and profit margins. However, these new capital-intensive technologies are still very expensive, and textile and clothing production is a relatively low profit-margin business, where the highest profits are captured in brand intellectual property rights and retail distribution. Thus, lower technology-intensive but efficient textile and apparel companies with specialisation and economies of scale can remain competitive. Section 2 summarises the technological changes in the (global) textile industry from a broader, historical perspective to contextualise current technological innovations related to digitalisation.

We argue that the sustainability shift in apparel and textile global supply chains has led to innovations that combine digitalisation and biotechnology in ways that will have bigger disruptive effects in the global apparel and textile industry, including new man-made cellulosic fibres, cotton and polyester chemical recycling technologies, and new textile machines and production process. Section 3 reviews these global trends. A few but large

[1] See the summary in Report on the Adoption of 4th Industrial Revolution Technologies in South African Industry, E. Lorenz, M. Tessarin and P. Morceiro, SARChI Industrial Development, University of Johannesburg, November 2019.

global apparel buyers see this sustainability shift as a way to create a competitive advantage in a highly competitive global industry by shifting early, and they are even investing in start-up companies creating new fibre and recycling technologies.[2] These first-mover buyers will set the new standard in the industry, and other buyers will imitate. Sustainable fibres and textile production will become the global norm, and thus constitute the next textile revolution.

The aim of this paper is to examine the extent to which South African textile firms are adopting 4IR technologies and environmental sustainability technologies in their business strategies. In doing so, it draws on original empirical material from a survey of a sample of textile firms carried out in August 2022. To contextualise the survey findings, we provide a detailed history of the South African textile and apparel industry up to the present period in Section 4, drawing on the existing published academic work and industry evaluations, as well as primary documents related to the current situation. This overview shows that the industry stagnated even before trade liberalisation in the mid-1990s and was not competitive at the time of opening to the global economy. This was because firms lacked specialisation and had not kept up with technological changes, which led to lower efficiencies in South African factories. As a result, many firms could not compete. The industry declined but was also restructured. Retailers gradually increased imports, as apparel and textile firms had not invested sufficiently in becoming competitive and industrial policies were limited and ineffective. Only when the South African retailers faced growing competition from international retail corporations in the late 2010s did the industry actors come together and commit to investments to make the local supply chain more competitive. It is in this context that some textile firms made investments in new machinery and digitalisation to increase the efficiency, quality and range of fashion fabric.

Section 5 explains the current landscape of the textile sub-sector in South Africa and the survey methodology. The survey findings presented and analysed in Section 6 indicate a quite limited adoption of 4IR technologies among textile firms. There was a clear correlation between the type of products and buyers of a specific textile firm, and whether it had adopted 4IR technologies to even a limited degree. Firms that produced relatively higher value products had adopted some aspects of 4IR and newer machines, whereas firms producing low-value products for retailers focussed on the low-value segment had not as their product type made such technologies unnecessary, and their profit margins were not capable of affording them in the short term. The textile firms performed poorly in terms of the strength of their sustainability strategy, which was limited to waste sorting and waste management for most firms. The findings of the survey point to structural constraints within the South

[2] Based on the authors' observations and interviews with apparel brands and retailers, as well as fibre technology firms at apparel and textile trade fairs, combined with online research regarding new fibre technologies and start-up firms in this sector.

African textile and apparel industry, and the general domestic economy, that limit the adoption of 4IR and sustainability technologies.

The domestic market orientation of most textile and apparel firms seems to be a limiting factor, as the domestic market is characterised by low purchasing power and thus limited demand, as well as demand for low-cost goods. Focussing only on the domestic market limited the growth and specialisation of firms, which in turn hampered the growth of the industry as a whole and allowed textile and apparel firms to fall behind the technological frontier. The result is an insufficient domestic supply chain in fashion fabrics and other intermediate inputs, which gives other countries a competitive advantage, even when they have higher wages, such as Turkey and China.

As a result, South Africa's textile and apparel industry is not competitive internationally, nor is it competitive nationally against imported clothing. The system of trade protection through tariffs combined with rebates on inputs that cannot be sourced locally further complicates the problem rather than ameliorating it, especially through the abuse of the system and the prevalence of illegal imports. The government's current vision for the sector and industrial policy approach laid out in the R-CTFL Master Plan does not identify these structural constraints, but considers the lack of competitiveness at an industry level. As a result, the industrial policy measures outlined in the Master Plan are unlikely to solve the competitiveness issue, even if individual textile, apparel and retailer firms adopt more 4IR and sustainability technologies. Furthermore, moving to the technological frontier of sustainability technologies in alternative sustainable fibres and textile production requires collaboration among firms in the industry, as well as partnerships with foreign firms and domestic firms outside the industry that can bring in new capabilities. Overall, to move the industry forward requires taking an industry perspective that is not only grounded in the needs of domestic retailers, but also outward-looking in terms of engaging with global trends and international partnerships.

2. Digital and Automation Technologies in the Apparel and Textile Industry

From the first industrial revolution and onwards, it was always about technological innovations in textile production, and not about clothing production. The industrial revolution centred on the mechanisation of cotton textile (cloth) production. It involved a new technology in an old industry. British innovations in spinning and weaving machinery led to massive increases in productivity. Countries were forced to emulate or see their artisanal textile production industries collapse under imports. European countries and the US emulated. The key to emulation was private and government efforts to 'steal' British technology. Textile production became characterised by rapid changes in technology during the 1800s, as firms across different countries engaged in incremental innovations and firms had to stay on top of that change or succumb to competitors. The scale of firms increased, as

did capital intensity, increasing the costs of starting a firm and thus raising the barriers to entry for new firms. When the British government allowed the export of textile machinery in 1843, its economy had moved on into the next leading sector, which was centred around the railroad and iron industries. Japan and elsewhere outside the West began to emulate in cotton textile production in the 1880s, as they could access the technology, but only Japan engaged in innovation. Toyota created a new kind of weaving loom that raised productivity compared to that in the West, and it soon dominated export markets and produced its own machinery. Notably, Toyota used profits from its automatic loom to finance its entry into manufacturing motor vehicles in the late 1930s, which was the new leading economic sector.[3]

Further innovations in textile production led to, or were linked to, leading sectors within new techno-economic paradigms (see Table 1). The first man-made fibre was rayon, which replaced silk imported from Japan and was based on chemistry research in Europe that was commercialised first in the US. Then the US firm DuPont created fibres based on polymer technology created through its own basic chemistry research. DuPont introduced nylon and commercialised it by making women's stockings, but nylon came to be used in many things, ushering in the polymer revolution that left us with a world of plastics. Japan caught up quickly in the man-made fibre revolution and chemical industry, which fed into other industries such as automobiles and electronics. South Korea and Taiwan also moved quickly into synthetic fibre manufacturing, and then to the petrochemical industry, through access to Japanese technology. Experience in capital-intensive synthetic textiles and then petrochemicals provided the experience, knowledge and skills in these countries to move into leading sectors in the fifth techno-economic paradigm, where they became technological leaders in digital TVs, microelectronics and mobile phones.

[3] This paragraph and the next two draw on research for a forthcoming paper on the role of textiles in industrialisation from a historical perspective. Some of the sources include Amsden, Alice. 2001. *The Rise of 'the Rest': Challenges to the West from late-industrializing Economies*. Oxford: Oxford University Press; Beckert, Sven. 2015. *Empire of Cotton: A global history*. New York: Alfred A. Knopf; Smitka, M (ed.) *The Textile Industry and the Rise of the Japanese Economy*. New York: Garland Publishing; Lazonick, W. 1981. Competition, Specialization and Industrial Decline. *Journal of Economic History* XLI, 1, pp. 31-38; Wray, M. 1957. *The Women's Outerwear Industry*. London: Gerald Duckworth and Co; McNamara, D. 2002. *Market and Society in Korea: Interest, Institutions and the Textile Industry*. London: Routledge; Leung, H.-C. 1997. Local Lives and Global Commodity Chains: Timing, Networking and the Hong Kong-based Garment Industry. PhD thesis, Department of Sociology, Duke University.

Table 1: Five technological revolutions in global capitalism

Techno-economic paradigm	Description	Main carrier and induced growth sectors	Technological leaders
First (1770s/80s to 1830s/40s)	Early mechanization	Textiles, textile chemicals & machinery, iron working	Britain France, Belgium
Second (1830/40s to 1880/90s)	Steam power and railway	Steam engines, machine tools, iron, railway equipment	Britain France, Belgium, Germany, USA
Third (1880/90s to 1930/40s)	Electrical & heavy engineering	Electrical engineering & machinery, cable & wire, armaments, steel ships, heavy chemicals	Germany, USA Britain, France, Belgium, Switzerland, Netherlands
Fourth (1930/40s to 1980/90s)	Fordist mass production	Automobiles, aircraft, consumer durables, petro-chemicals, synthetic materials	USA, Germany Other European, Japan, USSR, Canada, Australia
Fifth (1980/90s to now)	Information & communication	Computers, electronic capital goods, microelectronics, software, telecom equipment, optical fiber	Japan, USA, Germany, Sweden Taiwan, Korea, Canada, Australia

Source: Freeman and Perez (1988).

Ready-made garments emerged in the US for workers and the growing middle class in the second half of the 1850s. But it was not until the fashion industry emerged that a mass market in clothing emerged. The 'built in obsolescence' of fashion was key to allow clothing to compete with other items in the consumer budget; market demand for clothes had to be created continuously by marketing. From the beginning of ready-made garments, the functions of design, marketing and retail were performed by one firm that contracted out clothing manufacturing to other firms. The use of contracting reflected the low profits of producing clothes due to low capital requirements for entry and the relatively small size of operations, which meant high competition. Demand was always volatile and uncertain. Retailers shifted the volatility of seasonal consumer demand to contractors, and then required short delivery times. Prices had to be kept low relative to the average household income and had to compare favourably to what a neighbourhood seamstress would charge. Given limits to the mechanisation of sewing, and the need for low prices, clothing producers needed workers willing to accept a level of income much lower than most of the consumers. Thus, clothing production has always depended on socially disadvantaged groups in society who do not have the means to achieve an average level of earnings. Clothing production moved from place to place in search of low-cost labour: first within advanced countries (such as from the north to the south of the US), and then outside of them. These dynamics have always characterised apparel production, but they became globalised with the expansion of global supply chains. In sum, as textile production technology became easily accessible and new leading economic activities emerged, textile production lost its dynamic qualities: little technological change or productivity increases through incremental innovations.

What drove technological revolutions in the textile industry was the 'short cycle technology' of the early cotton textile machinery period and the early synthetic fibre production in the petrochemical period.[4] Computers and the internet in the ICT techno-economic period led to further automation in textile and sewing machinery, but not to fundamental changes in the machinery itself, resulting in further increases in productivity and quality. It also led to greater speed within global supply chains, and thus the increased fragmentation and dispersion of the chain across countries. Current applications of machine learning (AI), robotics, smart sensors, IoT and big data, and automation in the textile and apparel industry, do not seem to constitute a major disruption, or technological revolution, in the sector.[5]

Textile production was already widely automated because of micro-electronics that led to the widespread use of computer numerically controlled machinery since the 1980s (Kaplinsky 1985). This included spinning, sewing thread manufacturing, weaving, circular and flat knitting, as well as fabric spreading and cutting in the pre-assembly stage of clothing manufacture. However, the introduction of micro-electronics into assembly technology was limited and thus it remained reliant on labour-intensive techniques (Hoffman 1985). The introduction of automated machinery and robots in sewing operations has been more difficult due to the limpness of fabrics, the frequent need for manual pulling and slipping of material, and the complexities of the non-linear needle-fabric interaction during sewing (Altenburg et al. 2020:12). In the second half of the 2010s, there were companies working on different types of technology aimed at automating sewing operations using digitalisation, largely using vision identification. Robot applications for garment manufacturing require the combination of many capabilities: general robotics, software development, material handling, visioning systems and so on, making it difficult to achieve. According to expert interviews reported in Altenburg and colleagues (2020:18), it will take 15 to 20 years before digital automation in sewing will become relevant for any significant portion of the clothing industry, if not longer. Thus, in the near term, robots will not produce more cost-effectively than human labour.

Automation is less important than other applications of digital technologies being applied to smart factories and to manage global supply chains to increase speed and quality while reducing risks: digital design software, virtual sampling, material tracing. In smart factories, digitalisation is used to monitor machines and collect data that can be used for 'real-time' assessments of productivity and problem-shooting. The latest versions of electronic textile machines come with machine learning and the ability to suggest optimal settings without being explicitly programmed. Electronic sewing machines remember settings and then sew automatically, with workers moving the fabric. Retailers are increasingly focussing on e-commerce and using it to customise products. Online sales produce big data that can be analysed to better forecast fashion trends and to reduce inventory and unsold stock.

[4] On the concept of short cycle technology, see the work of Keun Lee (2013).

[5] This summary draws on the data and analysis presented in Altenburg et al. (2020).

Digitalisation can also be used to make the production process more consumer-centric or consumer-driven, shortening the time from creation to purchase and increasing customisation.

3. Sustainability Shift in Global Apparel Industry

Clothing production has doubled in the past fifteen years due to the fast fashion business model of global apparel brands and retailers.[6] More than half of that ends up in landfills and incinerators in less than a year. In 2020, the global fashion industry was estimated to account for at least 4% of greenhouse gas emissions globally, equivalent to the combined annual emissions of France, Germany and the United Kingdom.[7] It also accounted for 20% of global wastewater discharge into rivers and seas. Within apparel and footwear global supply chains, 71% of greenhouse gas emissions came from the production process, with the remainder generated by transport, packaging, retail operations, usage (wash and drying), and end-of-use in landfill or incineration. In the production process, the bulk of emissions come from the energy-intensive cultivation and production of raw material, yarn and fabric. Raw material production of cotton and man-made fibres accounts for the largest amount of GHG within the production process.

The negative environmental impact is set to triple by 2030 as production increases due to the growing world population and rising incomes in emerging economies. The global apparel industry must adopt circular economy principles because making more clothes with virgin resources will not keep the global fashion industry within planetary boundaries. Recognising this fact, European country governments and the European Union Commission have been at the forefront of the sustainability shift in the global fashion industry.[8] In 2018, the European Union Commission adopted a circular economy package that requires member states to ensure that textiles are collected separately, and the Waste Directive requires member states to set up such schemes by 2025 at the latest. This action was the first step in the use of regulation to create circular fashion: the re-use and recycling of clothing and the use of sustainable raw materials.[9] The EU European Green Deal (2019), the Circular Economy Action Plan (2020) and the Industrial Strategy (2020) all identified textiles as a priority sector in which the EU can pave the way to a carbon-neutral, circular economy.

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[6] Ellen MacArthur Foundation. 2017. A new textiles economy: Redesigning fashion's future. http://www.ellenmacarthurfoundtion.org/publications; Ellen MacArthur Foundation. 2020. Vision of a circular economy for fashion. http://www.ellenmacarthurfoundtion.org/publications

[7] Fashion on Climate: How the Fashion Industry Can Urgently Act to Reduce its Greenhouse Gas Emissions. McKinsey & Company, 2020. See also Jensen and Whitfield (2022).

[8] Questions and Answers on the EU Strategy for Sustainable and Circular Textiles, 30 March 2022, European Commission.

[9] Environmental impact of the textile and clothing industry: what consumers need to know, European Parliamentary Research Service Briefing, January 2019.

The EU Strategy for Sustainable and Circular Textiles, published in March 2022, aims to implement the commitments made in these documents. It includes new design requirements for textiles under the Ecodesign for Sustainable Products Regulation, setting mandatory minimums for the inclusion of recycled fibres in textiles. The proposed regulation would make sustainable textiles the norm in the EU and ban the destruction of unsold products under certain conditions, including unsold and returned textiles. It aims to reduce the 'throwaway' culture by boosting the market for recycled fibre and requiring apparel sold in Europe to be longer lasting and easier to repair.

The EU textile strategy also proposes to harmonise EU rules on extended producer responsibility for textiles and economic incentives to make products more sustainable through 'eco-modulation of fees'. It will support research, innovation and investments needed for this green transition and address challenges related to halting the export of textile waste, which includes second-hand clothing. The EU Commission proposal for new EU rules on waste shipments will only allow the export of textile waste to non-OECD countries if they can demonstrate their ability to manage it sustainably.

Furthermore, there are increased requirements in the EU and US for transparency in publicly listed corporations. The first set of regulations comprise disclosure directives that require both investors and lead firms to measure emissions and identify sustainability risks. At the forefront of these policies is the EU's Sustainable Finance Disclosure Regulation, which was passed in 2019 and came into force in 2021. In order to streamline the sustainability reporting of financial products with an environmental, social and governance (ESG) claim, fund managers have to assess sustainability risks and the negative material impact of their investments in a standardised manner before they can claim it as an ESG investment. Hence, if global apparel brands and retailers want to be eligible for a green product, they need to publish data on which investors can draw, particularly on their own emissions (scope 1 and 2 GHG) and energy sources. A further regulation, the Corporate Sustainability Reporting Directive, requires all publicly listed companies to disclose strategies on how they ensure environmental protection and a third-party audit of data published in sustainability reporting. The US government recently followed suit, with even stronger reporting requirements. From 2023 onwards, the US exchange supervisory authority will request all listed firms to disclose emission data on their own operations and those of their suppliers (scope 3 emissions).[10]

In response to this existing and anticipated legislation, global apparel brands and retailers are adopting strategies to reduce their scope 1, 2 and 3 greenhouse gas emissions. Of the top ten global buyers, most have targets to reduce scope 3 emissions by at least 20% by 2030, with

[10] Information on the EU Sustainable Finance Disclosure Regulation and Corporate Sustainability Reporting Directive can be found on the EU Commission website: https://finance.ec.europa.eu. On the new SEC rules, see https://www.sec.gov/news/press-release/2022-46.

H&M having the most ambitious goal of a 56% reduction in scope 3 emissions (Table 2). H&M also has the ambitious goal of 100% renewable energy use in its entire supply chain, with Adidas and VF adopting more modest targets. In terms of sustainable fibres, H&M again has the highest goal of 100% recycled or sustainable fibres in its products by 2030, with all other buyers having substantial goals, except for TJX (based in the US), Uniqlo (Japan) and Shein (China). Based on a survey among apparel brands and retailers undertaken in 2021, a McKinsey report shows that one in three respondents said they planned for more than 90% of their product to be made with sustainable fibres by 2025. Twenty-one percent of respondents aimed to replace at least 30% of their virgin cotton with recycled cotton by 2025.[11]

Table 2: Sustainability goals of top ten apparel brands/retailers*

Corporation	Revenue in $million (2021)	Goals on GHG 1 and 2 emissions (own operations)	Goals on GHG 3 emissions (supply chain)	Goals on renewable electricity in supply chain	Concrete goals on fibres
TJX	48.549	55% reduction by 2030 (2017 baseline)	None	None	None
Nike	46.716	70% reduction by 2030 (2015 baseline)	0% increase until 2025 (2020 baseline)	None	50% sustainable or recycled materials by 2025.**
Inditex	30.919	90% reduction by 2030 (2020 baseline)	20% reduction by 2030 (2020 baseline)	None	100% cotton and polyester from more sustainable sources by 2023. 100% polyester and linen from more sustainable sources by 2025.
Adidas	24.049	30% reduction by 2030 (2017 baseline)	30% reduction by 2030 (2017 baseline)	Adoption of renewable energy for core apparel and textile suppliers	Nine out of ten Adidas articles should be sustainable, meaning that they are made with environmentally preferred materials.
H&M	21.970	56% reduction by 2030 (2019 baseline)	56% reduction by 2030 (2019 baseline)	100% renewable energy by 2030 in entire supply chain	100% recycled or more sustainable by 2030. 30% recycled fibres by 2025.***

[11] 'Revamping fashion sourcing: Speed and flexibility to the fore', McKinsey Apparel CPO Survey 2021 by the Apparel, Fashion & Luxury Group, McKinsey & Company, November 2021.

Corporation	Revenue in $million (2021)	Goals on GHG 1 and 2 emissions (own operations)	Goals on GHG 3 emissions (supply chain)	Goals on renewable electricity in supply chain	Concrete goals on fibres
Fast Retailing (Uniqlo)	19.414	90% reduction by 2030 (2019 baseline)	20% reduction by 2030 (2019 baseline)	None	None
GAP	16.670	90% reduction by 2030 (2017 baseline)	30% reduction by 2030 (2017 baseline)	None	100% BCI cotton by 2025, now at 79%. 45% of polyester from recycled sources (rPET), currently at 10%.
Shein	15.700	42% reduction by 2030 (2021 baseline)	25% reduction by 2030 (2021 baseline)	None	None
VF	11.841	55% reduction by 2030 (2017 baseline year).	30% reduction by 2030 (2017 baseline)	Support for selected suppliers to install renewable energy	100% of cotton sourced to be grown in the US, Australia or under a third-party cotton-growing scheme by 2026 (currently at 79%). 50% of polyester will originate from recycled materials by 2026 (currently 26%).
PVH	9.154	30% reduction by 2030 (2017 baseline)	30% reduction by 2030 (2017 baseline)	None	Sourcing 100% of sustainable cotton (GOTS, BCI, organic) and viscose by 2025. 100% of polyester by 2030.

Notes: *Top ten apparel brands/retailers ranked by corporate revenue (2021). ** Apparel EPMs: recycled polyester, organic cotton, recycled cotton, third-party certified cotton. *** See Table with categories: I think more sustainable fibres apply to category A-C, and they want to avoid D. https://hmgroup.com/wp-content/uploads/2021/11/HM-Group-Material-Categorisation-2021-1.pdf.
Sources: Compiled by Felix Maile. Data was collected from corporations' sustainability impact reports (FY 2021), and via the progress report of the Science Based Targets Initiative (2021).

This wave of regulation is catalysing investments in innovations in alternative fibre technologies and chemical recycling technologies. There is a limited amount of organic cotton on the global market, 50% of which was supplied by India, but the recent exposure of fraudulent practices in organic cotton certification in India has cast doubt on the certification

process and posed reputational risks for buyers.[12] In response, non-profit organisations and apparel buyers are supporting farmers in India as well as other countries to produce regenerative organic cotton.[13]

As alternatives to virgin cotton, apparel buyers are looking at virgin materials that use less energy to produce, such as hemp and man-made cellulosic fibres. Viscose is an existing semi-synthetic cellulose fibre made from types of wood, but it is not considered very sustainable. Apparel buyers are supporting, and even investing in, start-up firms pioneering technologies to create sustainable man-made cellulosic fibres. For example, the Finnish start-up, Spinnova, produces a cellulosic fibre out of wood or waste from leather, textile or food. The patented Spinnova fibre creates zero waste or side streams, uses no microplastics, and involves minimal CO_2 emissions and water use. Spinnova works with global brand partners such as the H&M Group and Bestseller to create clothing lines using the Spinnova fibre.[14] Spinnova established commercial-scale factories in Finland in 2021 in partnership with Suzano, a major eucalyptus pulp producer, and with ECCO's leather partner, KT Trading, to create fibres out of leather waste. The latest new-to-market innovation in cellulosic fibres is by Fibre52 Cotton, which has created a cotton production process with minimal use of water and energy and only bio-active inputs that produces a fabric that is more durable and has moisture-management properties.

There are also fibre technology innovations based on recycling, including recycling textile waste, converting agro-waste from crops into natural fibres, and using microbes to produce fibres from agro-waste. Some of the most prominent examples include Renewcell's Circulose fibre (Sweden), Infinited Fiber's Infinna fibre (Finland), Birla's La Reviva fibre (India) and Evrnu's NuCycl technology (US).[15] These firms have patented (or patent pending) technology that uses chemical processes to recycle textile waste into a cellulosic fibre that can replace virgin cotton in spinning. Clear market signals of support and offtake agreements from apparel brands and their textile providers were crucial to allow these firms to raise financing for commercialisation. Furthermore, buyers like H&M and Levi's took direct shares in Renewcell.

In addition, recycled polyester technologies are developing rapidly. Polyester is the most popular material used in textile production due to its price and performance, and it represents

[12] That Organic Cotton T-Shirt May Not Be as Organic as You Think, by Alden Wicker, Emily Schmall, Suhasini Raj and Elizabeth Paton, 13 February 2022, The New York Times.

[13] Regenerative agriculture refers to agricultural practices that aim to help support biodiversity, enhance water cycles, improve soil health and sequester carbon – practices such as rotational grazing, cover cropping and no-till farming.

[14] 'Spinnova aims for 'holy grail' of fashion textiles', A. Friedman, 24 February 2022, Sourcing Journal; 'Jack & Jones releases its first product made with Spinnova fibers', 31 October 2022, Sourcing Journal.

[15] See for example, 'Finland wants to transform how we make clothes', M. Savage, 04/11/2022, BBC News; 'Renewcell's commercial-scale factory: dawn of a new era?', A. Harrell, 10/11/2022, Sourcing Journal; 'Evrnu Raises 9 Million USD to close the textile lifecycle loop', J. Binns, 03/10/2019, Sourcing Journal.

52% of global fibre production.[16] To date, most 'recycled polyester' fibres used in apparel production come from recycling polyethylene terephthalate (rPET). However, this solution is not very sustainable as it depends on producing new plastic and does not address polyester waste in used clothing. Innovations are required in textile-to-textile recycling processes, which are happening. New technologies include the Green Machine technology developed through a collaboration between the H&M Foundation and the Hong Kong Research Institute of Textiles and Apparel. It is the first technology that can separate cotton and polyester fibres in blended fabrics and extract the polyester for use in making new polyester fibres. This technology has been licensed to textile firms in Indonesia, Turkey and Cambodia as test cases for commercialisation, with buyers such as VF that have committed to taking the product. Buyers are waiting to see the cost of the recycled polyester at the commercialisation stage. Worn Again, a UK company, has also developed polymer recycling technology that converts polyester and polycotton blended fabric into new polyester fibres, and it also received funding from H&M.[17]

Besides fibre-to-fibre recycling, innovations are required to produce next-generation materials such as bio-synthetic ones that have the properties of synthetic material and can be used to replace fossil fuels.[18] We are likely to see such bio-synthetic materials in the near future as investments are made in this area, driven by EU legislation and buyers' shifting demands, which are creating new market opportunities for alternative fibres.

New textile machinery is emerging that combines sustainability and digitalisation. For example, the Italian weaving loom manufacturer Itema Group has produced an iSaver R9500-2denim rapier machine that significantly reduces raw materials and water usage.[19] The loom is already used by major denim manufacturers in Turkey, China and Egypt. Furthermore, textile manufacturers and apparel brands are working together to design more sustainable fabrics and finishes using digital technologies. To take another example, Calik created laser-friendly fabrics designed digitally with Jeanologia's eDesigner software in a special jeans collection that shows brands how they can eliminate sample waste by choosing fabrics that are compatible with the finishing technologies, using eco-friendly washes, and designing garments digitally.

[16] Textile Exchange, 2021, Preferred Fibre and Materials Marketing Report.

[17] See for example, 'H&M goes all in on Garment-chomping "Green Machine" amid chorus of recycling critics', J.M. Chua, 07/12/2021, Sourcing Journal; 'Green Machine launch planned to address Cambodia textile waste', H. Abdulla, 14/101/2021, Just-Style.com; http://www.wornagain.co.uk.

[18] 2025 Recycled Polyester Challenge: First Annual Report, July 2022, Textile Exchange.

[19] See https://sourcingjournal.com/denim/denim-mills/denim-premiere-vision-report-recycle-textile-waste-isko-officina-39-calik-391857/#recipient_hashed=6bfae6486b850607563519b8f7ac7d9b5d6577a13fea182e4e16d99cf736a3b0&recipient_salt=15be3b9302a5c89f6a3b7a3862be0a80c0b84c9a7299bdf83ffa614efdb8c173

Thus, future fibres will have a high technology content and require licensing technology for both man-made cellulosic fibres and the new wave of synthetics that seek to replace polymers. These technologies may have spillovers into other manufacturing sectors, resulting in something like the technological advancements in chemistry that led to the polymer revolution in the 1930s and the broader linkages and knowledge spillovers that it spurred in the domestic economies of Japan, South Korea and Taiwan, where local firms mastered the technology and then engaged in incremental innovations that produced proprietary technologies.

4. South Africa's Textile and Apparel Industry

The South African apparel and textile industry was well established by the second half of the twentieth century but oriented entirely to the domestic market. It developed under the isolation of apartheid sanctions and import substitution policies that created protective tariffs. After the end of apartheid in 1994, the new government adopted trade liberalisation, declaring that the country could not afford to sustain uncompetitive industries through import substitution or protectionist measures (van der Westhuizen 2006:5). In a context of reduced tariffs and the elimination of quotas, South African textile and apparel firms struggled to compete with imports from Asian countries with more competitive industries. South African firms were less efficient because they were far behind the technological frontier in the industry due to a lack of re-investment and their focus on the domestic market, which led to diversified product portfolios with smaller runs and thus did not reach the economies of scale of large factories in China or in another Asian countries that exported.

The industry declined but also went through a period of restructuring. Vertically disintegrated firms broke apart and focussed on specific activities. Many apparel factories closed, which had a knock-on effect in terms of demand for fabrics. As a result, many textile factories closed or reoriented to industrial, technical and niche areas where there was less international competition. Clothing firms outsourced the labour-intensive assembly part to many small and informal firms or set up assembly firms in Lesotho and Eswatini, where production costs were lower, and then focussed on the design element.

The industry then stagnated from the mid-2000s to the end of the 2010s, when another restructuring began. South African retailers had been content to import cheaper clothing and fabric from Asian countries and neighbouring Southern Africa countries. However, retailers also began to face higher competition in the domestic market from international clothing retail corporations. They sought to build a competitive advantage based on a quick response, which required greater localisation of production, including textile production for fabrics made up in South Africa.

4.1 Historical Developments in the Textile and Apparel Industry Leading to Decline

Import-protection measures on textile and apparel during the apartheid period consisted of a mixture of ad valorem and formula duties based on a specified import price, as well as a range of quantitative restrictions (Roberts and Thoburn 2003). The very high tariffs and duties were applied to specified textile products that were produced in South Africa, such as woven polyester fabric of specific weights. However, it was not uncommon for exemptions to tariffs to be granted to importers of fabrics for types of synthetic products and fabrics with specific finishes that were not produced in the country. Roberts and Thorburn (2003) note that textile had the highest tariff rate in 1990.

Many policy documents and industry statements locate the cause of the industry's decline in the rapid trade liberalisation from the mid-1990s, as the industry was not able to adjust to the new competitive environment and the emergence of China as a global apparel and textile producer. Reports agree that the industry declined due its lack of international competitiveness. However, this lack of competitiveness has deeper roots. Justin Barnes (2005:7) notes that due to focussing on the domestic market, firms were never able to achieve economies of scale. Christi van der Westhuizen (2006:4) emphasises that the industry already exhibited signs of stagnation in the 1970s and was in decline from the late 1980s. Drawing on studies undertaken in the early 1990s, van der Westhuizen argues that many family-run businesses opted for survival more than the maximisation of profits, and for reducing labour costs through movement to low-wage rural areas rather than economic upgrading. A small number of large, often vertically integrated, companies were responsible for a high degree of production, with cross-ownership prominent, and this caused high overheads.

The industry also suffered from low levels of capital investment. A survey of textile and apparel firms undertaken by Roberts and Thoburn (2003) indicates that firms had not upgraded their capital stock and in many cases were operating in the early 1990s with textile machinery that was 20 years old or more. Their findings show that firms that had invested in modern machinery were clearly more competitive. Other firms suffered from short-termism in their business strategies, in which high profits made under protection were not necessarily reinvested.

In the context of South Africa's accession to the WTO, the government reduced tariffs on apparel from 100% in 1993 to 40% by 2002 (Roberts and Thoburn 2003). Nominal tariffs had been lower for textile products, but effective rates of protection were higher due to quantitative restrictions and formula duties; as a result, liberalisation in the textile segment was greater than indicated by average tariff rates.

Apparel imports relative to the value of domestic sales (ex-factory) increased from 28% in 1990 to 41% in 1999 (Roberts and Thoburn 2003). Exposed to international competition, South African textile and apparel firms were inefficient; lacked capital, technology and

innovation; and had high labour and management costs relative to output (Barnes 2005). These firms responded with several restructuring strategies, few of which resulted in significant improvements in competitiveness. Productivity was increased through cost-minimisation and downsizing, rather than production growth (Barnes 2005).

Historically, textile firms tended to be vertically integrated, from spinning, weaving, dyeing, to finishing. Several firms closed spinning or weaving operations to concentrate on one part of the chain, but the ability of these firms to refocus and upgrade was linked to their access to finance for the investment required (Roberts and Thoburn 2003). Other firms simply closed or reduced their capacity. Firms that made investments in new machinery reduced the variety of products they manufactured, focussing on niche products in relation to which they competed on quality, design and delivery terms, rather than price.

South African apparel firms responded by outsourcing the labour-intensive assembly function, becoming design houses that focussed on securing orders from domestic retailers, designing clothes in collaboration with the retailer, and organising the production, logistics and delivery to retailers (van der Westhuizen 2006:9-11). The factories to which they outsourced assembly were either started by retrenched workers with equipment provided by former employers, or by retrenched workers starting small factories as a survival strategy. Van der Westhuizen argues that these small assembly factories engaged in a price war with each other, were under-capitalised, and that they could not afford the necessary investment to become competitive in the long run. The design houses recruited assembly factories from their network and spread orders among several factories to reduce the risk of non-delivery. Some big apparel manufacturers continued to produce apparel but augmented their production with imports from Asia (van der Westhuizen 2006:12).

Another restructuring strategy of apparel firms was to export to the US market as a result of the US Africa Growth and Opportunity Act (AGOA), which in March 2001 allowed South African apparel producers duty- and quota-free access to the US market. However, South African firms had to meet triple transformation rules of origin, which meant that yarn, fabric and apparel had to be produced in South Africa, or with yarn imported from the US. Apparel firms did not have the capacity to supply both domestic and export markets, so many failed to meet their domestic orders, and retailers turned to greater imports (Barnes and Morris 2014:9). Barnes (2005) notes that apparel exports were modest and primarily in basic commodities such as T-shirts.

The rapid depreciation of the rand in 2001/2002 made South African goods relatively cheaper. However, with the appreciation of the rand in 2003, South African firms lost that advantage and quickly became uncompetitive. Barnes (2005) argues that the South African firms' higher cost structure meant that they could not compete with firms in China, India, Indonesia, Turkey and Pakistan, especially on basic products. *South African firms also were constrained by what they could produce, given the shortage of domestically produced fabrics and limited variety of*

fabrics produced locally, and by the size of their factories, which could not meet the order volumes demanded by US buyers. Overall, the limited range of export-quality products that could be sourced from the South African industry reduced US buyers' interest in South Africa, as they preferred to source from countries that had larger industries that could offer a diverse range of products and thus limit transaction costs for the buyers.[20]

To encourage apparel firms to export, the South African government created the Duty Credit Certificate Scheme in 1993 by allowing firms to claim a rebate of duty on imported fabrics if they were used to produce apparel exports. However, firms were allowed to sell the rebates to any other importer of garments or textiles, which resulted in most credits being sold to retailers, which then used them to import garments (Barnes 2005:9). As a result, this industrial policy had little effect on spurring apparel exports, or helping firms become more competitive. Barnes (2005) finds that capital expenditure on new assets in the apparel sector from 1992 to 2002 was very low, and that many clothing firms relocated to non-metro areas, where they were able to pay lower wages as a way to compete. A survey of textile and apparel firms carried out in 2004 for the Textiles Federation found that textile firms were characterised by long lead times, poor delivery reliability and deteriorating quality performance, which also constrained the performance of apparel firms, which then had to import fabric (Barnes 2005). In the survey carried out by Roberts and Thoburn (2001), firms emphasised the unwillingness of commercial banks to lend to the textile and apparel industry as reducing their options, and their study also found that the financing provided by the Industrial Development Corporation to some selected firms had not been used well.

The Multi-Fibre Agreement (MFA) phase out that took effect at the start of 2005 ended all quotas on the trade of textile and apparel between WTO member states. China, which joined the WTO in 2001, benefitted the most, as it had the ability to produce a large range of items at international quality standards. Apparel imports to South Africa from China increased from 16.5% of the total rand value of clothing imports in 1995 to 74.2% in 2005 (Barnes and Morris 2014:10). Cheaper imports from China caused price deflation within the industry in South Africa, as it did globally.

Barnes and Morris (2014:12-13) argue that, instead of facing the challenges of the evolving global economy, textile and apparel firms, as well as trade unions, responded to the lack of competitiveness of the South African industry by lobbying for policies and approaches reminiscent of the previous import substitution industrialisation era. Instead of improving their operational performance as the best way to meet the competitive threat, they tried to bring back protection through tariffs and import controls. South African textile and apparel firms tended to see imports from China as 'unfair' competition and argued for new quotas. This claim that competition from China is 'unfair' is misguided. Rather, local firms in China

[20] Based on interviews with several apparel firms in Cape Town that had tried exporting to the US.

have built up their capabilities and benefitted from collective efficiencies derived from agglomeration in industrial parks as the result of the combination of firm-level strategies, federal and local government policies, and partnerships with foreign firms (Whitfield et al. 2021). Nevertheless, this lobbying resulted in the South African government imposing the China Restraint Agreement in 2007, which restricted apparel and textile imports from China for two years, and in the government raising the duty on imported apparel from 40% to 45%. The idea was that firms would use the respite to invest in new technology (Barnes and Morris 2014:14). However, the effect of this industrial policy was to send South African retailers to other Asian countries in search of imports and eventually to neighbouring countries in Southern Africa.

From 2010, apparel imports from Eswatini, Lesotho and Madagascar increased. Lesotho and Eswatini had no restrictions on exporting to South Africa, while Madagascar and Mauritius benefitted from duty-free export to South Africa under SADC with double transformation rules of origin. Taiwanese-owned firms in South Africa had already begun to relocate to Lesotho in the early 1980s to take advantage of lower costs, and this flow increased as other Taiwanese firms sought to take advantage of Lesotho's foreign investment incentives and under-utilised MFA quotas (Morris et al. 2016). Some South African apparel firms followed suit, with design houses located in South Africa and apparel factories moved to Lesotho or Eswatini (Morris et al. 2011). Imports from Madagascar largely came from Mauritian firms that had set up assembly factories in Madagascar (Morris and Staritz 2014; Whitfield and Staritz 2021).

Barnes and Morris (2014) emphasise that South African apparel firms eventually realised that they had to build a strategic alignment with the retailers driving the domestic value chain to secure more local orders. Some apparel, textile and retailers formed clusters in Cape Town and KwaZulu-Natal and focussed on shifting to a new business model based on speed and flexibility of supply. Retailers sought to minimise their inventories and increase their profit through repeatedly turning over stock within the year, which they could achieve by building local supply chains that included supplier firms with short production cycles and customised products based on point-of-sales information. This model was based on the success of Inditex/Zara and its regional sourcing patterns in Morocco and Turkey.

Implementing this model required that apparel and textile firms invest in improving their product flexibility, production capabilities and supply chain management skills (Barnes and Morris 2014:17). To help achieve this transition, the South African government introduced the Clothing and Textile Competitiveness Programme in 2010, which had two components: a production incentive programme and a competitiveness improvement programme. The production incentive programme aimed to support firm-level upgrading through re-capitalisation (Barnes and Morris 2014). Firms could access grants up to a level equal to 7.5%

of their manufacturing value added.[21] The grant could be used for the purchase of new machinery, upgrade existing machinery or factory equipment, develop skills, improve manufacturing processes, optimise material use, and develop new products or markets. All expenditure was supposed to be part of a clearly defined strategy (Barnes and Hartogh 2018:46). The competitiveness improvement programme provided grants to national and regional clusters, which managed the funds and assisted firms to implement lean manufacturing and other interventions. The cluster project manager conducted benchmark studies of firms to identify constraints and have an understanding of the firms' strategic focus, based on which interventions and projects were designed and implemented.

The Industrial Development Corporation managed the programmes on behalf of the Department of Trade and Industry. It developed a set of financial and operational metrics to measure the impact of the Clothing and Textile Competitiveness Programme. Based on a survey of 148 beneficiary firms in 2017, the Industrial Development Corporation found that, out of a total of 516 firms, there had been major improvements in competitiveness performance indicators, except for manufacturing value added as a percentage of sales. This reflects a reduction in gross margins, as manufacturer sales prices increased slower than their raw material purchases (Barnes and Hartogh 2018:47). This finding could be interpreted as showing that apparel and textile firms were still producing low-value, basic products, in relation to which the (global) trend is downward pressure on unit prices regardless of whether input prices are increasing. No other assessment is available of the impact of the Clothing and Textile Competitiveness Programme on improving apparel and textile firms' competitiveness and changing their business strategies.

On the retailer side, while South African retailers adopted some international trends, such as providing greater convenience and enhancing the customer experience, their focus remained on competitive pricing and enabling consumers (Barnes and Hartogh 2018:23). At the time, they did not move toward a greater integration of online and store experiences, advanced analytics, innovative materials and environmental sustainability, and traceability. Through the clusters, retailers worked with the best apparel manufacturers and design houses to put in place 'quick-response' platforms (Morris et al. 2021). If local apparel manufacturers produced small runs quickly to restock selling items, sourcing locally was cheaper than imports for a retailer's final margin, even if the unit price of products was slightly higher, because the retailer paid less to get product on shelves when it was needed.[22]

However, apparel manufacturers operating at the bottom and lower-middle end of the market responded in a different manner (Barnes and Morris 2014). Some relocated to Lesotho and Eswatini to access lower wages and more flexible labour market conditions, and then

[21] The programme originally also included an interest subsidy facility, but this was cancelled in 2014 (Barnes and Hartogh 2018).

[22] Point made by a local apparel manufacturing firm in an interview, 29 August 2022.

exported back to the South Africa market. Others operated assembly factories in Newcastle and Ladysmith supplying the design houses but ignored the bargaining council wages. A third layer consisted of very small firms in the informal economy.

Overall, apparel and textile manufacturers still struggled to upgrade production processes and expand the range of products that could be produced in South Africa. In interviews with retailers, design houses and manufacturers, it was pointed out that many textile and apparel firms still had poor production processes and a lack of modern equipment and IT systems, leading to inefficiencies compared to international suppliers and narrow product offerings (Barnes and Hartogh 2018:49-55). Capabilities in fabric production were diminished, especially in woven fabrics. There had been an exodus of skilled managers from the industry, leading to 'poor change management' and a lack of innovation at the firm level. Many firms had low production levels and were not able to produce at scale (achieve economies of scale), which would increase efficiency. Textile firms faced increased operating costs due to electricity and water issues, as well as poor infrastructure in industrial locations. They also noted that immigration regulations made it difficult to import highly skilled foreign labour, and labour regulations made it difficult to implement shift work and overtime on apparel factory floors, which was necessary to meet short deadlines and achieve speed to market.

As a result of these historical developments, clothing, textile, footwear and leather (CTFL) manufacturing accounted for only 0.37% of South Africa's GDP in 2015, declining from 0.47% in 2010. CTFL retailing, in contrast, was estimated to have contributed 1.03% of GDP. This shows that domestic manufacturers did not capitalise on domestic retail sales growth, and the gap was filled by imports (Barnes and Hartogh 2018). Apparel imports averaged high annual growth rates of 6.78% from 2007 to 2016 (Barnes and Hartogh 2018:32-33). In 2016, South Africa imported over 54% of its apparel from China, followed by Mauritius (7.5%), Madagascar (6.2%) and Lesotho (6.2%). In 2019, 35.9 billion rand worth of clothing was imported, of which about 58% was from China, while locally manufactured clothing was an estimated 25 billion rand (Trade and Industrial Policy Strategies [TIPS] 2021:11).

There was a steep decline in apparel production sales between 2007 and 2011, and then stagnation, and the same in textile production sales, except for a slight increase in growth in 2016 (Barnes and Hartogh 2018:27-28). ***Notably, only a small amount of textile production is supplied to the retail clothing chain***, with other textile categories including home textile, industrial textile and technical textiles. South African fabric imports grew at an annual average rate of 1.85% over the period 2007 to 2016, while fabric exports were negligible (Barnes and Hartogh 2018:36-37). Most South African fabric imports used for apparel production were from China, and those for home textile production were from Pakistan.

The textile and apparel industry still had some protection, with an ad valorem tariff structure of 15% for yarns, 22% for fabrics, 30% for home textiles and footwear, and 45% for apparel. There were duty-exempted products, typically on products that were unavailable in South

Africa. Barnes and Hartogh (2018:44) note that these duties were easy to manipulate through under-invoicing, product misdeclarations, or smuggling.

4.2 Current Digital and Automation Technologies and Sustainability Trends

South African retailers as well as textile and apparel manufacturers tended to focus on remaining cost competitive in the context of liberalised trade and a global economy where many developing countries have competitive textile and apparel export industries. As a result, retailers tapped into apparel global supply chains in the 2000s and consolidated their global supply chains in the 2010s. This globalisation trend continued, extending international competition into the retail sector as well with the entry of leading international retailers into the South African market.

International retailers such as Topshop entered the South African market via partnerships with local retailers, but H&M and ZARA entered the market independently and have threatened the SA retailers' market share.[23] As Barnes and Hartogh (2018:59) underscore, the South African textile and apparel industry was subject to international pressure that exposed weaknesses at all points of the domestic value chain. South African retailers had generally been followers in terms of digital technologies and exhibited overall low adoption rates and low levels of sophistication (Stewart 2018:10). Online sales platforms remained limited, so South African retailers could not use big data to analyse product and consumer trends.

One consequence of the increased competition facing retailers has been the provision of an incentive for greater collaboration within the industry. Threatened by international competition, South African retailers reiterated that their competitive advantage over international retailers was their quick response (speed to market and flexibility), based on understanding local market trends and sourcing locally.[24] As a result, retailers made a commitment to localisation and investments in building the local supply base, which shaped the government's new sector policy, the South African Retail-Clothing, Textile, Footwear and Leather Value Chain Master Plan to 2030, which was signed in 2019.25

The vision of the Master Plan is to create a competitive, sustainable and dynamic value chain that serves the domestic market and contributes to employment and advances economic inclusion by attracting Black industrialist investment and developing Black management and ownership as well as worker ownership. The Master Plan centres on retailers' commitment

[23] Spinks, R. 'Can international fashion brands compete in South Africa?', The Guardian, 14 March 2014. Available at https://www.theguardian.com/sustainable-business/sustainable-fashion-blog/international-fashion-brands-south-africa; Agbroko R. 'S. Africa: Topshop in for the kill S Africa: Topshop in for the kill on' Financial Times, 1 August 2012. Available at https://www.ft.com/content/68167b72-79c7-378c-a59b-3e45221886d0.

[24] The Wholesale and Retail Sector Education and Training Authority (2015:19).

[25] South African R-CTFL Value Chain Master Plan to 2030. Department of Trade, Industry and Competition, p.8-9.

to increase their local purchases to 65% by 2030, and investments in manufacturing and domestic value chain integration that can make that possible.

Five local retailers provided volume commitments to source from local manufacturers through the Retail-Driven Integrated Supply Chain Programme.[26] TFG and Truworths, two of the five largest South African retailers, have invested in building their design, product development and manufacturing capabilities.[27] Truworths acquired local design centre Barrie Cline and Bonwit in 2021, enhancing its ability to design and create unique ladieswear ranges, in addition to its previous focus on men's and children's wear, and to generate economies of scale in areas including fabric purchasing, production planning and logistics. Truworths' percentage of local apparel to total apparel purchases increased to 45% and was expected to increase to around 50% over the next few years.[28] TFG has built in-house design and manufacturing capabilities through purchasing local apparel manufacturer firms and assets and introducing lean production processes into those factories.[29] In 2021, 87% of units manufactured by the TFG Merchandise Supply Chain were quick-response units.[30] Retailers that have not invested in vertical integration are consolidating their supply chains to work with fewer direct suppliers globally and locally to have greater control over their value chains.

In addition, South African retailers were more rapidly picking up international trends related to developing omni-channels, especially online stores and advanced analytics, and are beginning to incorporate environmental sustainability and traceability into their business strategies. TFG and Truworths were investing in improving their online platforms, and Mr. Price was using advance analytics to shorten decision cycle times as well as investing in e-commerce.[31] Regarding sustainability, Woolworths is aiming to create a fully transparent, traceable and ethical supply chain by 2025, and is focused on achieving net zero carbon scope 1 and 2 emissions by 2040, as well as working with its top suppliers to set their own reduction

[26] Industrial Policy Action Plan (IPAP) 2018/19-2020/21: 10 Year Legacy Review, p. 119. https://www.gov.za/sites/default/files/gcis_document/201805/industrial-policy-action-plan.pdf

[27] Planting, S. The Foschini Group, South Africa's clothing industry success story, Daily Maverick, 19 June 2022. Available at https://www.dailymaverick.co.za/article/2022-06-19-the-foschini-group-south-africas-clothing-industry-success-story/. The Foschini Group (TFG) 2019 Integrated Annual Report https://tfglimited.co.za/wp-content/uploads/2020/02/Integrated-Annual-Report-2019.pdf

28 Truworths International 2021 Social Environmental Report. https://www.truworths.co.za/file/collections/2021_Truworths_Social_and_Environmental_Report.pdf

[29] The Foschini Group (TFG) 2021 Integrated Annual Report https://tfglimited.co.za/wp-content/uploads/2021/12/TFG_INTERACTIVE-IAR_2021.pdf

[30] In South Africa, TFG Merchandise Supply Chain directs the manufacturing of clothing, with 18% of TFG Africa's clothing procured from its own factories and other local CMT factories with whom TFG has strategic alliances. The Foschini Group (TFG) 2021 Integrated Annual Report https://tfglimited.co.za/wp-content/uploads/2021/12/TFG_INTERACTIVE-IAR_2021.pdf

[31] Mr Price Group Limited Integrated Report 2022 (4 APRIL 2021 – 2 APRIL 2022) Mr-Price-AIR-2022_Integrated.pdf (mrpricegroup.com).

targets (thus addressing scope 3 emissions).[32] Mr Price was mapping its first and second tier suppliers in order to create transparency as well as engaging in strategic supplier development.[33] More broadly, most retailers were incorporating more formalised processes of evaluating suppliers based on ethical and environmentally responsible behaviour.

Despite being developed through industry consultations, a review of global trends and the evidence-based experiences of comparator (middle-income) countries, the vision, objectives and commitments outlined in the Master Plan are inward looking. The central developmental role placed on retailers illustrates this. The Plan emphasises how the cost competitiveness, quick response and fast-fashion capabilities of retail supply chains are highly dependent on the ability of retailers to develop dedicated supply chains that are tightly integrated into their operating models. It supports further integration within the domestic supply chain, but with greater inclusion of Black investors, entrepreneurs and managers.

The core action commitments largely continue with the same industrial policy approach: stem illegal imports, protect domestic firms through tariffs combined with rebate measures on items that cannot be sourced locally, and interest-free loans with a significant grant element to domestic textile and apparel so that they can make the necessary investments in equipment, management and worker training. The Clothing, Textiles, Footwear, and Leather Growth Programme replaced the previous CTCP programme, but follows a similar logic by providing low-cost financing to domestic firms in alignment with the Master Plan's objectives.

Regardless of the inward-looking vision, the Master Plan focusses largely on supporting competitiveness at the firm level and neglects the industry-wide issues constraining the competitiveness of individual firms, as well as the industry as a whole. The key constraining issue is the very limited range of intermediate inputs that can be sourced within South Africa. Whether producing for the domestic market or exporting fashion apparel, most types of fabric have to be imported. Relying on imported intermediate inputs increases the lead time and thus decreases speed to market and flexibility. As a result, South African design houses and apparel-assembly firms have little advantage over imports, excepts in products that can be produced with existing fabric production, although these tend to be low-value products. This structural constraint is demonstrated empirically in the next sections.

[32] In the 2022 Fashion Transparency Index (FTI), Woolworths scored above the overall average and was also the highest-scoring South African retailer. FTI ranks 250 brands according to how much information they disclose about suppliers, supply chain policies and practices, as well as their social and environmental impacts. Woolworths Holdings Limited 2022 Good Business Journey Report. https://www.woolworthsholdings.co.za/wp-content/uploads/2022/09/2022-Good-Business-Journey-Report.pdf

[33] Mr Price Group Limited Integrated Report 2022 (4 APRIL 2021 – 2 APRIL 2022) Mr-Price-AIR-2022_Integrated.pdf (mrpricegroup.com).

5. Methodology for the Textile Firm Survey

Historically, and still today, most apparel and textile firms are in KwaZulu-Natal and the Western Cape, with factories emerging in Gauteng in recent decades. Most fabric production and finishing firms are in KwaZulu-Natal. Knit fabric and clothing dominate the South African industry due to the closure of weaving mills and spinning plants. Most woven fabric is industrial and technical fabric produced for industries, outdoor gear, technical clothing and protective wear. According to TIPS (2022), the textile manufacturing segment includes about 20 large firms, a high number of small firms, and informal operations, and the apparel manufacturing segment includes 800 firms, but only around 20 of them employ more than 500 workers.

We constructed a list of textile manufacturing firms engaged in spinning, weaving and/or knitting fabrics for apparel, home textile, industrial or technical products. We started with a general list of apparel and textile firms, including fabric importers, and narrowed it down to textile manufacturers. We then searched for the websites of these firms. If they had websites with contact emails, we contacted these firms by email to request an interview. Only a few firms responded to the interview requests. Through these firms, we acquired contacts to other textile firms. We also asked each firm at the interview for a list of all other textile firms operating in the same function as well as the buyers or suppliers of that firm. Through this snowballing technique, we came up with a list of 43 textile firms that were operating in 2022. We compared our list to the one in the TIPS 2021 CTFL report to create a final list. Our original list included more textile mills for apparel, while the TIPS list had more technical and home textile firms.

Table 3 contains the list of firms by company name and function or type of textile. We do not have employment figures for all the firms, so the size of all firms cannot be confirmed. However, from the firms that we interviewed, this list largely conforms to the TIPS description of about 20 large firms, as many of the firms in our list would be classified as medium or small. We consider a firm small if it has fewer than 200 employees; medium size if it has between 200 and 500 workers; and large if it has over 500 workers. There are a significant number of ‘commissioned knitters’, which are small or microenterprises that manufacture knit fabric on a few machines on a contract basis for bigger knit mills or for intermediaries, but we have not included these commissioned knitters in Table 3. The list does include the few large dyehouses that do commissioned dyeing for knit mills that lack dyeing facilities. The first half of the list comprises textile firms that primarily produce yarn and/or fabric for use in apparel.

Table 3: Textile firms in South Africa, 2022

Company name	Function/type of textile	End use of textile
Prilla	Cotton spinning	Textile firms that primarily produce yarn and/or fabric for use in apparel products
Tai Yuen	Spinning cotton and polyester yarn	
Tradelink	Spinning, knitting, dyehouse	
Standerton	Spinning yarn and woven industrial fabrics, some yarn sold to apparel textile mills	
Rotex	Knit mill, dyeing	
JMV textiles	Knit mill, dyeing	
Ninian and Lester	Knit mill	
Tomotex	Knit mill	
Seven Colours	Knit mill, dyeing, printing	
Sea Green	Knit mill	
Hammersdale Knitting	Knit mill, dyeing	
Royal Arch	Knit mill, dyeing	
Trojan Textiles	Knit mill	
Fleeceytex	Knit mill	
Powerhouse Knit	Knit mill	
Manhood	Woven mill	
Nu mym textiles	Woven mill	
Umzinto weaving mills	Woven mill	
Imraan Textile	Woven mill	
Da Gama Textiles	Weaving, dyeing, printing fabric for seShweshwe, workwear, home textiles	
Dyefin	Dyeing	
Mala	Dyeing	
Gelvenor	Technical textiles and uniforms	Textile firms that primarily produce yarn and/or fabric for use in home textiles, technical products and industrial products
Fibre2000	Knit fabric for bedding, but moving into knit fabric for apparel	
Desleetex	Mattress textile, woven and knit	
Nyathi textiles	Rotary printing for foam mattresses	
Maytex	Home textile	
Svenmill	Home textile, some technical textile	
Sheraton	Home textile	
Aranda Textile mills	Yarn, blankets and throws from wool and acrylic	

Old Nick Fabrics	Home textile	
Associated Spinners	Spinning acrylic yarns for home textiles	
Pres Les	Home textile	
Ahlesa Blankets	Woven acrylic blankets	
Beier Envirotec	Technical textiles	
Nettex	Home textiles, dyeing and printing	
Belgotex	Flooring, including carpeting	
Coralline Investments	Polypropylene fibre and yarn for industrial and technical use	
Yarntex	Yarns for home and industrial use	
South African Polypropylene	Polypropylene yarns	
Glodina Towelling	Woven and knit towel textile	
Sesli Textiles	Acrylic blankets	
Weaveit	Woven industrial and technical textile, home textiles	
Helm Textile	Woven home textiles	

Source: Created by the authors

We carried out a survey with 12 of the textile firms, eight of which are firms that primarily produce intermediate products (yarn, fabric, finished fabric, dyeing) for clothing final products sold to South African retailers. The other four firms produce home textiles or technical textiles. The survey included questions to capture data on the firm's (1) profile: date established, number of employees, functions, products, markets, buyers, unit prices and order sizes; (2) production and planning processes; and (3) environmental sustainability strategies. Regarding 4IR technologies, the survey specifically asked firms about their investments in machinery over the last five years; whether they had introduced new production or planning technologies over the last five years, which kinds and why; and what the impact of those technologies had been on overall employment in the firm and skills requirements. Regarding sustainability, firms were asked if they had a focus on increasing the environmental sustainability of their operations, and then specifically about different areas of sustainability such as renewable energy, reduction in water usage and recycling water, reducing toxic chemical use, closed-loop production processes, using more sustainable raw materials and materials innovations, and waste management.

The questionnaire was administered face-to-face by the authors during interviews at the firm. The firm visit included a tour of the firm's factory, which we used to triangulate firm answers to the survey questions with visual verification and follow-up questions on the factory floor. In the one case where a firm visit was not possible, the questionnaire was carried out face-

to-face through a virtual interview, and company documents were provided by the interviewee to confirm key aspects discussed in the interview.

6. Adoption of 4IR Technologies and Sustainability Strategies among Textile Firms

We assessed the surveyed textile firms in terms of their adoption of 4IR technologies and the strength of their sustainability strategy on a spectrum of none-limited-average-sophisticated, based on their answers to the survey questions. Table 4 provides an overview of the key characteristics of the surveyed firms, which have been anonymised, and our assessment of their 4IR technologies and sustainability strategy. Out of the 12 surveyed firms, seven were small, four were medium sized, and one was large.

In terms of adopting 4IR technologies, six of the 12 firms had not adopted any technologies, and three firms had adopted technologies to a limited or very limited extent. Of the remaining firms, two had adopted technologies to a level between limited and average, and only one firm had adopted 4IR technologies at a relatively more sophisticated level. The six firms with no 4IR technologies also had very old machines and had not invested much recently in upgrading their machinery, except in the case where a fire in the factory had required some investment. The types of technologies adopted by firms are presented in Table 5 and discussed in detail below. They are mostly related to increasing efficiency, which is in line with the findings of Andreoni and colleagues in other areas of the South African economy (Andreoni et al. 2021a:269).

In terms of sustainability, three of the 12 surveyed firms had no strategy. Most firms had a limited strategy. Even some firms that had not adopted any 4IR technologies had a limited sustainability strategy, but at the same time, few firms had anything more than these limited measures, which were driven more by necessity and cost savings than by environmental concerns or innovations. The sustainability measures are summarised in Table 6 and discussed in detail below.

L Firm, the only firm with relatively sophisticated adoption of 4IR and sustainability technologies, was the largest firm and the only firm that exported a majority of its products. It was also the only foreign firm, although it had been managed by South Africans with high autonomy. While this subsidiary of a foreign firm was managed autonomously and most of the ideas regarding technologies and sustainability seem to have been driven by the local executive management, the firm benefitted from financing for investments provided by the parent company in Europe.

Table 4: Firm profile and assessment of surveyed textile firms

Firm	Function	Date est.	Ownership	Emp.	Buyers	Product type	4IR tech adoption	Sustain. strategy
A	Spinning	1960	SoE (Family business, sold several times, bought by govt)	251	Domestic knit, towelling, weaving and sock textile firms	Cotton yarn	None	Limited
B	Knit textile, dyeing and finishing	1980	Local Has own design house, which outsources to apparel factories	172	Apparel firms that produce for TFG and Woolworths	Lycra cotton knit fabric, 40 different types of qualities	Limited	None
C	Knit textile	1987	Local Part of a group with design house and apparel factory in Lesotho	25	Mostly own factory Main retailer buyer is Mr Price	Low-quality knit fabric	None	None
D	Knit textile	1950s	Local Part of group with apparel factory and dyehouse	87	20% to 25% to own factory. Rest to apparel factories producing for TFG and Woolworths	Higher quality knit fabric	Limited	Limited
E	Dyeing and printing	1999	Local New shareholder in 2011	280	Knit mills	Dyeing and printing services	Limited to average	Limited
F	Knit, dyeing and finishing	1996	Local Has a design house, which outsources to apparel factories	400	60% fabric to design house, for Mr Price. Rest sold to retailers and for govt contracts	Low-quality knit fabric	Very limited	Limited
G	Woven mill	1994	Local	60	Domestic apparel factories	Polyviscose woven fabric, used for uniforms	Limited to average	Limited
H	Rotary printing	1976	Local	80	Domestic foam mattress manufacturers	Foam mattress covers	None	None
I	Knit and weaving for home textile	1994; 2014 started knitting	Local	86	Domestic bedding brands and retailers	Bedding materials, some apparel fabric	None	Limited
J	Knit and weaving for home textile	1962	Joint venture with foreign firm	167	Domestic mattress manufacturers	Mattress covers	None	Limited to average

Firm	Function	Date est.	Ownership	Emp.	Buyers	Product type	4IR tech adoption	Sustain. strategy
K	Weaving for home and technical textiles	1958	Local	250	Use 15% in home textile production; rest sold as fabric, some export	Upholstery fabric; some technical fabrics	None	Limited
L	Carpets and flooring	1970s	Subsidiary of foreign firm; 25% local ownership since 2022	600	30% domestic market; 70% export all over the world	Custom-made carpeting	Average to sophisticated	Average to sophisticated

Source: Created by the authors based on survey data

6.1 Adoption of 4IR Technologies

There is a notable correlation between the type of products and buyers, on the one hand, and whether the firm had adopted 4IR technologies to even a limited degree (see Table 4). Firms that produced products of relatively higher value (unit prices) had adopted some aspects of 4IR technologies, or at least had more computerised machines. Firms B and D, which produced higher quality knit fabric, had limited adoption, whereas Firms C and F, which produced low-quality knit fabric for retailers focusing on the low-cost market segment, had none or very limited adoption. The manager of Firm C noted that there is no advantage in computerised circular knit machines when his textile mill produces low-cost fabric for low-cost clothing. Newer, computerised knit machines can do more patterns and higher quality fabric, but he does not need that. He cannot afford the overheads of a more digitalised factory, given that he is struggling to produce fabric that can compete with basic knit imported fabric in terms of price per metre. He noted: 'The buyer type is a constraint on adopting technologies.'

Firm A, which also had not adopted any 4IR technologies, was a spinning company. Spinning is automated and thus expensive (capital intensive), but with very low margins because it produces a basic commodity product. The only advantage of Firm A is that it sources cotton domestically and regionally, and it is protected by trade tariffs that put a 15% duty on imports of cotton yarn. Firm A is a small spinning factory compared to firms in Mauritius and Asia, with just under 19 000 spindles and 2 400 open-end rotors. To be profitable, spinning firms either need to be very large scale, where profit is made on large volumes, or vertically integrated, with spinning and fabric production done together, and even including garment production. The other major spinning factory in South Africa has 40 000 spindles; it had been part of a vertically integrated factory setup from spinning to garments until a fire burned down the dyehouse in 2019. The only standalone spinning company in Mauritius, Tianli, has at least 50 000 spindles.

Most firms were old, established between the 1950s and 1980s, and had not constantly reinvested in new machinery to keep up with trends in technology. Some of them had made major investments in the 2010s, while others made minimal annual investments using grant money from the Production Incentive Programme and had at least a few new machines that were computerised. A few firms had not invested at all and had machinery that was 20 to 30 years old.

Table 5: Digitalisation and automation technologies used by the surveyed textile firms

Type of technology	Number of firms using this tech
Barcode system from fabric production to warehouse	3 (Firms B, D, E)
Computerised machines	7 firms with at least some machines
Computerised machines with data-monitoring system	3 (Firm D, G, L)
Data captured through machine monitoring used in ERP systems	2 (Firm D, L)
Digital printing with 3D designs	1 (Firm E)
Using IoT to create digital twin of factory	1 (Firm L)

Source: Created by the authors based on survey data

Firm B produced basic knit fabric with lycra but can do many types of quality. It had invested significantly in new machinery over the last five years, but this was partly because the dyeing and finishing areas of the factory burned down in 2016 and the owner had to buy new machines that came with the latest technologies, hence the dyeing and finishing sections had to be computerised. The firm built its own ERP system to plan the knitting and dyeing workflow that links the machines to the plan, and this increases the efficiency of production processes. The owner's main motivation was to increase productivity. The firm's 32 knitting machines were not computerised, which the owner said was not necessary given the type of fabric the firm produced. The factory had a barcode system, and the dye laboratory was state of the art, including a fully automatic (robotic) dye-mixing machine. The firm could digitalise each colour and store it on a computer. While highly digitalised, Firm B was relatively small for a knitting textile mill, which means that its cost per unit was higher than that of larger knit firms in other countries.

Firm G was a small woven textile mill with 28 machines. Its weaving machines were digitalised, and the firm established a data-monitoring system in 2016 to collect data on production processes. However, the firm did not use this data to improve factory processes. The owner had purchased 14 new machines, some to replace old ones and some to expand production. These machines include machine learning and can indicate optimal settings and diagnose problems. The owner was also setting up a dye plant to dye yarn. He made these investments

to meet international benchmarking but also noted that, since South African retailers have committed to buy more apparel locally, the orders are there, so he invested in production to meet it. The retailer commitments provided a big incentive for textile mills. Firm G produced woven fabric primarily for school uniforms. Its investments in new machinery that could produce a wider range and quality of woven fabrics opened the possibility to produce fashion apparel for South African retailers.

Firm D was a relatively small knitting textile mill with 30 machines. It was originally part of a large vertically integrated firm, but the spinning, weaving and dyeing sections were shut down by 2011. Instead, the remaining garment and knit textile segments of the group invested in an independent dyehouse. Since the restructuring, the group invested heavily in upgrading the knit textile machinery. The average machine age was eight to 10 years, as the firm continued to replace two machines annually. Older machines were retrofitted with a monitoring system that fed into a central data collection system and provided real-time reports. The next step for the firm was to display this data on screens in the factory. The firm bought this system from an external company. The motivating factor was to increase productivity and quality by using it to see where improvements could be made in the production process. However, Firm D was not using the system on the planning side yet. It took two years for workers to get used to the new machine monitoring system. The next step under way was to combine production and financial systems to allow for more automated planning and better cost-of-product estimates. The firm manager noted that the new technologies had allowed the firm to increase its volume by meeting its retailers' needs and attracting new buyers.

Firm D was a majority shareholder in Firm E, which specialised in dyeing and finishing, including printing, for knit fabrics. Firm E invested heavily in the 2010s, as the new shareholder brought capital, combined with grants under the government's Production Incentive Programme. The dyeing section was completely upgraded to a fully digitalised and automated system, with new machines that used less water and electricity. Firm E also invested in a digital printer that can do 3D designs. The plan was to get another one and eliminate rotary printing, but that plan stalled due to the Covid pandemic. However, the owner noted that customers were not ready to pay the cost of digital printing. He also noted that demand for his firm's dyeing and printing services had increased recently (the firm previously was not operating at full capacity), as retailers wanted to source more apparel locally, but that retailers can also be tempted away on price.

Firm L was the most advanced in its use of 4IR technologies. During the Covid lockdowns in South Africa, the firm used the time to create a plan for going digital. It built an app using blockchain technology through which customers could order their own floor and pay for it over time. The firm also employed new staff with 'smart factory' skills who created a digital twin of its factory using the internet of things. The digital twin was used to understand

machine and process levels to see where energy was consumed and thus where energy use could be reduced. This involved making all processes in the factory digital to collect the data. Firm L also launched a new ERP system designed by Microsoft. The system initially failed because it was too complicated for employees to use, but the firm management worked with Microsoft to simplify the system at the firm's cost. The main gains from the ERP system included greater visibility of stock, having the entire factory on one system, and the ability of customers to interface with it. The firm also launched digital platforms on its website where customers could do everything online, including seeing a visual of what the floor would look like in their rooms. These investments had huge financial and human resource costs, but the firm's management emphasised their longer time horizon and vision. The current chief financial officer, who joined the firm in 2019, has a background in 4IR and brought this focus to the business. The new chief executive officer, who took over in 2021, restructured the senior management.

6.2 Environmental Sustainability Elements Adopted

Almost all firms sorted their waste and then sold it to general waste management and recycling companies, or sold specific types of waste to individual companies for downcycling into particular products. Typically, waste management was a way to make money from waste and did not on its own constitute a sustainability strategy. However, Firms J and L had an official 'zero waste to landfill' policy. Notably, these two firms were subsidiaries (or joint ventures) with multinational corporations, where the commitment to a zero-waste policy generally was driven from the multinational company.

Table 6: Environmental sustainability elements adopted by the surveyed firms

Sustainability element	Number of firms adopting element
Waste management	Almost all firms
Zero landfill	2 (Firms J, L)
Renewable (solar) energy	1 (Firm L)
Effluent treatment plant	2 (Firms F, D)
Sustainable fibres	2 (Firms I, D)

Source: Created by the authors based on survey data

Only Firm L had a commitment to reduce its scope 1, 2 and 3 emissions by 40% in absolute terms by 2030. It was still in the process of collecting data and planning how to achieve the targets. It already had two solar installations and was in the process of installing a third one. Firm L used the Production Incentive Programme grant to buy more energy-efficient equipment and to finance its first solar installation, but then financed the second and third

from internal resources, notably with support from the parent company. It had replaced all lighting with more efficient lighting, increased the use of natural lighting, and installed motion sensors for lighting. However, Firm L still used coal boilers. No firms in the survey sample with coal boilers were yet to make the switch. Some firms had conducted research, with one firm deciding that it was not feasible and another doing trials.

A few other firms were looking into putting up solar panels at their factory but had not yet done so; in the case of Firm D, the owner of the building that it rents had put solar panels on the roof. The surveyed textile firms that were looking into solar panels to provide a small percentage of their energy needs were doing so clearly because the cost of electricity from the state provider had increased and become very unreliable. However, the cost of leasing solar panels was considered too high by some of these firms. Even though solar systems would start paying for themselves in the medium term, this was not an outlook that most companies demonstrated, except for Firm L.

Firms with dyeing facilities should have effluent treatment plants that treat the dye water before releasing it from the factory. The most sustainable way is to have zero liquid discharge from dyeing factories, in which the water is treated and then used again in the factory. Zero liquid discharge is an advanced wastewater treatment method that includes ultrafiltration, reverse osmosis, evaporation/crystallisation, and fractional electro-deionisation. Among the surveyed textiles firms in South Africa, most did not have their own effluent-treatment plant. Firm E used the common treatment plant in the industrial zone in which it was located. The industrial zone treatment plant released the water into the sea, but it did not remove all the salt in the water as it did not have reverse osmosis and membrane technology. Firm E wanted to construct its own plant with membrane technology to be more sustainable, but also so that its production could expand and not be limited by the amount of wastewater that could be treated in the common ETP in the industrial zone. However, Firm E was not considering zero liquid discharge technology, which it deemed too expensive and required chemicals that were not available in South Africa.

Other firms with dyeing capacity, such as Firm B, relied on municipal wastewater treatment facilities. Notably, Firm F constructed its own treatment plant in 2022 inspired by designs from India and Pakistan but building it in a cheaper way, after many years of just releasing the wastewater into the surrounding environment and receiving fines from the government.

Organic cotton and Better Cotton Initiative certified cotton are not available in South Africa, limiting the sustainability of cotton sourced domestically (Jenkin and Hattingh 2022:5). While there was a Sustainable Cotton initiative led by the retailer Mr Price with yarn produced at Firm A, the sustainability aspect of this initiative was on the social side in terms of guaranteed prices and not related to environmental practices. Most cotton sourced by Firm A came from the Southern African region and may have been BCI cotton, but since the firm mixes cotton

bales during production, the yarn output would not meet certification requirements if not all cotton it sourced was BCI cotton.

A few firms had started using more sustainable non-cotton fibres in a small portion of their products, but the cost of these fibres was deemed expensive for the South African market and there was not enough knowledge among consumers about alternative fibres. Firm I began producing bedding products using bamboo instead of cotton. This switch was partly driven by the rising price of cotton yarn compared to bamboo yarn, which the firm imported from India and China. It also used Tencel Lyocell yarn in some products due to demand from one buyer, but noted that the demand for Lyocell in the South African market was limited and that its big buyers were waiting to see the demand for Lyocell go up.[34] Firm I combined Tencel Lyocell with polyester in order to reduce the overall price of the product. Firm D had started to use bamboo and recycled Tencel (Refibra) in products for one buyer that was aiming for higher-end markets. The firm noted that the main issues were with availability and cost. It sourced the recycled Tencel from India.

Firm C used recycled polyester yarn in 70% to 80% of its polycotton knit fabric production, but this was because of price. Lower quality recycled polyester yarn was cheaper on international markets than virgin polyester yarn. Other firms commented that they were looking into using more sustainable fibres, but that such yarn was currently too expensive.

For Firm L, whose main raw materials were nylon and polypropylene fibres made from fossil fuels, moving to sustainable fibres was more difficult. The head of sustainability at Firm L noted that there were opportunities in Europe to access nylon with some recycled content, but that was not available in South Africa. What was needed in South Africa was local research and investment in recycled materials and alternative fibres.

Overall, there were few firms in South Africa engaging in fibre technology innovations or fibre-to-fibre recycling. Most fibre waste was downcycled into other products. The TIPS report on sustainability in the textile industry noted just one firm that was engaged in fibre-to-fibre recycling: a startup called Rewoven, which recycled post-production cotton fabric scraps into new fibres. Rewoven blends the recycled cotton fibres with recycled polyester fibres created from recycled rPET, and then spins and weaves a new fabric that is 60% recycled cotton and 40% recycled polyester (Jenkin and Hattingh 2022:29-30). Rewoven used a mechanical process to create recycled cotton fibres, which was from the older generation of technology and does not reflect the latest developments in the field of chemical recycling technologies. A TIPS 2022 report noted several challenges to recycling textiles, which were mentioned in its

[34] TENCEL™ Lyocell and Modal fibres are made from wood pulp. The certified biobased fibres are manufactured using an environmentally responsible production process. The company Tencel also recently launched its REFIBRA™ technology, based on upcycling cotton scraps from garment production into cotton pulp that is then added to wood pulp to produce TENCEL™ Lyocell fibres, containing one third recycled cotton fibres (see https://www.tencel.com/refibra).

interviews with industry actors and experts in South Africa (Jenkin and Hattingh 2002). However, these challenges are being overcome through the latest technology innovations discussed in Section 3 of this working paper.

6.3 Implications for Employment and Skills

Newer machines require fewer workers, but the surveyed textile firms that had bought new digitalised machines did not reduce their workforce, but rather redeployed these workers to other tasks or in the same section if the firm was expanding its production. Despite digitalisation, workers were still needed to tend machines. For example, with the barcode system, workers were still needed to weigh fabric and scan the barcodes at different stages of production. Much of the digitalisation technologies adopted were on the monitoring and planning side and thus did not displace workers, but rather enhanced existing systems by providing more data and the ability to use that data to make the firm more profitable.

The main change or disruption was that computerised machinery required a different skillset than the existing textile workers in factories had. Firms carried out the training in-house for upgrading workers' skills, sometimes bringing in outside experts. They noted that it was not a problem to train workers, who generally responded well, even if took some time to adjust to the new ways of doing things, but that it took time and financial resources. All firms noted that there was a general shortage of skilled labour for the textile industry and that workers are hired without even knowing the basics and had to be trained in the factory.

The adoption of 4IR technologies also required that firms create or expand in-house IT teams. However, firms noted that it was difficult and expensive to hire IT engineers in South Africa because the demand was high, and there also was a brain drain, as graduates are hired overseas.

7. Conclusion

The findings of the survey point to structural constraints within the South African textile and apparel industry and the general domestic economy that limit the adoption of 4IR and sustainability technologies. Becoming or remaining internationally competitive in manufacturing activities requires keeping pace with global technological trends and innovations. As Andreoni and Tregenna (2021:244-245) note, modern high-value manufacturing activities require cross-cutting capabilities in biotechnology, advanced materials, microelectronics and automation. Thus, for individual manufacturing industries in South Africa to 'keep pace', manufacturing industries in South Africa collectively need to keep pace so that firms in one industry can draw on the capabilities in other industries, with general educational and vocational institutions aimed at provided skilled labour in these areas. Given the general deindustrialisation trends and low fixed investments in manufacturing in South Africa over the past decades, this has not happened (Andreoni and Tregenna 2021; Zalk 2021).

The domestic market orientation of almost all firms seems to be a limiting factor for several reasons. South Africa is one of the most unequal countries in the world. In 2017, the richest 10% held 86% of the total wealth in the country, while the poorest 60% held only 7% of total wealth (Goga and Mondliwa 2021:165). Such high inequality leads to low purchasing power among a large portion of the population, hence the relatively small size of effective demand. As a result, many South African retailers focus on providing low-cost products, and this kind of buyer demand for low cost, low quality clothing does not provide an incentive for textile mills to invest in new machinery and production processes, because it is not necessary for low-cost products and their profit margins cannot cover the increased overheads. Even among the higher end retailers and brands aimed at higher value products, cost will still be an issue, especially when it comes to sustainable fibres, where cost parity has not yet been achieved with conventional fibres (but is likely to do so in the future). The new motivation among South African retailers to source more apparel locally to implement their quick-response business models has highlighted bottlenecks in the local supply chain, of which the most important is the *narrow range of domestically produced fabrics*.

Focussing only on the South African market has also allowed textile and apparel firms to fall far behind the technological frontier. One of the most important reasons to engage in exporting is that it requires, even forces, local firms to adopt and adapt foreign production process and machinery (soft and hard technologies), and thus build their capabilities and keep up with technological changes (see Lee 2013). In general, and similar to many Latin American countries, South Africa has been slow in linking up with manufacturing global value chains compared to Northeast and Southeast Asian countries (Andreoni et al. 2021b:304).

Engaging in apparel global value chains would provide higher demand and different types of buyers. However, South African apparel and textile firms would need to meet the order size, quality and speed-to-market requirements of US and European buyers. Doing so will require not only investments in new machines, sustainability technologies and production processes at the firm level, but also investments at the industry level to develop the supply chain within South Africa. Speed to market, whether it is global markets or South Africa, means short lead times, and that requires access to a wide range of fabrics and trims within the country or in neighbouring countries. A wide range of fabrics means sophisticated knitting and weaving as well as finishing processes, which in turn draw on the extensive portfolio of machines and production technologies now available on the global market and which are constantly evolving. In highly competitive apparel-exporting countries, such a wide range of fabric is provided by a division of labour and specialisation among firms. Furthermore, international and national firms supplying trims are drawn to invest in countries where there is a critical mass of textile and apparel production, as witnessed in other African countries such as Mauritius and Ethiopia.

The lack of international competitiveness of South Africa's textile and apparel industry does not emerge solely from the old technology and production processes found in many of its textile and apparel firms. It is an industry level problem. Taken as a whole, the South African industry does not have the specialisation required to make it competitive (in terms of variety, quality and speed to market), whether it is producing for the domestic or export market. Thus, government policies that focus only at the individual firm level and on firm-level 'best practices', as South Africa's current industrial policy approach in the sector does, will not succeed in achieving its objectives.

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