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The effects of climate change on South African labour markets: implications for fiscal and monetary policy planning

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Abstract

This paper examines the implications of physical climate change risks for South Africa's labour market and the resulting challenges for fiscal and monetary policymakers. Using the University of Pretoria General Equilibrium Model, we model three climate risk scenarios – declining agricultural productivity, increasing water scarcity and climate-induced labour migration – to assess their macroeconomic and employment effects. The results indicate that reduced agricultural productivity and climate-induced migration have the most significant negative impacts on employment, while the effects of water scarcity are comparatively muted. Across all scenarios, low-skilled workers are disproportionately affected, with climate-induced migration intensifying insider-outsider dynamics and depressing wages for the most vulnerable segments of the workforce. We argue that addressing these disruptions requires coordinated fiscal interventions – including active labour market policies and investment in climate-resilient infrastructure – alongside further research on the effect of climate change on employment and inflation dynamics in order to future-proof the South African Reserve Bank's monetary policy and forecasting frameworks.

JEL classification

E52, E58, J21, J68, Q54, Q58

Keywords

Climate change, labour markets, South Africa, central banking, fiscal policy, monetary policy, climate risks, general equilibrium modelling, employment, just transition

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1. Introduction[1]

Climate change and the low-carbon transition will affect labour markets in various, counteracting ways. Investment in low-carbon technologies and climate adaptation measures will increase demand for green jobs, while divestment from pollution-intensive sectors will slacken labour markets by stranding workers in fossil-based industries. Even under a moderate global warming scenario in which the low-carbon transition progresses, the physical effects of climate change will reduce labour productivity, especially in emerging markets and developing economies.

Southern African labour markets are especially exposed to these impacts due to their reliance on fossil fuels such as coal, as well as the large proportion of workers in sectors that are highly exposed to heat stress and other physical climate impacts, such as agriculture, construction and tourism. In addition, large numbers of workers in Southern African countries are employed in informal sectors with low adaptive capacity and limited social protection.

Such environmental risks add to existing pressures on the region's labour market. In South Africa, the official unemployment rate remains high at 31.9%, and there are also high rates of underutilisation and inequality (Statistics South Africa 2025). Labour market policy – in particular, the structural reforms necessary to tackle these challenges – traditionally falls in the domain of fiscal policymakers. However, the operations and frameworks of central banks such as the South African Reserve Bank (SARB) will also be affected by climate-related labour market risks. Central banks' inflation-targeting frameworks are largely built around the Phillips curve, the Beveridge curve or output gap estimates derived from Okun's coefficients, the non-accelerating inflation rate of unemployment and other analytical tools.

Despite the importance of employment to central banks, there is a notable gap in the literature around the macroeconomic impacts of climate change on labour markets.

[1] We acknowledge financial support from the SARB for this project. We thank Emanuel Moench for his thorough review and constructive comments on an earlier draft of this paper. We also thank Laurence Harris, Neryvia Pillay, Konstantin Makrelov and participants in the workshop on climate change and its implications for central banks in Southern Africa on 30–31 January 2025 for their helpful and insightful comments. Thanks, too, to the team at Clarity Global for editing this paper.

Most central banks and financial market supervision authorities have addressed climate change in the context of its implications for financial stability, such as the systemic risks that stranded assets and their cascading effects could have on the financial system (e.g. Caldecott 2018; Monasterolo 2020; Battiston, Dafermos and Monasterolo 2021). Employment-related environmental risks have received far less attention.

This paper addresses this gap by using a state-of-the-art computable general equilibrium (CGE) model to explore how environmental risks may disrupt employment in South Africa. It tests different climate change-related simulations to illustrate the effects of reduced agricultural productivity, water stress and heightened climate change-induced immigration on the South African labour market and the economy as a whole. We find strong negative employment and unequal distributional effects. We lay out ways in which these risks can be mitigated by fiscal policy, and how these risks might affect the effectiveness of monetary policy transmission under an inflation-targeting framework. This paper's findings are relevant to the SARB's future research agenda – in particular, its efforts to examine the implications of climate-related shocks for how it conducts monetary policy and ensures a sound and stable financial system. The evidence and findings presented in this paper may also prove valuable to other developing countries, especially those in Southern Africa with similar economic and labour market structures to South Africa.

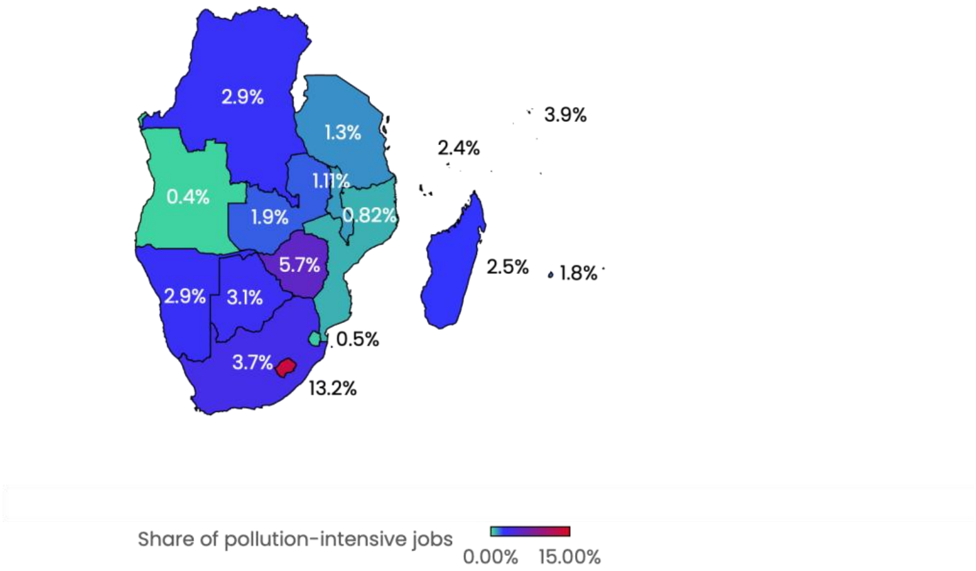
2. Literature and evidence review

2.1 Transition risks

Globally, it is estimated that around 1–2.5% of workers will be directly affected by the low-carbon transition over the next decade, meaning that they will either lose or have to change their jobs by 2030 (IMF 2022; Feyertag 2025). While this is substantial in absolute terms – implying that about 80 million jobs may be lost by 2030 (ILO 2018) – the employment effects of the low-carbon transition are modest when compared to similar periods of economic transformation (Magacho et al. 2023). About 4% of workers moved from industrial to service sector jobs during deindustrialisation in the 1980s, and 8% of workers switch jobs every year (IMF 2022).

Compared to the global average, South Africa's labour market is more exposed to transition risks due to its higher intensity of emissions and reliance on coal. While historical emissions are low (1.23%), current per capita emissions are 6.4 tonnes, less than half those of the United States (14.3 tonnes) but nearly 10 times that of neighbouring Zimbabwe (0.7 tonnes) (Ritchie, Rosado and Rosa 2025). The country emits approximately half the total carbon emissions for Africa, ranking 12th in the world for carbon emissions (Mohsin et al. 2019). The labour market is therefore more exposed to climate transition risks than most countries, with 3.7% of South Africa's labour force employed in pollution-intensive sectors compared to a global average of 2.4%. Within sub-Saharan Africa, South Africa is considered the fourth most exposed labour market to transition risks behind those of Botswana, Lesotho and Gabon (Feyertag 2025) (Figure 1).

Figure 1: Share of pollution-intensive jobs in Southern African Development Community labour markets



Source: Authors' own calculations based on Feyertag (2025)

This relatively high pollution intensity exposes South Africa's labour market to significant climate-related transition risks, which have been documented in various studies. Using the global E3ME-FTT model, Espagne et al. (2023) highlight South Africa's high dependence on coal exports and resulting exposure to global decarbonisation trajectories, which are estimated to reduce South Africa's energy exports, worsen its trade balance and reduce gross domestic product (GDP) by nearly 10% by 2050.

Versions of the South African Green Economy (SAGE) Model – a CGE model that has been used to assess South Africa's transition risk exposure – have also been used to analyse the impact of various carbon taxation and energy transition scenarios on the labour market (Anvari et al. 2022). For example, Alton et al. (2014) estimate that the phased introduction of a production-based carbon tax of US$30 per tonne of CO_2 emissions would reduce employment by 0.6% below the baseline. Schers (2018) finds that although a low carbon tax of US$18 per tonne of CO_2 would have negligible effects on employment, a carbon tax of US$55 per tonne would lead to higher unemployment.

Input-output models have also been used to assess labour market transition risks in the South African context. Godin and Hadji-Lazaro (2022) develop a demand-pull input-output model based on South Africa's Quarterly Labour Force Survey to assess the impacts of two shock scenarios, namely the loss of coal exports (coal shock) and less global demand for internal combustion engine vehicles, which they estimate would reduce employment by 0.42% and 0.79%, respectively.

The net employment effects of South Africa's low-carbon transition ultimately hinge on the speed of policy implementation, the particular policy mix applied and the success of these policies in creating forward and backward links between renewable energy and other domestic industries that offer opportunities for green job creation (Malik et al. 2021). More optimistic projections of the low-carbon transition's impact on employment can be derived by forecasting changes in the energy mix towards renewable sources. Renewable energy and other low-carbon technologies (e.g. electric vehicle manufacturing)[2] are generally considered more labour-intensive than their fossil-based counterparts (Rutovitz, Dominish and Downes 2015; Montt et al. 2018; Cotterman et al. 2024) and new investment is predicted to spur indirect demand for new jobs in sectors such as transport and construction (Chateau, Bibas and Lanzi 2018; Botta 2019; Fragkiadakis et al. 2023).

Although the higher labour intensity of renewables will diminish over time due to technological advances, capital efficiency gains, and lower operational and

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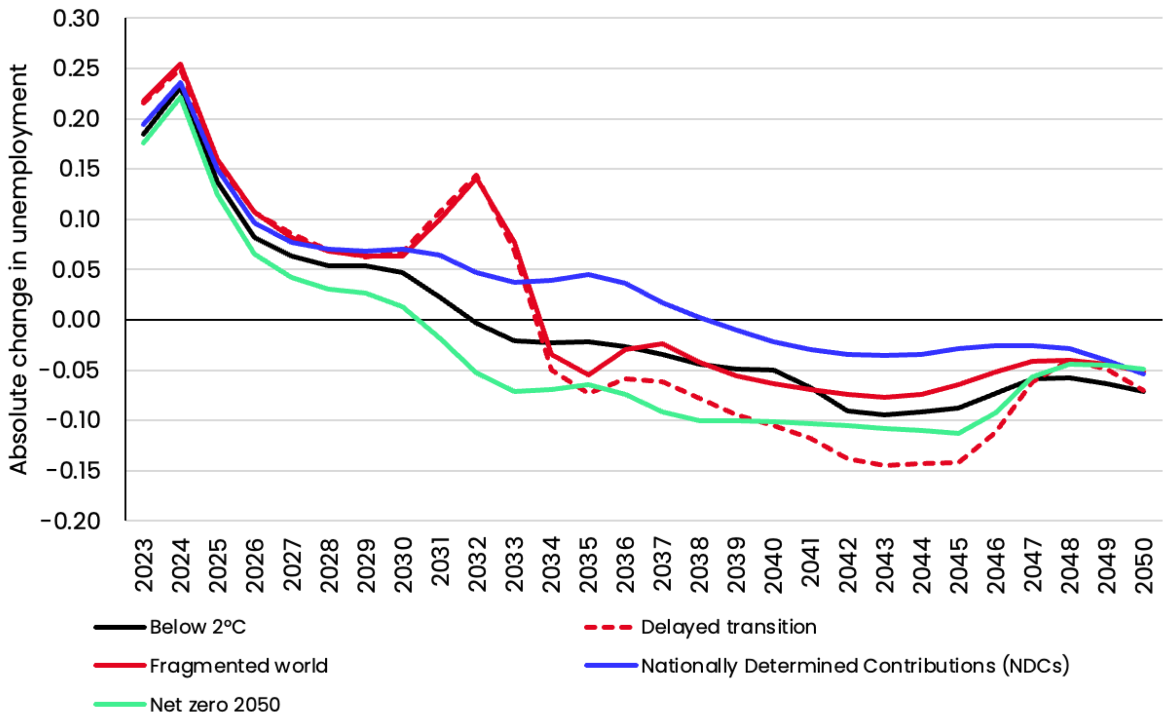
2 Provided that new battery production capacity is on-shored (Cotterman et al. 2024).

maintenance requirements (Malik et al. 2021; Espagne et al. 2023; NGFS 2024), the number of jobs created in green industries is expected to surpass the number of jobs lost in pollution-intensive sectors, even in South Africa's relatively transition-exposed labour market. In absolute terms, using a multiregional input-output model, the International Labour Organization (2018) estimates that the net growth of green jobs until 2030 under the 2°C energy scenario compared with 'business as usual' (BAU) will be 112 000. A more recent estimate by Financial Sector Deepening Africa is that the low-carbon transition will create between 85 000 and 275 000 green jobs by 2030, mainly in energy, agriculture and nature (Financial Sector Deepening Africa 2024). Using the LUT Energy System Transition Model, Oyewo et al. (2019) show that a 100% renewable energy scenario would lead to the direct creation of 408 000 jobs by 2035. Similarly, in a paper based on collaborative research by the Industrial Development Corporation (IDC) of South Africa, the Development Bank of Southern Africa (DBSA), and Trade & Industrial Policy Strategies (TIPS), Maia et al. (2011) estimate the employment potential in the formal sector of the green economy in South Africa to be about 98 000 new direct jobs in the short term (2011–2012), almost 255 000 in the medium term (2013–2017) and around 462 000 employment opportunities or part-time jobs in the long term (2018–2025).

Relative to BAU scenarios, the impact of the low-carbon transition on employment or unemployment is also generally considered positive. An early scenario analysis by Rutovitz (2010) suggests that even when taking into account job losses, an ambitious policy scenario in which South Africa cuts its emissions by 60% would result in 27% more jobs. Using the SAGE model, Musango, Brent and Bassi (2014) estimate that green economy scenarios produce up to 10.5% more jobs. Similarly, by linking the e-SAGE CGE model with an energy-system optimisation model (TIMES), Altieri et al. (2016) estimate that decarbonising South Africa's energy sector in line with global climate and local development objectives would reduce unemployment from 25% in 2010 to 12% in 2025. Using SATIMGE, which combines an integrated energy systems model with National Treasury's e-SAGE model, Hartley et al. (2019) find that net employment increases by 5.5% until 2050 under a scenario which assumes renewable energy deployment and conservative costs. Finally, by adapting a global demand-driven growth model developed by Rezei, Taylor and Foley (2018) to South Africa, Omer and Capaldo (2023) estimate that the employment-population ratio would increase from 28% under a BAU scenario to 38% under a climate change mitigation scenario accompanied by expansionary fiscal and monetary policies.

Ultimately, the realisation of long-term employment growth depends on the effective implementation of climate policies, as illustrated by the Network for Greening the Financial System (NGFS) scenarios. These show that under scenarios of fragmented global action or delayed transition, South Africa's labour market is expected to experience significant unemployment shocks in the medium term (2030–2035) (Figure 2). By contrast, coordinated and timely policy measures are expected to mitigate these disruptions and ensure sustainable labour market outcomes.[3]

Figure 2: Absolute change in unemployment under NGFS climate scenarios in South Africa



Source: NGFS (2023)

A major constraint of econometric models and other estimates of the net employment impact of the low-carbon transition is that they do not take into account distributional

3 The timing and magnitude of the impact of different scenarios on unemployment varies according to the three choices of model used: MESSAGEix-GLOBIUM 2.0, REMIND-MAgPIE 3.3-4.8 and GCAM 6.0. However, broadly speaking, the overall direction and structure of the pattern of predicted change in unemployment is similar across the models used.

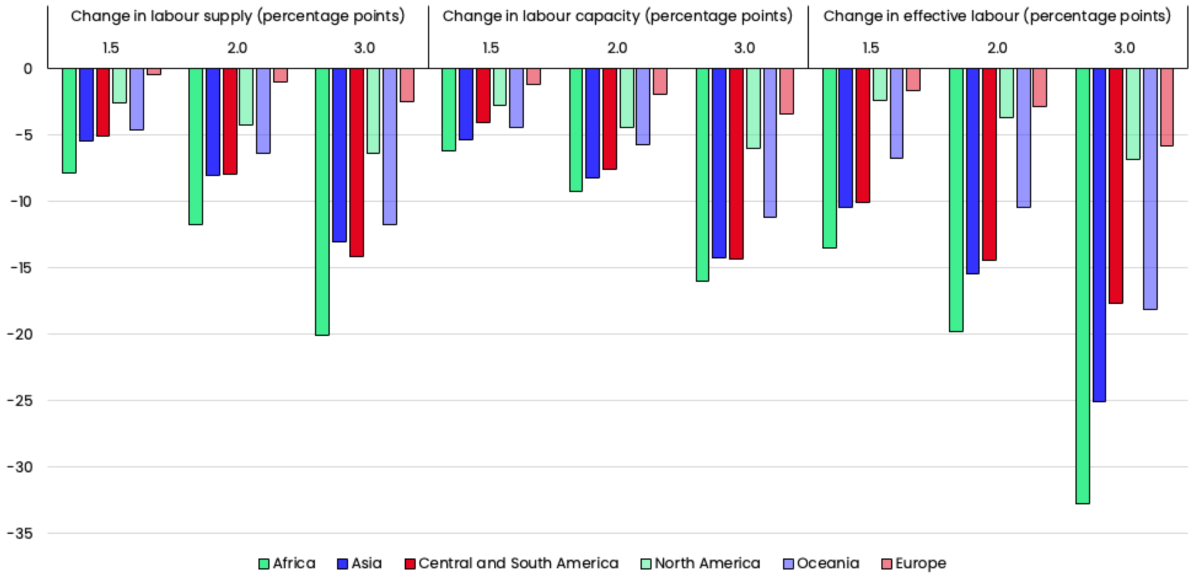
effects or inefficiencies in the labour market. Both are substantial in South Africa. Structural challenges persist that prevent the efficient reallocation of jobs and potentially result in hysteresis effects, even where net job demand is positive. Lower salaries and benefits, spatial differences between new employment in the renewable energy sector and current employment in coal-mining areas, and skills mismatches act as practical barriers that prevent those who lose their jobs in pollution-intensive industries from taking up jobs in green growth sectors, leading to regional unemployment (Hanto et al. 2022).

In particular, researchers have drawn attention to the regionally concentrated impacts of the coal transition on employment and unemployment in Mpumalanga and Limpopo (e.g. Spencer et al. 2017; Burton, Caetano and McCall 2018; Burton, Marquard and McCall 2019; Makgetla et al. 2019; Malik et al. 2021; Hägele, Iacobuţă and Tops 2022; Bhorat et al. 2024). While these are generally overlooked in country-level assessments, using a multiregional, comparative-static CGE model for South Africa, Bohlmann et al. (2019) show that under a scenario in which South Africa switches from coal to a cleaner energy mix, semi-skilled employment would drop by 2–3% in Mpumalanga despite the nationwide impact on employment being negligible. Similarly, Hanto et al. (2021) extend the Global Energy System Model to analyse the employment effects of a 2°C scenario, confirming that while the growth of jobs in renewable energy will far outweigh the loss of jobs in pollution-intensive sectors overall, this does not hold for Mpumalanga. Both quantitative and qualitative research on the low-carbon transition's uneven distributional effects on employment in South Africa have led to frequent calls for a 'just' or equitable transition (e.g. Burton, Marquard and McCall 2019; TIPS 2019; Nel, Marais and Mqotyana 2023).

2.2 Physical risks

Regrettably, the depth and breadth of literature on the employment impacts of the low-carbon transition in South Africa does not extend to the impact of climate-related physical risks. Globally, it is expected that even under an ambitious scenario in which emissions are reduced to keep global warming under 1.5°C, the growing frequency and intensity of heat stress episodes will reduce the total hours of work by 2.2% by 2030, which is equivalent to 80 million full-time jobs (ILO 2019). This reduction in working hours is due to heat stress, absenteeism or fatigue in sectors reliant on outdoor or physical labour (Dell, Jones and Olken 2012; Dasgupta et al. 2024). In agriculture, mining, manufacturing and construction, heat-related declines in effective labour capacity are already significant, with losses projected to reach close to 35% in highly exposed African countries under a 3°C warming scenario (Dasgupta et al. 2024) (Figure 3).

Figure 3: Percentage-point change in labour supply outcomes by warming level relative to pre-industrial period



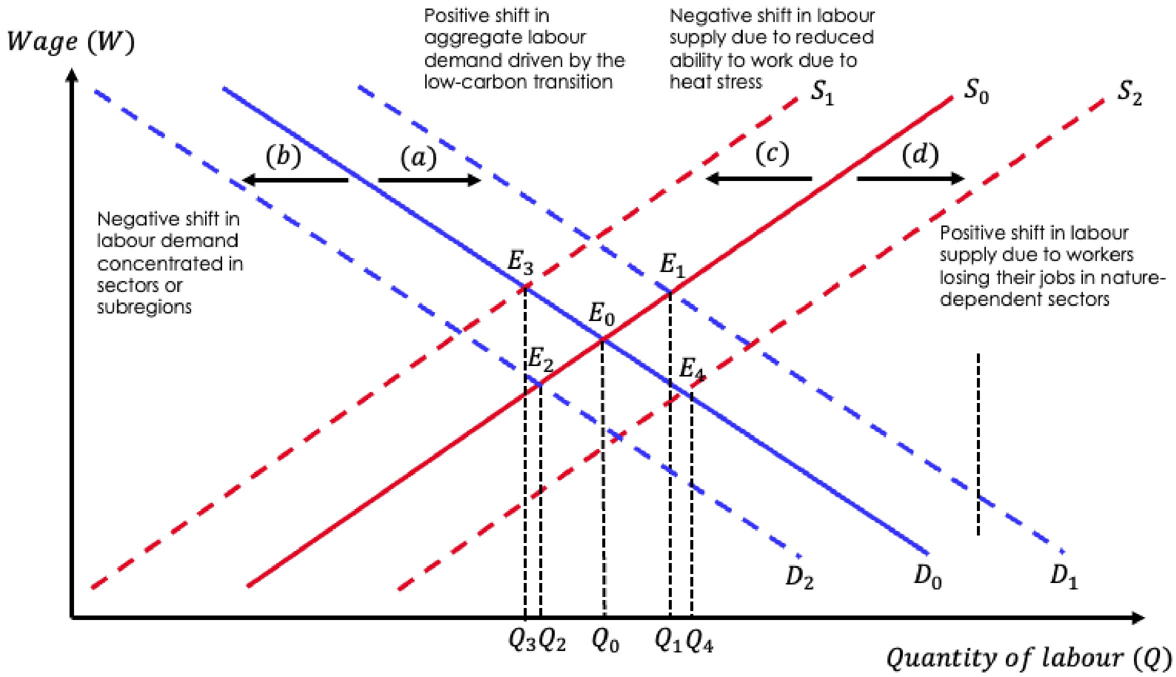
Note: The results are presented under a 'high' scenario.

Source: Adapted from Dasgupta et al. (2024)

Emerging markets and developing economies, including South Africa, are disproportionately exposed to physical climate risks due to their dependence on agriculture, the presence of large informal labour markets and limited adaptive capacity. In South Africa, 25.6% of jobs are in climate-exposed sectors such as agriculture or construction, requiring outdoor, daytime and physical work (Feyertag 2025). The intensity and duration of heatwaves in South Africa is expected to rise sharply, which will limit workers' capacity to perform outdoor manual labour (Scholes and Engelbrecht 2021). Qualitative research has found that high temperatures have a wide range of effects, such as difficulty maintaining work level and output during very hot weather (Mathee, Oba and Rose 2010; Kjellstrom et al. 2014; Manyuchi et al. 2022) and an exponential decline in the performance of manual labour tasks above 'wet bulb temperatures' (Wyndham 1969). Furthermore, health impacts such as heat-related mortality (Wichmann 2017; Scovronick et al. 2018; Vicedo-Cabrera et al. 2021) and poor mental health (Kim et al. 2019) have been attributed to greater heat exposure caused by climate change in South Africa.

However, modelling the impacts of heat stress and other physical risks on labour markets is complex (Figure 4). Physical climate shocks such as heat stress can reduce labour productivity and capacity, effectively reducing labour supply. At the same time, workers may search for new opportunities in less climate-exposed sectors, leading to high unemployment, urban migration or cross-border displacement (Hassler, Krusell and Olovsson 2024). For example, high temperatures and precipitation extremes have been found to be linked to increased migration out of rural areas among black and low-income communities in South Africa (Mastrorillo et al. 2016). This is especially the case where physical climate impacts are compounded by ecosystem stresses caused by environmental degradation, forcing workers to diversify or migrate (Kangalawe et al. 2017; Hove and Gweme 2018; Trisos et al. 2022). In-country or cross-border migration could lead to reduced labour supply in rural areas that are highly exposed to physical climate effects, while increasing labour supply (and therefore potentially unemployment) in urban areas or in other countries.

Figure 4: Stylised labour demand curve illustrating impact of environmental risks on the labour market



Source: Feyertag (2025)

A small number of studies have estimated the impact of physical climate risks on labour supply. Notably, Shayegh, Manoussi and Dasgupta (2020) and Shayegh and Dasgupta (2022) use micro-survey data to estimate that output per adult will drop by 11 percentage points under a severe climate scenario due to higher temperatures. The distribution of these effects is uneven, with low-skilled workers and women being disproportionately affected. Using similar methods, Gray, Taraz and Halliday (2023) combine high-resolution weather data with individual-level survey data to analyse the impact of droughts and high temperatures on employment outcomes, finding that increases in drought reduce overall employment, especially in the tertiary sector, among informal workers, and in provinces with a higher reliance on tourism. At an international level, analysis of global climate models under a high emissions scenario (RCP8.5) by Gosling, Zaherpour and Szewczyk (2019) singles out South Africa as a country facing one of the largest declines in labour productivity at 15%.

Less is known about the extent to which these productivity declines translate into South Africa's labour market dynamics, such as increased unemployment, migration or reduced demand for labour. Only a few forward-looking, economy-wide analyses of the impact of physical climate risks on employment and unemployment exist in South Africa. One notable exception is a draft paper by Chitiga et al. (2019), who adjust the PEP-1-t CGE model to assess the impact of physical climate change via reduced agricultural productivity, water scarcity and migration shocks on various economic variables, including unemployment. This paper builds on that work to increase the understanding of the physical effects of climate change on labour markets in South Africa and the implications for the SARB and other monetary authorities in the region.

3. Methodology and empirical approach

3.1 Overview and methodology

To analyse the potential physical impacts of climate change on South Africa's labour market, we use the University of Pretoria General Equilibrium Model (UPGEM). Building on Chitiga et al. (2019), we model scenarios related to agricultural productivity, water scarcity shocks and migration shocks. UPGEM is a large-scale dynamic economic model of South Africa designed to provide quantitative estimates of the economy-wide effects of policy proposals or other exogenous shocks, such as climate change.

The original MONASH model on which UPGEM is based is fully documented in Dixon and Rimmer (2002) and Dixon, Koopman and Rimmer (2013), with Bohlmann et al. (2015) providing a local application using UPGEM. The general equilibrium core of UPGEM is made up of a linearised system of equations describing the theory underlying the behaviour of participants in the economy. It contains equations describing, among others, the nature of markets; intermediate demand for inputs to be used in the production of commodities; final demand for goods and services by households; demand for inputs for capital creation and the determination of investment; government demand for commodities; and foreign demand for exported goods. The UPGEM database,[4] combined with the model's rigorous theoretical specification, describes the main real interlinkages in the South African economy. The theory of the model, depicting typical optimisation behaviour associated with conventional neoclassical microeconomics, is then essentially a set of equations that describe how the values in the database move through time and in response to any given policy shock.

CGE models are primarily designed to isolate and measure the effects of a shock and provide a credible explanation for the simulation results produced by referring only to the model's theoretical specification, database and closure conditions or assumptions. Dynamic models, such as the version of UPGEM used here, also offer explicit BAU baseline projections and detail on the adjustment path caused by the shock over time. The CGE methodology suggests that a good way to examine the impacts of any exogenous shock or policy intervention is to compute the differences between a scenario in which the shock has occurred – the policy simulation – and a counterfactual scenario in which the particular shock under examination did not occur – the baseline scenario. Results are then reported as percentage deviations over time between the 'baseline' simulation run and 'policy' simulation run. In the next section, we describe in more detail the various scenarios considered in this paper.

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4 The current core UPGEM database for South Africa was produced using the final 2019 supply-use tables published by Statistics South Africa in combination with various other supplementary data sources following the process described in Roos, Adams and van Heerden (2015).

3.2 Scenarios

We model three long-term climate change scenarios and describe how they affect the South African economy as a whole, emphasising the effects on employment, relative to a BAU baseline scenario. To avoid discussing exact magnitudes of climate-related shocks, our strategy is to use simple 1% benchmark shocks in terms of the size of the annual shocks implemented over a 15-year window of our overall simulation period. The results of these benchmarked shocks can then be used to extrapolate what the effects of different long-term climate outcomes may be depending on what level of persistence and severity is anticipated, given the inherent uncertainty surrounding such estimates. We acknowledge that this is a non-exhaustive list of climate-related disruptions that ignores likely indirect or second-round effects such as increased financial market instability. Nonetheless, the scenarios modelled here capture key direct impacts identified in the literature and aim to provide strong evidence of their economy-wide effects in South Africa, with specific reference to labour markets and in the context of policy planning by the SARB.

The proposed scenarios can be summarised as follows:

1. BAU baseline scenario: unperturbed baseline where the economy grows following long-term projections and trends without explicit consideration of the effects of climate change.
2. Agriculture: simulating the unmitigated effects of climate change in the form of reduced productivity in the agricultural sector by reducing its total factor productivity and land productivity by a benchmark of 1% each year over a 15-year period.
3. Water: simulating the unmitigated effects of climate change in the form of reduced water availability in South Africa due to less rainfall and increasing droughts through a 1% decrease in the availability of water each year over a 15-year period.
4. Labour: simulating the unmitigated effects of climate change in the form of climate-induced labour migration from other Southern African countries affected by increasing temperature extremes and other extreme weather events caused by climate change.

4. Results

4.1 BAU scenario

The BAU baseline scenario, also often referred to as the unperturbed baseline scenario, implements an unsophisticated view of the economy's future evolution from 2023 up to 2050, combining available short-term historical and forecast data with longer-term trend projections. In this typical application of the baseline, we only consider projections at a macroeconomic level. We therefore see very little in terms of structural change or shifts in the economy relative to the status quo reflected through the model's base year data for 2022. As the policy simulations aim to capture the identified climate change effects, we do not consider any such direct climate-related effects in the projection of the BAU baseline.

As described in Dixon and Rimmer (2002), setting up the baseline forecast closure to facilitate the input of exogenous projections requires appropriate changes to the closure settings of the model. For example, to exogenise and shock GDP with its projected values requires a variable such as total factor productivity to be endogenised. Similarly, to exogenise and shock exports with its projected values requires a variable such as a shifter for the position of the export demand curve to be endogenised.

The BAU baseline simulation uses the latest available data from sources such as South Africa's National Treasury (2025), Statistics South Africa (2023, 2024) and the International Monetary Fund (2025) to produce plausible short- to medium-term projections across a broad range of macroeconomic variables. To allow for a smoother baseline trajectory, we take the average of 2023–2024 historical data and 2025–2027 forecast data. Beyond that, macroeconomic projections that are calibrated to the SARB's current view of 2.5% long-term real GDP growth under a zero-output-gap steady-state scenario (SARB 2024) are implemented up to 2050 for only the main macro variables, while taking into consideration other long-term projections in Fontagné, Perego and Santoni (2022).

Given our baseline forecast inputs and assumptions for the 2023–2050 period, the following notable outcomes are produced:

1. Real GDP grows at an average annual rate of 2.3%, or 89.1% cumulatively, over the 28-year simulation horizon up to 2050.
2. Investment expenditure of 3.0% on average, alongside relatively weak total factor productivity growth, leads to capital per worker growth being the main contributor to GDP growth over the forecast period.
3. Moderate employment growth of 46.6% relative to labour force growth of 32.1% is exogenously projected together with overall real wage growth of 15.1% over the 2023–2050 period.
4. Other long-term macro projections that endogenously follow from the exogenous forecasts imposed include a slight increase in the current account deficit in the long run (import growth exceeds export growth), a relatively stable government budget deficit position (a slight annual deficit position in the short to medium run gradually moves to a surplus position by 2040, leading to a decline in the overall debt-to-GDP ratio in the long run), and private household consumption and general government expenditure growth that move in line with GDP growth.

Table 1 summarises the key macroeconomic baseline forecast outcomes simulated over the 2023–2050 period. It is worth noting again that these projections are only intended to produce a plausible BAU picture of the economy against which particular policy shocks can be measured. While these projections will undoubtedly differ from a 2050 reality, they do not invalidate or make the baseline forecast simulation any less useful given their intention. Importantly, policy simulation results, when presented as percentage deviations, are also robust to changes in the baseline path (Dixon, Koopman and Rimmer 2013).

Table 1: BAU baseline simulation results

BAU forecast	2023–24 annual avg	2025–27 annual avg	2028–50 annual avg	2023–50 cumulative	2023–50 annual avg
Real GDP	0.8	1.8	2.5	89.1	2.3
Consumption	0.9	1.8	2.4	86.5	2.2
Investment	0.6	4.0	3.1	129.1	3.0
Government	1.5	1.3	2.4	85.3	2.2
Exports	0.8	3.2	2.4	80.1	2.1
Imports	-0.5	3.3	2.6	98.8	2.4
Productivity	-0.9	-0.1	0.1	2.0	0.1
CPI inflation	5.0	4.5	4.0	210.1	4.1
Employment	0.5	1.0	1.5	46.6	1.4
Real wages	0.5	0.5	0.5	15.1	0.5
Population	1.0	1.0	1.0	32.1	1.0

4.2 Agricultural and land productivity scenario

The first perturbed, or policy shock, scenario captures the predicted deterioration in agricultural productivity in South Africa as a result of climate change. Although the direction of change is certain (Intergovernmental Panel on Climate Change 2023), the long-term magnitudes of such productivity changes are uncertain, hence our adoption of the 1% benchmark approach described earlier. We impose an annual 1% negative shock to the total factor productivity of composite capital and labour resources, as well as land, in the agricultural sector for 15 consecutive years. This has the effect of exogenously reducing overall primary factor, including land, productivity in the agricultural sector by a cumulative 16.1% over the simulation period. Results should therefore be interpreted as such, that is, for a 15-year period (up to 2040) of gradual deterioration in agricultural productivity due to climate change before stabilising at that level for the remainder of the simulation period up to 2050. At this stage, we do not impose any shock on productivity for the rest of the world.

The results of the simulation are not surprising. The first-round effect of the shock is to raise domestic agricultural sector output prices. Field crop prices rise by 19.5%, horticulture prices by 18.5% and livestock prices by 22.1% in the long run. These price increases feed into the food manufacturing sector, in particular meat processing, which sees its prices rise by 11.3% in the long run. Most other food manufacturing sector products see price increases of between 3% and 5% relative to the BAU baseline. These impacts may be considered smaller than anticipated given the severity of the shocks on primary sector agricultural productivity and, indirectly, prices. The main reason for this is that users of agricultural output, which include the food manufacturing sector and direct household consumers, can substitute outputs with relatively cheaper imported versions of those agricultural commodities, assuming that productivity shocks do not affect the production of agricultural commodities in other countries. For example, the model shows that demand for imported livestock increases by 53% in the long run. Imports of processed meat products rise by 22%. Imports of virtually all other primary sector agricultural products and secondary sector food manufacturing products increase as a result of the domestic price increase. The main effect of this substitution with imported versions of these products is that it protects domestic consumers from facing even greater price increases, thereby allowing consumption to be higher than would otherwise have been possible. This is illustrated by a fall of only 4.3% in the consumption of meat products, despite the large domestic price increase.

The labour market effects are notable. On aggregate, the interplay between employment and wages is clear. The model's labour market mechanism is designed to move employment back to the baseline in the post-shock period (2040–2050), with real wages adjusting to help achieve this. Given the deterioration of land productivity combined with a fixed amount of land used for production, the cost of capital attributed to land rises substantially. Under our modelled assumptions, the impact of falling total factor productivity – that is, more capital and labour required per unit of output – actually works to offset the damage to employment in the sector in the short to medium run, despite falling output levels, as capital levels take time to adjust. However, real wages fall on the back of the reduced productivity, and continue to do so up to 2050 as the labour market mechanism pushes to restore employment to baseline levels. Should the shock be restricted to labour productivity, with higher substitution elasticities between capital and labour possible in the long run, the impact on employment and real wages will be significantly worse as there will be greater use of capital.

Table 2 summarises the key macro- and industry-level percentage deviations caused by the agricultural productivity shocks, relative to the BAU baseline, over the short, medium and long term using the standard version of UPGEM.

Table 2: Scenario 1 simulation results (% deviation)

Policy shock scenario 1: agricultural productivity	2030	2040	2050
Macro-level activity			
Real GDP	-0.20%	-0.61%	-0.55%
Consumption	-0.21%	-0.68%	-0.67%
Exports	-0.21%	-0.46%	-0.24%
Imports	-0.13%	-0.24%	-0.03%
Employment	-0.14%	-0.31%	-0.10%
Real wages	-0.24%	-1.40%	-2.16%
Industry-level activity			
Field crops output	-4.30%	-12.90%	-14.30%
Field crops imports	11.90%	41.40%	45.10%
Livestock output	-2.80%	-9.30%	-11.40%
Livestock imports	14.70%	49.20%	53.90%
Processed meat output	-2.30%	-8.40%	-11.20%
Processed meat imports	4.80%	17.80%	22.60%
Household consumption			
Processed meat products	-0.85%	-3.27%	-4.33%
Fruit and vegetable products	-0.23%	-0.94%	-1.21%
Grain mill products	-0.23%	-0.98%	-1.25%
Leather products	-0.30%	-1.35%	-1.98%

4.3 Water scarcity scenario

The second perturbed, or policy shock, scenario captures the predicted deterioration of water availability to the general economy as a result of climate change. Water in this context should be thought of as piped water typically procured through normal market mechanisms from municipalities or directly from water boards. Industrial users such as the soft drink industry and households are the biggest consumers of piped or tap water. Following our benchmark approach, we impose an annual 1% negative shock to the total factor productivity of composite capital and labour resources in the water sector for 15 consecutive years as a proxy for increased water scarcity. This has the effect of exogenously reducing productivity in the water sector by a cumulative 16.1% over the simulation period. At this stage, we do not impose any shock on productivity for the rest of the world, but given South Africa’s limited trade of fresh water, this assumption does not play a significant role.

The first-round effect of the shock is to raise domestic water sector output prices, peaking at 17.4% above baseline levels in 2040. Water output to the economy falls by 3.8% as a result of the decline in total factor productivity and rising prices, adequately capturing a scenario of increased water scarcity. The price increase of water feeds into many other industrial sectors that use a relatively large amount of water – for example, mining and non-alcoholic beverages. However, household consumption of water is most significantly affected, with a drop of 5.9% expected in the long run.

The labour market effects of the water scarcity scenario as modelled here in isolation are not significant, with aggregate employment falling by only 0.04% and real wages by 0.27% below baseline levels in 2040. Piped or tap water makes up a relatively small percentage of even heavy users' overall expenditure basket, and is also a capital-intensive industry, hence its limited impact. However, it should be noted that none of the three scenarios will occur in isolation, and that these effects, as well as those in the preceding and next scenarios, should be aggregated to have a more complete understanding of the effects of climate change. Moreover, extreme water restriction scenarios, such as the Western Cape's near day-zero experience in 2018–19, suggests that the severity of these shocks may far exceed the benchmark magnitudes implemented here. Regardless of the severity of the shock, all key macro variables paint a predictably negative picture of the economy-wide effects of lower water sector productivity and increased water scarcity.

Table 3 summarises the key macro-level percentage deviations caused by the water shocks, relative to the BAU baseline, over the short, medium and long term using the standard version of UPGEM.

Table 3: Scenario 2 simulation results (% deviation)

Policy shock scenario 2: water scarcity	2030	2040	2050
Macro-level activity			
Real GDP	-0.06%	-0.11%	-0.06%
Consumption	-0.07%	-0.14%	-0.10%
Exports	-0.05%	-0.12%	-0.07%
Imports	-0.02%	-0.04%	-0.04%
Employment	-0.07%	-0.04%	-0.00%
Real wages	-0.04%	-0.27%	-0.23%
Household consumption			
Food products	-0.04%	-0.09%	-0.05%
Non-alcoholic beverages	-0.12%	-0.28%	-0.21%

4.4 Labour immigration scenario

The third perturbed, or policy shock, scenario captures a potential increase in climate-induced labour migration to South Africa. This scenario envisions South Africa offering relatively better living prospects than more severely climate-impacted sub-Saharan countries, leading to immigration and an increase in labour supply.

For this simulation, a simple short- and long-run comparative-static simulation following our benchmark approach may at first appear to be the most appropriate choice when using the standard version of UPGEM. As is typical of most CGE models, UPGEM's standard labour market mechanism forces employment to endogenously return to its baseline path in the long run following a shock, with real wages adjusting to clear the market. Another key UPGEM parameter is the capital-labour substitution elasticity, which for long-run simulations is set at a relatively moderate 0.5. However, with the exogenous increase in labour supply in this application, real wages are therefore forced to fall relative to baseline levels to absorb the additional labour and prevent unemployment levels from rising. In reality, if real wages are not allowed to adjust downwards, unemployment will subsequently increase relative to baseline levels in the absence of any demand-side boost to the economy relative to the baseline. In addition, the standard version of UPGEM does not explicitly account for unemployed workers, and views the long-run baseline level of employment as the equivalent of a full employment level. Regardless of which assumption is believed to be more appropriate for South Africa in the long run, either outcome would exacerbate an already critical situation, especially at the lower end of the labour market, of high unemployment and relatively low wage levels.

A larger labour force, when absorbed into employment in South Africa, may increase GDP, as suggested by the comparative-static modelling results, but not necessarily GDP per capita. The nature of the immigration modelled here is unlikely to generate an increase in total factor or labour productivity, and lower-paid jobs are likely the first to see a substantial increase in labour supply, where South Africa already faces a high level of structural unemployment. The required drop in real wages to facilitate no increase in unemployment may not be viable should immigration levels rise to substantial levels. However, the standard version of UPGEM is unable to explicitly give insight into the dynamics of such a scenario.

To better understand the employment (and unemployment) dynamics of a scenario that involves changes in labour immigration relative to the baseline, and that also considers the skill characteristics of potential migrants, a more sophisticated labour market mechanism needs to be implemented. For this scenario, we incorporate a labour-migration module adapted from the USAGE-M CGE model documented in Dixon, Johnson and Rimmer (2011) and first used in a South African context in Bohlmann (2011). The shock represents a benchmark increase of roughly 500 000 additional medium- and low-skilled migrants, or about 3% of the employed number of workers in the baseline, entering the South African labour force.

The shock has a number of contrasting effects on the local economy. While the sheer increase in workers generates a slight increase in output as measured by GDP (0.73% in the long run based on the benchmark shock), employment for local South African workers falls relative to the baseline. Since the inflow of migrants in this scenario is restricted to medium- and low-skilled migrants only, the competition for the limited number of vacancies has a detrimental effect on the chances of local workers finding jobs, partly due to the slightly lower relative wages of the immigrant workers in the initial calibration of the labour-migration module's database. While overall employment rises across all occupation types, the detail regarding who is getting those jobs may be an important factor for local policymakers to consider. GDP per capita on aggregate also falls below baseline levels. Naturally, if the type of immigration is expanded to include skilled workers from the rest of the world, employment for local workers in those jobs may not fall significantly, but real wages are likely to come under more pressure.

Table 4 summarises the key macro- and skill-level percentage deviations caused by the labour supply shocks, relative to the BAU baseline, over the short and medium term using the labour-migration enhanced version of UPGEM.

Table 4: Scenario 3 simulation results (% deviation)

Policy shock scenario 3: labour immigration	Short run 2030	Long run 2040
Macro-level activity		
Real GDP	0.06%	0.73%
Consumption	0.07%	0.67%
Exports	-0.03%	0.50%
Imports	0.15%	0.61%
Employment (jobs)	0.76%	1.97%
Employment (wage bill weighted)	0.13%	0.92%
Real wages	-0.18%	-0.64%
Employment of legal South African residents by skill type (jobs)		
Legislators, senior officials and managers	0.08%	0.92%
Professionals	0.07%	0.90%
Technicians and associate professionals	0.08%	0.91%
Office and customer service clerks	-0.43%	0.14%
Service and sales workers	-0.87%	-0.85%
Skilled agricultural and fishery workers	-3.73%	-5.37%
Craft and related trades workers	-2.12%	-2.87%
Plant and machine operators	-0.99%	-0.98%
Elementary occupations	-2.17%	-2.92%
Domestic helpers and cleaners	-2.59%	-3.56%

5. Discussion and implications for fiscal and monetary authorities

The scenarios modelled in this paper capture some of the primary economic shocks associated with the physical impacts of climate change on agricultural productivity, water stress and climate-induced migration. As these shocks are likely to occur simultaneously, one of the advantages of CGE models is their ability to clearly show the direction of change and the relative economy-wide impacts of these shocks when considered in isolation. Overall, the simulations suggest that reduced agricultural productivity and climate-induced migration would have the largest negative impacts on the labour market, while the effects of water stress are muted. To our knowledge, this is the first paper to assess the impact of physical climate change risks on employment in South Africa and its implications for fiscal and monetary policy.

This information can be used by monetary and fiscal policymakers to anticipate policy responses that can mitigate the impact of these shocks on inflation and employment, as well as integrating these responses into medium- to long-term policy planning and policy research efforts. The broad policy implications arising from the results of the CGE modelling are discussed below. As UPGEM does not explicitly account for monetary or fiscal policy dynamics, we refrain from using the results to speculate on how policymakers should adjust specific policy tools, but rather draw together policy recommendations from existing literature.

5.1 Employment effects

Two main channels of harmful employment effects arise from the analysis. The first is a fall in total factor productivity as a result of reduced agricultural productivity. While this works to offset reductions in the employment level caused by falling output by requiring more capital and labour per unit of output, it inevitably leads to a fall in the quality of employment available to South Africans.

The second and perhaps more consequential channel is the impact of climate-induced migration on insider-outsider dynamics (Lindbeck and Snower 1988; Rueda 2005; Galí 2020). The increased inflow of medium- and low-skilled workers using the labour-migration enhanced version of UPGEM shows that lower-skilled workers in South Africa will suffer employment and wage losses, while employment levels increase for high-skilled workers relative to the baseline (Table 4). This would strengthen existing insider-outsider dynamics in South Africa's labour market (Viegi and Dadam 2023) while exacerbating an already critical situation among medium- and low-skilled workers.

Both findings are relevant to South Africa's longstanding structural labour market issues. Since the global financial crisis (GFC), the economy has struggled to produce sufficient vacancies to absorb newcomers to the labour market. Economic shocks such as the GFC or the COVID-19 pandemic have had persistent scarring or hysteresis effects on the labour market, especially among lower-skilled workers (Banerjee et al. 2008; Kerr, Wittenberg and Arrow 2013; Viegi and Dadam 2023).

The low impact of the water stress scenario contradicts recent analysis of the direct and indirect dependencies of South Africa's economic sectors to water-related ecosystem services (Hadji-Lazaro et al. 2025; Godin, Maurin and Calas 2026). For instance, Hadji-Lazaro et al. (2025) use an extended multi-regional input-output table to estimate that 5.1% of South Africa's employment (852 000 jobs) is dependent on water and is concentrated in water-sensitive municipalities in provinces such as Mpumalanga, the Eastern Cape, Limpopo and the Free State. The assumptions of the water stress scenario modelled in this paper likely underestimate the breadth of exposure from the input-output approach because it proxies water scarcity through a decline in the total factor productivity of the piped water sector rather than modelling a direct reduction in water supply (including surface water) to all dependent industries. Future research could incorporate the sectoral water-dependency scores from Hadji-Lazaro et al. (2025) or the WWF Water Risk Filter's spatially explicit water stress data into the CGE framework to analyse the effect of water stress on sectors such as mining, manufacturing or agriculture that depend heavily on surface water through ecosystem services that sit outside the piped water system.

5.2 Fiscal policy implications

As mentioned, it is not possible to draft detailed policy recommendations based on the findings, because UPGEM does not incorporate policy dynamics. However, the findings do help us understand which labour market transmission channels climate shocks are likely to trigger, which in turn providers broader policy recommendations on the types of policy packages that are likely to mitigate these effects.

A major contribution of this paper is that physical climate change is likely to add to the uneven distributional employment effects of the low-carbon transition. While the aggregate employment impact of the low-carbon transition in South Africa is likely to be positive, it will have negative distributional effects on specific provinces and sectors (Hanto et al. 2022; Bhorat et al. 2024). Our analysis suggests that distributional effects between workers in higher and lower skill groups are likely to be reinforced by climate-induced medium- and low-skilled migration from neighbouring countries.

The uneven distributional employment effects of climate change and the low-carbon transition are also likely to reinforce existing structural issues in South Africa's labour market. These issues have been attributed to structural changes in labour demand due to skill-biased technological progress, as well as institutional constraints on the labour supply side due to the presence of bargaining institutions (Viegi 2015) or the legacy of apartheid on the education system, which has disrupted school-to-work transitions and led to high unemployment among young, mostly black, South Africans. The unemployment rate has also been observed as being higher among women than men (Loewald, Makrelov and Wörgötter 2021).

Distributional labour market effects can be tackled through appropriate fiscal allocations to support certain micro-policies. These include (i) improvements to the effectiveness of labour market institutions such as Public Employment Services; (ii) the targeted use of active labour market policies such as job placements; (iii) increasing the attractiveness of the technical and vocational education and training system by increasing industry involvement and offering tax support for the employment of graduates in priority sectors; (iv) increased labour market flexibility by linking employment protection to employment tenure and easing skilled immigration; and (v) increased competition in product and services markets by reducing barriers to entry for foreign firms or excessive administrative burdens on small businesses (Groepe 2015; Koske et al. 2015; Loewald, Makrelov and Wörgötter 2021). Employment equity and black economic empowerment policies may also be effective in addressing the structural causes of unemployment among disadvantaged groups.

Many of these policies have long been recognised as a priority in South Africa, given the high labour utilisation gap compared with other emerging economies (Anand, Kothari and Kumar 2016; Loewald, Makrelov and Wörgötter 2021). For example, South Africa's National Development Plan (National Planning Commission 2012) has a strong focus on supporting employment growth, including through greater flexibility in the labour market. Some policies have since been implemented, such as the employment tax incentive, which has largely been seen to have had a positive impact on job creation among smaller firms (Bhorat et al. 2020; Ebrahim, Leibbrandt and Ranchhod 2017; National Treasury 2016).

While the National Development Plan also included a focus on the pivotal role of industrial policy in supporting employment, targeted fiscal support has largely been granted to capital-intensive sectors such as automated car manufacturing (Loewald, Makrelov and Wörgötter 2021). Shifting fiscal support to small and innovative firms in regional green trade and digital sectors, as well as towards climate-related infrastructure investment in electricity and transportation has been highlighted as an opportunity to stimulate job growth in the South African economy (World Bank 2025). Infrastructure investments not only create direct jobs, but improve the long-term productivity of the economy by providing network services and thereby acting as multipliers for start-ups and innovative small businesses to create jobs (Loewald, Makrelov and Wörgötter 2021).

5.3 Monetary policy implications

Monetary policy has little to no direct influence on the structural factors that underpin high unemployment in South Africa (Vermeulen 2017), or on the supply-side effects that climate shocks are likely to have (e.g. on the influx of lower-skilled workers), according to the findings of the analysis. However, monetary authorities including the SARB monitor and analyse labour market indicators to inform and calibrate monetary policy decisions using tools such as the Phillips curve and the Taylor rule, which provide critical insights on domestic inflationary pressure, volatility in the real economy and the transmission of monetary policy. The Phillips curve (Phillips 1958), in particular, remains a key tool for forecasting inflation as part of South Africa's flexible inflation-targeting framework (Smal, Pretorius and Ehlers 2007).

By contributing to existing structural unemployment among medium- and low-skilled workers in the South African labour market and by reducing total factor productivity and the natural rate of unemployment, climate shocks may weaken the Phillips curve. Labour market frictions and low labour market utilisation impose a constraint on monetary policy by reducing the responsiveness of wage setting to shocks and thereby reducing the effectiveness and efficiency of monetary policy within an inflation-targeting regime, which South Africa has had in place since 2000 (Viegi 2015; Bhattarai 2016).

There have already been longstanding debates over a flattened or even 'dead' Phillips curve in South Africa (Hodge 2005; Burger and Markinkow 2006; Burger and du Plessis 2013; Viegi 2015; Kabundi, Schaling and Some 2019; Botha, Kuhn and Steenkamp 2020; Kabundi, Schaling and Some 2016; Vermeulen 2017; Reid and Siklos 2021; Viegi and Dadam 2020, 2023; Du Rand, Hollander and van Lill 2023; Foresto, Reid and Rakgalakane 2025). A weakened trade-off between inflation and employment slack has, for example, been observed in the post-apartheid (Viegi 2015) and post-GFC period (Viegi 2015; Vermeulen, 2017; Reid and Siklos 2021; Foresto, Reid and Rakgalakane 2025) – a finding that is consistent with the experience of other emerging market economies (Blanchard, Cerutti and Summers 2015).

Climate shocks may further weaken the Phillips curve in the South African context and could be the focus of future research studies. For example, post-COVID studies have assessed whether a flat Phillips curve is instead limited to a low-inflation regime, but turns significant in a high-inflation environment, thereby becoming non-linear and state-dependent (Kabundi, Schaling and Some 2019; Du Rand, Hollander and van Lill 2023; Foresto, Reid and Rakgalakane 2025). While the UPGEM methodology is not conducive towards assessing short-term climate shocks to employment, a future avenue of research could assess short-term impacts of extreme weather events or climate-related tipping points (e.g. the Western Cape's near day-zero experience in 2018–19) on the Phillips curve in climate-exposed economies. This would add to existing empirical evidence of the importance of supply shocks in explaining employment and growth (Viegi and Dadam 2023).

Another avenue of research of interest to monetary policy actors relates to the reduced agricultural productivity scenario. UPGEM's scenarios show small effects on employment and inflation because of the ability of consumers to pivot towards cheaper imported versions of agricultural commodities. This is because the model assumes that productivity shocks do not affect the production of agricultural commodities in other countries. As climate shocks can be regional and increasingly global, this assumption may not hold and could lead to significantly higher inflationary, employment and real exchange rate effects.

6. Conclusion

This paper fills an important gap in the growing literature on the employment implications of the low-carbon transition and climate change. Using UPGEM, it finds that physical climate risks in South Africa are likely to reduce employment and lead to disproportionate impacts on South Africa's low-skilled workforce. These findings add to existing studies that document South Africa's high exposure to climate transition risks and its concentrated impact on workers in fossil-fuel-based sectors.

The findings reveal several broad policy recommendations focused mainly on fiscal authorities. Targeted interventions are required to address the uneven distributional effects of climate change on employment, particularly among medium- and low-skilled workers. These include strengthening active labour market policies such as job placements, improving the responsiveness of the technical and vocational education and training system to the demands of a climate-affected economy, and directing fiscal support towards green industries and climate-resilient infrastructure. Given that climate-induced migration is likely to intensify insider-outsider dynamics in South Africa's labour market, the effects of physical climate change should also be integrated into broader just transition planning.

While the SARB's primary mandate centres on price stability, the findings suggest that climate-related labour market disruptions may weaken the inflation-employment trade-off captured by the Phillips curve, with implications for the calibration and transmission of monetary policy. Future research efforts aimed at monitoring climate-sensitive labour market indicators would enhance the SARB's capacity to anticipate and respond to these evolving dynamics.

Several avenues for future research emerge from this analysis. First, the assumption in UPGEM that climate-related agricultural productivity shocks do not simultaneously affect other countries warrants further investigation; relaxing this assumption, particularly in the context of regionally correlated climate shocks across Southern Africa, could reveal significantly larger inflationary, employment and real exchange rate effects. Second, while this paper focuses on long-term structural shocks, future work could examine the short-term macroeconomic impacts of acute climate events, such as droughts or extreme heat episodes, on the Phillips curve and other monetary policy frameworks in climate-exposed economies. Finally, extending the CGE framework to incorporate explicit monetary and fiscal policy dynamics would allow for a more rigorous assessment of optimal policy responses to climate-induced labour market disruptions.

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