DEVELOPMENT SOUTHERN AFRICA
https://doi.org/10.1080/0376835X.2025.2523779

Routledge
Taylor & Francis Group

The employment-effects of greening the South African economy

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ABSTRACT

This study aims to develop a method for classifying occupations into green and non-green jobs and examines the impact of the green economy on employment. It focuses on patterns across industries and the characteristics of individuals employed as the country transitions to a green economy. The study utilises the local Organising Framework for Occupations (OFO) and the International Occupational Information Network (O*NET) to categorise jobs, applying parametric and non-parametric approaches to identify the determinants of green jobs. The proportion of green jobs in South Africa has been slowly increasing, constituting 13.8% of all jobs in 2024. These jobs are mainly found in utilities, mining, construction, and finance. They are primarily occupied by younger individuals with moderate education. Most positions are held by men, with white and black individuals as the main demographic groups, largely within the formal sector. These findings are important for policies promoting inclusive green economy growth.

ARTICLE HISTORY
Received 25 November 2024
Accepted 17 June 2025

KEYWORDS
Green jobs; employment; classification; parametric and non-parametric approaches

JEL
CODES: J21; Q01

1. Introduction

Green economies prioritise environmental sustainability, resource efficiency, and the well-being of present and future generations by reducing the negative impacts of economic activities such as environmental degradation, resource depletion, and social inequality (ILO, 2023). Countries globally are transitioning to greener economies to address climate change, biodiversity loss, unemployment, and economic development (Rodríguez, 2019; ILO, 2023). This transition relies on green jobs that reorient traditional sectors such as energy, construction, manufacturing, transport, and agriculture towards

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Supplemental data for this article can be accessed online at https://doi.org/10.1080/0376835X.2025.2523779.

sustainability (Vona et al., 2015; Consoli et al., 2016; ILO, 2022; IRENA & ILO, 2022; Granata & Posadas, 2024). These roles combine technical expertise with green competencies (Consoli et al., 2016). However, developing nations face challenges, particularly high unemployment and limited skilled labour for emerging green industries, necessitating cohesive policies, clear job classifications, and education investments to align skills with opportunities (ILO, 2023; Mirzania et al., 2023).

In South Africa, the green economy holds significant potential for job creation, notably in renewable energy, yet it faces challenges such as low economic growth, skills shortages, limited technological capacity, outdated energy infrastructure, political constraints, and weak institutions (Gulati et al., 2018; DFFE, 2022; Mirzania et al., 2023). Unemployment remains a major socio-economic challenge, averaging over 27% between 2008 and 2024, with youth unemployment currently at 45.5% (StatsSA, 2024a, 2025). A green economy could alleviate this pressure, especially for young people and women, by generating employment in fields like renewable energy and sustainable agriculture, provided skills training matches these expanding sectors (Castillo, 2023; ILO & Fundación ONCE, 2023; Mirzania et al., 2023).

Over the years, South Africa has seen the emergence of green initiatives in energy, agriculture, and waste management. However, progress has been uneven, and assessing their contribution to job creation remains challenging due to the lack of a consistent definition of green jobs (PAGE, 2017; Vesere et al., 2021; ILO & Fundación ONCE, 2023). This absence complicates measurement, leading to varied methodologies and classifications (Dierdorff et al., 2009; Vesere et al., 2021; ILO, 2023). The ILO defines green jobs as decent roles contributing to environmental preservation or restoration, spanning traditional sectors like manufacturing and construction as well as emerging areas such as renewable energy and energy efficiency (ILO, 2022; ILO, 2023). However, not all sectors that improve their environmental footprint qualify as green; for instance, mining remains carbon-intensive despite reductions in its environmental impact (Hassan et al., 2024).

Accurately measuring green jobs require clear statistical definitions, often lacking in developing countries. In South Africa, empirical evidence on the correlation between the greening of jobs and the accumulation of green jobs over time is lacking. Unlike previous studies focusing on developed countries or broad classifications (Vona et al., 2015; Consoli et al., 2016), this research adapts the Organising Framework for Occupations (OFO) and the Occupational Information Network (O*NET) to South Africa's Quarterly Labour Force Survey (QLFS) data and analyses green jobs from 2008 to 2024. Our aim is to develop a comprehensive classification method for green and non-green jobs in the context of South Africa. This new classification will enable us to track the evolution of green and non-green jobs across all sectors and analyse their patterns and determinants. Establishing a standardised green jobs classification will help researchers, policymakers, and investors monitor progress in green sectors effectively. Furthermore, findings of this study will provide actionable insights for policymakers, helping them formulate effective green economy policies that promote job creation and sustainability.

The rest of this paper is organised as follows: Section 2 provides background information on South Africa's economy and its employment landscape. Section 3 reviews the literature on the green economy, including its implications for employment and the classification of green and non-green jobs. Section 4 discusses the data and methods used, investigates factors associated with green employment, and creates a classification standard for green jobs in South Africa. Section 5 presents the study's results, and Section 6 concludes with policy recommendations.

2. Background

South Africa's economy depends heavily on sectors such as mining, manufacturing, trade, finance, agriculture, construction, and transport (StatsSA, 2023). Historically rooted in agriculture, mining, and manufacturing, South Africa has gradually shifted towards a service-oriented structure, with financial and business services and trade now leading in value-added and employment opportunities (Bhorat et al., 2020; StatsSA, 2023; StatsSA, 2024a). The financial and services sector contributes 26.7% to GDP, followed by the personal services sector at 17.9%, manufacturing at 12.6%, trade at 12.4%, and transport, storage, and communication, and government services at approximately 9% each (see Figure A1 in the Appendix), while agriculture, construction, and utilities each account for about 2.5%. However, the industrial sector remains one of the world's most carbon-intensive, heavily reliant on fossil fuels, particularly coal, and faces growing pressure to decarbonise (PCC, 2022; Mirzania et al., 2023; Winkler & Black, 2024).

This shift towards decarbonisation, while necessary for environmental sustainability, adds another layer of complexity to South Africa's labour market challenges. Despite diversification in some sectors, the labour market continues to struggle with high unemployment, with many people employed in the informal economy, where jobs are often unstable and low-wage, disproportionately affecting women (StatsSA, 2024a). The legacy of apartheid further exacerbates these issues by continuing to shape inequalities in education and employment, hindering adaptation to the changing economic landscape (De Lannoy et al., 2018; TIPS, 2021; Habiyaremye et al., 2022; PCC, 2022). Moreover, there is a significant skills mismatch: education and training systems are lagging behind the needs of emerging green sectors, leaving workers unprepared for these roles (De Lannoy et al., 2018; PCC, 2022; Mirzania et al., 2023; CSIR, 2024). Addressing these disparities and skill gaps is crucial for an equitable transition to a green economy.

While carbon-intensive industries dominate, green sectors such as renewable energy, sustainable agriculture, and green transport remain underdeveloped (PCC, 2022; Mirzania et al., 2023; Winkler & Black, 2024). This disparity presents a dual challenge: reducing emissions in established sectors while expanding sustainable alternatives. The infrastructure, built around fossil fuel systems, requires substantial upgrades to support these cleaner technologies (PCC, 2022; Mirzania et al., 2023; Winkler & Black, 2024). To tackle these issues, the government has introduced policies like the Green Economy Accord, Green Transport Strategy (2018–50), Electric Vehicles White Paper, Just Energy Transition Investment Plan (JET-IP) (2023–7), and the Framework for a Just Transition outlined by the Presidential Climate Commission (PCC) (SA Government, 2011; DOT, 2018; PCC, 2022; DTIC, 2023; The Presidency of South Africa, 2023). These aim to decarbonise utilities and transport while fostering green job growth, though success depends on shifting employment to cleaner sectors and supporting affected workers and communities (PCC, 2022; Mirzania et al., 2023).

A further obstacle is the lack of a standardised green job classification system, which hinders monitoring of job creation, resource allocation, and progress evaluation (Hassan et al., 2024). Countries like Germany and the United States have robust frameworks. China excels in green technology, India progresses in solar and wind, and Norway and New Zealand advance towards carbon neutrality through strong commitments and investment. South Africa can draw lessons from these examples to improve data systems, define green employment clearly, and align policies with labour market trends, ensuring effective support for its green transition (Hassan et al., 2024).

3. Literature review

The transition to a green economy is crucial for reducing carbon emissions and promoting economic sustainability, a process rooted in the theory of structural change, which asserts that economies transform over time from traditional to more advanced sectors (Lewis, 1954; Kuznets, 1971). In the context of sustainability, this theory suggests that as economies prioritise environmental goals, employment shifts from traditional sectors like fossil fuels to green sectors, such as renewable energy (Bohlmann et al., 2023; ILO & Fundación ONCE, 2023; Mirzania et al., 2023). This study employs this framework to analyse green job patterns in South Africa, using the OFO and the O*NET as practical tools to classify green and non-green jobs (DHET, 2013; Vona et al., 2015; Consoli et al., 2016; ILO, 2022). Globally, renewable energy jobs grew by 5.8% in 2021 to 12.7 million, with projections of 38.2 million jobs by 2030, potentially reaching 139 million jobs under ambitious scenarios (IRENA & ILO, 2022, p. 8). However, job distribution varies. Coal-dependent countries like China and the United States offset fossil fuel losses with gains in renewables, while developing nations like Jordan, Mexico, and Latvia experience growth in green sectors, highlighting diverse pathways in the green transition (Cai et al. 2011; ILO, 2014; Haerer & Pratson, 2015; Vesere et al., 2021; Suta et al., 2023). Gender disparities persist, with women holding only one-third of renewable energy jobs, often in lower-paying roles (IRENA & ILO, 2022).

A significant challenge in studying green jobs is the lack of a uniform definition, leading to inconsistent classification methods, such as industry-based, skills-based, or task-based approaches (Bezdek et al., 2008; Haerer & Pratson, 2015; Vona et al. 2015, Consoli et al. 2016; Rodríguez, 2019; Sulich & Rutkowska, 2020; García Vaquero et al., 2021). As noted in the introduction, the ILO defines green jobs as decent roles that preserve or restore the environment across both traditional sectors, like manufacturing and construction, and emerging sectors, like renewable energy and energy efficiency (ILO, 2022; ILO, 2023). This study adopts this definition due to its relevance to South Africa's green transition goals. Green jobs span energy, recycling, agriculture, and transport, reducing resource use and emissions. Direct roles include solar installation and wind turbine maintenance, while indirect roles encompass policy advocacy and research (UNEP et al., 2008; Cleary & Kopicki, 2009). However, distinguishing green from non-green jobs is challenging, as the boundary often blurs across sectors. In agriculture, organic farming qualifies as green due to its sustainability focus, whereas traditional farming typically does not. This variation extends to skill requirements: some green roles, like waste management, demand minimal technical qualifications, unlike others that require specialised training. Such overlaps complicate classification efforts. Likewise, in manufacturing, a sheet metal worker in wind turbine production performs a green role by incorporating sustainability tasks, whereas a carpenter installing energy-efficient windows does so by adapting traditional skills. This study adopts a task-based approach to address these nuances, aligning with international standards to provide clarity (UNEP et al., 2008; Cleary & Kopicki, 2009).

The perspective on green jobs in Africa reflects unique socio-economic and environmental challenges shaped by limited infrastructure, skill gaps, and climate injustice (African Union, 2023). Data scarcity complicates measurement, yet estimates indicate significant potential, such as in the renewable energy sectors of Mauritius and Tunisia (Sultan & Harsdorff, 2014; Lehr et al., 2016). Efforts to promote green jobs are gaining momentum across the continent, driven by the Green Jobs Programme, which has supported initiatives in countries including Egypt, Kenya, Mauritius, Namibia, Senegal, South Africa, Tanzania, Tunisia, Uganda, Zambia, and Zimbabwe (ILO, 2024). These efforts, tied to renewable energy, sustainable agriculture, and waste management, offer inclusive growth opportunities, particularly for rural and informal economies (African Union, 2023; ILO, 2024). The African Union's Agenda 2063 further emphasises traditional knowledge and practices as vital for sustainable development and economic diversification, enhancing the continent's green transition (African Union, 2023).

South Africa exemplifies this potential within a complex economic context, aligning with the background's focus on structural shifts from carbon-intensive industries and persistent unemployment challenges. Studies underscore the job creation prospects of this green transition. Bohlmann et al. (2023) suggest that greener electricity could stimulate economic growth, despite losses in coal-dependent regions, while Kiss-Dobronyi et al. (2023) argue that green policies might enhance GDP and employment. Maia et al. (2011) estimates over 462,000 jobs could emerge in energy, resource efficiency, and pollution mitigation, supported by over 1,000 initiatives launched between 2010 and 2016 in agriculture, conservation, and waste management (PAGE, 2017). The Just Energy Transition (JET) initiatives guide this shift, aiming to balance sustainability with equity (Swilling & Annecke, 2012; PCC, 2022).

Nevertheless, significant barriers persist. South Africa's coal dependency and governance challenges threaten progress, with electricity distribution tensions noted by Baker and Phillips (2019) and global-local policy integration critiques from Death (2014) (Winkler & Black, 2024). Skills shortages in renewable energy and environmental management further complicate the transition, potentially exacerbating inequality by excluding workers from emerging opportunities unless adequate training is provided (Rosenberg et al., 2018; CSIR, 2024). The Just Energy Transition Partnership (JETP) seeks to fund this shift, yet Boulle (2023), Fakir (2023), and Lenferna (2023) question its equity for marginalised workers, while AIDC et al. (2020) highlight Eskom's role in balancing decarbonisation with labour interests. These challenges are compounded by the lack of a standardised green job classification system and robust data to track progress in the transition. Without such clarity, the opportunities risk widening disparities rather than fostering inclusive growth. This study addresses this by developing a comprehensive framework to classify green jobs and understand their determinants, offering a pathway to align South Africa's transition with equitable outcomes.

4. Data and methodology

This section covers the data, definition, and measurement adopted for green jobs in our study.

4.1. Measuring and classification of green jobs

South Africa faces challenges in classifying green and non-green jobs. Existing data sets do not provide detailed information on specific occupations. Currently, South Africa uses the South African Standard Classification of Occupations (SASCO) 2003[1] system, which is less detailed than those used in most developed countries and the OFO system, which includes some green occupations[2] but is not comprehensive (DHET, 2013; CSIR, 2024). A recent skills report found that many green occupations are not reflected in the OFO (CSIR, 2024), highlighting the need for a more specific classification method for South Africa's green jobs. This study uniquely integrates SASCO, OFO, and O*NET with insights from local policy and past studies (DHET, 2013; Vona et al., 2015; Consoli et al., 2016; DOT, 2018; DFFE, 2022; ILO, 2022; CSIR, 2024) to classify occupations.

More precisely, we combine both the skills/occupational-based method and the industry-based approaches to categorise green and non-green jobs, utilising the SASCO, OFO, and O*NET classifications. The OFO, a South African skills-based coding system, served as our initial reference point for classifying jobs, while O*NET, an internationally recognised occupational database, supplements this with data from the U.S. green economy programme, based on expert and worker surveys. Although O*NET pertains to the U.S. economy, it assists in categorising South Africa's occupations, given the lack of a comprehensive local system, and aligns empirical findings with theoretical expectations of structural economic shifts. Together, these policy-oriented and data-driven frameworks operationalise the classification of green jobs, a method adopted by researchers globally and acknowledged by the ILO (Vona et al., 2015; Consoli et al., 2016; ILO, 2022). For occupations not included in the OFO, we relied on SASCO and O*NET data to distinguish between green and non-green roles. For more information on how we classified the jobs refer to the Appendix, Section 1.

4.2. Data and descriptive statistics

The study utilises data from all the survey quarters between 2008 and 2024 of the Quarterly Labour Force Survey (QLFS) published by Statistics South Africa (StatsSA). The QLFS is a household-based sample survey designed to capture information on the labour market participation of individuals aged 15 years and above residing in South Africa. The QLFS survey data contains both occupational and industry information for surveyed individuals, coded based on SASCO and Standard Industry Classification (SIC). Our focus is on individuals within the age of 15–64 years old, as this range is commonly used in South African labour force surveys and is considered representative of the working-age population (StatsSA, 2024b). Across the 68 surveys included in this study, a total of 3,111,909 individuals were surveyed, with 1,704,832 reporting their employment

[1]SASCO is derived from the International Standard Classification of Occupations (ISCO-08).
[2]These occupations are classified using the O*NET classification from the USA (DHET, 2013).

status. Since this analysis examines the determinants of green jobs based on occupations, we restricted the sample to employed individuals, reducing it to 1,234,795 after excluding the unemployed. Encouragingly, all employed individuals in this sample reported their occupations, encompassing 402 distinct occupations. We then classified these occupations into green and non-green jobs, primarily using OFO and O*NET classifications. A job is classified as green if it is listed as such in either the OFO or O*NET classification. In sorting the occupations, we manually categorised them into green and non-green jobs before further cleaning the data using the STATA[3] software. Some occupations had no labels, so we used SASCO codes to classify them. For survey years before 2008, we found that all occupations lacked labels, so we excluded them from our analysis, focusing on the survey years 2008-24, where there was reasonable consistency in the occupation labels.[4] A short version of some of the jobs classified as green is provided in Table A1 in the Appendix.

Following past studies (Consoli et al., 2016; Doan et al., 2022; Granata & Posadas, 2024), we define our main outcome variable, 'green job,' as a binary variable that takes a value of 1 if an individual holds a green job and 0 otherwise. In analysing the determinants of green jobs, we also accounted for control variables commonly used in the literature, including gender, age, race, education, experience, and the sector and industry of employment (Vona et al., 2015; Consoli et al., 2016; Vona et al., 2019; Sulich & Rutkowska, 2020; García Vaquero et al., 2021). We define these variables as follows: gender (1 = male; 0 = female), area of residence (urban = 1, rural = 0), race (African/Black = 1, Coloured = 2, Indian/Asian = 3, White = 4), sector of employment (formal = 1, informal = 0), and industry of employment (agriculture = 1, mining = 2, manufacturing = 3, utilities = 4, construction = 5, trade = 6, transport = 7, financial services = 8, community services = 9, private households = 10, other = 11). Education, age, and experience are continuous variables. Experience is calculated by subtracting the year an individual entered the organisation from the year the survey was conducted.

We provide key summary statistics for our main sample in Table 1, which includes both green and non-green occupation holders (section A), as well as for a subsample of individuals with green-related occupations only (section B). Our main sample reveals that out of all individuals reporting their employment status, 73.1% were employed. Within our main sample (section A), 72.5% were engaged in the formal sector, with only 13.8% holding green-related jobs. Demographically, 46.9% of these workers were female, and 74.2% resided in urban areas, with black Africans representing the majority at 74.1%. In terms of education attainment, 1.4% had no schooling, 8.4% had primary school or less, 68.4% had at least some secondary schooling, 17.2% had attended some college, and 4.5% held a degree or above. Notably, individuals aged 30–34 and 35–39 comprised the largest cohorts. Regarding the industrial distribution of employment in our main sample, 11.1% were employed in manufacturing, 23.5% in community and social services, 21.1% in trade, 5.6% in transport, 12.9% in the financial services, and 5.7% in agriculture (see Table 2, column 2). Most employed individuals worked in elementary occupations (23.8%), followed by sales and services (15.5%), and craft and related trades (11.7%) (see Table 3, column 2).

[3]STATA is a statistical software for data analysis.
[4]Details on our job classification are in our STATA code and Excel sheet, available upon request.

Table 1. Descriptive statistics.

Variable		Total	Share (%)
Employment status	Unemployed	470 037	27.6
	Employed	1 234 795	72.4
A. Main sample: Individuals who are employed			
Green job	Green	170 902	13.8
	Non-green	1 063 893	86.2
Sector	Formal	210 911	72.5
	Informal	80 096	27.5
Gender	Female	579 085	46.9
	Male	655 710	53.1
Area of residence	Rural	318 269	25.8
	Urban	916 526	74.2
Race	African/Black	915 231	74.1
	Coloured	151 741	12.3
	Indian	36 019	2.9
	White	131 804	10.7
Level of education	None	17 638	1.4
	Primary school or less	103 522	8.4
	High school	844 990	68.4
	College	212 507	17.2
	Graduate degree and above	56 138	4.5
Age group	15–19	10 487	0.8
	20–24	93 265	7.6
	25–29	167 415	13.6
	30–34	189 552	15.4
	35–39	186 466	15.1
	40–44	175 551	14.2
	45–49	155 131	12.6
	50–54	129 071	10.5
	55–59	90 957	7.4
	60–64	36 899	3.0
B. Individuals with green jobs			
Sector	Formal	145 842.0	85.3
	Informal	25 060.0	14.7
Gender	Female	27 114	15.9
	Male	143 788	84.1
Area of residence	Rural	39 541	23.1
	Urban	131 361	76.9
Race	African/Black	122 100	71.4
	Coloured	17 991	10.5
	Indian	4621	2.7
	White	26 190	15.3
Level of education	None	1671	1.0
	Primary school or less	10 384	6.1
	High school	118 637	69.4
	College	34 202	20.0
	Graduate degree and above	6008	3.5
Age group	15–19	809	0.5
	20–24	10 698	6.3
	25–29	23 583	13.8
	30–34	29 319	17.2
	35–39	28 324	16.6
	40–44	25 092	14.7
	45–49	20 319	11.9
	50–54	16 158	9.5
	55–59	11 609	6.8
	60–64	5000	2.9

Source(s): Author's calculations, StatsSA QLFS data.

To understand the characteristics of individuals with green-related occupations, we present the statistics for this group in section B of Table 1, excluding those with non-green-related occupations. The statistics show that 85.3% were engaged in the formal

Table 2. Employment by industry.

Industry	Total jobs (1)	Share (%) (2)	Green jobs (3)	Share (%) (4)
Agriculture	69 992	5.7	12 254	7.17
Mining	32 939	2.7	15 843	9.3
Manufacturing	137 179	11.1	20 436	12.0
Utilities	8792	0.7	4786	2.8
Construction	96 651	7.8	21 940	12.8
Trade	260 259	21.1	21 512	12.6
Transport	68 504	5.6	12 001	7.0
Finance	159 002	12.9	46 502	27.2
Community and social services	290 709	23.5	15 443	9.0
Private households	110 375	8.9	165	0.1
Other	393	0.0	20	0.0
Total	1 234 794	100	170 902	100

Source(s): Author's calculations, StatsSA QLFS data.

Table 3. Employment by occupation.

Occupation	Total jobs (1)	Share (%) (2)	Green jobs (3)	Share (%) (4)
Managers	90513	7.3	17 908	10.5
Professionals	64 400	5.2	7383	4.3
Technical	123 608	10.0	21 612	12.7
Clerks	129 287	10.5	0	0.0
Sales and services	190 960	15.5	43 796	25.6
Skilled agriculture	7226	0.6	6033	3.5
Craft and related trade	144 117	11.7	51 937	30.4
Plant and machine operators	101 440	8.2	17 446	10.2
Elementary	294 400	23.8	4787	2.8
Domestic workers	88 626	7.2	0	0.0
Other	217	0.0	0	0.0
Total	1 234 794	100.00	170 902	100.00

Source(s): Author's calculations, StatsSA QLFS data.

sector, with men constituting 84.1% of the sample. Additionally, 12% of green-related workers were in manufacturing, 12.6% in trade, 7% in transport, 9.3% in mining, 12.8% in construction, 2.8% in utilities, and 27.2% in the finance sector (see Table 2, column 4). The main occupation groups for these individuals included plant and machine operators (10.2%), managers (10.5%), sales and services (25.6%), and craft and related trades (30.4%) (see Table 3, column 4). Demographically, individuals with green skills-related occupations (Table 1, section B) closely mirror those of the main sample (Table 1, section A).

We acknowledge potential selection bias as our analysis focuses on employed individuals. Statistical tests show significant differences between the full and retained samples, indicating systematic differences between employed and unemployed individuals (see Table A2). While this limits generalisability, restricting the analysis to employed individuals is necessary since green job classification relies on occupation. Thus, our estimates are valid for employed individuals and should be interpreted accordingly.

4.3. Methodology

To understand the pattern of green and non-green jobs and their determinants, we employ a combination of parametric and non-parametric techniques. Given the binary nature of the outcome variable of interest (green job = 1, non-green job = 0), the parametric technique entails a logistic regression model, appropriately weighted to the population, and robust to heteroskedasticity as specified in equation (1).

$$G_i = L(\alpha T + \beta X_i') + \mu \tag{1}$$

where X_i' denotes all explanatory variables, including age, gender, rural/urban, education, experience, race, sector and industry of employment, and regional fixed effects. L is the functional notation for the standard logistic distribution, and T is the trend variable that adjusts for the time intervals between survey years. In further analyses, we use quarter of survey dummies to control for time-specific factors that change each year and are common to all provinces or individuals within a given year.

To obtain the probability of G_i (the outcome variable, green job), we express equation (1) in probability form as follows:

$$Logit(P/(1-P)) = \alpha T + \beta X_i'$$

where $Logit(P)$ is a linear function of X_i'. This implies that $P = e^{\alpha T + \beta X_i'}/(1 + e^{\alpha T + \beta X_i'})$ (Berger, 2017). Thus, even if X_i' is zero, P will always lie between 0 and 1, ensuring that the probability of having a green job remains within this range. The marginal effects for the outcome variable are subsequently reported.

The non-parametric technique entails graphical illustrations based on Cleveland's (1979) non-parametric locally weighted scatterplot smoothing, known as Lowess (or loess). Lowess does not impose a functional form on the data, rather it allows the data to determine the shape of the relationship between two variables. Consider an unspecified empirical relationship, as in (2).

$$G_i = f(x_i) + u_i \tag{2}$$

u_i is assumed to be uncorrelated with the variable of interest, x_i, and the function f is to be estimated. It is estimated from weighted linear models in neighbourhoods of x_i, with weights w_i.

$$w_{ik} = \frac{c_i}{\rho} d\left(\frac{x_i - x_j}{\rho}\right)$$

The constant c_i normalises the weights to sum to one, ρ is a bandwidth, and d is a function that treats observations further away as being less important. In this analysis, d is the tricube function.

$$d(t) = \{(1 - t^3)^3 \quad if\ t \in [0,\ 1]\ \ 0 \quad Otherwise$$

For the analysis G_i represents the outcome variable (green job), for selected years and socio-demographic subsets, and x is age; we graphically illustrate the estimated relationship. We specify a constant bandwidth of 0.8, implying that 80% of the sample was used to smooth each point.

5. Results and analysis

To track the evolution of green and non-green jobs in South Africa and examine their determinants, we first present trends in overall employment and green jobs graphically to gain deeper insights into South Africa's employment landscape. Figure A2 in the appendix depicts the employment trend from 2008 to 2024, showing a decline from 77.9% in the fourth quarter (Q4) of 2008 to 64.7% in Q4 2021, exacerbated by COVID-19 between 2019 and 2021. However, there was a recovery from 2022 onwards, reaching 68.1% in Q4 2024. Concurrently, the proportion of individuals with green jobs increased marginally from 12.4% to 14.8% over the same period (see Figure 1). The proportion of green jobs aligns with findings from other developing countries, such as Indonesia (15%) and Vietnam (41%) using a broadly green definition (Doan et al., 2022; Granata & Posadas, 2024), and is comparable to the U.S. figures from 2011 to 2012, which ranged from 9.8% to 12.3% for broadly green jobs (Consoli et al., 2016).

Notably, Figure 2 highlights that the majority of green job holders are young people aged between 24 and 40, reflecting the emerging nature of the green economy and the adaptability of the younger generation to acquire requisite skills. Given that green transition policies targe shows various economic sectors employing people of all working ages; several studies have highlighted the significance of age structure and socio-demographic factors in examining green job skills, determinants and coverage. Thus, we depict the results for the smoothed scatter lowess graphs plotted by age. Consistent with the summary statistics, Figures 3 and 4 indicate that green jobs are more prevalent among the younger population, who also tend to have less work experience, compared to the older population. Figure 5 shows that these younger individuals also have fewer years of schooling, further supporting the observation that the potential for green jobs

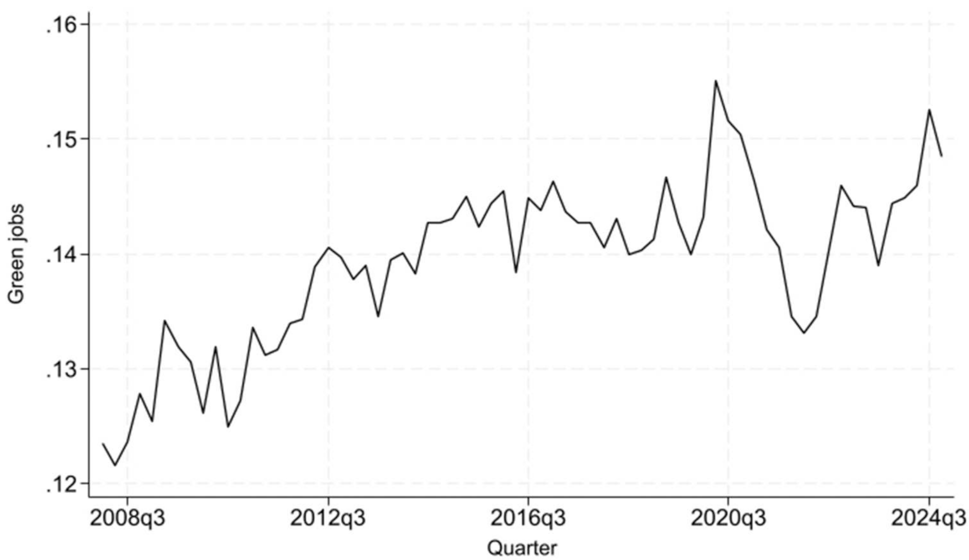

Figure 1. Share of green jobs over time (non lowess). Source(s): Author's calculations, StatsSA QLFS data.

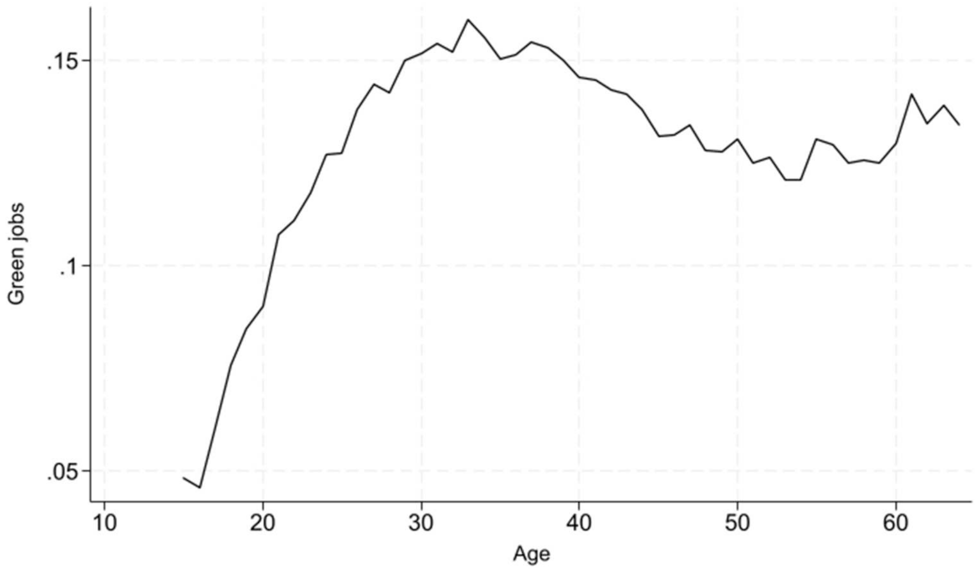

Figure 2. Share of green occupations by age (non lowess). Source(s): Author's calculations, StatsSA QLFS data.

to address youth unemployment is huge. Regarding gender parity in green jobs, our findings reveal that men are more likely than women to hold green skill-related jobs (Figure 6). Additionally, our analysis demonstrates that living in urban areas and being a black person increases the probability of securing a green job (Figures A3 and A4).

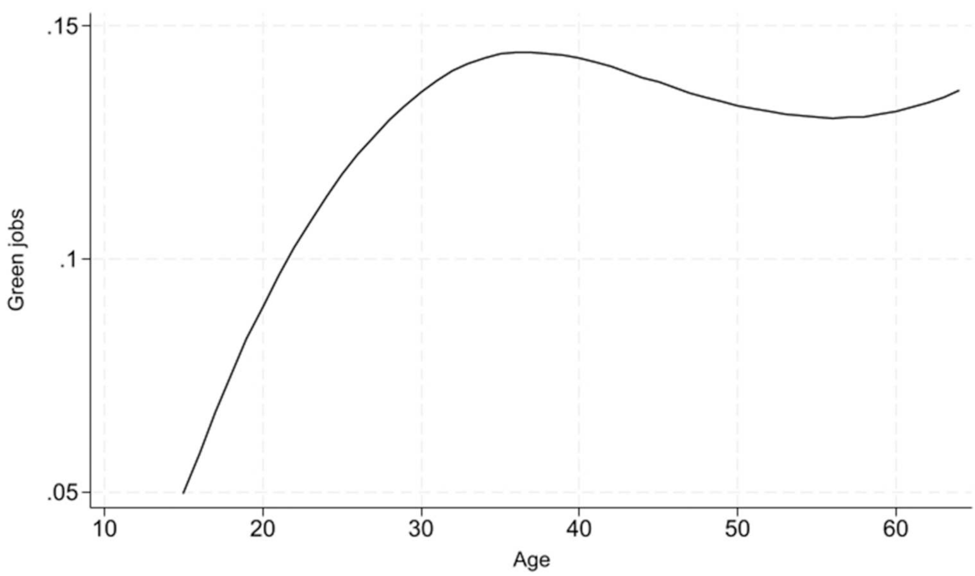

Figure 3. Share of green occupations by age (lowess). Source(s): Author's calculations, StatsSA QLFS data.

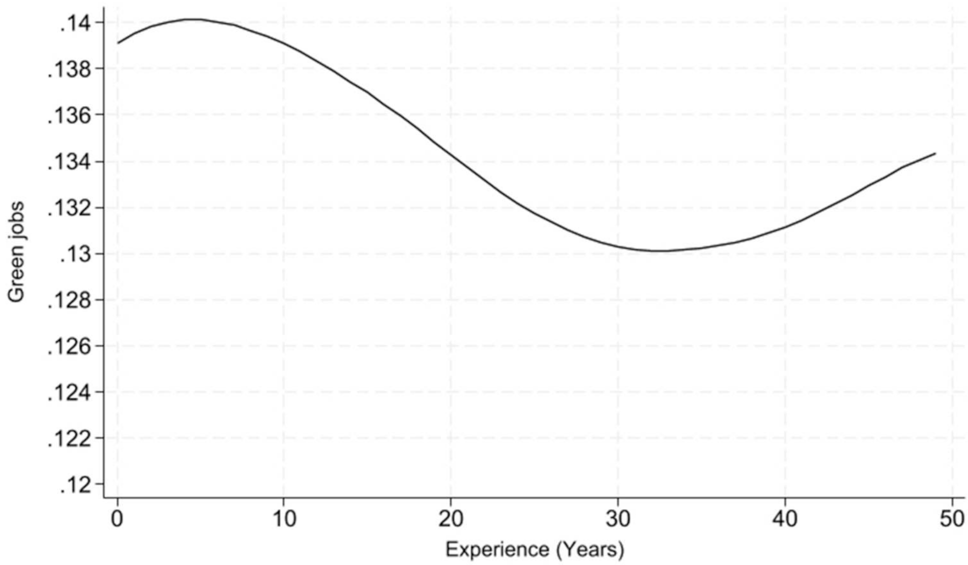

Figure 4. Share of green occupations by experience (lowess). Source(s): Author's calculations, StatsSA QLFS data.

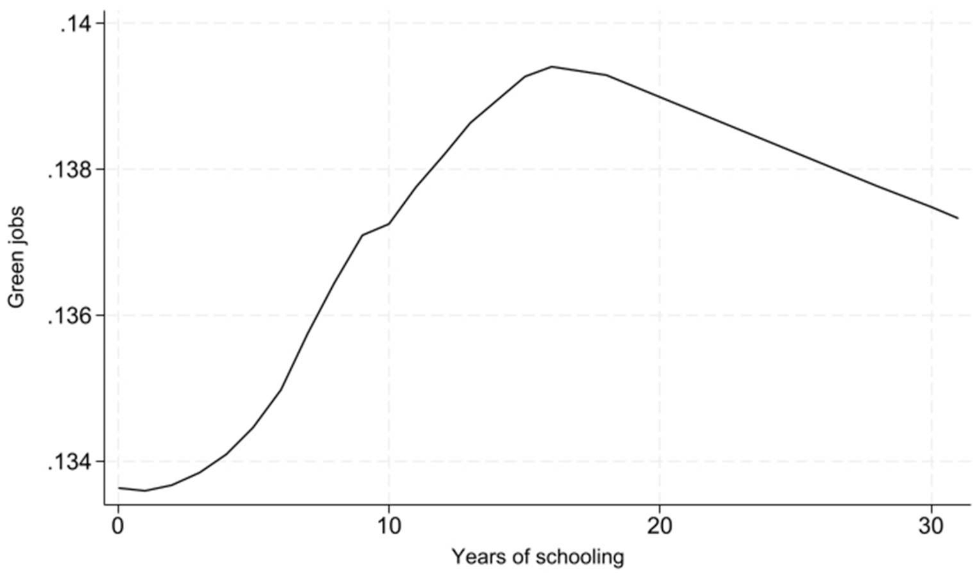

Figure 5. Share of green occupations by education (lowess). Source(s): Author's calculations, StatsSA QLFS data.

Furthermore, working in the formal sector significantly raises the chances of having a green-skilled occupation (Figure A5). Employment in the utilities, finance, mining, and transport industries also substantially boosts the likelihood of holding a green occupation (Figure 7). While Figures 1–5 use simple binary trends for clarity, Figures 6 and 7

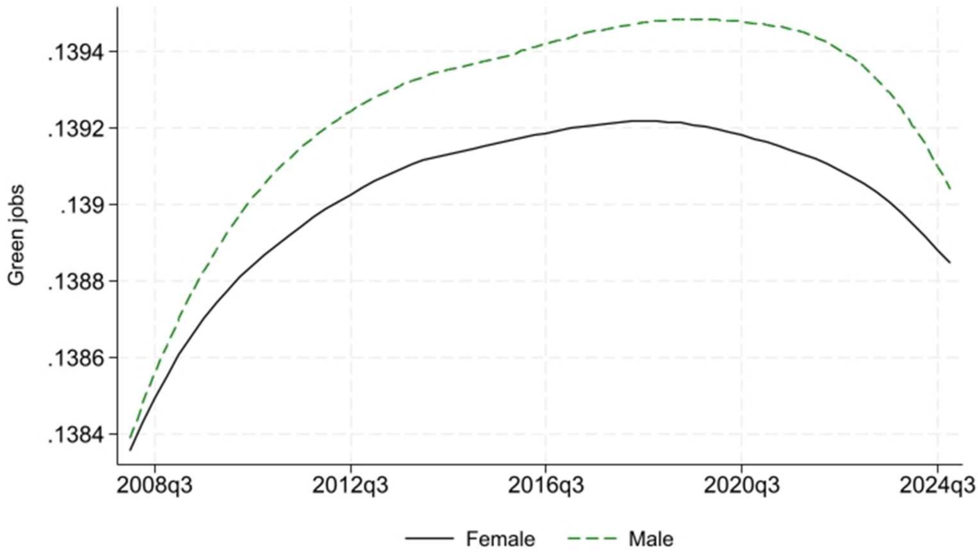

Figure 6. Share of green occupations by gender (lowess). Source(s): Author's calculations, StatsSA QLFS data.

disaggregate green jobs by gender and industry, revealing complexity beyond the binary classification. However, these scatter plots do not account for other individual-specific variables, and the observed relationships might change when we include these factors in our analysis.

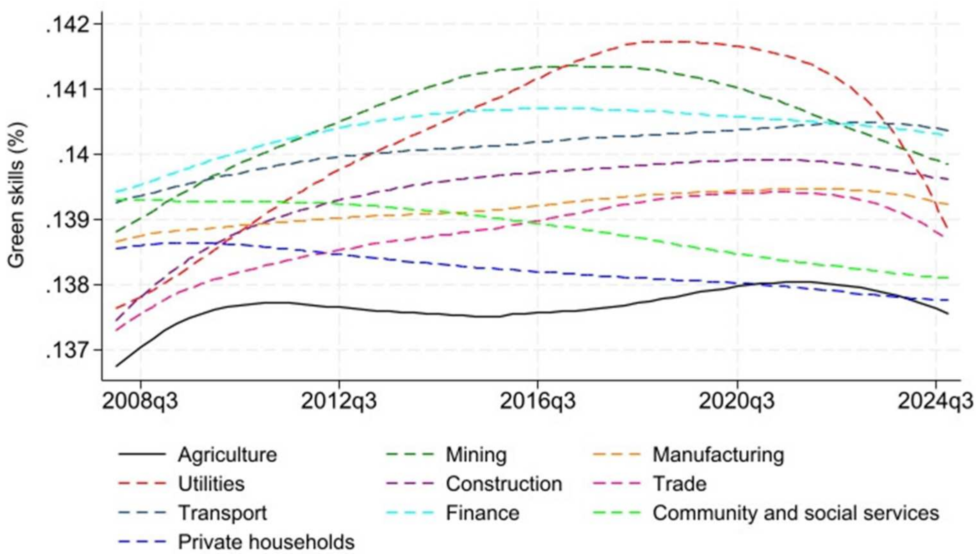

Figure 7. Share of green occupations by industry (lowess). Source(s): Author's calculations, StatsSA QLFS data.

Table 4. The determinants of green jobs (logit regression model).

	Green job (1)	dy/dx (2)	Odds ratio (3)	Green job (4)
Age	0.059***	0.006***	1.061***	0.059***
	(0.002)	(0.000)	(0.003)	(0.002)
Age^2	−0.001***	−0.000***	0.999***	−0.001***
	(0.000)	(0.000)	(0.000)	(0.000)
Gender	1.413***	0.152***	4.110 ***	1.413***
	(0.009)	(0.001)	(0.037)	(0.009)
Urban	0.146***	0.015***	1.158***	0.148***
	(0.010)	(0.01)	(0.011)	(0.010)
Black/African	0.130***	0.014***	1.139***	0.130***
	(0.013)	(0.001)	(0.015)	(0.013)
Indian/Asian	−0.268***	−0.025***	0.765***	−0.268***
	(0.025)	(0.002)	(0.020)	(0.025)
White	0.232***	0.025***	1.261***	0.233***
	(0.016)	(0.002)	(0.020)	(0.016)
Year of schooling	0.069***	0.007***	1.071***	0.068***
	(0.003)	(0.000)	(0.003)	(0.003)
Years of schooling^2	−0.002***	−0.000***	0.998***	−0.002***
	(0.000)	(0.000)	(0.000)	(0.000)
Informal	−0.305***	−0.031***	0.737***	−0.304***
	(0.010)	(0.001)	(0.007)	(0.010)
Experience	0.011***	0.001***	1.011***	0.011***
	(0.001)	(0.000)	(0.001)	(0.001)
Experience^2	−0.000	−0.000***	1.000	−0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Mining	1.079***	0.182***	2.941***	1.078***
	(0.020)	(0.003)	(0.059)	(0.020)
Manufacturing	−0.216***	−0.026***	.806***	−0.216**
	(0.017)	(0.002)	(0.014)	(0.017)
Utilities	1.527***	0.276***	4.603***	1.527***
	(0.031)	(0.006)	(0.142)	(0.031)
Construction	0.213***	0.029***	1.237***	0.212***
	(0.016)	(0.002)	(0.020)	(0.016)
Trade	−0.647***	−0.069***	0.523***	−0.648***
	(0.017)	(0.001)	(0.009)	(0.017)
Transport	−0.225***	−0.027***	0.799***	−0.226***
	(0.019)	(0.002)	(0.015)	(0.019)
Finance	0.709***	0.111***	2.033***	0.710**
	(0.016)	(0.002)	(0.033)	(0.016)
Community; social services	−1.145***	−0.103***	0.318***	−1.146***
	(0.018)	(0.002)	(0.006)	(0.018)
Private households	−4.122***	−0.161***	0.016***	−4. 123***
	(0.093)	(0.002)	(0.002)	(0.093)
Other	−1.246***	−0.109***	0.288*	−1.247*
	(0. 299)	(0.015)	(0.086)	(0.299)
Constant	−4.547***		0.011***	−4.653***
	(0.051)		(0.001)	(0.056)
Trend	Yes	Yes	Yes	No
Survey dummies	No	No	No	Yes
Regional fixed effects	Yes	Yes	Yes	Yes
Observations	1 234 795	1 234 795	1 234 795	1 234 795
Pseudo R-squared	0.167		0.167	0.167
%age correctly predicted	86.27		86.27	86.27

Notes: Standard errors in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. Coloured is the reference category for race, and agriculture for industry.
Source(s): Author's estimates, StatsSA QLFS data.

The results for the parametric estimation technique, specifically the logit regression model, are presented in Table 4. In columns (1) to (3), we estimate our model with the trend variable, and in column (4), we use the quarter of survey dummies instead of the trend. The results in Table 4, columns (1) and (3), suggest that individuals employed in utilities, mining, construction, and finance are more likely to have green jobs than those in agriculture. In contrast, those working in manufacturing, transport, trade, private households, and community or social services are less likely to hold a green job compared to those in agriculture. Conversely, those employed in the informal sector are less likely to have a green job. Additionally, as age, experience, and education increase, the likelihood of having a green job decreases. This may be because these sectors/jobs are relatively new, attracting younger individuals, while older, more experienced individuals tend to remain in their traditional occupations.

The average marginal effects are presented in column (2) of Table 4. The average marginal effects indicate that being male increases the likelihood of having a green job by 15.2%, while employment in the informal sector decreases this likelihood by 3.1%. Black/African and white individuals are more likely to have a green job by 1.4% and 2.5%, respectively, compared to Coloured individuals. In contrast, Indian individuals are 2.5% less likely to have a green job than Coloureds. Employment in the mining, utilities, construction, and finance industries increases the likelihood of having a green job by 18.2%, 27.6%, 2.9%, and 11.1%, respectively, compared to those in agriculture. On the other hand, working in the manufacturing, transport, community and social services sector, trade, private households, and other sectors decreases the likelihood by 2.6%, 2.7% 10.3%, 6.9%, 16.1%, and 10.9%, respectively, compared to those in agriculture. These results hold even when we include year-of-survey fixed effects in column (4). It is important to note that the logit model accurately predicts approximately 86.3% of cases, indicating its strong predictive power for our outcome variable.

5.1. Robustness checks

In this section, we extend our analysis beyond the binary green versus non-green classification by developing a multidimensional framework that incorporates three dimensions: the presence of green jobs, the carbon intensity of the industry, and the industry's employment intensity. Drawing on Wills (2022), we utilise the pre-existing classification of industries into four quadrants based on Standard Industrial Classification (SIC) codes: high employment and low carbon intensity, low employment and low carbon intensity, low employment and high carbon intensity, and high employment and high carbon intensity. We link the industry codes in our dataset to these established quadrants and cross-tabulate them with green and non-green occupations to produce eight distinct categories (see Figure 8).[5] This approach, exemplified by categories such as 'Green EmpHigh CarbonLow' (green jobs in high-employment, low-emission sectors), offers a more nuanced depiction of the green labour market and its relevance to just transition strategies. Figure 8 illustrates the employment share across these categories, highlighting the presence of green jobs in both carbon-intensive sectors and low-carbon sectors, consistent with our main findings in Section 5.

However, despite the large overall sample size, this refined classification reveals a significant limitation: green jobs constitute only 13.8% of the dataset, with non-green jobs accounting for 86.2%%. When we subdivide them into the eight categories, the small

[5]The categorisation is performed in Stata, and the code is available upon request.

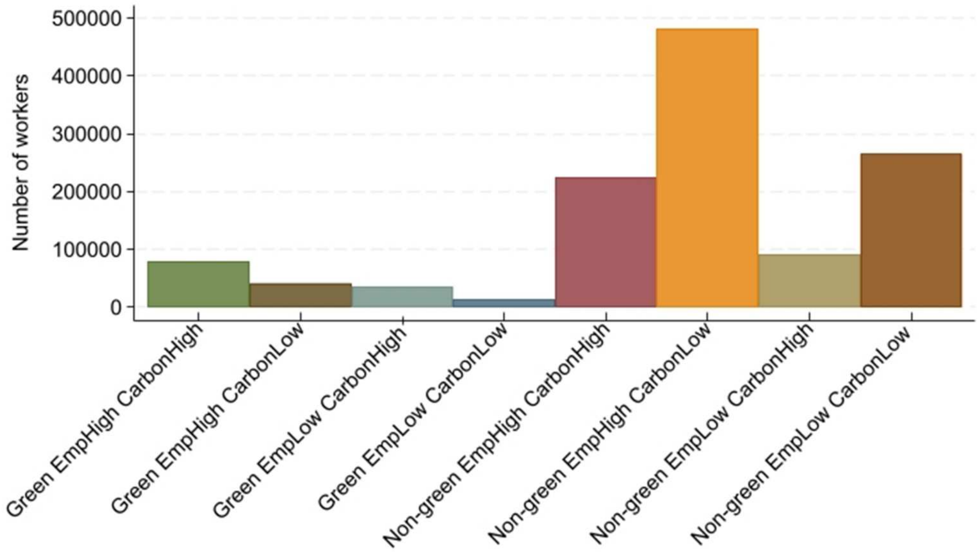

Figure 8. Number of employed persons by industry's employment intensity and carbon intensity.

proportion of green jobs results in substantially reduced sample sizes per category, rendering regression analyses statistically underpowered and producing unreliable results. Consequently, further quantitative exploration beyond descriptive statistics proves unfeasible. This constraint supports our reliance on the binary outcome variable in the primary analysis, which, while simplifying the complex spectrum of green occupations, ensures robust and interpretable findings. The trade-off between granularity and analytical tractability underlines the appropriateness of the binary approach for this study, although we suggest that future research can build on our multidimensional framework to explore these dynamics in greater detail when the green industry is grown enough.

6. Conclusion and recommendations

Given the potential of the green economy to create jobs in South Africa, this paper classified South African jobs into green and non-green categories using plausible classification approaches. It provided insights into recent developments in the green economy and estimated the determinants of green jobs, guided by the ILO, OFO, and O*NET. The findings indicated that the green sector has experienced slow growth. The sector mainly comprises younger individuals with fewer years of education and experience, men, and those employed in the formal sector, particularly within the utilities, mining, construction, and finance industries. This demographic profile aligns with findings from other developing countries (Doan et al., 2022; Granata & Posadas, 2024), but contrasts with findings from developed countries, where green occupations typically exhibit higher levels of formal education, work experience, and on-the-job training (Consoli et al., 2016; García Vaquero et al., 2021). This is because the green economy is a relatively new concept, and many countries, including South Africa, are still in the early stages of developing the necessary human resource skills. Younger individuals are better positioned to acquire these skills while pursuing their studies compared to older individuals.

Nonetheless, there is notable potential for re-skilling the older generation, which could further support the growth of the green economy and alleviate unemployment. Additionally, South Africa has not yet established a comprehensive classification system for green and non-green jobs, nor fully transitioned to the ISCO-08 framework. As a result, our classification of occupations into green or non-green jobs relies on the OFO system, supplemented with the O*NET classification from the USA. Updating the current OFO to include all relevant occupations could slightly alter the findings, as the USA classification used for some industries reflects a different level of development compared to South Africa. This highlights the need for a tailored classification system that accurately reflects South Africa's green economy's unique characteristics and development stage.

We recommend that the country develop its own comprehensive classification system for green and non-green jobs encompassing the entire economy. This will enable more accurate tracking of progress toward a green economy, facilitate targeted policymaking, and better assess job creation potential in various green sectors. Improving data collection methods and reporting standards related to green jobs will provide clearer insights into the sector's dynamics, including regularly updating the classifications to reflect new and emerging green occupations. Clear classification and tracking can help mitigate fears of job losses in traditional sectors such as coal mining by highlighting opportunities for skill transfer and job creation within green sectors.

Policies should aim to increase diversity within the green sector by encouraging the participation of women and underrepresented groups. Tailored support for sectors such as utilities, mining, construction, and finance can drive growth and innovation within the green economy. Promoting curricula in tertiary institutions that align with the future of work is essential to equip the workforce with the skills needed for a sustainable and inclusive green economy. Specific skills required for the green transition include technical competencies related to renewable energy, energy efficiency, green hydrogen, sustainable practices and green technologies, soft skills like problem-solving, adaptability, and the ability to work in interdisciplinary teams.

Finally, while we acknowledge the limitations of the QLFS, including its cross-sectional nature and reliance on self-reported data, it remains a key resource for understanding labour market trends in South Africa. Future research could enhance the robustness of findings by supplementing QLFS data with additional sources, such as employer surveys or administrative records. Further studies should also focus on the evolving nature of green jobs, including tracking the skills gap and investigating how the green economy is transforming different sectors.

Disclosure statement

No potential conflict of interest was reported by the authors.

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