



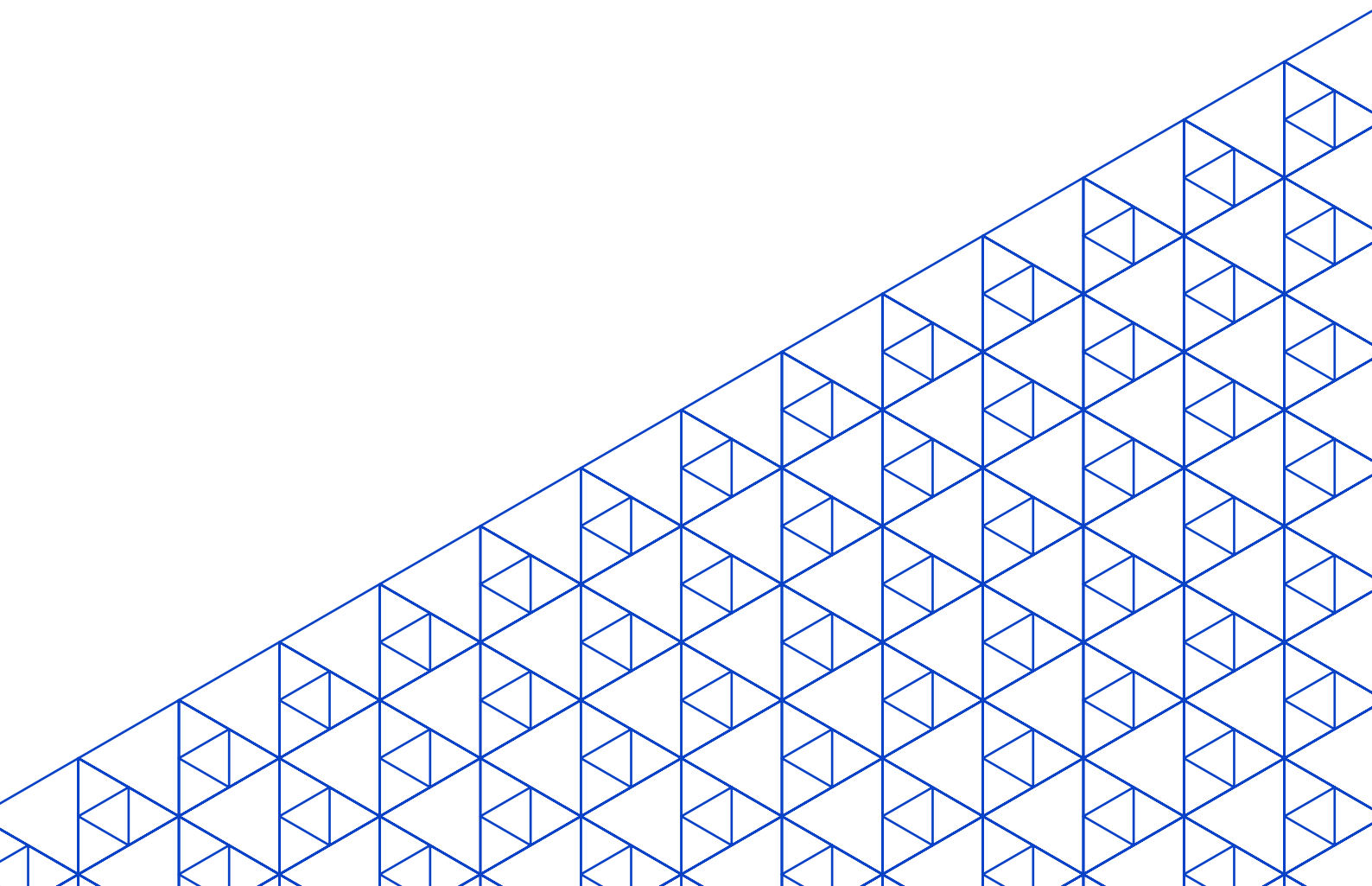
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► The employment effects of industrial symbiosis networks in the South African informal sector

Authors / Kiera Crowe Pettersson and Riaan Rossouwa



▶ **The employment effects of industrial symbiosis networks in the South African informal sector**

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Foreword

The world of work is currently experiencing major transformations related to technology, innovation, demography, organization of work and production, and environmental protection, all of which are redefining the role of work in society. Accordingly, the ILO Research Department deems it essential to examine and analyse these changes at the global level, and in particular their effects on employment.

Over the past few years, production and technological innovation have played a pivotal role in the growth of “green” industries and have contributed to the advancement of the United Nations Sustainable Development Goals by promoting the circular economy. One manifestation of the circular economy is “industrial symbiosis”, which refers to the coming together of traditionally separate entities in a collective approach in order to exploit and maximize the competitive advantage arising from the physical exchange of materials, energy, water and by-products in production processes.

The economic and environmental impacts of industrial symbiosis networks have been thoroughly examined, whereas their effects on employment have received rather less attention. The research presented in this report offers an innovative approach: it is one of the very first studies to analyse the relationship between employment and industrial symbiosis in Africa. Its findings are therefore likely to be of interest not only to researchers dealing with the implications of a just transition and green jobs at the global level, but also to workers’ and employers’ organizations and to leaders and policymakers who are responsible for the design of national policies on employment and environmental protection.

The present study on South Africa was prepared under the technical direction of Maria Sabrina De Gobbi of the ILO Research Department in Geneva, in collaboration with the ILO Decent Work Team for Eastern and Southern Africa and Country Office for South Africa, Botswana, Lesotho and Eswatini (hereafter “ILO Pretoria Office”). This report is part of a broader research project on the employment impacts of industrial symbiosis networks in Africa and Latin America.

We extend our deep appreciation to the former Director of the ILO Pretoria Office, Joni Musabayana, for the logistical assistance provided. This study could not have been completed without the invaluable technical support from several colleagues at the ILO headquarters in Geneva: Mette Grangaard Lund, Junior Professional Officer on Green Jobs; Christoph Ernst, Team Lead for Investments, Sectoral Strategies and Transitions; Luke Carroll, Junior Technical Officer on the Circular Economy; and Tahmina Mahmud, Junior Programme Technical Officer. Joaquín Etoarena Hormaeche, ILO National Coordinator for the United Nations Partnership for Action on Green Economy (PAGE) in Argentina also provided very useful feedback.

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Richard Samans
Director
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Executive summary

A deep dive into industrial symbiosis within South Africa's informal economy, particularly in the provinces of Gauteng and the Western Cape, unveils a complex interplay between employment dynamics, formalization and sustainability. This study focuses specifically on value chains in the textile and construction industries, with primary and secondary data sourced at a regional level from Gauteng and the Western Cape covering the dimensions of race, skill level and gender.

Analysis of this primary and secondary data, conducted to determine the substitution effect along with direct, indirect and induced employment effects, reveals in each case a positive impact of industrial symbiosis on job creation in the textile and construction sectors. In the textile sector, the symbiosis network replaced 110 individuals, resulting in an employment base of 2,851 workers. The substitution effect here contributed to the creation of 605 direct jobs, while the activity effect further expanded the workforce by an additional 107 positions. All in all, this translates into a substantial 25 per cent increase in total employment between 2018 and 2022. In the textile sector, the substitution effect is the primary driver of the positive impact of industrial symbiosis on employment, as the process of utilizing textile waste creates a surge in demand for labour, goods and services.

The positive impact of industrial symbiosis is even more pronounced in the construction sector. With 26 individuals replaced, the base scenario yielded an employment base of 2,071 workers. The substitution effect here resulted in the creation of 514 direct jobs, while the activity effect contributed an additional 57 positions. This translates into an impressive 28 per cent increase in total employment between 2018 and 2022. In the construction sector, the activity effect plays a greater role in driving positive impacts. This is due to the nature of the construction industry, where activities related to building and infrastructure development inherently lead to increased economic activity, owing to the need for skilled labour, materials and services. Nevertheless, the substitution effect also plays a significant role in this sector, contributing to the positive impacts on employment and economic activity. This can be ascribed to the processes involved in repurposing construction waste, which creates additional demand for labour, goods and services, ultimately leading to a positive ripple effect throughout the economy.

Around 15 per cent of the workforce in the textile sector and 37 per cent in the construction sector are in informal employment. Whereas the level of employment (both formal and informal) in textiles has been decreasing over the past few years, the construction sector remains a cornerstone of the South African economy and exerts considerable influence over both employment and economic output. In 2022, the sector exhibited a promising increase in its employment-to-output ratio, signalling a potential growth trajectory. In both sectors, industrial symbiosis networks leverage the existing waste streams to unlock economic potential. By reusing and repurposing waste materials, these networks address environmental concerns and stimulate economic growth. This dual benefit of reducing waste and driving economic activity exemplifies the ability of industrial symbiosis to foster sustainable and resilient industries.

Reflecting a shift towards formalization, organizations like Taking Care of Business are coming to play an integral role in the balance of formal and informal work. This organization, which is active in the textile sector, is creating an enabling environment for traditionally informal workers and entrepreneurs to grow their businesses. At the same time, it is helping to develop a more systematized employment infrastructure. Primary data from worker surveys indicates a high level of contentment among workers, which can be explained by greater occupational stability, opportunities for skills acquisition and improved remuneration. Nonetheless, many workers are concerned about income instability and the ever-rising cost of living.

The informal construction sector presents a more heterogeneous picture. In their responses to the survey, informal workers in that sector shared aspirations ranging from the acquisition of tangible assets to the adoption of measures for addressing occupational hazards. A recurrent theme was the desire for operational stability and career growth.

A comparative analysis of the primary data collected for the textile and construction sectors provides insights into the impact of industrial symbiosis on employment dynamics. The textile sector, for example, has a high level of female participation, with women accounting for 87 per cent of the workforce. Furthermore, the considerable representation of individuals without a secondary education, who make up 21 per cent of the workforce, is in line with efforts to promote broad-based inclusivity. In stark contrast, the construction sector is characterized by a modest level of female representation, with women accounting for just 31 per cent of the workforce, and by the absence of individuals without a secondary education. This highlights the need for a sector-specific approach to formalization initiatives.

Examination of the regional employment dynamics within Gauteng and the Western Cape turns up additional layers of complexity. In particular, women account for 47 per cent of the unemployed in Gauteng and for 49 per cent in the Western Cape. Moreover, in both Gauteng and the Western Cape, 9 per cent of unemployed women lack a secondary education.

South Africa's adoption of industrial symbiosis in the informal economy is a process accompanied by diverse challenges, opportunities and aspirations. The textile industry exemplifies the potential of symbiosis to promote inclusivity, employment growth and formalization, while the construction sector serves as a reminder of persisting disparities and challenges. The insights presented here can help policymakers to navigate this terrain. In particular, it is clear that fostering inclusivity, prioritizing safety and recognizing possible limits to formalization are key. The overarching goal should be to create a structured, inclusive and dynamic employment landscape that allows the power of industrial symbiosis to be fully harnessed.

Definition of terms

Term	Definition
Decent work	The ILO defines decent work as “productive work for women and men in conditions of freedom, equity, security and human dignity”. In general, work is considered as decent when: ▶ it pays a fair income; ▶ it guarantees a secure form of employment and safe working conditions; ▶ it ensures equal opportunities and treatment for all; ▶ it includes social protection for workers and their families; ▶ it offers prospects for personal development and encourages social integration; ▶ workers are free to express their concerns and to organize.
Employment	Total employment comprises both formal and informal employment. The employed population is defined as the number of people aged between 15 and 65 years currently working. Work is defined as any activity carried out by the respondent for pay, profit or household gain during the reference week (where “household gain” includes unpaid family members helping out in a family business).
Employment multipliers	The concept of an employment multiplier is used in multiplier analysis. It refers to the ratio of the change in total employment of workers in all sectors of an economy to the change in employment of workers directly engaged in a particular sector (Fjeldsted 1990).
Exports	Exports of goods and services from South Africa to the rest of the world.
Formal labour	All occupations in the formal sector, including high-skilled, skilled and semi skilled labour.
Gross domestic product at market prices	The total monetary or market value of all the finished goods and services produced within a country's borders in a specific period. As a broad measure of overall domestic production, it serves as a comprehensive “scorecard” of a country's economic health. Using the income approach, it may be defined as “the sum of all incomes earned in the process of producing goods and services (payment of salaries, gross operating margin and mixed income) plus taxes on production and imports and minus subsidies” (France, INSEE 2021).
Gross value added at basic prices	Gross value added (GVA) measures the value of goods and services produced in an area, industry or sector of an economy. GVA at basic prices has in many cases replaced gross domestic product (GDP) at factor cost as an indicator of output. If the value added of the agriculture, industry and services sectors is calculated at purchaser values, GVA at basic prices is derived by subtracting net product taxes from GDP. (World Bank, n.d.)
Industrial symbiosis	A system of symbiotic exchanges of production wastes, by-products and utilities, together with other forms of collaboration, among co-located traditionally separate industrial entities.
Informal jobs/labour	Informal employment refers to people in precarious employment situations, irrespective of whether the entity for which they work is in the formal or informal sector. Informal employment, therefore, comprises all workers in the informal sector, employees in the formal sector and people working in private households who are not entitled to, or who do not receive, basic benefits such as a pension or health insurance contributions from their employer, and who do not have a written contract of employment. The data used for modelling is collected by public entities, and it often fails to capture groups such as waste pickers in the informal sector. (Statistics South Africa 2010)
Informal sector	The informal sector consists of: ▶ employees working in establishments that employ fewer than five employees and do not deduct income tax from their salary or wage; and ▶ employers, own-account workers and people helping unpaid in a household business who are not registered for either income tax or value-added tax.
Input-output analysis	Input-output analysis is a form of macroeconomic analysis based on the interdependencies between different economic sectors or industries. This method is commonly used for estimating the impacts of positive or negative economic shocks and analysing the ripple effect of these throughout an economy.

List of abbreviations

GDP	gross domestic product
GISP	Gauteng Industrial Symbiosis Programme
SALDRU	Southern Africa Labour and Development Research Unit
TAB	The Appliance Bank
TCB	Taking Care of Business
WISP	Western Cape Industrial Symbiosis Programme

► 1. Introduction

This report deals with the intricate dynamics of employment effects within industrial symbiosis networks, specifically focusing on the informal sector in the South African provinces of Gauteng and the Western Cape. Rooted in the principles of the circular economy, industrial symbiosis fosters collaboration among traditionally distinct industries and presents a significant opportunity for economic growth in developing countries like South Africa. The circular economy, which is characterized by the recycling, repair and reuse of products and materials, has gained prominence in developing countries in recent years (Lahme et al. 2020). Central to this paradigm is industrial symbiosis, a collaborative approach that promotes the exchange of materials, energy, water and by-products among industries (Chertow 2000). While the environmental and economic impacts of industrial symbiosis are well documented, the social dimensions, particularly its effects on employment and job quality, remain under-explored (Neves et al. 2020). The present study addresses this gap by examining the employment dynamics of industrial symbiosis networks in the South African informal economy.

The initial scoping for the report was framed by a series of critical questions:

1. What are the nuanced employment effects, both quantitative and qualitative, of industrial symbiosis networks in the South African informal economy, with account taken of the challenges in achieving decent work?
2. How do these networks positively influence informal jobs and enterprises, and what insights can be gained from these effects?
3. How do large formal enterprises interact with smaller informal firms within these networks, and what are the unintended consequences, if any?
4. What critical success factors drive positive employment outcomes in industrial symbiosis, especially in terms of formalizing jobs and empowering women?
5. What barriers impede the realization of positive employment results, particularly as regards formalizing informal jobs?
6. What recommendations can the private sector and national and local governments adopt to foster job creation, the formalization of employment and the enhancement of job quality within industrial symbiosis networks?
7. Are specific skill sets required for jobs created through industrial symbiosis in the South African labour market, and are the skills in question readily available?

This study relies on both quantitative and qualitative methods. It begins with a review of the national and international literature, drawing on the foundational definition of industrial symbiosis by Chertow (2000). A case study, the Western Cape Industrial Symbiosis Programme, offers invaluable insights into employment impacts and opportunities for job formalization. The report focuses on two value chains in South Africa, namely textiles and construction, which were chosen in view of local data availability and access, and also bearing in mind global concerns over the environmental impact and waste management challenges of both sectors.

The collection of primary data was carried out through structured interviews with five enterprise managers and representatives of employers' organizations across informal and formal enterprises. Additionally, surveys were distributed among workers in informal jobs and enterprises, providing an essential first-hand perspective on job quality and formalization. A total of 18 workers were interviewed. It is worth noting that, in many cases, the line between operating as an informal worker and entrepreneurship is blurred, as such workers often have other people in their employ on an informal basis.

While it was feasible to conduct interviews with the managers of more formal enterprises by digital means of communication, there were several obstacles in gathering insights from workers (both formal and informal),

including widespread public transport strikes and flooding. Owing to time- and access-related constraints, representatives of workers' organizations and trade unions were not interviewed.

Linkages were identified among the organizations included in the analysis of the textile value chain, involving the exchange of materials from automotive upholstery producers and other industrial textile manufacturers that are subsequently used to create new fabrics and products further down the value chain. Over and above that, one organization engaged in industrial symbiosis – specifically in receiving materials and by-products from a range of manufacturers as feedstock in replacement of raw materials for the creation of saleable products – also provides skills training. Those receiving such training are additionally taught how to run enterprises operating on the principles of a reclaim- and repair-based economy. Several of these individuals have gone on to run their own small businesses using textile by-products – some formal, others informal.

With regard to the construction value chain, linkages were largely anchored around demolition, the exchange of materials and timber use. Again, these materials are used in replacement of raw materials for business creation through secondary sector development, and such activities are highly dependent on logistics and transport. In most cases, materials feed back into the built environment, though there is also some activity at the bottom of the value chain, as sawdust from timber is used in small-scale agriculture for mulch and composting. As with the textile value chain, there is a balance of informal and formal enterprises, with most observations in our study referring to small firms and microenterprises.

For the greater part, this report consists of:

1. An exploration of existing industrial symbiosis networks, particularly those involved in the Western Cape Industrial Symbiosis Programme. This section looks at the origins and characteristics of such networks, the member enterprises and, most importantly, the intricate employment dynamics arising from industrial symbiosis.
2. A detailed examination of employment effects, the aim being to provide an overview of job creation, the skill sets required, workers' perceptions of working conditions, and formalization efforts within member enterprises. Moreover, this section considers the broader value chain, unravelling the indirect employment effects of industrial symbiosis.

This study provides a nuanced understanding of the employment landscape in South Africa's informal sector, shedding light on the interactions between industry and labour.

► 2. Literature review

Industrial symbiosis is an emerging approach that promotes collaboration and resource-sharing among industries, aiming to enhance environmental sustainability and economic efficiency. In the context of South Africa, where economic development problems and environmental challenges coexist, industrial symbiosis has attracted considerable attention as a possible solution. Industrial symbiosis can be defined as a system of symbiotic exchanges of production wastes, by-products and utilities, together with other forms of collaboration, among co-located traditionally separate industrial entities (Chertow 2000). This section reviews the national literature on the employment effects of industrial symbiosis in South Africa, the aim being to shed light on the potential impacts of industrial symbiosis on employment, workforce dynamics and the broader socio-economic landscape. For the purposes of this study, and in view of the value chains identified in the textile and construction sectors, the focus is mostly on the exchange of waste and by-products.

2.1. Social and economic impact of industrial symbiosis in South Africa

By providing skills, opportunities and access to resources, industrial symbiosis networks can play an instrumental role in fostering sustainable employment and economic growth within such critical sectors as textiles and construction. This is amply demonstrated in a recent collaborative report by the Southern Africa Labour and Development Research Unit (SALDRU) and the Greenlight Office on the programme known as The Appliance Bank (TAB), which offers profound quantitative insights into its impact (SALDRU and Greenlight Office 2021). The initiative, designed to empower unemployed fathers by providing them with technical training in the repair of small appliances, has had impressive results. Partnering with major retail entities such as Clicks, Checkers and Home of Living Brands, the TAB programme received damaged or customer-returned appliances, which were then repaired by participants and sold within their communities. Participants also offered repair services more widely.

One critical aspect examined in the above-mentioned report was participants' scores on the Poverty Spotlight app, which measures levels of deprivation across various dimensions, with lower scores indicating lower levels of deprivation. Participants in the TAB programme generally exhibited higher Poverty Spotlight scores for most indicators. Their performance in the "income and employment" dimension was particularly noteworthy: the mean survey score was 9.84 (out of a maximum of 15), which suggests that there is room for improvement. Nevertheless, the report identified a positive trend over time, reflecting the efforts of the organizations involved to tackle deprivation. Over the first year of the programme, nearly 82 per cent of participants had improved their score, with an average improvement of 7.6 points. This trend persisted in the second year, with 85 per cent of participants improving their score and the average improvement at the end of that year being 5.5 points (SALDRU and Greenlight Office 2021). Significantly, most of the improvement was concentrated in the programme's first year, underscoring the importance of early intervention.

Comparison with a similar programme, Taking Care of Business (TCB), revealed that while TAB participants demonstrated a slightly slower rate of improvement in the first year, they outperformed TCB participants, particularly in the "income and employment" dimension, during the second year. This highlights the unique dynamics of participant groups and programmes, emphasizing the need for tailored strategies.

Crucially, the report identified specific challenges faced by participants in the TAB programme, including challenges related to family savings, access to credit facilities, budgeting and income generation. Family savings and income security emerged as particularly formidable areas requiring attention (SALDRU and Greenlight Office 2021). The concrete quantitative data presented in that report can inform adjustments and refinements to the programme so that it is better able to meet the specific needs of participants.

2.2. Policy and regulatory framework

The role of government policies and regulatory frameworks in shaping the success of industrial symbiosis cannot be overestimated. Studies like that by O'Carroll et al. (2017) have argued that supportive policies and subsidies designed to incentivize collaborative initiatives and resource-sharing can significantly amplify the "triple bottom line" (social, environmental, economic) effects of industrial symbiosis. Conversely, the absence of clear policies, along with regulatory barriers, may hinder the growth of industrial symbiosis initiatives and limit their ability to generate employment opportunities. The relevant challenges and constraints posed by the regulatory landscape in South Africa are as follows:

- 1. National Environmental Management: Waste Act, 2008 (Act No. 59 of 2008).** This law is aimed at promoting efficient and effective waste management in South Africa. However, it lacks specific provisions that address industrial symbiosis explicitly. This may create uncertainties and challenges for industries seeking to formalize symbiotic relationships involving waste exchange and resource-sharing.

2. National Environmental Management: Waste Amendment Act, 2014 (Act No. 26 of 2014). This amending legislation introduced the concept of extended producer responsibility and the requirement to have waste management plans in place for specific waste streams. Although the new concept is intended to encourage industries to take responsibility for their waste, it may not adequately address the complexities and benefits of industrial symbiosis, where waste from one industry becomes a valuable resource for another.

3. Water Services Act, 1997 (Act No. 108 of 1997). This law regulates water use and water pollution control. However, it does not contain specific provisions for the exchange and reuse of water among industries, which are essential aspects of industrial symbiosis. A lack of clear guidelines on water-sharing may discourage businesses from exploring symbiotic opportunities.

4. National Environmental Management: Air Quality Act, 2004 (Act No. 39 of 2004). This law focuses primarily on air pollution control, emissions standards and atmospheric impacts. While it addresses emissions from individual industries, it may be said to neglect the potential for collective reduction of emissions that can be achieved through symbiotic arrangements.

5. Lack of interdepartmental coordination. The formalization of industrial symbiosis requires coordination among various government departments responsible for waste management, water, air quality and industry regulation. The lack of such coordination, and more generally of a holistic approach, may lead to conflicting regulations and create challenges for businesses seeking to engage in symbiotic relationships.

6. Incentive mechanisms. The regulatory environment in South Africa may not provide for sufficient incentives to encourage businesses to adopt industrial symbiosis. Financial and non financial incentives, such as subsidies, tax benefits, grants and recognition, could drive greater formalization and participation in symbiotic initiatives.

7. Liability and risk-sharing. The existing regulatory framework may not provide clarity on liability- and risk-sharing arrangements between the industries involved in industrial symbiosis. Any ambiguity on these matters may deter businesses from pursuing symbiotic relationships because of the fear of potential legal and financial repercussions.

2.3. Challenges and constraints

To effectively analyse the challenges to, and constraints on, efforts to unlock the employment potential of industrial symbiosis in South Africa, it is essential to consider both the broader context of industrial development in the region and specific initiatives within the country.

In a study of industrialization in Botswana and the United Republic of Tanzania, Mkwizu and Monametsi (2021) identified some challenges that are common to all countries in the region, including South Africa:

- ▶ **Policy implementation challenges.** The implementation of policies is often hindered by duplication of efforts and competing objectives. This is best exemplified by the Western Cape Industrial Symbiosis Programme, where competition between public- and private-sector interests caused bottlenecks. This challenge was largely overcome through the establishment of public-private partnerships (EBRD, n.d.).
- ▶ **Governance challenges.** A poor level of participation by the private sector and limited accountability hamper governance in the industrial sector.

Energy supply constraints. Frequent power shortages and load shedding are significant hindrances to industrial progress.
- ▶ **Low innovation.** Limited investment in research and development (R&D) and weak interlinkages between creative industries and R&D institutions pose innovation challenges.
- ▶ **Extensive informal sector.** The informal sector, which accounts for a substantial part of gross domestic product (GDP) in the region's countries, is often excluded from formal industrial strategies.
- ▶ **Skills gaps.** Mismatches between labour market demand and the skills offered by workers present additional challenges for industrial development.

While industrial symbiosis holds great promise for employment generation in South Africa, several challenges must be addressed if it is to be implemented effectively. Turken and Geda (2020) have identified further obstacles relating to logistics, information-sharing and inter-firm cooperation. Understanding and overcoming these challenges is critical to fully harness the employment generation potential of industrial symbiosis.

2.4. Nexus between environmental sustainability, economic resilience and employment generation

An essential aspect of industrial symbiosis is its ability to address environmental, economic and employment concerns simultaneously. Research by Nkosi et al. (2019) illustrates how resource efficient practices and waste exchange can not only reduce environmental impacts but also lead to increased job opportunities in South Africa's industrial sectors. The nexus between environmental sustainability, economic resilience and employment generation highlights the potential of industrial symbiosis as a holistic approach for tackling the country's pressing challenges.

The national literature on the employment effects of industrial symbiosis in South Africa demonstrates a growing interest in such schemes as a means of fostering economic growth, improving workforce dynamics and enhancing environmental sustainability (Govender 2017). The studies reviewed by that author emphasize how industrial symbiosis can create new job opportunities, promote skills development and contribute to the socio-economic advancement of local communities (Govender 2017). However, challenges related to policy design and implementation, collaboration and logistics must be addressed in order to fully leverage the employment generation benefits of industrial symbiosis in South Africa. Moving forward, policymakers, industrial leaders and researchers need to work together to design and implement effective industrial symbiosis initiatives that are aligned with the country's economic and environmental objectives (O'Carroll et al. 2017).

2.5. Broad overview of existing industrial symbiosis networks

The Gauteng Industrial Symbiosis Programme (GISP) and the Western Cape Industrial Symbiosis Programme (WISP) are exemplary models of sustainable economic development in South Africa. While our primary focus lies on the impressive achievements under WISP, it is crucial to acknowledge the broader landscape of industrial symbiosis networks. According to Oguntoye et al. (2019), GISP accounts for around 10 per cent of total GDP in sub-Saharan Africa, or 7 per cent of the entire African continent's GDP. This confirms the significant economic potential arising from the introduction and expansion of industrial symbiosis initiatives in South Africa and across Africa as a whole (Madanhire and Mbohwa 2017). Such initiatives are redefining how resources are used to reduce waste and mitigate environmental impacts.

WISP represents a sustainable economic development paradigm implemented in South Africa's Western Cape province. Launched in May 2013, WISP has sought to strategically tackle the rising costs of energy and other inputs encountered by businesses. It operates on a model of industrial symbiosis, whereby unused resources are repurposed in the operations of other entities, fostering a more circular and efficient economy. WISP is facilitated by GreenCape, a sector development agency specifically dedicated to advancing the green economy. GreenCape draws inspiration from the successful National Industrial Symbiosis Programme in the United Kingdom of Great Britain and Northern Ireland, adapting and implementing best practices to suit the South African context. As a key player in the green economy, GreenCape actively promotes sustainable business practices, renewable energy and environmental resilience in the country. WISP encourages mutually beneficial links between companies from various industrial sectors, allowing them to share underutilized resources and reduce costs while operating more sustainably. WISP cuts across different industries and business sizes, with a team of facilitators working to identify potential synergies through workshops, meetings and industry events.

With regard to gender-inclusive employment, WISP has played a vital role in empowering women in both formal and informal sectors. Although there is no specific sex-disaggregated data in the available information, it is clear that the programme has notably increased opportunities for women, especially in informal activities within its network. This commitment to gender inclusivity ties in with the broader aim of fostering decent work and ensuring fair and equitable opportunities for all participants. Moreover, WISP recognizes the importance of occupational safety and health considerations. Such considerations are integral to the success of WISP, as the emphasis is on creating a work environment that prioritizes the well-being and safety of all individuals engaged in the synergies facilitated by the programme. This holistic approach not only contributes to gender inclusivity but also reflects the programme's dedication to promoting decent work practices within the industries it serves.

The success of WISP can be ascribed to meticulous planning and efficient execution. As shown in table 1, there have been a total of 231 successful synergies over the past decade, comprising 81 “continuous synergies” and 150 “batch synergies”.¹ These synergies, spanning industries such as textiles, food, manufacturing, and electronics, have significantly contributed to waste diversion and generated economic benefits.

More specifically, the 231 synergies orchestrated by WISP since its inception have helped to divert 139,685 tonnes of waste from landfills, resulting in a substantial reduction of 410,745 tonnes in greenhouse gas emissions. Economically, the programme has generated over 155 million South African rand in benefits, including additional revenue, cost savings and private investments. This success has translated into the creation of 411 jobs since 2013, providing a fillip to the local community.

A closer examination of the impact of WISP on job creation reveals that 126 direct jobs were created, as reported by the companies involved, along with 285 indirect and induced jobs (table 1). Information on the types of jobs created their distribution across large and small enterprises, job stability and gender distribution would be essential to attain a comprehensive understanding of the impact. Unfortunately, specific details on these aspects are not to be found in the available data.

However, a case study on the collaboration between EnviroServe and Combo Timber Structures within the WISP framework notes the creation of jobs in various areas related to wood remanufacturing and the utilization of secondary products (Redflank 2021). The symbiosis between the two companies, centred on the remanufacturing of broken pallets into new usable pallets, has led to the creation of various roles related to wood processing and pallet production. In addition, further job opportunities are likely to arise from the repurposing of offcuts to make kennels and fire starters, for example. The overall impact of the collaboration includes the creation of three permanent jobs in Combo Timber Structures to manage the increased volumes of wood. Although specific job titles or roles are not mentioned in this case study, it does illustrate the potential for job creation across wood related industries (including the creation of jobs in operational management) thanks to industrial symbiosis (Redflank 2021).

Furthermore, WISP boasts a strong return on investment, generating an economic benefit of 8.31 rand for every rand of funding. While scaling up this model may pose regulatory and infrastructural challenges, the experience gained through WISP offers invaluable insights for those considering similar initiatives to promote sustainable economic development.

¹ Personal communication from Taahirah Ghoo in the form of an email dated 24 August 2023 with “GreenCape – WISP dashboard for the last 10 years” in the subject line.

► **Table 1. Key statistics for the Western Cape Industrial Symbiosis Programme, 2013–23**

Outputs	Over ten years (2013–23)	Notes
Total successful synergies and connections	231	Synergies over ten years. Over the last two years, only introductions exceeding 100 tonnes per annum have been tracked.
Continuous synergies	81	Synergies that occur repeatedly
Batch synergies	150	Synergies that occur as a once-off between two companies
Waste diversion (tonnes)	139 685.00	–
Additional revenue (rand)	78 311 030.02	Additional revenue for the waste generator (through payment for the waste) or for the offtaker (through payment for removal of the waste)
Cost savings (rand)	55 996 238.51	Savings for the offtaker (as it does not have to pay for virgin material) or for the waste generator (as it does not have to pay for disposal)
Private investment (rand)	20 832 259.00	Capital investment required to preprocess the waste for reuse
Total economic benefits (rand)	155 139 527.53	Sum of the three items above
Reduction of GHG emissions from fossil fuels (tonnes CO₂e)	410 745.00	–
Reported job creation	126	Direct jobs (reported by either company in a synergetic relationship)
Inferred job creation	285	Indirect and induced jobs
Return on investment		
Ratio of economic benefits to funding	8.31	For every rand in funding, 8.31 rand in economic benefits are generated
Cost to create a job (rand)	45 425.79	–
Cost to divert one tonne of waste from landfill (rand)	133.66	–

Note: CO₂e = carbon dioxide equivalent emission; GHG = greenhouse gas

Source: Personal communication dated 24 August 2023 from Taahirah Ghoor.

The programme's success is multifaceted and can be attributed to favourable government policies; collaboration with International Synergies, a network of diverse companies; and strong support from high-level stakeholders. WISP has played a crucial role in ensuring that carbon and resource-efficiency targets outlined in both national and Western Cape policies are met. However, among the challenges faced by the programme are the complexity of the regulatory framework, high transport costs and a limited interest in alternative materials. These need to be carefully addressed, and robust public-private collaboration is required to pave the way for more seamless implementation of the programme.

While celebrating the commendable achievements of WISP, it is important to recognize that attempts to introduce similar initiatives elsewhere in the country could run up against regulatory and infrastructural challenges. As a pioneering model, WISP showcases innovative waste management practices and testifies to the potential of industrial symbiosis to generate significant economic and environmental benefits. Its success in the Western Cape offers valuable insights that can inform and guide the implementation of similar programmes in other regions.

► 3. Overview of industrial symbiosis in the South African textile and construction sectors

South Africa has witnessed a notable surge in industrial activities in recent years, raising concerns about resource consumption, waste generation and environmental sustainability (Arndt, Davies and Thurlow 2019). Industries are actively addressing these challenges through innovative strategies to mitigate their environmental impact while maintaining productivity and profitability (Cohen 2006). One such strategy that is gaining traction is industrial symbiosis, which emphasizes collaboration and resource exchange among co-located industries. By leveraging each other's waste streams and by products, companies within a symbiotic network can achieve significant efficiencies in resource utilization, reduce waste generation and even create new revenue streams. This ties in with sustainable business practices and contributes to the broader goal of establishing a circular economy.

The textile and construction sectors, which play a pivotal role in South Africa's industrial landscape, have been major drivers of economic growth. However, they also face unique challenges, such as resource-intensive production processes, waste generation and compliance with environmental standards (Godfrey 2021). Given their significance, a thorough review of industrial symbiosis within these sectors is imperative.

In South African textiles, industrial symbiosis networks take shape through collaborative initiatives such as the training programme of The Clothing Bank (renamed "Taking Care of Business" in September 2022), which operates across multiple branches in Cape Town, Johannesburg, Durban, East London and Paarl. Under this programme, unemployed mothers are provided with training and access to discounted clothing that they can sell, resulting in profitable businesses and economic empowerment. In general, the geographical distribution of textile activities across the country's provinces suggests that there is considerable potential for regional industrial symbiosis, allowing local strengths and resources to be optimized for mutual benefit.

In the construction sector, industrial symbiosis networks are implicit in the employment dynamics, that sector being notably reliant on large amounts of both formal and informal labour. Since provinces such as Gauteng and KwaZulu-Natal are central hubs for construction activities, there is good reason to believe that the strategic integration of industries there into symbiotic networks can amplify synergistic benefits.

3.1. Description of the symbiosis networks in each sector

This subsection provides a detailed summary of the symbiosis networks underpinning the dynamics of the textile and construction sectors in South Africa. These networks constitute collaborative ecosystems that can foster economic empowerment, sustainability and regional growth.

Textile sector: This sector's symbiosis network is characterized by collaborative initiatives aimed at promoting economic empowerment and sustainable business practices, especially for informal workers. A prominent example is the training programme under The Clothing Bank (now Taking Care of Business), which operates across multiple branches in Cape Town, Johannesburg, Durban, East London and Paarl. Through this network, unemployed mothers are able to receive training, access discounted clothing and embark on entrepreneurial ventures, resulting in the creation of profitable businesses. The symbiotic relationship here involves the exchange of knowledge, resources and discounted goods, and it contributes to economic resilience and empowerment within the textile sector.

Construction sector: This sector's symbiosis network reflects its reliance on both formal and informal employment, the emphasis being on regional concentrations and collaborative strategies. Provinces such as Gauteng and KwaZulu-Natal emerge as sectoral hubs, illustrating the geographical dimension of symbiotic relationships. The symbiosis network here involves a collaborative employment landscape where formal and informal workers contribute to the sector's robust performance. The implicit symbiosis lies in the sector's ability to create diverse job opportunities and generate economic growth. However, there is a need for tailored approaches to address the unique challenges faced by formal and informal construction workers alike.

These symbiosis networks exemplify collaborative ecosystems within their respective sectors and the ways in which resources, knowledge and support can be shared for mutual benefit and common sustainable growth.

3.2. Insights from survey responses

The responses to the surveys conducted for this study offer valuable insights that can further inform the development and enhancement of industrial symbiosis networks in both the textile and construction sectors:

- 1. Training programmes and skills development:** The survey conducted in the textile sector reveals that such programmes are key to developing entrepreneurial skills among informal workers. Ensuring that similar training opportunities are available through industrial symbiosis networks can enhance the skill sets of workers, fostering self-sufficiency and resilience. These programmes do not require participants to set up formalized enterprises, but they do equip them with the skills required for that.
- 2. Start-up costs and support systems:** The responses of informal workers in the construction sector point to varying start-up costs and reliance on support systems. Understanding these financial and social dynamics can inform the establishment of support mechanisms within industrial symbiosis networks, ensuring that participants have the necessary resources for sustainable operations.
- 3. Geographical considerations:** The geographical distribution of activities in both sectors highlights the importance of a regional approach to industrial symbiosis. Tailoring symbiotic initiatives to leverage the strengths of specific regions, as observed in the provinces of Gauteng and KwaZulu-Natal, can optimize collaboration and resource utilization.
- 4. Income disparities and support:** Addressing income disparities, especially disparities between formal and informal workers, is crucial in industrial symbiosis networks. From the surveys it is clear that there is a need for initiatives that ensure fair remuneration, financial support and the inclusion of informal workers in the broader economic framework.
- 5. Entrepreneurial spirit:** The survey findings highlight the strong entrepreneurial spirit of informal workers. Tapping into this spirit within industrial symbiosis networks can create innovative collaborations and business models, resulting in a more resilient and dynamic economic ecosystem. Entrepreneurship was a very relevant topic in the responses of informal workers, among whom the boundary between a worker and a microenterprise is blurred. Although the reasons are not entirely clear, the high level of informality among survey respondents could be attributed either to the fact that several of them were migrants or to the perceived costs and bureaucratic challenges involved in registering and operating as a formal enterprise.

In summary, the survey responses provide nuanced insights that can be integrated into the design and implementation of industrial symbiosis networks. These insights contribute to a more comprehensive understanding of the workforce dynamics and facilitate the development of strategies that cater to the unique needs and challenges observed in both the textile and construction sectors.

► 4 Methodology

4.1. Research design

This study employs a “mixed methods” approach, combining quantitative and qualitative methodologies to comprehensively assess the employment impacts of industrial symbiosis networks. The quantitative framework is informed by the research conducted by Abriata and Masut (2021) in Argentina, which provides a robust foundation for our own investigation.

The initial phase consisted of an extensive review of national and international publications and pertinent documents on industrial symbiosis in South Africa. The definition of industrial symbiosis advanced by Chertow (2000) was the guiding framework for evaluating existing cases. A detailed analysis of the Western Cape Industrial Symbiosis Programme (WISP) was conducted, focusing on both quantitative and qualitative dimensions of its employment effects. Special attention was given to discerning the mechanisms associated with job and enterprise formalization through industrial symbiosis.

Our methodology builds on the foundations laid by Martin and Harris (2018), incorporating elements from Kühnen and Hahn (2018), but also from Ibáñez-Forés et al. (2019), as exemplified in Ríos and Rodríguez (2021) for the case of Colombia. In estimating employment multipliers, we followed the approach outlined in Abriata and Masut (2021).

Primary data was collected using the following tools:

- ▶ Interviews were conducted with enterprise managers and representatives of employers' organizations.
- ▶ Surveys of individuals engaged in both formal and informal employment were carried out, covering various enterprises. The data was categorized by age and sex for clarity.

An interview guide and survey questionnaires were submitted to the ILO for review and approval (see Appendix A). A key focus was on the questionnaire directed at informal workers, which sought to gauge the quality of their employment and identify any positive impacts of industrial symbiosis in terms of their formalization.

The study considers various indicators, such as the number of jobs created or sustained, the skill sets required for jobs resulting from industrial symbiosis, the emergence of new enterprises, the formalization of jobs and enterprises with associated characteristics, changes in wages and working hours, female employment rates, advancements in occupational safety and health, and activities fostering social dialogue conducive to industrial symbiosis. It is crucial to emphasize that, in instances where quantitative data is unavailable, these indicators are discussed qualitatively. In addition, the study aims to fill the data gap concerning the quality of jobs arising from industrial symbiosis within informal settings and enterprises. Employment within large formal enterprises has already been examined in similar ILO studies covering different countries. The primary emphasis here lies, therefore, on informal enterprises and jobs within industrial symbiosis networks.

4.2. Data collection

Primary information for the case studies was gathered through a series of interviews with experts in the field of industrial symbiosis. To obtain a comprehensive picture of various sectors and regions, we contacted representatives from the public sector, business associations and specialists in the circular economy. This diverse group provided valuable insights, offering a broad overview of industrial symbiosis in South Africa and detailed knowledge of specific cases. Attempts were made to engage with a representative of an international organization as well, but that person regrettably declined to participate on this occasion. The interviews took the form of mainly ad hoc conversations, which accounts for the wide range of perspectives, experiences and advice shared. A breakdown of the key informants can be found in tables 3, 4 and 6.

For the case studies, data collection involved remote and partially structured surveys. While the interview format occasionally posed challenges in aligning responses with the questionnaire's structure, it also provided highly pertinent information, supporting further insights and analysis. Three workers from the formal textile sector were interviewed, as were 13 workers from the informal textile sector. In the construction sector, eight informal workers were surveyed. The enterprise responses covered waste streams from formal textile companies (two), informal textile companies (one), informal construction companies (one) and formal construction companies (one).

In addition to primary data, we supplemented our research with information and data from secondary sources. Firstly, we used a national input-output table for South Africa based on 2022 prices, sourced from the consultancy firm Quantec in 2023.² This data set was used to calculate coefficients related to intersectoral requirements and employment multipliers per unit of expenditure. Industry data was gathered from Quantec³ and the South Africa Regional Explorer⁴ of S&P Global Market Intelligence. In addition, we also relied on journalistic publications to evaluate industrial symbiosis networks, explicitly drawing from news reports on project launches or successes.

4.3. Surveys for the selected sectors

The surveys conducted for each case study of industrial symbiosis in South Africa were primarily of a preliminary and exploratory nature. Our working hypothesis posited that industrial symbiosis can be observed across a diverse range of economic activities and geographical regions within the country. We employed a descriptive approach to substantiate this hypothesis, drawing on information gathered from interviews, the existing literature and journalistic publications. Following the surveys, the cases were summarized (with a focus on the technical aspects, that is, on the processes involved), categorized by economic sector and geographically situated.

4.4. Assessing the impact

4.4.1. Quantitative impact

The methodology outlined in this subsection is based on a translation of the corresponding subsection of Abriata and Masut (2021). First of all, an “expansion factor” is determined for each company surveyed. Since the surveys could not feasibly cover all companies participating in a symbiosis scheme, a practical approach to gauge the scheme’s overall impact is to multiply the number of jobs created in a surveyed company (and the amount of costs incurred) by a factor that reflects the degree of a company’s representation within the context of the total number of companies playing a similar role in the scheme. This expansion factor functions like the weights used in certain surveys. Appendix C provides a more detailed explanation of the calculation methodology and the corresponding formula.

The direct effects are computed on the basis of the responses to interview questions 14, 20 and 21 in conjunction with the expansion factor. This method distinguishes between the substitution effect (*FDSE*) and the activity effect (*FDAE*). Further details of the calculations involved are given in Appendix C.

The total indirect effect of the symbiosis scheme, denoted as *FITE*, can likewise be decomposed into the substitution effect (*FISE*) and the activity effect (*FIAE*). Both are estimated by analysing the changes in costs incurred and their influence on employment demand in other sectors of the economy. First of all, the employment generated by direct suppliers is estimated on the basis of changes in the costs of companies, categorized by economic sector. This information is derived from the responses to interview questions 5, 6, 8 and 10. We consider analysis of the induced effect to be less relevant, as it predominantly operates through consumption, which accounts for two thirds of the national aggregate demand in South Africa. Consequently, employment in induced activities is expected to closely reflect the existing socio-demographic composition even when symbiosis is not present. The specific formulas are given in Appendix C.

To make it possible to express impacts in relative terms, a “base” employment indicator is constructed. This indicator, known as *LBTE*, quantifies the total employment generated by the companies in the symbiosis scheme in the absence of waste reuse. The calculations are detailed in Appendix C.

² Specifically from the Quantec EasyData Industry Service, <https://www.quantec.co.za/easydata/industry-subscription/>. Details of the foundational data for construction of the input-output table are outlined in Appendix B.

³ Specifically from the Quantec EasyData Regional Service, <https://www.quantec.co.za/easydata/regional-subscription/>.

⁴ Available at <https://www.spglobal.com/marketintelligence/en/mi/products/south-africa-regional-explorer-geographic-economic-demographic-data.html>.

Finally, the overall impact on total employment of the companies participating in the scheme, denoted as $FLTE$, is given by the sum of these three effects:

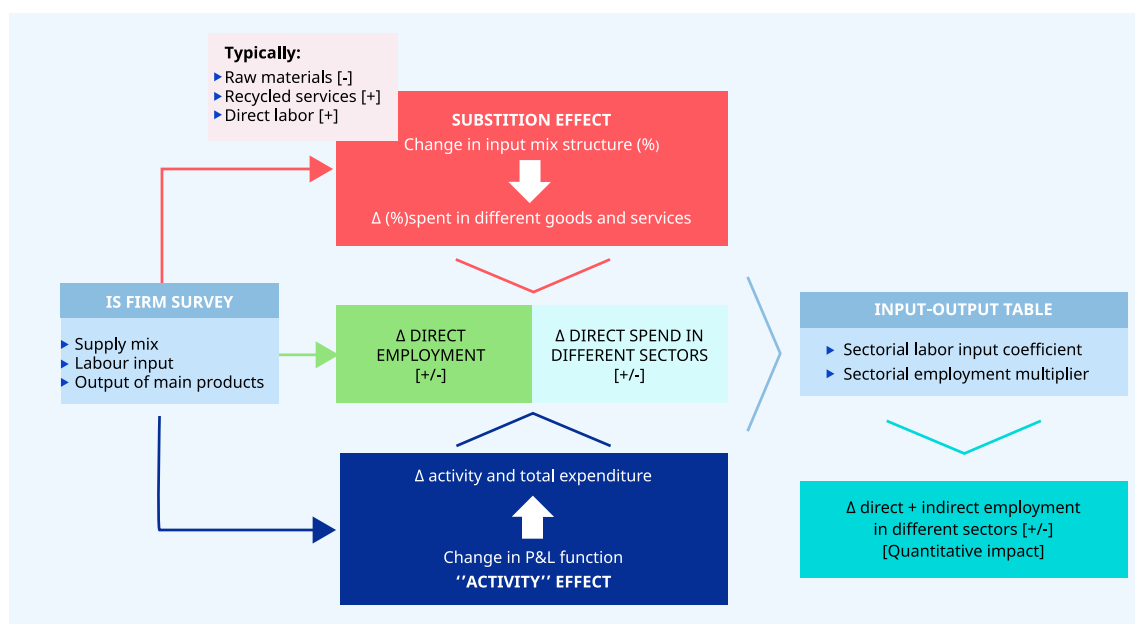
$$FLTE = FDSE + FDAE + FITE$$

To contextualize this overall impact in terms of relative magnitude, it is expressed as a proportion of the counterfactual employment when there is no symbiosis, denoted as $FLTR$:

$$FLTR = FLTE / LBTE$$

The methodology for quantitative impact assessment is summarized in figure 1.

► **Figure 1. Methodology for assessing the quantitative impact of industrial symbiosis**



Source: Abriata and Masut (2023).

4.4.2. Qualitative impact

Composition effect

In assessing the qualitative dimension of job creation, we apply the same approach as Abriata and Masut (2021), which is based on a perspective of equal opportunities. The approach involves measuring the share of different socio-demographic groups in the employment change brought about by the industrial symbiosis scheme.

With regard to direct effects in terms of employment change, our data enables us to measure:

- the share of female jobs in the total number of jobs created or destroyed;
- the share of individuals without a secondary education in the total number of jobs created or destroyed;
- the share of women without a secondary education in the total number of jobs created or destroyed.

Effect on conditions of work

We evaluated and analysed the impact of industrial symbiosis on occupational risk and worker training by drawing on the insights and descriptions provided in interviews and secondary sources. To explore these aspects, we specifically asked about them in our worker surveys, and we complemented this information with details sourced from academic papers and reports.

4.5. Limitations

The methodology used has several inherent limitations. Firstly, it does not provide for a comprehensive or systematic examination of industrial symbiosis networks in South Africa. The surveys conducted as part of the case studies are not exhaustive either, as these networks comprise a far larger number of enterprises than those actually surveyed. In addition, there is a notable lack of data from worker or labour force surveys, which could have enriched the data set and allowed the testing of various hypotheses, particularly those regarding qualitative impacts. However, gathering such data was challenging, not just owing to standard access-related issues but also because of specific instances of force majeure during the data collection stage of the study. In particular, violent strikes and severe flooding in the Western Cape forced many workers (formal and informal) to stay at home in line with safety precautions. This meant that when access was possible, many workers were making up for lost time and were therefore less willing to participate in the survey.

Furthermore, it is essential to note that the accuracy of all computations of indirect effects relies on the aforementioned input-output table based on 2022 data, which is the most recent official record available for South Africa that offers the necessary sectoral granularity. Use of that table implies accepting its underlying assumptions, including the assumption of fixed proportions in production functions.

The South African economy has grappled with notable supply constraints over the past decade, which has been marked by severe electricity supply disruptions and a gradual deterioration in rail infrastructure. The inadequacies in electricity generation capacity have been exacerbated by prolonged delays in completing the construction of major new coal-fired power stations (Medupi and Kusile) and a persistent rise in unplanned outages at existing power stations despite the steady addition of independently produced renewable energy to the national grid. Furthermore, the price of electricity surged by 241 per cent from December 2009 to December 2022, which is more than twice the 92.8 per cent increase in the overall consumer price index over the same period. The swiftly escalating cost and unreliable availability of electricity in South Africa have substantially hampered output growth in the domestic economy (Venter and Wolhuter 2023).

The presence of binding supply-side constraints, such as the aforementioned electricity supply disruptions and infrastructure deterioration, poses a challenge to our methodology. These constraints may have an impact on economic expansion, invalidating the assumption that demand alone dictates activity levels. The methodology also relies on assumptions about constant prices and on adherence to specifications of the Leontief production function with regard to preferences and technology. This would imply that consumers consume in fixed proportions and producers use inputs in fixed proportions, either because of stable relative prices or because of the constant input-output coefficients of technologies according to the Leontief model, which may not fully capture the dynamic and, at the same time, constrained nature of the South African economic environment (Ngandu, Garcia and Arndt 2010).

To meet the rigorous requirements of our methodology, we found it imperative to enhance the quality and quantity of the data beyond what was gathered from primary and secondary sources. This involved performing transformations and imputations on numerical data, and making inferences regarding responses that were either missing or deemed to be of suboptimal quality.

► 5. Results and discussion

The following subsections provide a detailed analysis of the data collected for our case studies.

5.1. Textile sector

5.1.1. Brief characterization of the sector

This characterization is based on the key statistics for the South African textile sector from 2018 to 2022, as summarized in table 2. The sector plays a significant role in the country's economy. In 2022, its employment to output ratio stood at 1.03, indicating a slight increase in output per employee compared with previous years. The ratio of remuneration to value added remained relatively stable, ranging from 47.3 to 50.6 per cent over the past five years, which suggests that a significant proportion of the value generated in the sector goes towards employee compensation.

The remuneration per employee increased significantly from 145,487 rand in 2018 to 181,970 rand in 2022. This suggests that employees in the sector have experienced an improvement in their earnings. However, it is essential to note that this data refers to both formal and informal workers.

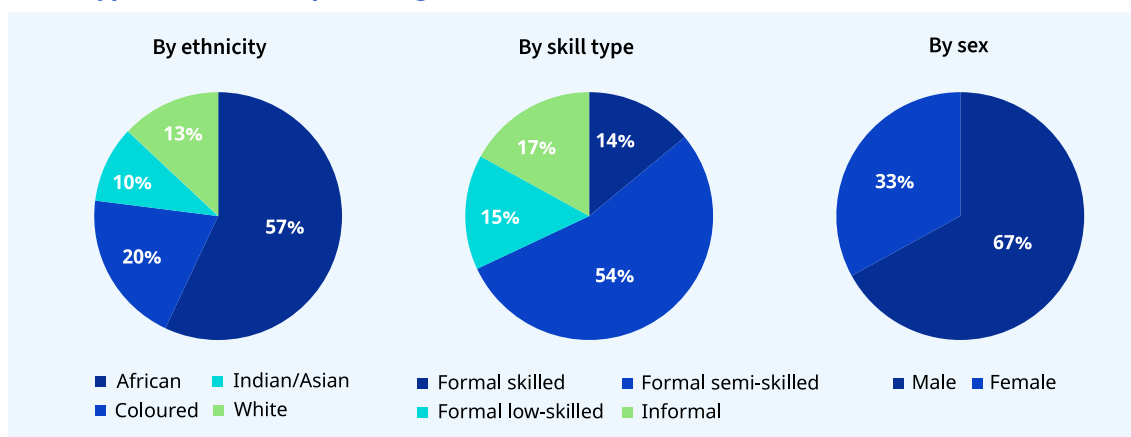
The unit labour cost has steadily increased, with the cost of labour relative to output rising from an index of 114.4 in 2018 (the base year being 2015) to 136.6 in 2022. This may have implications for the sector's competitiveness.

In terms of employment, the South African textile sector has seen a decline in both formal and informal employment over the past five years. In 2018, the total number of employees (formal and informal) was 108,384, but by 2022 it had decreased to 86,608. Formal employment has also declined, dropping from 86,481 in 2018 to 71,231 in 2022. On the other hand, informal employment in the sector has fluctuated, reaching its lowest point in 2021 at 11,687 employees, before rising to 15,377 in 2022.

Geographically, activities in the textile sector are distributed across various provinces. In particular, Gauteng is a significant hub for the sector, with gross value added at basic prices reaching 6.92 billion rand in 2022. This indicates that Gauteng makes a substantial contribution to the sector's overall economic output. Meanwhile, the Western Cape is the leading province when it comes to total employment in the textile sector. This could be due to the historical presence of the industry and accessibility to resources there. KwaZulu-Natal and Gauteng follow closely behind, likewise making significant contributions to the sector's employment landscape.

Furthermore, the data show that the textile sector has a relatively higher concentration of formal employment compared with informal employment. Thus, in 2022, formal employment accounted for approximately 82 per cent of total employment in the sector.

► **Figure 2. Breakdown of employment in the South African textile sector by ethnicity, skill type and sex, 2022 (percentage)**



Source: Quantec EasyData Industry Service, <https://www.quantec.co.za/easydata/industry-subscription/>.

Analysis of the employment distribution in the textile sector sheds light on the composition of the workforce (see figure 2). In terms of ethnicity, workers of African descent dominate with a share of 57 per cent, followed by Coloureds at 20 per cent, Whites at 13 per cent and Indian/Asians at 10 per cent. In terms of skill type, 14 per cent of the sector's workforce are formal skilled workers, 54 per cent are formal semi skilled, 15 per cent are formal low-skilled and 17 per cent are engaged in informal roles. Disaggregation by sex indicates that 67 per cent of the sector's workforce are male, while 33 per cent are female. As already mentioned, the textile sector leans towards a higher concentration of formal employment, which accounts for around 82 per cent of the total workforce. These valuable insights into the demographic make-up and skills composition of the textile industry's workforce can inform interventions and strategies to enhance diversity and productivity within both the formal and informal segments.

From examination of the table of imports it is evident that the textile sector relies significantly on the importing of specific goods. Major imports include woven fabrics of synthetic filaments, woven cotton fabrics, synthetic staple yarn, cotton yarn, and woven fabrics of artificial and synthetic fibres. These imported goods contribute significantly to the production processes within the textile industry.

Furthermore, there has been a consistent increase in the value of such imports from 2018 to 2022. This suggests a growing dependence on imported inputs in the production of textiles, clothing and leather goods. Demand for these imports is highest in the provinces of KwaZulu-Natal and Gauteng, but the Western Cape, the Eastern Cape and Mpumalanga also exhibit substantial import figures, reflecting the sector's widespread reliance on imported inputs. This highlights the importance of taking international trade dynamics and supply chain dependencies into account when studying the textile industry.

Overall, the South African textile sector has undergone some shifts in employment patterns and productivity over the past five years. Although remuneration per employee has increased, the sector is having to contend with rising labour costs. In addition, production activities are concentrated in provinces like Gauteng, which plays a pivotal role in the sector's contribution to the economy.

► **Table 2. Key statistics on the South African textile sector, 2018–22**

Year	Employment to output ratio	Remuneration to value added ratio	Remuneration per employee (rand)	Unit labour cost (index 2015=100)	Formal employment (No. of employees)	Informal employment (No. of employees)	Gross value added at basic prices (million rand, current prices)
2018	1.35	47.28	145 487	114.42	86 481	21 903	26 819.15
2019	1.29	49.05	149 027	117.14	86 313	20 312	26 490.47
2020	1.21	50.59	151 044	121.61	75 506	15 083	22 839.62
2021	1.02	49.23	174 333	127.94	70 028	11 687	25 282.32
2022	1.03	48.80	181 970	136.56	71 231	15 377	27 322.81

Source: Quantec EasyData Industry Service, <https://www.quantec.co.za/easydata/industry-subscription/>.

Analysis of key statistics from 2018 to 2022 provides a comprehensive overview of the textile sector in South Africa (table 2). While the remuneration per employee increased notably, indicating improved earnings, there was a concurrent rise in unit labour costs that points to potential constraints on competitiveness. The decline in total employment, affecting both the formal and informal segments, raises concerns about the textile sector's capacity to create jobs. Provinces such as Gauteng and KwaZulu-Natal have emerged as key players in the sector, making distinct contributions to economic output and import demand. The sector's dependency on imported goods underscores the need for strategies to enhance its competitive edge, especially in the face of significant competition from overseas markets. This analysis can help in understanding the broader implications of industrial symbiosis networks for the South African textile sector, providing valuable insights for further study and policy considerations.

5.1.2. Description of the industrial symbiosis network

Understanding the intricate dynamics of the South African textile sector is particularly relevant to industrial symbiosis, where inter-industry collaboration is paramount for achieving a circular economy.

The rise in remuneration per employee, indicating improved earnings for the sector's workers, ties in with the goals of industrial symbiosis networks. Such networks seek to create sustainable economic opportunities, and the textile sector's progress in that regard is encouraging. However, the concurrent increase in unit labour cost points to potential challenges that industrial symbiosis initiatives must tackle to ensure competitiveness.

The decline in total employment, affecting both the formal and informal segments of the textile sector, highlights the need for employment-centric strategies to be adopted within industrial symbiosis networks. By considering the nuances of employment patterns observed in the sector, symbiotic initiatives can be tailored to maximize their potential to create jobs.

Furthermore, the regional distribution of textiles activities underscores the importance of strategic placement of enterprises participating in industrial symbiosis networks. Given their substantial contributions to economic output and import demand, provinces such as Gauteng and KwaZulu-Natal could serve as major nodes within such networks. A better understanding of these regional dynamics can inform the design and implementation of effective industrial symbiosis initiatives.

The textile sector's reliance on imported goods implies an opportunity for symbiotic networks to bolster domestic production and reduce dependency on external sources. Industrial symbiosis can contribute to a more self-reliant and resilient sector by fostering synergies between industries. As already mentioned, the improvement in workers' earnings in the textile sector is aligned with the goals of sustainable economic growth through symbiotic networks. However, there is a need for targeted strategies to deal with challenges related to labour costs and employment trends. A consideration of regional strengths and import depend-

encies would open up strategic avenues for symbiotic initiatives to enhance the sector's competitiveness and resilience. The findings presented here can serve as a basis for further exploration of the potential benefits of more widespread industrial symbiosis.

The industrial symbiosis network in the South African textile sector is characterized by a complex web of interactions. For formal workers, the symbiotic relationships extend across different enterprises, each playing a distinct role in the sector's overall ecosystem. Table 3 summarizes the results of a survey conducted among three formal workers in the sector. The respondents brought a wide range of experience and skills to their current roles, in which they had been working from 16 months to 11 years. Their backgrounds are varied: the first had previously worked in an energy utility company, the second in a toyshop and the third in the healthcare sector. They have transitioned successfully to their current positions, with two respondents now on full-time permanent contracts with additional benefits. Their roles have enabled them to use and develop interpersonal, communication and administrative skills, acquired through a combination of previous work experience, formal education and on-the-job training.

With regard to the costs involved in changing jobs, one respondent had incurred relocation expenses, another was facing commuting costs, while the third had not encountered significant costs. All three respondents were satisfied with their current position and felt well-treated at work. As for remuneration, one respondent earned 22,000 rand a month: this allowed her to support her family, though she noted the high cost of living. Another believed that she could earn more in the corporate sector, given her qualifications and experience. None of the respondents received extra grants or government assistance. Responses on health insurance were mixed, with one respondent having private insurance and another expressing a desire for health insurance to be included in the benefits package. All agreed that their equipment was adequate but that it could be improved. The work schedule was typically seven to eight hours a day, five days a week, with 22 to 23 days of annual leave and flexible leave policies. Sick leave generally required a doctor's note to justify absences lasting more than three days.

Overall, the survey serves to illustrate the experiences of formal workers in the South African textile sector, focusing on their job satisfaction, working conditions and support systems.

► Table 3. Summary of responses to the survey of formal workers in the South African textile sector, September–October 2023

Respondent	Demographics	Job tenure	Years in similar jobs	Previous work	Contract in previous job	Current contract	Skills used	Learning experience	Job change cost	Job satisfaction	Treated well at work?	Monthly earnings	Enough to live on?	Grants or assistance	Health insurance	Support infrastructure (equipment etc.) is adequate?	Working hours (daily, weekly)	Leave days	Sick days	Easy to take sick leave?
T-F-A	54; female; South African	16 months	n/a	Energy provider	Permanent employee	Manager, permanent position	Interpersonal, communication and administrative skills	Had prior administrative experience and interpersonal skills through church. Learned system functions on the job.	Relocation costs	Yes	Yes	Not specified	Yes	No	Yes, privately	Yes	Standard	21 days	Not specified	Very much so, more than 3 days requires doctor's note; Friday or Monday requires doctor's note
T-F-B	38; female; South African	11 years	Not at a similar job, worked in retail	Toyshop	Standard permanent employment contract	Full-time permanent employment contract, with some benefits	Communication and people skills; delegation, problem solving, crisis management	Developed communication and people skills through retail; other skills learned on the job with mentoring	No	Yes	Yes	22,000 rand	No	No	No	Yes, with room for improvement	7–8 hrs/day, 5 days/week	22–23 days	Not specified	Yes, with doctor's note for more than 3 days
T-F-C	39; female; South African	4.5 years	3 years	Maternal Health Trust	Normal employment contract	Full-time permanent employment contract, with benefits	Strategy, vision, leadership, problem solving, HR factors	Studied HR management and psychology, gained various skills through previous jobs	Petrol costs for commuting	Yes	Yes	Not specified	Yes	No	No	Yes, proactive management	7.5 hrs/day, 5 days/week	22–23 days	n/a	n/a

n/a = not applicable; HR = human resources.

The results of the survey of informal workers in the South African textile sector are summarized in table 4. The symbiotic network there involves a diverse range of individuals engaged in various types of informal work, from clothes-selling to beadwork, often facilitated through programmes such as Taking Care of Business (TCB). They contribute to the network by providing goods and services, often reaching customers through various channels such as taxi ranks, social media and word of mouth. Experience levels vary, with some participants having been in their current job for just a few months, and others boasting three years or more of experience. Significantly, many have transitioned from formal to informal employment, adapting their job roles and skills in the process.

Entrepreneurial skills are prominent among the individuals surveyed, including problem-solving, market awareness, creative thinking, bookkeeping and time management. These skills were either pre-existing or were honed through the TCB programme, for example. Start-up costs and equipment needs are diverse: some individuals required only a minimal investment, while others had to purchase a significant amount of equipment or rent spaces. The incomes earned by participants in the network are crucial to enable them to support their families; some also receive government grants. Job satisfaction levels vary, with some participants enjoying their work, while others face challenges and are treated poorly. Sick leave policies are not uniform: some respondents reported working despite being ill, while others had to rely on family support in such situations. A common aspiration among the participants is to grow their businesses, which involves, among other things, aiming for more stable selling spaces, the acquisition of additional equipment and being able to offer a wider range of products.

These insights provide a snapshot of the diverse experiences of, and challenges faced by, informal workers in the textile sector in Cape Town and Gauteng. They illustrate the resilience, adaptability and entrepreneurial spirit of individuals engaged in this sector.

In summary, the industrial symbiosis network in the South African textile sector is based on a rich tapestry of connections and dependencies, with formal and informal workers contributing to the sector's overall resilience and competitiveness. The symbiotic relationships encompass a spectrum of skills, experiences and enterprises, creating a dynamic and interconnected ecosystem within the textile industry.

► Table 4. Summary of responses to the survey of informal workers in the South African textile sector, August–October 2023

Respondent	Demo-graphics	Job tenure	Previous work	Contract in previous job	Skills used	Learning experience	Start-up costs	Job satisfaction	Treated well at work?	Support infrastructure (equipment etc.) is adequate?	Working hours per day	Working days per week	Type of waste	Customers buying waste	Pricing of waste sold	Income shared with anyone?	Daily earnings	Enough to live on?	Grants received	Sick leave policy
T-I-A	21; male; South African	1.5 years	Spaza shop	No	Driving	Used earlier savings to learn how to drive; found someone to teach him	700 rand for driver's licence	Unsure	Yes	Owens light truck for work; hopes to own car eventually	9–11 hours	Mon–Fri	Doors and windows from old houses	Various locations in the north	100–200 rand	No, uses employer's truck	Around 500 rand	Not really	No	Works unless very sick
T-I-B	33; female; South African	2 years, 4 months	Graduate of TCB programme; informal seller of clothing, shoes, snacks and food at Nyanga taxi rank.	No	Entrepreneurial skills, problem-solving, market awareness, creative thinking, time management	Had some entrepreneurial skills before, learned more at TCB	Bought a gazebo / metal stand for 1,800 rand; rents space at Nyanga taxi rank for 350 rand a month	Yes, but challenging	Yes	TCB provided support, but she had not properly appreciated its importance before graduating. TCB offered extensive assistance, including life coaches and counsellors.	6–7 hours	Every day	None	Customers at Nyanga taxi rank, malls, passers-by	2.5 times cost price	Supports family (four brothers, three children)	300 rand on average	Too little	Two children receive grants	No
T-I-C	45; female; South African	3.5 years	Had not been working for years before joining TCB. Was unemployed and very depressed.	Yes, full-time 1 year contract	Sewing, business skills, market awareness, interior decoration, fashion	Started sewing in school, learned more at TCB	80 rand a month for spot at Mfuleni taxi rank	Yes	Yes	No sewing machine; relies on TCB equipment. After graduation, limited to weekly shopping. Planning to buy own sewing machine. Desire more men's clothing for daily sales.	6–8 hours	5–6 days	Repaired clothing	Customers at Mfuleni taxi rank, residents in Gugulethu	At least 2.5 times cost price	Supports family (four children, three grandchildren)	700–800 rand	Yes	None	Necessary to report and provide proof of sickness. Someone helps with the selling when she is unwell.
T-I-D	38; female; South African	2 years, 9 months	Ambassador for TCB programme; informal clothes seller in Delft, through WhatsApp and Facebook; Formerly at Woolworths	Yes, casual permanent employee	Record-keeping, people skills, market awareness, finding new customers	Had entrepreneurial skills before, learned more at TCB	350 rand a month for renting spot at Nyanga taxi rank	Yes, but challenging	Yes	Wishes to have gazebo and permanent container in the future; needs a greater and better supply of men's clothing	6–7 hours	5–6 days	None	Customers in Delft, Nyanga taxi rank, WhatsApp, Facebook	At least 2.5 times cost price	Supports family (four children)	250–1,000 rand	Not enough	One child receives a grant	At TCB, reporting is mandatory; cannot stay at home. Doctor's certificate required for medical appointments. If she is sick and cannot sell, this is accepted.
T-I-E	39; female; South African	1 year	“Enterprise Development Lady” under TCB programme; clothes seller near Mfuleni taxi rank; street cleaner under EPWP	Yes, 1 year full-time contract	Entrepreneurial skills, money management, saving, separating business and personal life	Learned about business and saving at TCB	80 rand a month for spot near Mfuleni taxi rank	Yes	Yes	Wants gazebo and steady supply of in-demand clothing, currently reliant on TCB equipment	6–8 hours	5 days	Repaired clothing	Customers near Mfuleni taxi rank, residents in Mfuleni	At least 2.5 times cost price	Supports family (four children)	700–800 rand	Yes	None	Daughter covers stand for her if unwell. Proof of sickness required for TCB absence; non-compliance results in a one-week shopping ban.
T-I-F	40; female; South African	1 year	Participant in the Remake programme at TCB; clothes seller in Strand; Cleaner at City of Cape Town	Yes (full time permanent)	Fashion, sewing, business, people skills	Basic sewing; learned advanced sewing, business, quality	Started with little capital, received fabric donations	Yes	Yes	Does not have a gazebo or shelter. Would like to be able to buy in bulk and have a more steady, reliable supply of in-demand clothing.	8–10 hours	5–6 days	Repaired clothing	Customers in Strand, Somerset West	2.5 times cost price	Supports family (husband, two children, extended family)	700–1,000 rand	Yes	None	Report and bring certificate for TCB absence. No sales when too sick. Husband helps with social media. Teaching nieces about business, but it is unsafe for them to go out into local neighbourhoods.

Respondent	Demographics	Job tenure	Previous work	Contract in previous job	Skills used	Learning experience	Start-up costs	Job satisfaction	Treated well at work?	Support infrastructure (equipment etc.) is adequate?	Working hours per day	Working days per week	Type of waste	Customers buying waste	Pricing of waste sold	Income shared with anyone?	Daily earnings	Enough to live on?	Grants received	Sick leave policy
T-I-G	35; female; South African	1 year	Participant in the Remake programme at TCB; clothes and beads seller on WhatsApp, Facebook and at a public market next to police station in Kraaifontein; sometimes works as a hairstylist when other business is slow. Previously selling to friends and family	No	Business skills, people skills, quality management	Had basic sewing skills, learned more at TCB	Taxi fare for transport	Yes	Yes, treated well at TCB and in her business. The only problem is that people in the community like to buy on credit.	Needs a gazebo and more variety in products	Varies depending on orders	Varies depending on orders	None	Customers through WhatsApp, Facebook, public market in Kraaifontein	Varies depending on item	Supports child, niece, husband	800–1,500 rand	Not enough, but improving	None	Report and update management when sick; husband helps when possible.
T-I-H	36; female; South African	5 months	Participant in Remake programme at TCB; clothes seller primarily in local neighbourhood in Nyanga and through WhatsApp; Helped mother with clothing business	Yes (3 months)	Sewing, business skills, customer care	Helped mother with clothing business, learned more at TCB	None, used existing resources	Yes	Yes	Saving for overlocker, currently using small sewing machine	6–7 hours	6 days	None	Customers in Nyanga, church members, WhatsApp	At least 2.5 times cost price	Supports family (mother, children)	500 rand (cash) + 2,000–2,300 rand (credit)	Not enough, but at least something	None	No backup plan when sick; husband can help if available
T-I-I	37; female; South African	1 year	Participant in the Remake programme at TCB; clothes seller in local community in Crossroads and at church; sometimes baking work at the end of the month if not enough money made selling clothes. Community care worker for those living with tuberculosis and HIV/AIDS	Yes (full time permanent)	Fashion, sewing, business skills, planning and saving, customer care, proactivity, discipline	Acquired basics at Learn to Earn, gained more advanced skills at TCB	500 rand for sewing machine	Yes	Yes	Saving for cover seam machine and overlocker	5–7 hours	7 days	Fabric offcuts, old clothes	Community in Crossroads, church members	At least 2.5 times cost price	Supports children, nephew, sister	1,000 rand (cash) or more	Not enough	Yes, three government grants for children	Necessary to report and show doctor's note if sick; husband helps when possible
T-I-J	42; female; South African	1 year	Participant in the Remake programme at TCB; clothes seller in local community (Khayelitsha), and at different markets. Unemployed (stay-at-home mother)	No	Sewing and pattern-making, technical knowledge about sewing machinery and equipment, financial skills, quality management, creativity, confidence, people skills, customer care	Acquired basics at Learn to Earn, gained advanced skills at TCB	None, used existing resources	Yes, loves the work	Yes	Wants permanent stand or gazebo; greater availability of men's clothing	7 hours	4 days	None	Community in Khayelitsha, markets, malls	At least 2.5 times cost price	Supports children (aged 13 and 9 years), nephew, sister	200 rand on an average day, 500 rand on a good day.	No, though she is earning more than before. Would like to be able to afford a house of her own and a car.	None	No backup plan when sick; husband can help deliver orders

Respondent	Demo-graphics	Job tenure	Previous work	Contract in previous job	Skills used	Learning experience	Start-up costs	Job satisfaction	Treated well at work?	Support infrastructure (equipment etc.) is adequate?	Working hours per day	Working days per week	Type of waste	Customers buying waste	Pricing of waste sold	Income shared with anyone?	Daily earnings	Enough to live on?	Grants received	Sick leave policy
T-I-K	42; female; South African	3.5 years	Participant in the Remake programme at TCB; clothes seller in local community (Khayelitsha). Community care worker for those living with tuberculosis and HIV/AIDS	Yes (full time permanent)	Fashion, sewing, business skills, planning and saving, customer care	Acquired basics at Learn to Earn, gained advanced skills at TCB	50 rand a month for spot at Khayelitsha taxi rank	Yes	Yes	Saving for cover seam machine or plain machine	7 hours	4 days	None	Community in Khayelitsha	At least 2.5 times cost price	Supports two children and one nephew, mother, sister	1,000 rand or more	Too little	Yes, three government grants for children	Necessary to report and provide doctor's note if sick; husband can help with deliveries
T-I-L	39; female; South African	7 months	"Enterprise Development Lady" at TCB; clothes seller to passers-by at a stand in Mfuleni. Uses WhatsApp and word of mouth to advertise and market the clothes; her children also help with this. Sometimes sells at markets organized by TCB. Domestic worker in private homes	No	Creativity, marketing, financial management, confidence	Learned about business and self-esteem at TCB	Only taxi fare for transport	Yes, loves the work	Challenging; some customers bargain or steal	Needs a gazebo, greater availability of men's clothing	4 hours	4 days	None	Passers-by in Mfuleni, social media, referrals	2.5 times cost price	Supports five children; husband is unemployed	200 rand on average	Not enough	None	Necessary to report and provide proof of sickness; children help with advertising
T-I-M	36; female; South African	2.5 years	Graduate of TCB Business Resell programme. Seller of clothing, food (primarily meat) and homeware from home and sometimes door to door in local neighbourhood, among church members and via social media. Cleaner (1 day a week), occasionally provides assistance in sister's clothing business	No	Financial and entrepreneurial skills, continuous business expansion, product variety, "know your customer", market awareness, creativity, fashion	Familiar with business from sister, gained advanced skills at TCB	No start up capital needed	Yes, but challenging	Some customers try to lower prices	Graduates need more support; needs gazebo	4 hours	Varies	Clothing from TCB, meat from wholesaler, cake crumbs	Neighbourhood, church members, social media	At least 2.5 times cost price	Supports family (husband, children)	Varies (80–700 rand)	Business goes up and down	None	No backup plan when sick; children help with business

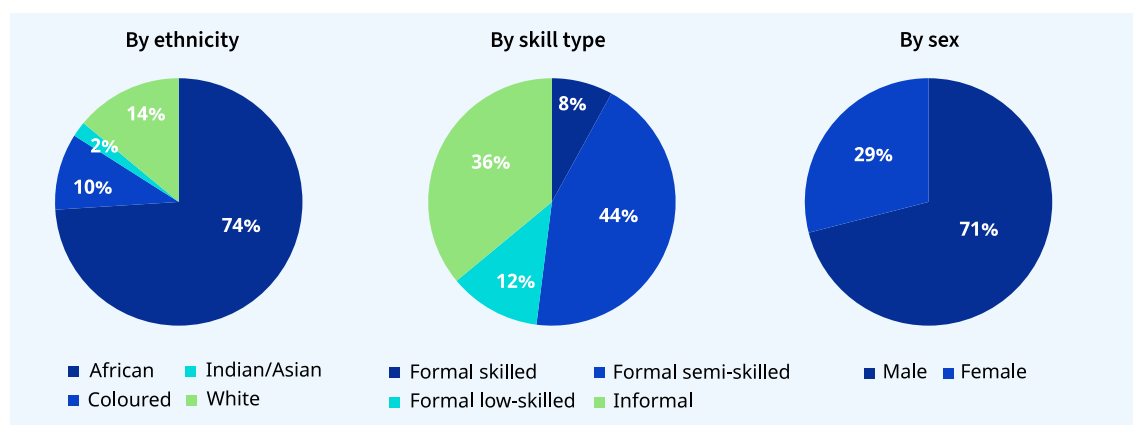
EPWP = Expanded Public Works Programme; TCB = Taking Care of Business.

5.2 Construction sector

5.2.1. Brief characterization of the sector

The following discussion is based on the key statistics for the South African construction sector from 2018 to 2022, as summarized in table 5. The construction sector is a cornerstone of the country's economy, with substantial influence over both employment and economic output. In 2022, the sector exhibited a promising increase in its employment to output ratio, signalling a potential growth trajectory. This suggests a favourable outlook for the construction industry in the coming years. Moreover, the stable ratio of remuneration to value added indicates efficiency in converting inputs into value-added output, reflecting the sector's robust performance.

► **Figure 3. Breakdown of employment in the South African construction sector by ethnicity, skill type and sex, 2022 (percentage)**



Source: Quantec EasyData Industry Service, <https://www.quantec.co.za/easydata/industry-subscription/>.

The construction sector is a major driver of employment in South Africa, its workforce numbering over 820,000 individuals in 2022. This sector has a diverse demographic composition (see figure 3). In terms of ethnicity, a majority of workers (74 per cent) are of African descent, followed by Whites at 14 per cent, Coloureds at 10 per cent, and Indian/Asians at 2 per cent of the total construction workforce.

The employment distribution by skill type reveals a hierarchical structure within the construction workforce, ranging from formal skilled workers to formal semi-skilled and low-skilled workers. Formal employment accounts for 64 per cent of the total workforce, highlighting the importance of skilled roles within the construction sector. Specifically, formal skilled workers comprise 8 per cent of total employment in the sector, while formal semi-skilled and low-skilled workers account, respectively, for 44 per cent and 12 per cent of the total.

On the other hand, informal employment, which accounts for 36 per cent of the construction workforce, contributes substantially to the overall employment landscape, reflecting the sector's adaptability and the existence of diverse roles that fall outside the formal structure.

In terms of gender distribution, male workers make up 71 per cent of the construction workforce, while female workers account for 29 per cent.

This employment diversity reflects the multifaceted nature of the construction industry, where individuals from various demographic backgrounds and skill levels collaborate to contribute to the sector's growth and dynamism.

Gauteng and KwaZulu-Natal are the leading provinces in terms of driving employment and output in the construction industry. With over 281,000 individuals employed in the sector, Gauteng emerges as the most influential region in that regard, closely followed by KwaZulu-Natal, with more than 127,000 construction workers. Provinces such as the Northern Cape and the Free State have comparatively smaller construction sectors, reflecting their lower population densities and urban development levels.

The sector exhibits a diverse employment landscape that encompasses formal and informal workers. While formal employment offers stability and social protections, informal employment provides flexibility, albeit without those safeguards. Informal labour contributes significantly to the sector, with around 300,000 individuals participating in informal construction activities in 2022. This dual nature of employment necessitates tailored approaches to address the distinct needs and challenges faced by formal and informal workers.

Notably, there is a disparity in remuneration between the two categories of workers. In 2022, formal employees received an average remuneration of approximately 172,117 rand, while their informal counterparts received considerably less, namely an average of 17,964 rand. This underscores the importance of initiatives aimed at enhancing conditions and opportunities for informal labourers in the construction sector.

Analysis of the survey responses of informal construction workers (summarized in table 6) sheds light on the contextual factors that may be contributing to the observed difference in remuneration. For instance, respondent C-I-A, a 21-year-old South African man, operates in the construction sector as a secondary job while managing a spaza (a small unofficial shop): the flexibility and part-time engagement pursued may be behind the lower daily earnings that he reported. Respondent C-I-B, a 28-year-old Zimbabwean man, transitioned from his uncle's business to informal construction, illustrating the diverse backgrounds of informal workers. Respondent C-I-D, a 35-year-old South African woman, had a previous contract as a street cleaner with the City of Cape Town and engaged in sewing and business activities. The lower daily earnings may be influenced by the practice of sharing income with her children, impacting her overall earnings. Additionally, the variable nature of her work may contribute to fluctuations in income.

Furthermore, the cases of workers such as respondent C-I-E, a 36-year-old South African man, and respondent C-I-F, a 39-year-old South African man, who are able to draw on their past experience in a shipping company and a security firm, respectively, highlight the influence of prior skills on the type of work undertaken in the informal construction sector. Significantly, the daily earnings of respondent C-I-G, a 22-year-old Malawian man who engages in various tasks related to collection, sorting and driving, demonstrate the potential for income variability within the sector.

The respondents in the survey came from diverse backgrounds and brought varying levels of experience to their current roles, ranging from newcomers to those who had worked for many years in various fields, including teaching and security work. Their skills were often acquired on the job or through informal training, as in the case of respondent C-I-C, who independently taught himself business management for his start-up, or that of respondent C-I-B, who was able to apply record keeping skills learned from his uncle. The start-up costs for these workers varied significantly, with some, like respondent C-I-D, incurring minimal expenses, while others, like respondent C-I-C, had to invest heavily in materials and infrastructure.

The workers generally expressed job satisfaction, valuing the opportunity to work and achieve economic independence, despite facing challenges such as safety concerns, the need for better equipment and customer-related issues. Their incomes are highly variable, ranging from 100 to 8,000 rand per day, and many share their earnings with family members. Some also receive government grants for additional financial support. Support networks play a vital role, especially during sickness, with some workers having family members or colleagues to cover for them, while others, like respondent C-I-G, rely on industry connections for replacements.

On the whole, this survey illustrates the diverse experiences of, and challenges faced by, informal workers in the construction sector, highlighting the importance of providing targeted support and resources to enhance their livelihoods.

The diversity in demographics, work arrangements and tasks undertaken by informal construction workers underscores the need for a nuanced understanding of the sector.

► **Table 5. Key statistics on the South African construction sector, 2018–22**

Year	Employment to output ratio	Remuneration to value added ratio	Remuneration per employee (rand)	Unit labour cost (index 2015=100)	Formal employment (No. of employees)	Informal employment (No. of employees)	Gross value added at basic prices (million rand, current prices)
2018	2.08	61.38	172 117	121.63	522 159	299 839	163 385.12
2019	1.95	60.99	159 174	125.58	556 116	228 779	165 682.24
2020	2.00	64.19	152 228	129.30	569 204	283 036	137 623.82
2021	1.78	63.35	161 823	135.98	613 392	337 707	142 387.82
2022	1.81	62.47	156 269	142.84	630 267	381 534	146 599.82

Source: Quantec EasyData Industry Service, <https://www.quantec.co.za/easydata/industry-subscription/>.

In summary, the construction sector is a linchpin of the South African economy in terms of generating employment opportunities and driving economic growth. Given the duality between formal and informal employment and regional disparities, carefully tailored strategies are required to foster inclusivity and sustainability within the industry. Efforts geared towards formalization and improving conditions for informal workers are imperative to build a more equitable and resilient construction sector in South Africa.

5.2.2. Description of the industrial symbiosis network

The dynamics in South Africa's construction sector are relevant to the broader context of industrial symbiosis. Understanding the intricacies of employment patterns and economic contributions in the construction industry can yield valuable insights for the potential integration of symbiotic networks.

In particular, the sector's reliance on formal and informal labour points to the need for inclusive approaches in industrial symbiosis initiatives. Efforts to enhance conditions for informal workers, akin to strategies required in the construction sector, should also be undertaken in the development of industrial symbiosis networks. This would ensure that such networks accommodate the diverse workforce composition often seen in sectors like construction.

Moreover, the regional distribution of construction activities, with Gauteng and KwaZulu-Natal being the leading provinces in terms of employment, confirms the significance of geographical concentration in economic sectors. This insight can inform the planning and establishment of industrial symbiosis networks, where it is important to take into account the strategic placement of participating industries so as to maximize synergistic benefits.

The construction sector's pivotal role in job creation and economic advancement bodes well for the impact that industrial symbiosis could have on local economies. By fostering collaborative relationships between industries, symbiosis can drive employment opportunities and stimulate economic growth in South Africa, much like the construction sector has already done.

The insights gained from analysis of employment patterns in the construction sector and its contributions to the economy offer a valuable framework for understanding the potential dynamics of industrial symbiosis networks, specifically among the informal workers surveyed for this study. A case in point is the symbiotic relationship between local builders and suppliers of construction materials. In this network, informal workers, both formal and informal, play a crucial role as end users and collectors of waste materials. Builders benefit from a cost-effective source of the materials such as doors and windows for construction, while waste collectors have access to a steady supply for their recycling efforts. This interdependence reflects the importance of inclusivity, regional considerations, and the broader economic impact of symbiotic relationships within the construction sector – aspects that are highly relevant to the design and implementation of effective industrial symbiosis initiatives in South Africa.

► Table 6. Summary of responses to the survey of informal workers in the South African construction sector, September–October 2023

Respondent	Demographics	Job tenure	Previous work	Contract in previous job	Skills used	Learning experience	Start-up cost	Job satisfaction	Treated well at work?	Support infrastructure (equipment etc.) is adequate?	Working hours	Type of waste collected	Customers buying waste	Pricing of waste sold	Income shared with anyone?	Daily earnings	Enough to live on?	Grants received	Sick leave
C-I-A	21; male; South African	1.5 years	Spaza shop	No	Driving	On the job with guidance	Approx. 700 rand for licence	Satisfied, but unsure about future	Yes	No ownership of vehicle	9–11 hrs/day, Mon–Fri	Doors, windows, etc.	Local buyers	100–200 rand	No	Approx. 500 rand	No	No	Continues working unless very sick
C-I-B	28; male; Zimbabwean	6 years	Uncle's business	n/a – unemployed	Record-keeping	Learned from uncle	No initial cost	Satisfied, but finds job challenging	Yes	Needs more computers	7–9 hrs/day, 5 days/week	Mostly timber	Local carpenters	100–1,500 rand	Yes, shared	Approx. 520 rand	Yes	No	Yes, some pay cuts
C-I-C	54; male; Zimbabwean	±20 years	Teacher	Yes	Business management	Started from scratch with savings	Initial materials cost (not specified)	Satisfied; busy but glad to be able to help his family	Yes	A new truck would help	12 hrs/day, every day	Doors, windows, etc.	Local buyers	100–200 rand	Yes, income is for family	Variable (up to 8,000 rand)	No	No	Yes, but still works when sick
C-I-D	35; female; South African	1 year	City of Cape Town (street cleaning)	3-month contract	Sewing, business skills	Learning at TCB	Only transport cost	Enjoys the work, but has some safety concerns	Yes	Wants more machinery	7 hrs/day, 5 days/week	Sells sewn items	Community members	100–300 rand	Shared with children	Variable (up to 400 rand)	No	Yes, children receive	No response provided
C-I-E	36; male; South African	3 years	Shipping company	Yes	Warehouse work, material collection	Similar to previous job	No specified initial cost	Content with work	Yes	May need a forklift	10 hrs/day, 5 days/week	Wood, tiles, etc.	Builders, renovators	Varies by item	Yes, shared	Approx. 800 rand/day	No	No	Yes, seeks replacements
C-I-F	39; male; South African	8 years	Security company	Yes	Security duties	Experience in same field	No	Satisfied, but has some safety concerns	Yes	Safety equipment needed	Varies (up to 12 hrs/day)	Various construction materials	Builders, homeowners	Not specified	Yes, shared	Approx. 800 rand/day	No	No	No response provided
C-I-G	22; male; Malawian	3 years	Farming	No	Collection, sorting, driving	Basic knowledge from farming	Purchased small car with brother	Aiming to grow his business	Yes	Some equipment upgrades desired	Varies (2–12 hrs/day)	Woodchips, sawdust	Local community members	20 rand/kg	Yes, shared	Up to 1,600 rand/day	No	No	Yes, seeks replacements

TCB = Taking Care of Business.

5.2.3. Quantitative impact

In certain instances, adjustments were necessary to address gaps and limitations in the survey data and the responses collected. This involved making inferences and using responses to related questions as proxies to perform accurate calculations.

The findings of this study demonstrate a notable positive quantitative impact of industrial symbiosis on job generation, as summarized in tables 7 to 10.

► **Table 7. Impact of industrial symbiosis on total job creation in the textile and construction sectors, South Africa, 2018–22**

Waste stream (type of company)	No. of jobs replaced	Base employment	No. of jobs created through substitution effect	No. of jobs created through activity effect	Total impact (% increase)
Textiles	110	2 851	605	107	25%
Construction	26	2 071	514	57	28%

Source: Authors' calculations based on the methodology of Abriata and Masut (2021).

As can be seen from table 7, the total quantitative impact of the selected symbiosis networks on job creation in South Africa is highly significant. In the textile sector, the symbiosis network replaced 110 jobs, resulting in a base employment of 2,851 workers. The substitution effect in this case created an impressive 605 jobs in total, while the activity effect further added 107 jobs to the workforce. This translates into a 25 per cent increase in total employment between 2018 and 2022.

In the construction sector, the impact is even more pronounced. With 26 jobs replaced, the base scenario yielded a base employment of 2,071 workers. The substitution effect here led to the creation of 514 jobs in total, while the activity effect contributed an additional 57 jobs. This translates into an impressive 28 per cent increase in total employment between 2018 and 2022.

In the textile sector, the substitution effect is the primary driver of the positive impact of industrial symbiosis on employment. This is because the processes involved in utilizing textile waste create a surge in demand for labour, goods and services. Essentially, by repurposing textile waste, companies generate new economic activity that would not exist if the waste were discarded. This leads to additional jobs and economic value within the sector. On the other hand, while still present, the activity effect is comparatively small. This is because textile production relies heavily on the volume of raw materials received, and the remuneration for waste does not significantly alter the sector's overall profitability. The focus of the industrial symbiosis network in this sector lies on addressing the crucial logistical challenge of disposing of waste without causing environmental harm, thereby leading to positive economic outcomes.

In the construction sector, the activity effect is more prominent in driving the positive impact of industrial symbiosis. This is due to the nature of the construction industry, where activities related to building and infrastructure development inherently lead to increased economic activity, as reflected in the need for skilled labour, materials and services. The substitution effect also plays a significant role in this sector, contributing to the positive impact of symbiosis on employment and economic activity. This effect arises from the processes involved in repurposing construction waste, which leads to additional demand for labour, goods and services, ultimately creating positive economic ripples.

In both sectors, the symbiosis networks leverage the existing waste streams to unlock economic potential. By reusing and repurposing waste materials, these networks address environmental concerns and stimulate economic growth. This dual benefit of reducing waste and driving economic activity exemplifies the ability of industrial symbiosis to foster sustainable and resilient industries.

5.2.4. Direct effect

The symbiosis networks in the textile and construction sectors in South Africa have been found to have a notable direct impact (see table 8). In the textile sector, the symbiosis network replaced 110 jobs in the base scenario, resulting in a base employment of 457 individuals. In this case, the substitution effect led to the creation of 84 direct jobs, while the activity effect further added 18 direct jobs to the workforce. Industrial symbiosis increased total employment in the textile sector by 22 per cent between 2018 and 2022.

► **Table 8. Impact of industrial symbiosis on direct job creation in the textile and construction sectors, South Africa, 2018–22**

Waste stream (type of company)	No. of jobs replaced	Base employment	No. of jobs created through substitution effect	No. of jobs created through activity effect	Total impact (% increase)
Textiles	110	457	84	18	22%
Construction	26	319	26	2	9%

Source: Authors' calculations based on the methodology of Abriata and Masut (2021).

In the construction sector, the direct impact was also significant. With 26 jobs replaced, the base scenario yielded an employment base of 319 workers. The substitution effect added 26 direct jobs to the workforce, while the activity effect contributed an additional 2 positions. Industrial symbiosis led to a 9 per cent increase in total employment in the construction sector between 2018 and 2022.

These positive direct effects in both sectors confirm the potential of symbiosis networks to generate employment and contribute to economic growth.

5.2.5. Indirect effect

The positive indirect impacts of industrial symbiosis within the textile and construction sectors are evident, as indicated in table 9. The changes to production processes and increased overall activity translate into heightened expenditures along the value chain, subsequently leading to the creation of additional jobs. In the baseline scenario for the textile sector, the initial employment stands at 1,264 individuals. The substitution effect contributed to an extra 10 indirect jobs, complemented by an additional 4 positions through the activity effect. Consequently, industrial symbiosis brought about a 1 per cent increase in indirect employment between 2018 and 2022. These newly created indirect jobs in the textile sector encompass diverse activities throughout the value chain, such as weaving and the manufacture of cushions and carpets using collected waste materials.

For the construction sector, the impact is also notable. With no specific number of jobs replaced provided, the base scenario yielded a base employment of 489 workers. The substitution effect added 9 indirect jobs, while the activity effect contributed an additional 13 positions. Industrial symbiosis thus resulted in a 4 per cent increase in indirect employment between 2018 and 2022. The indirect jobs created in the construction sector are linked to specific activities along the value chain, such as the salvaging of materials, the collection of demolition waste and various other construction-related tasks.

► **Table 9. Impact of industrial symbiosis on indirect job creation in the textile and construction sectors, South Africa, 2018–22**

Waste stream (type of company)	No. of jobs replaced	Base employment	No. of jobs created through substitution effect	No. of jobs created through activity effect	Total impact (% increase)
Textiles	–	1 264	10	4	1%
Construction	–	489	9	13	4%

Source: Authors' calculations based on the methodology of Abriata and Masut (2021).

In summary, the symbiosis networks in the textile and construction sectors have demonstrated positive indirect impacts, indicating their potential to generate employment and contribute to economic growth in South Africa.

5.2.6. Induced effect

The induced effect is a straightforward extension of the direct and indirect effects. It encompasses the additional jobs created as a result of increased economic activity generated by the initial employment boost. More specifically, the induced effect reflects the way in which an expanded demand for goods and services leads to further job opportunities across various sectors (see table 10).

In the case of the textile sector, the survey conducted and the approach used do not allow us to calculate the number of individuals replaced. The base employment stood at 1,129 workers. The substitution effect led to the creation of 511 induced jobs, while the activity effect contributed an additional 85 positions. This translates into a significant 53 per cent increase in induced employment between 2018 and 2022. The surge in textile demand as a result of industrial symbiosis triggers an economic cascade. The textile industry experiences heightened production and increased employment, with wholesalers playing a pivotal role in efficient distribution of the textiles. Retailers benefit from the upswing, witnessing increased sales and employment. The transport sector is in high gear, ensuring seamless logistics. Beyond the immediate players, companies in diverse business areas also enjoy heightened demand, highlighting the interconnected nature of industries. Symbiotic relationships thus foster economic growth as the induced effect weaves together the fortunes of the textile, wholesale, retail and transport sectors.

Similarly, in the construction sector, our methodology does not allow calculation of the number of individuals replaced. However, the base employment stood at 1,264 workers. The substitution effect here resulted in an impressive 480 induced jobs, while the activity effect contributed an additional 42 positions. This translates into a substantial 41 per cent increase in induced employment between 2018 and 2022. The construction sector's upswing reverberates across diverse industries. Mining experiences heightened demand for materials such as coal, iron ore and non-metallic minerals, leading to increased extraction activities. Manufacturing sees a surge in various outputs, from wood and paper to chemicals and metal products. Transport services thrive with the increased movement of construction materials. Wholesale and retail trade benefit from the construction sector's expansion, reflecting its central role in supply chains. By creating induced jobs in such sectors as agriculture, mining, manufacturing and services, the symbiosis network's impact extends beyond direct construction-related activities and can help to promote a robust economic ecosystem.

► **Table 10. Impact of industrial symbiosis in the textile and construction sectors on induced job creation in all sectors, South Africa, 2018–22**

Waste stream (type of company)	No. of jobs replaced	Base employment	No. of jobs created through substitution effect	No. of jobs created through activity effect	Total impact (% increase)
Textiles	–	1 129	511	85	53%
Construction	–	1 264	480	42	41%

Source: Authors' calculations based on the methodology of Abriata and Masut (2021).

Overall, the induced effects testify to the substantial economic impact of the symbiosis networks in both the textile and construction sectors. The expansion of economic activity not only leads to job creation but also contributes to overall economic growth and development in South Africa.

5.2.7. Qualitative impact

Several noteworthy insights have emerged from our survey of formal and informal workers in the South African textile and construction sectors.

Qualitative impact: Unveiling the dynamics of symbiosis networks

The symbiosis networks within South Africa's textile and construction sectors function as collaborative ecosystems, fostering economic empowerment, sustainability and regional growth. The textile sector's symbiosis network, illustrated by initiatives like the TCB programme, comprises multiple branches that enhance economic resilience for informal workers. Through this network, unemployed mothers receive training, gain access to discounted clothing and are empowered to venture into entrepreneurship, establishing a symbiotic relationship grounded in the exchange of knowledge, resources and discounted goods.

In the construction sector's symbiosis network, the interplay between formal and informal employment has resulted in the emergence of pivotal hubs in such provinces as Gauteng and KwaZulu Natal. This highlights regional concentrations and collaborative strategies. The network creates a variety of job opportunities by drawing on tailored approaches to address unique challenges.

Textile sector: Formal and informal perspectives

Examination of the responses to a survey of formal and informal textile workers helps to provide a nuanced understanding of the impact of industrial symbiosis. Three individuals from diverse backgrounds within the formal industry shared their perspectives. An education manager at an energy producer who transitioned to a permanent managerial position in a textile company emphasized the importance of interpersonal skills and expressed satisfaction with her new job. An operations manager at TCB said that she found fulfilment in her varied role, acknowledging the challenges but appreciating her remuneration. A branch manager at TCB praised the supportive work environment and the positive transformations that had been enabled by the TCB programme.

Informal traders in Cape Town: Resilience and aspirations

An informal community of traders within Cape Town's historic neighbourhoods significantly contributes to the city's vibrancy. The survey responses shed light on the challenges that they face, their aspirations and the collective tenacity behind their trading activities. Despite a perpetual scarcity of resources, these traders demonstrate great inventiveness and determination. Their aspirations to acquire better equipment such as a truck or sewing machine reflect a common yearning for autonomy. The web of relationships binding these traders to their communities is characterized by sustainability and resourcefulness.

The impact of industrial symbiosis programmes: Bridging the formal and informal sectors

Survey studies collectively underscore the positive impact of programmes like TCB on the formal textile sector workforce in South Africa. Stable employment, skills acquisition, job satisfaction and adequate remuneration are prominent themes in the survey responses. While employees generally express contentment with their working conditions, there is a shared recognition of the potential for higher earnings in view of their qualifications and experience. These responses underline the importance of stable employment and supportive work environments in fostering job satisfaction and personal growth.

Informal construction sector: Unveiling challenges and aspirations

The survey of informal construction workers yielded valuable insights into the employment effects of industrial symbiosis networks in the South African informal economy. The responses illustrate the diversity of workers engaged in that sector with regard to their levels of experience, skills and challenges faced. Many respondents noted the importance of equipment, ownership and safety, and likewise the need for growth and stability in their businesses. These insights offer valuable information for policymakers and stakeholders aiming to enhance job creation and formalization within industrial symbiosis networks.

5.2.8. Composition effect

To further analyse the impact of industrial symbiosis on job creation, we examine the associated “composition effect” using an approach similar to that of Abriata and Masut (2021), with a focus on equal opportunities. This involves evaluating the share of various socio-demographic groups in the employment changes resulting from industrial symbiosis. The qualitative indicators for the direct employment effects are based on measuring the proportion of women, individuals without secondary education and women without secondary education in the total number of jobs created or destroyed. Since induced job creation operates primarily through consumption, we considered it less pertinent to analyse the composition of induced employment changes, which are expected to reflect the existing socio demographic composition in the absence of symbiosis.

Analysis of the employment effects of industrial symbiosis networks in the South African informal economy, specifically focusing on the provinces of Gauteng and the Western Cape, reveals notable disparities between the textile and construction industries (see table 11). In the textile sector, a striking 87 per cent of the total jobs created or destroyed as a result of the implementation of industrial symbiosis were held by women. Moreover, 21 per cent of these positions were filled by individuals without a secondary education, which suggests that industrial symbiosis is an inclusive approach that provides opportunities for those with lower educational attainment.

The impact of industrial symbiosis on employment dynamics in the construction sector was quite different. Only 31 per cent of the total jobs created or destroyed were held by women, suggesting a comparatively lower level of female participation in the workforce influenced by industrial symbiosis in that sector. Significantly, no jobs were created or eliminated for individuals without a secondary education in the construction sector, which may indicate that higher levels of education or specialized skills are required in that field.

To contextualize these findings, table 11 also provides some relevant information on the broader regional labour markets of Gauteng and the Western Cape, specifically on the proportion of unemployment in each province accounted for by women and individuals without a secondary education.

► **Table 11. Composition of employment changes generated by industrial symbiosis in the textile and construction sectors; and characteristics of the regional labour market (Gauteng and Western Cape), 2022**

Direct and indirect job creation	Textiles	Construction
Share of women in the total number of jobs created or destroyed	87%	31%
Share of individuals without secondary education in the total jobs created or destroyed	21%	0%
Share of women without secondary education in the total jobs created or destroyed	17%	0%
Characteristics of the regional labour market	Gauteng	Western Cape
Share of women in regional unemployment	47%	49%
Share of individuals without secondary education in regional unemployment	20%	17%
Share of women without secondary education in regional unemployment	9%	9%

Source: Authors' calculations based on the methodology of Abriata and Masut (2021).

In summary, the findings presented here highlight the transformative impact of industrial symbiosis networks in the South African informal economy, particularly in the textile sector, where a substantial increase in employment opportunities for women and individuals without secondary education was observed.

► 6. Conclusions and recommendations

Industrial symbiosis, as evidenced by its implementation in South Africa, stands out as an important mechanism for fostering both employment growth and formalization. This study has revealed how industrial symbiosis networks have a positive impact on informal jobs and enterprises, highlighting cases where individuals have been able to acquire valuable technical and entrepreneurial expertise. While such positive effects as stable employment, skills acquisition, job satisfaction and adequate remuneration manifest themselves clearly, it is not so easy to identify the impact of industrial symbiosis on the formalization of informal jobs. Nevertheless, the textile and construction sectors provide compelling narratives of how interconnected business relationships can pave the way for job creation and facilitate a shift from informal to formal economic activities.

This is best exemplified by the Taking Care of Business (TCB) programme, which provides skills training supported by the application of industrial symbiosis in practice. The use of materials and by-products from across the textile value chain keeps input costs for TCB low and shows those enrolled in the programme how they, too, can minimize the variable costs of business operation. By providing opportunities for personal growth, the TCB programme plays a pivotal role in bridging the divide between the informal and formal segments of the economy. While those enrolled receive business training which could potentially lead to formalization, many participants still continue to operate their microenterprises informally. This shortcom-

ing could be addressed through policy and regulatory changes. As industrial symbiosis has been shown to have positive employment effects in the textile sector, investing in such linkages could help to reverse the overall decline in textile jobs. Furthermore, the textile sector's reliance on imported goods presents an opportunity for symbiotic networks to bolster domestic production and reduce dependency on external sources. Industrial symbiosis can contribute to a more self-reliant and resilient textile sector by fostering synergies between industries. Our estimates indicate that from 2018 to 2022 employment increased by 25 per cent in this sector thanks to industrial symbiosis.

While job growth in the traditional construction sector remains sturdy without industrial symbiosis interventions, it is clear that such linkages would enable further growth. Indeed, our modelling suggests that a 28 per cent increase of total job creation occurred during the period from 2018 to 2022 through the employment effects of industrial symbiosis. Given that informal workers account for 37 per cent of the construction sector's workforce, and given also the stark difference in average remuneration between formal and informal construction workers (172,117 rand versus 17,964 rand), it is essential that the Government should intervene to promote formalization of the sector. This would not only support the sector specifically, but, owing to the nature of the construction industry, also lead to increased economic activity overall.

In both sectors, industrial symbiosis networks leverage the existing waste streams to unlock economic potential. The ensuing demand for skilled labour, goods and services drives employment. By reusing and repurposing waste materials, these networks address environmental concerns and stimulate economic growth. This dual benefit of reducing waste and driving economic activity exemplifies the ability of industrial symbiosis to foster sustainable and resilient industries. However, more needs to be done to promote the transition from informal to formal employment. A targeted approach will be crucial to ensure that formalization is not only widespread but also balanced and inclusive. Building on continued research and practical implementation, industrial symbiosis networks can help to transform South Africa's industrial landscape and contribute to a more sustainable and prosperous future.

This process would be supported by implementation of the following recommendations:

- ▶ **Expansion of symbiotic networks** – Given their positive impact on employment in the textile and construction sectors, policymakers would be well advised to promote and expand industrial symbiosis networks in other sectors across the country. Drawing on the success of the Gauteng and Western Cape Industrial Symbiosis Programmes, a tailored regional focus for each of the provinces that recognizes the unique characteristics of their labour markets, sectoral demands and environmental challenges would ensure more effective formalization and employment growth. This could be achieved by identifying linkages across sectors and by developing business cases at the level of micro, small and medium-sized enterprises.
- ▶ **Resource allocation** – The informal traders and workers surveyed for this study emphasized the importance of resource ownership. Policies that facilitate access to essential tools, machinery and vehicles could help to catalyse formalization.
- ▶ **Expanded research** – It is necessary to explore the hurdles to formalization in both of the sectors studied and more broadly in South Africa. It is clear that informality contributes significantly to the economic make-up of the country, but in order to fully capture the potential of informal activities and support decent work, more research is required to understand why those with high business acumen and access to resources are continuing to operate informally.

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Appendix A. Interview guide

- ▶ Greetings and introduction to the project.
- ▶ Introduce yourself and the purpose of the interview.
- ▶ Confidentiality and study identifiers.
- ▶ Ask for permission to record the interview, ensuring the interviewee is at ease.
- ▶ Make it clear that no personal information will be shared, and that the information gathered will be aggregated.
- ▶ A simple agreement in line with the Protection of Personal Information Act should be signed before proceeding.

Questionnaire for enterprises

1. Name and address of organization

.....

2. Years operational

.....

3. Can you provide a brief overview of your enterprise and its involvement in industrial symbiosis?

.....

4. What are the specific industrial symbiosis initiatives or networks in which you participate?

.....

5. How do you collaborate with other organizations in your network? How frequently are you in contact?

a. What forms of communication do you use?...

b. How formal is the level of engagement and resource- and information-sharing in your network?

c. Are there contracts in place?

d. How supportive is your network in terms of helping your organization to grow?

.....

6. Do you sell any of your waste streams/by-products to other companies?

a. Who buys your waste/by-products?

b. At what price do you sell your waste/by-products?

c. How are they used?

.....

7. Who takes your waste for free?

.....

8. What by-products do you use?

- a. At what price do you buy them?
- b. How do you use them?
- c. Do you get any for free?

9. Could any of your raw materials possibly be replaced with a by-product or waste product? If yes, please specify

10. What is the most important parameter in determining whether a by-product can be used as an input in your production processes?

- a. The content of heavy metals and other polluting substances
- b. Geographical and seasonal limitations
- c. Problems related to hygiene
- d. Regulations and fees
- e. Problems of odour or aesthetics
- f. The environmental policy of your enterprise
- g. Tradition
- h. Safe/stable and reliable delivery
- i. Technical limitations
- j. Others

11. What were your motivations for engaging or participating in industrial symbiosis?

12. Have there been more jobs created (informal or formal), new skills developed or other impacts on the workforce as a result of this work?

13. Have you faced any challenges in how you go about implementing/maintaining industrial symbiosis practices? How do you resolve or address these?

14. How do you manage the different waste streams?

- a. Disposal
- b. Reuse internally
- c. Recycle internally
- d. Energy recovery internally
- e. Disposal
- f. Recycle externally
- g. Other waste management measures (including transport)

15. Is there the possibility of selling/recycling/reusing/recovering any of the waste streams that are currently disposed of? Would that increase the labour force needed?

16. What is the role of the Government, industry and non-profit organizations in the industrial symbiosis work you carry out?

.....

17. Do you receive support from the Government in relation to industrial symbiosis? And in relation to the jobs that such symbiosis creates?

.....

18. What could the Government do better to support industrial symbiosis and/or employment creation?

.....

19. How many people work in your company? Could you provide me with further demographic information on individuals from marginalized groups (i.e. women, migrants, young people, persons with disabilities) who are employed there? How has this changed over time?

.....

20. How many jobs do specific waste streams require?

.....

21. How are the skills for those jobs segmented demographically?

.....

22. Would you have generated more, less or the same revenue because of this work?

.....

Questionnaire for formal workers

1. Name and organization
2. Demographics (age; gender identifier; nationality)
3. How long have you been working here?
4. How long have you worked in a similar job?
5. Where did you work before?
6. What kind of contract did you have before?
7. What kind of contract do you have now?
8. What kind of skills do you use in this job?
9. How much did you already know before you started working in this job and how much did you have to learn? How did you learn what you had to learn (on the job alone, someone explained it to you informally, etc.)?
10. Did it cost you anything to change jobs?
11. Do you like working here?
12. Do you feel you are treated well?
13. How much do you earn?
14. Is it enough to support yourself?

15. Do you receive any government grants or assistance as well?
16. Do you have health insurance?
17. Are you provided with the right equipment to do the work you do? Is there anything that could be better?
18. How many hours do you work in a day? How often do you work each week?
19. How many days of leave do you get?
20. How many sick days are you entitled to?
21. Is it straightforward for you to take those days when you need to?

Questionnaire for informal workers

1. Name and place of work
2. Demographics (age; gender identifier; nationality)
3. How long have you been doing this job?
4. Where did you work before?
5. Did you have a contract in your previous job?
6. What kind of skills do you use in this job?
7. How much did you already know before you started working in this job and how much did you have to learn? How did you learn what you had to learn (on the job alone, someone explained it to you informally, etc.)
8. Did it cost you anything to start doing this job?
9. Do you like this job?
10. Do you feel you are treated well?
11. Do you have the right equipment to do the work you do? Is there anything that could be better?
12. How many hours do you work in a day? How often do you work each week?
13. What kind of waste do you find?
14. Whom do you sell it to?
15. For how much?
16. Do you share this money with anyone?
17. Do you find it enough to support yourself?
18. Do you receive any grants?
19. What happens when you are sick?

Appendix B. Methodology for quantitative impact assessment

This appendix draws on the work of Abriata and Masut (2021).

Expansion factor

The first step in the methodology involves determining an “expansion factor” for each company surveyed so that the observations made for each one can be “expanded” to the whole sector.

The roles played by the companies participating in an industrial symbiosis scheme are defined by the products that they manufacture and by the waste that they generate. For the purposes of this study, such an approach provides a fairly accurate characterization of all the types of companies that may be involved in such a scheme.

The use of expansion factors relies on having a metric that captures a company’s share in the overall role played by all companies of the same type. The choice of metric depends on its relevance to measuring these aspects and on data availability. Since our primary concern is the number of jobs, we opted to “expand” the responses of individual enterprises using variables that reflect economic activity levels, such as employee count, processed volume and sales figures, rather than the sheer number of companies.

We may then define the expansion factor xf for each company i . It is calculated as the quotient of the value of the individual metric M_i and the sum of the total values of the metric for each main good or service b and residue or by-product z :

$$xf_i = \frac{M_{i,b,z}}{\sum_i M_{i,b,z}}$$

Direct effect

The initial measure of impact is the net direct employment resulting from the substitution effect in the industrial symbiosis scheme, denoted as $FDSE$. This value is directly derived from the aggregated responses to question 12 ($r12$) for each company i participating in the scheme.

$$FDSE = \sum_i FDS_i$$

$$FDS_i = xf_i \times r12_i$$

Subsequently, we compute the net direct employment resulting from the activity effect, $FDAE$, by utilizing the responses to questions 19 ($r19$) and 22 ($r22$), through the following formula:⁵

$$FDAE = \sum_i FDA_i$$

$$FDA_i = xf_i \times r22_i \times \left(\frac{r19_i}{1 + r22_i} \right)$$

5 The specific questions used may be consulted in the “Questionnaire for enterprises” in Appendix A.

This formula operates under the assumption that the labour input per unit produced remains constant, implying that the percentage increase in sales is mirrored in employment. However, this assumption is disregarded if more accurate information on the income elasticity of employment⁶ is available.

The total direct effect, *FDTE*, is obtained by adding the net direct employment generated by both types of effects:

$$FDTE = FDSE + FDAE$$

Indirect effect

The total indirect effect of the industrial symbiosis scheme, *FITE*, can be further categorized into a substitution effect (*FIS*) and an activity effect (*FIA*). Both aspects are evaluated by examining the variations in costs (Δx_a for the activity effect and Δx_s for the substitution effect) in sector *s*. These values are derived from responses to questions 8, 6, 4 and 5. Subsequently, they are multiplied by the corresponding sectoral employment coefficients (*k*) and multipliers (*m*), accounting for employment generated through companies' input costs.

$$FITE = FISE + FIAE$$

$$FISE = \sum_i FIS_i$$

$$FIS_i = \sum_s x f_i \times \Delta x_{s,i} \times k_s \times (m_s - 1)$$

$$FIAE = \sum_i FIA_i$$

$$FIA_i = \sum_s x f_i \times \Delta x_{a,i} \times k_s \times (m_s - 1)$$

Induced effect

In this step, we estimate the wage bill resulting from the overall impact of industrial symbiosis on employment. By applying a Keynesian multiplier and an employment coefficient to this estimate, we calculate the increase in the wage bill that can be attributed to industrial symbiosis. We determine this increase by considering both direct and indirect effects on employment and average sectoral wages. Subsequently, we apply a multiplier based on consumption and import propensities of the relevant sectors, multiplying the outcome by the average employment in the economy for each South African rand of value added.

The total induced effect of the industrial symbiosis scheme, denoted as *FNTE*, relies on sectoral employment as determined by the preceding formulas:

$$FNTE = mk \times \frac{L}{VA} \times \sum_s \{ \bar{W}_s \times [(FDS_i + FDA_i) \times IB_{i,s} + (x f_i \times \Delta x_{s,i} + x f_i \times \Delta x_{a,i}) \times k_s \times (m_s - 1)] \}$$

⁶ Employment-income elasticity is a measure that quantifies the percentage change in employment in response to a 1 per cent change in income. It reflects the sensitivity or responsiveness of employment levels to fluctuations in income within an economic system.

The Keynesian demand multiplier (mk) is computed based on 2022 data using the following formula, with pmc representing the marginal propensity to consume and cip indicating the imported content per unit of product:

$$mk = \frac{1}{1 - pmc \times (1 - cip)}$$

With pmc at 94 per cent and cip at 23 per cent in 2022, the multiplier mk is calculated as 3.58. In the formula giving the total induced effect, L and VA represent employment and total value added in the South African economy, respectively. $\bar{w}_s$ denotes the average annual remuneration per worker in sector s . IB is a binary indicator (taking the value 1 if company i in the symbiosis network belongs to sector s). The expression in square brackets represents the direct and indirect effects for each sector. When multiplied by average salaries, it yields the wage bill generated by each sector. Multiplying the total of these wage bills by mk gives the added value to the economy arising from spending or consumption of goods and services by individuals who earn a salary or wages. Finally, multiplying this amount by the employment factor per unit of value added, $\frac{L}{VA}$, provides the employment generated by the induced effect.

Base employment

To comprehensively gauge the impact of industrial symbiosis, it is essential to have a counterfactual scenario representing the absence of symbiosis. We refer to the employment indicators in that scenario as “base” indicators; these serve as a benchmark for expressing employment effects in relative terms as percentage variations.

The total base employment ($LBTE$) includes three components: direct base employment ($LBDE$), indirect base employment ($LBIE$) and induced base employment ($LBNE$). $LBDE$ is determined from the response to question 19 in the company questionnaire ($r19$), which, however, is already influenced by certain effects (namely, FDS and FDA). To get $LBDE$, we take the number in that response and multiply it by the expansion factor, and finally subtract both FDS and FDA . $LBIE$ is then directly calculated from $LBDE$, by applying the corresponding sectoral employment multiplier. $LBNE$ is derived from direct base employment, incorporating a set of multipliers.

$$LBTE = LBDE + LBIE + LBNE$$

$$LBDE = \sum_i LBD_i$$

$$LBD_i = \sum_i x f_i \times r20_i - FDS_i - FDA_i$$

$$LBNE = \sum_i LBN_i$$

$$LBN_i = LBD_i \times mk \times \frac{L}{VA} \times \sum_s \left(\frac{k_{s,i}}{d_{s,i}} \times \bar{w}_s \right)$$

The induced employment generated by each company is calculated by multiplying the direct base employment by the Keynesian multiplier, the sectoral employment coefficient, and the sectoral wage bill of the direct and indirect employment requirements for each direct job. This calculation takes into account how much a company pays on average (average salary or $\bar{w}_s$) and the share of a company's workforce needs (both direct and indirect) relative to the total workforce needs in that industry, which makes it possible to determine the induced employment for each company.

Total effect

The total employment effect of the industrial symbiosis scheme, $FLTE$, is the sum of these three effects:

$$FLTE = FDTE + FITE + FNTE$$

To quantify this effect in terms of relative impact, $FLTR$, we express it as a proportion of the employment in a counterfactual scenario where there is no symbiosis:

$$FLTR = \frac{FLTE}{LBTE}$$