TRADE & INDUSTRIAL POLICY STRATEGIES

INDUSTRY STUDY

Technological Change in the Plastics Industry

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TIPS industry studies aim to provide a comprehensive overview of key trends in leading industries in South Africa. For each industry covered, working papers will be published on basic economic trends, including value added, employment, investment and market structure; trade by major product and country; impact on the environment as well as threats and opportunities arising from the climate crisis; and the implications of emerging technologies. The studies aim to provide background for policymakers and researchers, and to strengthen our understanding of current challenges and opportunities in each industry as a basis for a more strategic response.

This industry study is part of a series looking at the global plastics industry landscape. It analyses technological advancements in the subsector, focusing on international and domestic trends in materials, digital technologies, products, and processes.

Author: Rapula Diale, TIPS Economist

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INTRODUCTION

This study aims to provide an understanding of both the domestic and international trends in the plastics value chain. The aim is to understand the key drivers that shape the global plastics industry landscape. To achieve this goal, data gathered from diverse sources was used to present an overview of the plastics industry.

By scrutinising trends in the industry this study considers pathways for growth in the South African plastics industry, while also highlighting areas where interventions may be required to bolster competitiveness. Moreover, it analyses opportunities and risks stemming from international trends.

This study is part of a series of reports that studies and present a comprehensive view of the plastics value chain, dissecting various facets and intricacies shaping the industry' landscape. Each report sheds light on distinct segments, offering invaluable insights into the dynamics of the global plastics market.

Report 1: Explores the South African plastics industry and examines the primary plastics and plastics goods subsectors by analysing existing economics outcomes, labour market dynamics, market structure, key market players, policies debates, and practices. The study provides an understanding of the domestic industry while situating it within the broader global context. Through this exploration, opportunities and challenges within the sector are unearthed, offering stakeholders a comprehensive perspective on the South African plastics landscape. (see **Industry Study: Plastics**)

Report 2: Explores a broader scope, encompassing both domestic and international markets to provide an understanding of the global plastics subsector. By unpacking the global trade and key drivers influencing plastic usage on a global scale, it offers a comprehensive understanding of market dynamics. Drawing data from diverse sources, the study bridges information gaps, providing insights into different facets of the plastics value chain — from production and consumption patterns to trade and investment flows. (see **Industry Study: South Africa's International Trade in Plastic**)

Report 3: This report analyses technological advancements in the subsector, focusing on international and domestic trends in materials, digital technologies, products, and processes. It also examines the challenges related to the absorption and domestic institutionalisation of these technologies and their impact on local firms. Finally, the paper explores domestic support incentives for companies to adopt these technologies. The studies aim to guide stakeholders with insights into the process and product technologies in the plastics value chain. This report covers the different manufacturing technologies including material compositions as well as processes to drive efficiency, durability, and eco-friendliness.

Together, these reports form a cohesive narrative, highlighting the dynamics of the plastics value chain. By examining both local and global perspectives, stakeholders have information to navigate challenges, opportunities, and innovation in this industry.

SECTION ONE: INTERNATIONAL TECHNOLOGICAL TRENDS

Technological advancements in the plastics industry have far-reaching implications for existing firms, including improved and different input materials, enhanced processes, greater production efficiency, and increased digitalisation. These developments have enabled smaller industry players to access the market and acquire capabilities that were previously exclusive to medium and large companies, particularly in the plastic product manufacturing segment of the value chain. As a result, competition and product quality in the plastics industry continue to increase.

Some of the leading technological developments in the plastics value chain are described in the following subsections. The advancements are classified into material technology, and digital technologies.

Material technologies

Technological change in raw materials involves changes in the extraction and synthesis of raw materials used in plastic production for the purpose of developing advanced plastic materials with enhanced degradability, strength, durability, heat resistance, and biodegradability. It encompasses nanocomposites, bioplastics, smart polymers, and specialty additives designed to meet specific performance requirements. These changes are being driven by the rising demand for an alternative to fossil fuel feedstock in the production of plastics and as an attempt to improve the sustainable production of plastics. This include use of alternative feedstocks, including plant-based material, additives in fossil fuel-based plastics and green hydrogen (Maimele, 2024). These alternatives include the development of bioplastics, which can be taken to mean one of two things. The first covers plant-based plastics, wherein biomass is used as feedstock to produce plastic material (OECD, 2020). These types of plastic may or may not be degradable. Second, bioplastics can also be taken to mean biogradable plastics, which may be a plant-based plastic or fossil fuel-based plastic that has the ability to disintegrate or decompose. While the two are vastly different, in some instances they are used interchangeably or without clarity as to which “bio” is the “bio” in “bioplastics” refers.

Biodegradable plastics, primarily used in single-use applications such as packaging, textiles, agriculture, and horticulture, have garnered attention for their potential to degrade into carbon dioxide, water, biomass in natural environments and. in some instances, microplastics. The period from 1995 to 2017 witnessed a significant surge in patents for this innovative material, with an annual increase of 100%. Over the final four years of this period, an average of 228 patents were granted annually. Despite this, global production capacities of biodegradable plastics remained modest, reaching 1.2 million tonnes in 2019, representing less than 0.3% of total plastics production (OECD, 2020).

However, the pace of patent development and innovation has decelerated due to challenges related to the material's inability to effectively decompose under ambient conditions. While biodegradable plastics can decompose under industrial settings, this process cannot be replicated in natural environments. For instance, certain polymers like polylactic acid (PLA) necessitate temperatures exceeding 60°C, typical of industrial composting. In addition, biodegradation relies on specific conditions including enzyme concentration, microbial strains, and other factors (OECD, 2020). Consequently, the transition to biodegradable plastics has sparked debates about their suitability for fostering a sustainable future.

Furthermore, even when fossil fuel-based biodegradable plastics degrade, they often break down into microplastics, presenting additional environmental risks. The additives used to enhance biogradability may also pose a challenge in the ability to recycle the plastic material. This underscores the complexities and trade-offs associated with the adoption of biodegradable plastics in efforts to mitigate plastic pollution and promote environmental sustainability.

Nonetheless, biodegradable plastics may offer distinct advantages in some instances. Moreover, the diversity of compostable plastics available suggests that continued innovation in this domain holds promise for the development of superior polymers and the exploration of novel applications.

Conversely, on a global scale, production of biomass-based plastics totalled 19 million tonnes, accounting for 6% of the world's plastic output (Maimele, 2024). Projections indicate that this figure is set to increase to 10% of global plastic production by 2025. The growth in demand for such plastics is anticipated to be propelled by the expanding market for biodegradable polymers, particularly in regions like Brazil, China, and India.

This growth trajectory is expected to be underpinned by heightened interest in specific polymers such as polyhydroxyalkanoates (PHA) and polylactic acid (PLA), owing to their versatility across diverse sectors including packaging, textiles, fibres, and medical applications. However, a critical challenge arises from the competition for resources, with the diversion of arable land from food production to feedstock cultivation for plastics manufacturing posing a significant risk to global food security (Maimele, 2024).

Production and process technologies

Additive manufacturing and 3D printing

Additive manufacturing (AM) technologies are increasingly used in the plastics industry for rapid prototyping, customised production, and small-batch manufacturing. These technologies allow for precise control over material deposition, enabling complex geometries and functional integration (Statista, n.d.).

Additive manufacturing technologies use 3D printers to fabricate three-dimensional objects directly from digital prototypes and models. The scope of printable objects spans from minuscule nanoscale components to expansive structures (Cunningham, 2021; Ramalingam et al., 2016). While initially recognised for its impact on plastic goods manufacturing, this versatile technology transcends materials. It can process an array of materials ranging from ceramics, metals, and graphene to unconventional mediums such as glass, paper, food types, and even biomaterial such as tissues (Carvalho, 2020). Such versatility enables the application of additive manufacturing across diverse industries including automotive, construction, and food production, among others, revolutionising traditional manufacturing processes.

AM technologies entail the input of raw materials, available in various forms such as powders, filaments, liquids, or sheets into the 3D printers (Ramalingam et *a*l., 2016). Subsequently, these materials undergo processing to enable the printer to deposit and shape them into successive layers, gradually constructing the desired product. Depending on the specific technology, material deposition may involve melting the material before layering or using lasers to solidify each deposited layer.

3D printing emerges as a transformative force in manufacturing, offering a multitude of benefits across various stages of production. First, it streamlines the manufacturing process by eliminating or significantly reducing conventional steps such as design, parts production, and assembly. This efficiency not only accelerates time-to-market but also minimises logistical complexities and associated costs. Second, 3D printing offers flexibility, enabling swift modifications and enhancements to designs with a minimal impact time or costs (Cunningham, 2021). This agility empowers manufacturers to faster iterate processes and product prototypes, adapt to evolving requirements, and optimise product performance. In addition, the technology unlocks new frontiers in design complexity, allowing for the creation of objects that were previously unattainable using traditional techniques. From intricate internal structures that enhance strength and functionality to lightweight components that boost performance, 3D printing opens avenues for innovation and creativity. Moreover, by fabricating objects layer by layer, 3D printing minimises waste production during manufacturing processes, aligning with sustainability goals, and reducing environmental impact.

Additive manufacturing and 3D printing is gaining popularity with an increasing number of 3DP technologies being developed, tested, and adapted in different settings. Since the early 1990s, additive manufacturing and 3D printing have experienced a steady average increase of 26% per annum to reach a global market value of US$5.1 billion in 2015 (Ramalingam et al., 2016) and is expected to grow to US37.5 billion in 2026 (Statista, n.d.).

While additive manufacturing and 3D printing have witnessed remarkable advancements, propelled by rapidly improving technologies, falling raw material costs, and accessible printer prices, they still grapple with certain limitations (Ramalingam et al., 2016). These constraints vary across different printing techniques and impede the technology's full potential. One significant limitation is the relatively slow build speed inherent in many AM processes. Despite strides in speed enhancement, the pace of production remains a challenge, hindering scalability and mass production capabilities.

In addition, there are constraints on object size, with certain printing methods imposing limitations on the dimensions of the produced objects (Mondliwa and Monaco, 2020). The high cost of materials constitutes another obstacle, particularly for specialised or high-performance materials, impacting the economic feasibility of 3D printing applications (Plastics Technology, n.d.). Furthermore, while AM enables the fabrication of intricate designs, some printed objects may exhibit limited strength, compromising their utility in certain applications. These limitations underscore the ongoing need for research and development efforts to address technical constraints and enhance the efficacy of AM and 3D printing technologies.

Digitalisation

Digital technologies are bringing about major transformation in the plastics industry, enabling improved process monitoring and controls, automation, and predictive maintenance. This includes a wide variety of technologies such as the integration of IoT (Internet of Things) devices, data analytics, AI (Artificial Intelligence), and digital twins to optimise production processes and supply chain management (Plastics Technology, n.d.). These technologies, described in the following subsectors, are expected to increase productivity, improve product quality and reduce waste. While these technological changes are transformative in the plastics industry, these technologies are applicable to wide range industries (Plastivision. n.d.).

Internet of Things (IoT)

In the plastics industry, the integration of IoT technologies includes cyber-physical systems (CPS) and cloud manufacturing (Mondliwa and Monaco, 2020). IoT entails the embedding of sensors and connectivity features into machinery and equipment, facilitating real-time data collection on various parameters such as temperature, and production rates (Mokoena,2022). This data is then transmitted to centralised systems for analysis and decision-making. The value proposition of IoT lies in its ability to enable predictive maintenance, optimise processes, and enhance quality control with unprecedented accuracy.

Data analytics in the plastics industry

Data technologies play a pivotal role in processing and extracting actionable insights from the vast volumes of data generated by IoT devices. Through sophisticated analytics and data visualisation techniques, manufacturers can identify patterns, detect anomalies, and uncover optimisation opportunities across the entire production chain (Carvalho et al., 2020). Big Data analytics, by integrating real-time and historic data, can predict equipment failure or the need for maintenance as well as reduce defects and production errors, thereby optimise resource utilisation, minimise waste, and streamline supply chain operations, driving cost savings and operational efficiencies.

Artificial Intelligence (AI)

AI algorithms, fuelled by the vast influx of data generated by IoT devices, and the data collected empower manufacturers to harness predictive analytics, machine learning, and cognitive capabilities. AI-driven systems autonomously detect and classify defects in real-time, ensuring that only products meeting stringent quality standards are released into the market (Carvalho et al., 2020). AI also enables optimisation opportunities across the entire production chain, from resource utilisation to supply chain operations, driving cost savings and operational efficiencies.

SECTION TWO: USE OF THE TECHNOLOGIES IN SOUTH AFRICA

This section discusses ways in which frontier technological advancements are reshaping the industry. It first provides an overview of the use of new technologies in South Africa. It then explores the impact of new technologies on firms, highlighting companies embracing these innovations, and identifying the crucial role played by supporting institutions in fostering this technological leap.

Overview of the use of the new technologies in South Africa

The South African plastics sector holds a limited position within the global plastic industry, where major players like China, Germany, and the US dominate global production and trade (Diale, 2024). It is no different when it comes to technological developments. In this regard, Mondliwa and Monaco (2020) argue that the South African plastic industry has lagged behind in its technological advances and performance compared to other upper-middle-income countries. Furthermore, Mokoena (2021) suggests that the low uptake can be attributed to two key factors. First, that businesses in the domestic industry tend to be more concerned with day to day operations and staying in business than actively tracking and adopting new technologies. Second is that, because the industry is capital-intensive and the cost of replacing old equipment is high, this causes a major challenge for many smaller manufacturers. Therefore, the focus becomes ensuring the existing machinery is kept or frontier technologies are gradually phased-in. While businesses may have some willingness to adopt new technologies, they are faced with uncertainty around the expected output amid current economic conditions, and the rapid developments of frontier technologies.

Although these developments are progressing quickly and increasingly becoming affordable, the cost and practicalities of adoption pose a significant challenge to the many small to medium-scale businesses operating in the sector. Therefore, businesses need to evaluate the costs and benefits of adoption to determine the most effective strategies. Despite the potential productivity gains of 6.3% to 9.8% (equivalent to R4.79 billion to R7.45 billion) from implementing automation and digitalisation in the plastics conversion industry, South Africa has not yet realised these benefits (Mondliwa and Monaco, 2020). According to Mondliwa and Monaco, this is due to the slow pace of adopting digitalisation and automation in production systems.

The adoption of frontier technologies by South African industries, including the plastics industry has largely been low and varies significantly across segments of the industry. Much of the uptake of frontier technology in the plastics value chain has been in the high-value segments of the industry, such as those parts of the industry producing automotive components, medical devices and engineering plastics. These segments of the plastic value chain in South Africa are typically dominated by multinational companies or are required to supply multinational companies to specific performance standards that require the latest technologies. The ability for these segments to adopt frontier technologies is in part due the access to the research and development and testing facilities of the multinational corporations (MCNs), many of which are located in in the home country of the MNC (Bell, Mondliwa and Nyamwena, 2021). The level of investment in the research and development in frontier technologies within the domestic industry remains low. However, it is worth noting that the presence of MNCs, particularly in the automotive industry, provide an opportunity for technological spillovers to other sectors and industries, a key feature of the South African industrial policy.

Adoption support institutions

South Africa has a network of institutions that support firms to embrace these technologies. Services offered by science councils, universities, and the public sector are a way of driving innovation in the country's plastics value chain, as shown in Table 1. This includes assisting with the acquisition and implementation of cutting-edge tools to providing expert guidance on adaptation and ongoing support, to allow firms to unlock the full potential of these technologies.

In the public sector, for instance, the Department of Science and Innovation and the Council for Scientific and Industrial Research (CSIR) are actively involved in developing innovative solutions for the plastics sector. Their focus includes research and development of polymers and additives, such as nanocomposites in plastic packaging to extend food shelf life. They are also working on the development of degradable bioplastic bags, advancing recycling technologies, and establishing testing facilities and conducting life cycle analyses.

Table 1: Key Academic Institutions advancing Technological developments in plastics

Institution	Other Support type
Stellenbosch University	Stellenbosch University's Department of Chemistry and Polymer Science offers academic courses for innovation in the plastics industry. From Honours to PhD programmes, their focus on polymer science fuels the development of new materials. This is further augmented by their strong material science research, ensuring a deep understanding of material properties and functionalities. In additional, the Rapid Product Development Laboratory serves as a valuable resource for researchers, both internal and external. By providing facilities and expertise to translate ideas into prototypes, this lab accelerates the development of novel plastic materials and technologies, bringing them closer to market realities.

The Vaal University of Technology	South African companies looking to refine their plastics operations can benefit from the expertise of Ametex, a division of the Vaal University of Technology. Ametex targets increased efficiency and profitability for plastics manufacturers by offering a unique combination of software, training, and industry knowledge. As the exclusive distributor for MAGMA (GmbH) and SIGMA (GmbH) simulation software in South Africa, Ametex equips companies with industry-leading tools to optimize injection moulding processes. Its specialist knowledge extends beyond software, providing training and comprehensive industry support to ensure clients achieve optimal results (VUT Research, n.d.).
The Central University of Technology	For companies seeking to leverage the potential of 3D printing in plastics, the Centre for Rapid Prototyping and Manufacturing (CRPM) at the Central University of Technology presents a valuable resource. Established in 1997, the CRPM boasts extensive experience in additive manufacturing technologies, including rapid prototyping, manufacturing, tooling, and even medical product development. This expertise extends beyond research, as the CRPM actively undertakes commercial projects, offering companies the opportunity to explore and integrate 3D printing into their plastics operations. With a focus on innovation and real-world applications, the CRPM can be a key partner for businesses seeking to advance their use of plastics through cutting-edge 3D printing techniques.

Source: Compiled by author using data from https://www.vut.ac.za/ametex/, https://www.cut.ac.za/crpm and https://academic.sun.ac.za/polymer/. *Note*: Academic institutions that only provide academic course were not included in this table.

SECTION THREE: CONCLUSION

This report highlights the revolutionary potential of new technologies in the plastics industry. These advancements offer substantial benefits like better efficiency, eco-friendly practices, and high-quality products. The widespread relevance of these technologies means that manufacturing companies cannot afford to disregard them. Ignoring these advancements could lead to significant repercussions, such as becoming uncompetitive in the market.

While parts of the South Africa's plastics sector struggles to keep up with the global trends, there are areas that are already adopters of these technologies and benefit from the developments in the technological change. The presence of international companies brings technological advantages, and local universities and research institutions are actively developing new materials and processes. By embracing these advancements and working together, the South African plastics industry can navigate the global market, stay competitive, and contribute to a more sustainable future.

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