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Understanding the climate change-gender nexus: the economic impacts on South African women

Martin Henseler^a and Helene Maisonnave,^{b,*}

^a Université de Rouen Normandie, Normandie Univ, LERN UR 4702, 3 avenue Pasteur, 76186 ROUEN Cedex 1, France

^b Université Le Havre Normandie, Normandie Univ, EDEHN UR 7263, 25 Rue Philippe Lebon, 76600, Le Havre, France

* Corresponding author: helene.maisonnave@univ-lehavre.fr

Orcid Martin Henseler : <https://orcid.org/0000-0002-6621-4453>

Orcid Helene Maisonnave: <https://orcid.org/0000-0003-2535-8669>

Abstract

The nexus between climate change and gender is complex, and sectoral and socio-economic impacts are difficult to understand. In developing countries, climate change impacts women more than men. Women have lower resilience capacities and less economic opportunity. At the same time, as economic actors, women are essential. In this paper, we analyse the impacts of climate change on economic sectors and how they spill over to women in South Africa. Here, gender inequality is high and likely to increase because of climate change. Using a recursive dynamic computable general equilibrium model, we analyse how climate change impacts economic growth and women through different economic shocks and channels. By linking a microeconomic simulation to the macroeconomic framework, we analyse the impact of climate change on female-headed households. The results show that the climate shock negatively impacts productivity, labour demand and economic growth. These negative impacts translate to households by increasing prices and decreasing purchasing power. The impacts on poverty are stronger for female-headed households than for male-headed households. Thus, policies need to address the problem of climate change, which is widening the gender gaps between men and women, not only under pro-poor and pro-gender objectives but also under pro-growth objectives.

Keywords: climate change, economic growth, poverty, gender, South Africa

1. Introduction

The adverse effects of climate change are experienced worldwide (Dell *et al* 2012, 2014, Graff Zivin and Neidell 2014, Burke *et al* 2015, Colacito *et al* 2019, Acevedo *et al* 2020), and poor countries are even more affected (IPCC 2014, Tol 2018; Kahn, 2005; Shepherd *et al.* 2013; Winsemius *et al.* 2018). In developing countries, climate change impacts women more than men (Björnberg and Hansson, 2013; Denton, 2002; Goh, 2012; Quisumbing *et al.*, 2018; Sorensen *et al.*, 2018) and creates problems for gender equity and economic growth. Women have lower resilience capacities to cope with the impacts of climate change because of unequal access to productive resources such as land or other assets (Deressa and Hassan 2009, Eastin 2018, Mehar *et al* 2016, Mersha and Van Laerhoven 2016, Terry 2009). Many women work in climate-sensitive sectors such as agriculture or tourism and face significant gender gaps in salary (Doss *et al* 2018, 2015, Doss 2018, SOFA Team and Doss 2011). Women are mainly responsible for domestic work, which reduces their time available for economic opportunities (Elson 1999, Fontana and Van Der Meulen Rodgers 2005). The impacts of climate change increase the time requirements for domestic work and widen the gaps between paid and unpaid work. Indeed, after floods, it will take longer for women to fetch water or collect wood, reducing the available time for paid activity. Understanding the nexus between climate change and gender, with its sectoral and socio-economic impacts, is the basis for designing counteracting policies to mitigate the impacts of climate change on women (Alston 2014, Denton 2002, Pearse 2017, Terry 2009).

In South Africa, women play a key role in economic growth and face high gender inequalities (Department of Women 2015). The country is exposed to impacts of climate change (Ziervogel *et al* 2014, Ayugi *et al* 2022, DEA (Department of Environmental Affairs) 2016) that may increase gender inequalities to the disadvantage of women (Flatø *et al* 2017). The labour participation rate is lower for women than for men (in 2022, it was 50.7 per cent for women and 63.2 per cent for men (Stats SA 2022, ILO 2022)). Women work mainly as low-skilled workers (Espí *et al* 2019, Gradín 2021) and in a narrow range of sectors: agriculture, food processing, textiles, and tourism (Mosomi 2019). The unemployment rate is higher for women than for men (e.g., in 2021, it was 36.4 per cent for women and 33 per cent for men (Stats SA 2022, ILO 2022)). Furthermore, women work significantly more time carrying out domestic tasks than men. While women work on average 4.36 hours per day unpaid for domestic tasks, men work only 2.16 hours per day for unpaid domestic tasks (Budlender *et al* 2001, Charmes 2006). With lower access to the paid labour market and lower paid salaries, women experience higher rates of poverty (Sulla and Zikhali 2018), which is likely to worsen with the future impacts of climate change. Shayegh *et al* (2021) find that in South Africa, high temperatures reduce the weekly labour supply more sharply for ‘low-skilled’ than for ‘high-skilled’ South African workers. Moreover, Shayegh and Dasgupta (2022) find that the working hours of South African low-skilled women are more impacted by the effects of higher temperatures.

Various studies have analysed the impacts of climate change on women (see Chitiga-Mabugu *et al.* (2023) for a review). Earlier studies described the general impacts qualitatively (e.g., Denton, 2002; Pearse, 2017). Later studies focused on specific impacts and provided quantitative analysis, e.g., of impacts on women in the agricultural sector (Eastin 2018). Finally, recent studies have extended the scope from gendered impacts to women's role in climate change adaptation and mitigation (e.g., Gardezi *et al.*, 2022; Huyer and Partey, 2020). However, while these studies provide valuable information on sector-specific impacts and measures at the

microeconomic level, they do not provide information about economy-wide impacts at the macroeconomic level.

In the present article, we analyse the sector-specific impacts of climate change on women in South Africa and the microeconomic impacts on women's poverty. To simulate and analyse the macroeconomic impacts, we use a recursive dynamic computable general equilibrium (CGE) model; to analyse the microeconomic impacts, we apply a distributional analysis as a microsimulation and poverty analysis.

CGE models have been used to analyse the climate impact in South Africa. For instance, (Calzadilla *et al* 2014) employ a CGE model to find significant impacts of climate change on agricultural production and economic growth. Decreasing precipitation reduces the national GDP by 0.6 per cent. Compensating for these losses requires an increase in productivity of 20 per cent. Using a CGE model, Cullis *et al* (2015) simulate the impacts of different economic shocks on agriculture, water supply and infrastructure. They find a decrease in South Africa's GDP by up to 3.8 per cent. Climate change mainly impacts agriculture, which reduces production, while non-agricultural sectors expand. Consequently, many unskilled workers change from agriculture to non-agricultural sectors. Poverty is exacerbated, particularly in the poor regions of the country.

Recent studies have employed a gender-sensitive CGE model to analyse the impact of climate change on women in Western Africa and Latin America. Sawadogo and Fofana (2021) show that in Burkina Faso, climate change impacts women's economic activities more than men's economic activities. For Bolivia, Escalante and Maisonnave (2022a) find that female-headed households in particular suffer from the impacts of climate change due to a decrease in income and increased food prices. Furthermore, they find that mainly female labour is affected, as women drop out of the labour market, and that female-headed households experience more increases in poverty than male-headed households. In another paper, Escalante and Maisonnave (2022b) show that in Bolivia, women's food security is particularly vulnerable, depending on the regional climate impacts on agricultural production.

This paper builds on previous studies and aims to make several contributions. First, we build a recursive dynamic gender-aware CGE model that considers domestic production, where unpaid household chores are mainly carried out by women. Second, we consider the impacts on different sectors of the economy, not only agricultural sectors. Indeed, we consider the potential drop in the tourism sector as well as problems in the water sector. Third, we assess the socio-economic impact of climate disasters on women's poverty. Thus, this study draws attention to a phenomenon that is still largely unquantified in the literature and that will make it possible to implement specific policies for women.

2. Method

We use a recursive dynamic CGE model combined with a microsimulation to evaluate the impacts of climate change on women's poverty in South Africa. CGE models are appropriate tools for simulating and analysing the direct and indirect impacts of climate change on the different institutions in an economy. We then link the CGE model with the microsimulation model to assess the redistributive impacts of climate change on poverty.

2.1. Macroeconomic model

To represent the South African economy, we develop a recursive dynamic single-country CGE model by customizing the CGE standard model PEP-1-t (Decaluwé *et al* 2013). Figure 1a presents schematically the CGE model with its markets, institutions, agents and sectors with their monetary flows and interlinkages. For the mathematical presentation of the model see Appendix A1 to A4 (Supplementary Material) and for the detailed information of the standard

model see the documentation in Decaluwé *et al* (2013). The database used for the CGE model is a 2015 Social Accounting Matrix (SAM) based on that of van Seventer and Davis (2019). We disaggregate the 2015 SAM as gender specific concerning labour types and households using the National Income Dynamics Study (NIDS) 2015 and the Living Condition Survey (LCS) 2015. Consequently, the sectors are aggregated into the 10 sectors identified in the NIDS.

We include 10 activities and 19 commodities in the model, with each activity using capital, labour (skilled and unskilled) and intermediate goods consumption to produce output. Production follows a Leontief-type function between value added and intermediate consumption at the top level and for each activity. Value added is a constant elasticity of substitution (CES) function of composite labour and capital. Composite labour is disaggregated based on skill levels following a CES function (skilled and unskilled). Skilled workers have at least completed secondary education (grade 12), while unskilled workers have a middle school education at most (maximum grade 11). At the bottom of the tree, each type of labour is disaggregated into male and female, representing workers as men and women.

In the model, we distinguish four different institutions: households, firms, the government, and the rest of the world. Households are disaggregated per decile of income and gender and receive income from labour, capital and transfers. Poor households with small incomes mainly receive transfers from the government and income from unskilled labour. The richest households mainly receive income from dividends and highly skilled labour. Households use their income to pay taxes or transfers to other institutions, to consume and to save. Household consumption is modelled as a linear expenditure system subject to budget constraints. Firms derive their income from capital and transfers from other institutions. They pay income taxes and transfers to other institutions (dividends). The government's income is derived from direct taxes paid by households and firms, indirect taxes on domestic sales, import tariffs, transfers from other institutions, and a share of capital income. Government savings equal the government's income minus its consumption and transfers paid to other institutions.

Capital is sector specific, and the stock of capital of each sector depends on the new investments made in the sector in the previous period. The allocation of new investment follows the accumulation equation (Jung and Thorbecke 2003). Labour is mobile across sectors. Following the work of Fofana *et al* (2003), we consider an endogenous gendered labour supply subject to the time that households devote to their market and nonmarket activities. We consider that each individual in the household has a fixed number of hours to allocate between leisure, paid work and unpaid work for the production of nonmarket commodities, e.g., childcare, cooking, and firewood and water collection.

As mentioned earlier, South African women with primary education spend, on average, 4.48 hours per day on unpaid activities and 2.20 hours per day on paid activities. Men spend 2.12 hours per day less on unpaid activities and 3.58 hours per day more time on market activities than women. The time spent on domestic tasks decreases with the increase in the level of education for both men and women. Skilled women (with tertiary education) spend 3.59 hours per day on unpaid activities and 4.70 hours per day on paid activities; skilled men spend 1.91 hours per day on unpaid activities and 6.03 hours per day on paid activities (Rubiano-Matulevich and Viollaz 2019).

Technically, following Fofana *et al.* (2003), we assume that households maximize their utility by allocating their time between paid and unpaid work and leisure under the constraint of their full income. Full income is the sum of the different incomes from paid work, nonlabour incomes (such as transfers), and income from home production, which is valued as its opportunity cost on the labour market. The production function for home production is a constant elasticity of substitution (CES) function between male and female labour, disaggregated by skills. By

defining a low value of substitution elasticity, we reflect the rigidity between male and female labour (Fontana *et al* 2020, Fontana and Wood 2000).

Additional data, such as income elasticity from Burger *et al.* (2017a) and trade elasticities from Ntombela *et al* (2018), are used to operationalize the model further. We model the trade between South Africa and the rest of the world based on the assumption of the imperfect substitutability of commodities given their origin (the Armington assumption). We assume a finite elasticity of export demand to reflect the competitiveness of local producers in international markets. South African producers need to be more competitive than foreign producers to increase their global market shares. In terms of closure rules, the nominal exchange rate is the numeraire. The rest of the world’s savings are assumed to be fixed. Finally, South Africa takes world prices as given, which follows from the assumption that the country is a small open country.

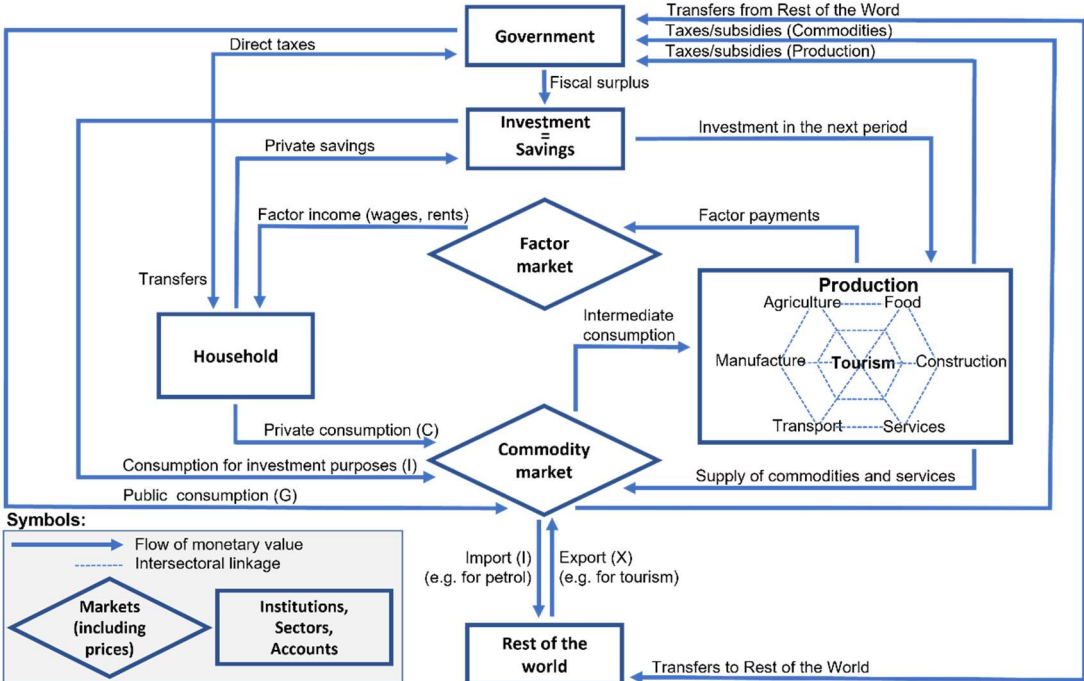


Figure 1: Schematic presentation of a CGE model

2.2. Microeconomic model

CGE models alone cannot provide insights into the impacts of climate change on poverty. To enable such explicit poverty and distributional analysis, we link the CGE model to a micro module using a top-down approach, as presented by Cockburn *et al* (2014). In each scenario, we apply the percentage changes in households’ consumption spending to the households in the microdata, i.e., the Living Condition Survey (LCS) 2014-2015 (Stats SA 2017a). Furthermore, we apply the percentage change in the consumer price to the poverty line and simulate the change in purchasing power. For each scenario, we compute the poverty index based on Foster *et al.* (1984) and compare the change in indicators to the business-as-usual (BAU) scenario. We compute the indicators for the national sample and regional sample oriented towards Stats SA (2018) and Stats SA (2019).

3. Scenarios

To analyse the impacts of climate change on the economy and women, we simulate two scenarios: a "moderate scenario" and a "severe scenario". We orient them towards the policy scenarios presented by Fawcett *et al* (2015): the "reference-low policy scenario" and the "no-policy scenario". The "reference-low policy scenario" is the basis for our "moderate scenario", which assumes a moderate increase in global greenhouse gas emissions until 2100 and mild to moderate economic impacts. The "no-policy scenario" is the basis for our "severe scenario", which assumes an extreme increase in greenhouse gas emissions until 2100 and strong economic impacts. We assume that climate shocks will impact the economy under different channels in agricultural and non-agricultural sectors. Therefore, we highlight five channels through which weather shocks can affect the economic sectors in South Africa:

- (1) Climate change decreases agricultural productivity through changes in precipitation, temperature, climate variability, evapotranspiration, and freshwater availability (Calzadilla *et al* 2014). In addition to the direct impact on crop productivity, climate change can increase yield losses caused by pests (e.g., locust infestation) and soil degradation. Furthermore, harvest and production factors can be lost by extreme weather events (floods, draughts). We derive the shocks of climate impacts on agricultural productivity from the studies by Calzadilla *et al* (2014), Cullis *et al* (2015) and Tadesse (2010).
- (2) Climate change negatively impacts agricultural production in most countries worldwide. Thus, the supply of agricultural commodities for export markets decreases, while the demand in import markets increases. Additionally, climate change increases competition for land (e.g., between food and energy production or mining), and increasing demand caused by increasing population increases the demand for food and food prices. We derive the magnitude of changes from Baker *et al* (2018), Dumortier *et al* (2021) and the World Bank (2022b), and we apply the same dynamic to the shocks to productivity.
- (3) While changes in water demand for agricultural supply (e.g., irrigation) and precipitation are represented as impacts on agricultural productivity, the decrease in water supply for households and industry is also assumed to decrease. Extreme weather events, droughts, irregular precipitation, and continuously increasing evapotranspiration reduce the availability of water in water bodies, decreasing the supply of water. We derive the magnitude of shocks from the studies by Cullis *et al* (2015), Du Plessis and Kalima (2021) and Olabanji *et al* (2020).
- (4) Weather events impact tourism (Thomas *et al* 2013), e.g., extreme weather events, and the reduction of sightseeing goals (such as ecosystems for safaris) reduces attractiveness. Weather events affect transport, infrastructure, and tourism activities. The extremes in temperature and changes in weather patterns can impact the attractiveness of tourist destinations (Golder Associates 2011). Based on the study by Mathivha *et al* (2017) on international tourism arrivals and research on annual temperature and precipitation by the World Bank (2022a, 2022c), we compute the decrease in tourism arrivals for historical years, which we use to derive the scenario assumptions. Many women work in the tourism service sector (hotels, restaurants). Thus, fewer tourists negatively impact women's jobs in this sector. By also demanding food for restaurants, the impacts on the tourism sector spill over to the agri-food sector. Gray *et al* (2022) show that drought negatively impacts the tertiary sector and, specifically, the tourism sector in South Africa.
- (5) Capital depreciation: As noted by Fankhauser and Tol (2005) and Stern (2013), it is likely that climate change will impact the depreciation rate of capital, consequently affecting the longevity of the capital stock. Extreme weather events such as floods can

cause permanent damage to capital infrastructure. Being exposed to an extreme event can increase wear and tear, and consequently, a larger amount of investment will be used to compensate for the depreciation (Dietz and Stern, 2015; Tsigaris and Wood, 2019). To take this phenomenon into account in our model, we increase the rate of depreciation for affected sectors (agriculture and tourism) starting in 2030. The increase is constant over time and the same for both scenarios.

We simulate the period from 2015 to 2050. To represent the short- and medium-term impacts, we apply shocks with increasing magnitude from 2025 to 2040. To simulate the long term, we retain the magnitude of 2040 for the years after 2040. Finally, we compare the scenarios with the business-as-usual (BAU) scenario, which follows a steady path from 2015 to 2050 without climate change shocks. Table 1 presents the assumptions for the simulated shocks while Figure 2 presents schematically the CGE model with the simulated economic shock on agricultural productivity and markets, on water supply and tourism demand.

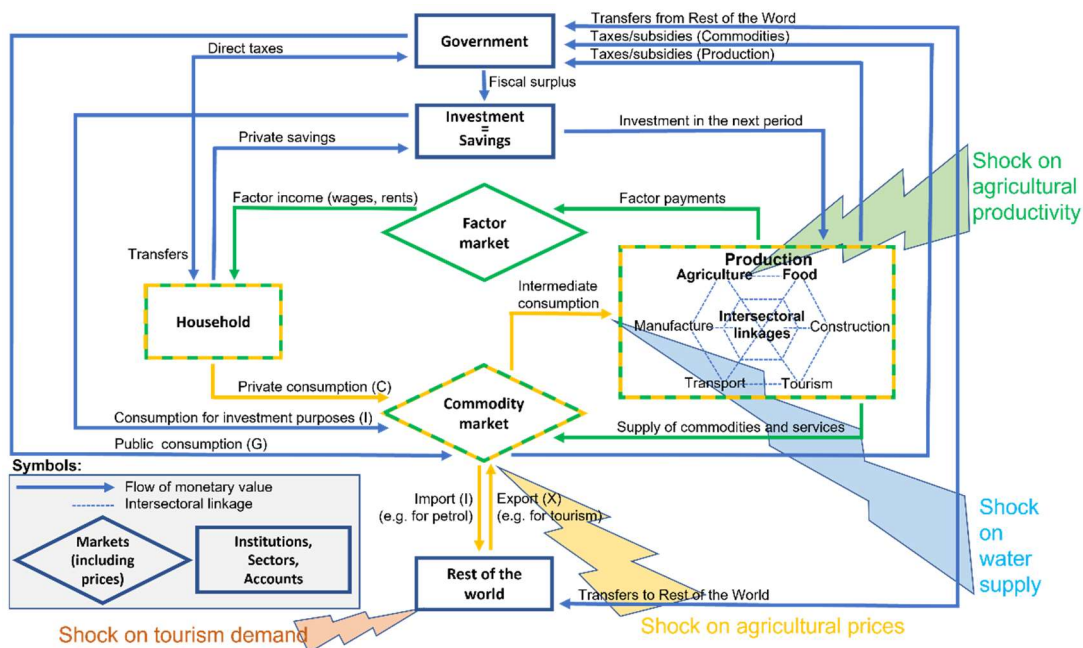


Figure 2: Schematic presentation of the channels impacted in the CGE model

Table 1: Overview of the assumptions of the simulated scenario impacts

		Moderate Scenario			Severe Scenario		
		2025	2030	2040 ^a	2025	2030	2040 ^a
Agricultural productivity ^b	Total factor productivity	-5	-10 ^a	-15	-10	-17.5 ^a	-25
	Capital depreciation		increase			increase	
Agricultural trade ^c	World prices	10	15 ^a	20	20	30 ^a	40
Freshwater supply ^d	Total factor productivity	-5	-10 ^a	-15	-10	-17.5 ^a	-25
	Capital depreciation		increase			increase	
Tourism demand ^c	Tourist arrivals	-2	-4.5 ^a	-7	-9	-11 ^a	-13

Notes: (a) In the years between 2025 and 2040, the shock gradually increases. The table is represented as linear interpolation in 2030. (b) Based on the results and assumptions of Calzadilla et al. (2014), Cullis et al., (2015) and Tadesse (2010). (c) We derive the magnitude of changes from Baker et al. (2018), Dumortier et al. (2021) and the World Bank (2022a). (d) We derive the magnitude of changes from Cullis et al. (2015), Olabanji et al. (2020) and du Plessis and Kalima (2021).

4. Results and discussion

4.1. Macroeconomic impacts

The simulated impacts of climate change result in decreased aggregated economic performance, represented by a decreasing real GDP. In the moderate scenario, in 2050, real GDP decreases by 1.9 per cent, and in the severe scenario, it decreases by 2.3 per cent (Table 2). The sectors negatively affected by climate change (agriculture, water and tourism) decrease their production. For the agricultural sector, the drop in productivity and capital depreciation reduce production and the intermediate consumption of products from backwards-linked sectors. However, increased world agricultural prices accompany these negative impacts on production. Therefore, South African producers aim to export more agricultural products for higher prices, increasing production despite decreased productivity. The increasing world prices partially compensate for the losses of agricultural income from the impacts of climate change (Table 3).

The sectors directly impacted by climate change reduce their production, which, on the one hand, impacts their supply of intermediate commodities to other sectors (linked forwards) and, on the other hand, their demand for commodities from other sectors (linked backwards). Thus, interlinked sectors in the economy are indirectly impacted by the responses of the directly impacted sectors. Furthermore, the sectors change their demand for labour depending on the sector-specific reactions (Table 3). For example, the drop in productivity in the water sector reduces the water supply and increases the price of water. The price increase impacts all forwards-linked sectors using water for production and households. The decrease in tourism spills over to the demand for services in hotels and restaurants. The tourism industry reduces production and fires workers, among whom women are highly represented (Table 3). As a result of all decreases in productivity and production in different sectors, commodity prices increase, represented by a high producer price index. Decreased exports and increased imports compensate for the reduced domestic supply after 2040 (Table 2). The change in the magnitude of the results between 2030 and subsequent years (2040, 2050) is explained by the fact that from 2030 we assume that the depreciation of capital in the agricultural, water and tourism increases. Indeed, from 2030 for these three sectors, it becomes more expensive to maintain the existing capital stock, and therefore the three sectors are much less attractive in terms of new investments. Consequently, production falls further.

Table 2: Impacts on macroeconomic indicators (in % change to the BAU)

	Moderate Scenario			Severe Scenario		
	2030	2040	2050	2030	2040	2050
GDP real	-0.4	-1.6	-1.9	-1.1	-2.1	-2.3
Production	-12.9	-58.2	-70.7	-31.4	-70.6	-79.9
Real private consumption	-9.0	-38.5	-40.5	-21.7	-51.4	-51.5
Change in consumer price index	0.8	2.7	2.8	1.9	3.7	3.7
Exports	-2.9	-96.2	-103	-10.2	-104	-106
Imports	-18.2	23.1	26.3	-37.6	1.5	4.0
Total labour demand	-0.82	-8.26	-21.5	-5.10	-4.97	-17.6
Investment budget	1.10	2.71	2.45	2.46	4.05	3.67

Table 3: Impacts on production and labour demand (in % change to the BAU)

		Moderate Scenario			Severe Scenario		
		2030	2040	2050	2030	2040	2050
Production	Agriculture ^a	-1.08	-13.30	-12.53	-2.02	-14.52	-13.46
	Mining	-0.63	-0.73	0.05	-1.35	-0.93	0.37
	Manufacturing	-0.60	-2.95	-3.15	-1.37	-3.99	-4.07
	Electricity and water	-12.1	-51.0	-68.0	-29.7	-61.5	-76.0
	Construction	0.69	2.69	3.87	1.60	4.14	5.74
	Transport ^b	1.00	5.10	7.34	2.39	6.29	8.34
	Tourism	-0.08	-0.48	-1.21	-0.80	-2.26	-3.39
	Financial services	0.05	1.09	1.10	0.10	0.99	1.05
	Administration	-0.22	-0.35	-0.49	-0.51	-0.56	-0.68
	Private sector	0.10	1.77	2.27	0.23	1.79	2.23
Labour demand	Agriculture	9.51	29.3	27.6	20.8	44.7	42.8
	Mining	-1.04	-1.82	-0.46	-2.22	-1.80	0.08
	Manufacturing	-0.78	-4.33	-4.12	-1.79	-5.48	-5.10
	Electricity and water	-11.5	-41.7	-55.7	-28.5	-53.0	-65.9
	Construction	1.14	2.94	3.78	2.76	4.81	5.78
	Transport ^b	1.84	7.09	8.48	4.54	8.27	9.13
	Tourism	-0.05	-1.88	-2.58	-1.06	-4.26	-5.25
	Financial services	0.20	1.01	0.80	0.49	1.08	0.81
	Administration	-0.28	-0.44	-0.62	-0.63	-0.69	-0.85
	Private sector	0.17	1.60	1.31	0.49	1.38	0.87

Notes: a) Including fishery and forestry, b) including trade and communication

In the mid and long term, the impact on total labour demand is negative (Table 2), but it differs by sector, skills and gender. Unskilled male workers benefit from the positive impact on the construction and transport sectors. As the investment budget increases (Table 2), the sectors that produce investment goods increase (e.g., construction, transport). These sectors are intensive in unskilled male workers. Given the drop in labour demand in the paid market, unpaid work increases, particularly for women.

Table 4: Impacts on labour demand by labour type (in % change to the BAU)

		Moderate Scenario			Severe Scenario		
		2030	2040	2050	2030	2040	2050
Agriculture ^a	unskilled male	9.08	27.6	25.5	19.7	42.1	39.8
	unskilled female	9.29	28.6	26.6	20.3	43.6	41.6
	skilled male	9.78	30.3	28.8	21.5	46.3	44.6
	skilled female	9.88	30.8	29.4	21.8	47.0	45.5
Mining	unskilled male	-1.57	-3.53	-2.61	-3.45	-4.21	-2.76
	unskilled female	-1.38	-2.81	-1.74	-3.02	-3.15	-1.54
	skilled male	-0.93	-1.48	-0.04	-1.96	-1.31	0.66
	skilled female	-0.83	-1.12	0.46	-1.72	-0.85	1.25
Manufacturing	unskilled male	-1.34	-6.08	-6.30	-3.10	-7.91	-7.93
	unskilled female	-1.15	-5.38	-5.46	-2.66	-6.89	-6.77
	skilled male	-0.71	-4.13	-3.88	-1.63	-5.19	-4.77
	skilled female	-0.62	-3.78	-3.40	-1.39	-4.74	-4.21
Electricity and water	unskilled male	-12.1	-42.9	-56.8	-29.6	-54.31	-67.0
	unskilled female	-11.9	-42.5	-56.4	-29.3	-53.81	-66.6
	skilled male	-11.5	-41.7	-55.6	-28.5	-52.92	-65.9
	skilled female	-11.4	-41.4	-55.4	-28.3	-52.70	-65.7
Construction	unskilled male	0.64	1.30	1.75	1.57	2.45	3.03
	unskilled female	0.84	2.05	2.65	2.03	3.59	4.32
	skilled male	1.30	3.43	4.40	3.13	5.53	6.62
	skilled female	1.39	3.81	4.92	3.38	6.03	7.25
Transport ^b	unskilled male	1.27	5.16	6.07	3.17	5.51	5.92
	unskilled female	1.47	5.94	7.02	3.64	6.68	7.25
	skilled male	1.94	7.43	8.91	4.79	8.77	9.71
	skilled female	2.04	7.82	9.45	5.04	9.28	10.4
Tourism	unskilled male	-0.63	-3.74	-4.89	-2.42	-6.79	-8.18
	unskilled female	-0.44	-3.02	-4.04	-1.98	-5.76	-7.03
	skilled male	0.01	-1.74	-2.42	-0.94	-4.06	-5.03
	skilled female	0.10	-1.38	-1.93	-0.70	-3.60	-4.47
Financial services	unskilled male	-0.49	-1.25	-2.02	-1.15	-2.08	-2.86
	unskilled female	-0.30	-0.52	-1.15	-0.70	-1.00	-1.64
	skilled male	0.16	0.88	0.61	0.40	0.91	0.60
	skilled female	0.26	1.25	1.12	0.65	1.39	1.19
Administration	unskilled male	-0.93	-2.58	-3.30	-2.19	-3.67	-4.32
	unskilled female	-0.74	-1.85	-2.44	-1.74	-2.60	-3.12
	skilled male	-0.29	-0.51	-0.73	-0.67	-0.77	-0.96
	skilled female	-0.20	-0.14	-0.23	-0.43	-0.30	-0.38
Private sector	unskilled male	-0.18	0.35	-0.25	-0.35	-0.39	-1.17
	unskilled female	0.01	1.10	0.64	0.10	0.71	0.07
	skilled male	0.45	2.42	2.36	1.17	2.49	2.18
	skilled female	0.54	2.79	2.87	1.41	2.97	2.78

Notes: a) Including fishery and forestry, b) including trade and communication

The depreciation of capital in agriculture increases the price of capital and favours labour as a production factor. Therefore, the nominal wages for labour, agricultural labour, increase. Moreover, the wage increase is higher for unskilled men than for women. Therefore, the nominal income increases for each household. Nevertheless, the income increase is insufficient to compensate for the increase in consumer prices. Thus, households' real consumption decreases despite increased income (Table 5).

Table 5: Impacts on households' real consumption (in % change to the BAU)

		Moderate Scenario			Severe Scenarios		
		2030	2040	2050	2030	2040	2050
Real consumption budget	1st decile MHH	-0.50	-1.91	-1.93	-1.17	-2.60	-2.52
	1st decile FHH	-0.52	-1.93	-1.95	-1.21	-2.64	-2.55
	2nd decile MHH	-0.49	-1.87	-1.89	-1.15	-2.54	-2.46
	2nd decile FHH	-0.49	-1.88	-1.93	-1.15	-2.56	-2.51
	3rd decile MHH	-0.49	-1.90	-1.96	-1.16	-2.57	-2.54
	3rd decile FHH	-0.49	-1.89	-1.95	-1.15	-2.57	-2.52
	4th decile MHH	-0.45	-1.83	-1.90	-1.08	-2.47	-2.44
	4th decile FHH	-0.47	-1.86	-1.93	-1.11	-2.51	-2.49
	5th decile MHH	-0.42	-1.79	-1.86	-1.02	-2.39	-2.38
	5th decile FHH	-0.41	-1.75	-1.82	-0.99	-2.34	-2.32
	6th decile MHH	-0.39	-1.76	-1.83	-0.94	-2.33	-2.32
	6th decile FHH	-0.40	-1.80	-1.88	-0.96	-2.39	-2.38
	7th decile MHH	-0.41	-1.89	-2.01	-0.99	-2.48	-2.53
	7th decile FHH	-0.41	-1.87	-2.00	-0.99	-2.46	-2.51
	8th decile MHH	-0.41	-1.94	-2.08	-1.00	-2.55	-2.61
	8th decile FHH	-0.41	-1.93	-2.06	-0.99	-2.52	-2.58
	9th decile MHH	-0.47	-2.16	-2.34	-1.13	-2.84	-2.93
	9th decile FHH	-0.47	-2.20	-2.33	-1.12	-2.88	-2.93
	10th decile MHH	-0.49	-2.22	-2.42	-1.18	-2.91	-3.03
	10th decile FHH	-0.49	-2.18	-2.40	-1.18	-2.86	-3.00

Notes: MHH: Male Headed Households; FHH: Female Headed Households.

4.2. Microeconomic impacts

Table 6 presents the change in the poverty indicators for South Africa and the difference in changes between female-headed households (FHHs) and male-headed households (MHHs). We compute the poverty indicators based on an upper-bound poverty line. The upper-bound poverty line indicates the benchmark above which households can purchase adequate food and non-food items. We orient the computation of the poverty indicators at the national level towards Stats SA (2018) and at the regional level towards Stats SA (2017b). The indicators show that female-headed households are poorer than male-headed households. The headcount, poverty gap and severity indicators are one and a half to two times higher for female-headed households than for male-headed households. As can be expected from the worsened economic conditions, the three poverty indicators increase for male- and female-headed households. In the moderate scenario, the poverty headcount increases more than in the simulation year 2040. In the severe scenario, the increase exceeds more than 1 percentage point 10 years earlier in 2030.

Table 6: Change in poverty indicators in percentage points and the difference between female-headed households and male-headed households

		BAU	Moderate Scenario			Severe Scenario		
		2015	2030	2040	2050	2030	2040	2050
		per cent	percentage points					
National	Poverty headcount (FGT0)	40.0	0.449	1.677	1.754	1.099	2.327	2.322
	Poverty gap (FGT1)	16.9	0.296	1.056	1.105	0.705	1.466	1.459
	Poverty severity (FGT2)	9.4	0.197	0.704	0.735	0.302	0.815	0.830
Male-headed households (MHHs)	Poverty headcount (FGT0)	33.0	0.500	1.600	1.677	1.078	2.258	2.258
	Poverty gap (FGT1)	13.0	0.259	0.923	0.965	0.618	1.284	1.276
	Poverty severity (FGT2)	6.8	0.161	0.575	0.600	0.384	0.803	0.797
Female-headed households (FHHs)	Poverty headcount (FGT0)	49.9	0.470	1.587	1.651	1.001	2.233	2.237
	Poverty gap (FGT1)	23.5	0.336	1.197	1.255	0.798	1.656	1.651
	Poverty severity (FGT2)	13.9	0.247	0.881	0.921	0.588	1.224	1.218

At a regional level, the differences between the changes in poverty indicators are heterogeneous. Figures 3 and 4 present the difference in changes in poverty incidence (FGT0) and poverty severity (FGT2). The colour indicates the difference between the change for female- and male-headed households. The distributional pattern is similar between the moderate and severe scenarios, while the more intensive colours indicate a larger magnitude in the severe scenario. Figures 3a and b show that the poverty headcount (FGT0) worsens more for women than for men in the reddish-coloured provinces of Northern Cape, Western Cape and Gauteng. In these provinces, the share of female-headed households is more than that in the other provinces coloured in yellow, green and blue, indicating a positive difference. The situation is worsening more for male-headed households.

Figures 4a and b present the regional difference in changes for the poverty severity indicator (FGT2). In all provinces, the impact on poverty severity (FGT2) is stronger for women than for men, particularly for the provinces on the west–east belt. In Gauteng, the impact is less strong. With the larger cities of Johannesburg and Pretoria, the job and income opportunities and financial support for poor households might be higher than in other more rural provinces. More income opportunities and financial support explain a buffering effect for worsening poverty in Gauteng. The interpretation of the regional results requires attention since we simulated the climate change shocks at the country level and translated them in the distributional analysis to the household and regional levels. Since climate change shocks are regionally heterogeneous, a more consistent analysis would require the simulation of the impacts of climate change at the regional level.

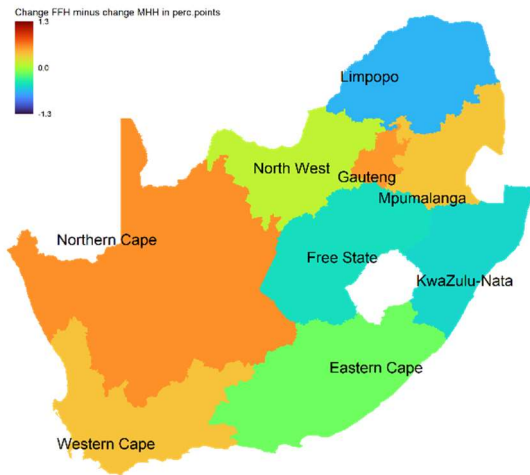


Figure 3a: Difference in the change in the poverty headcount index (FGT0), computed as the change in FHHs minus the change in MHHs in the moderate scenario in 2040

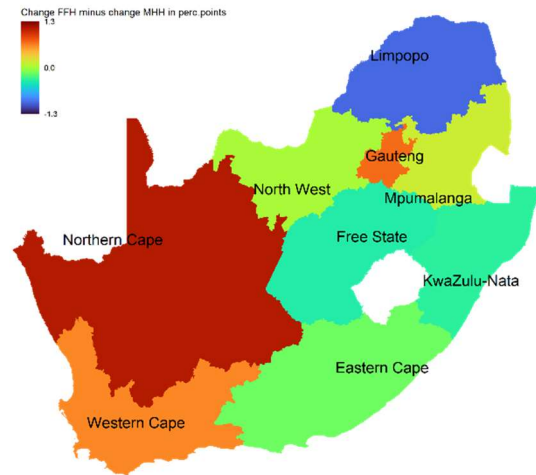


Figure 3b: Difference in the change in the poverty headcount index (FGT0), computed as the change in FHHs minus the change in MHHs in the severe scenario in 2040

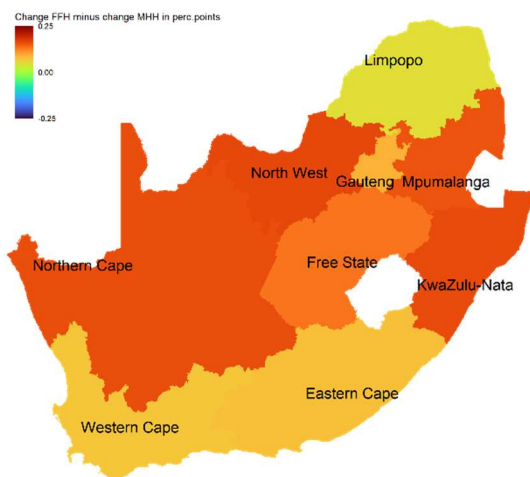


Figure 4a: Difference in the change in the poverty severity index (FGT2), computed as the change in FHHs minus the change in MHHs in the moderate scenario in 2040

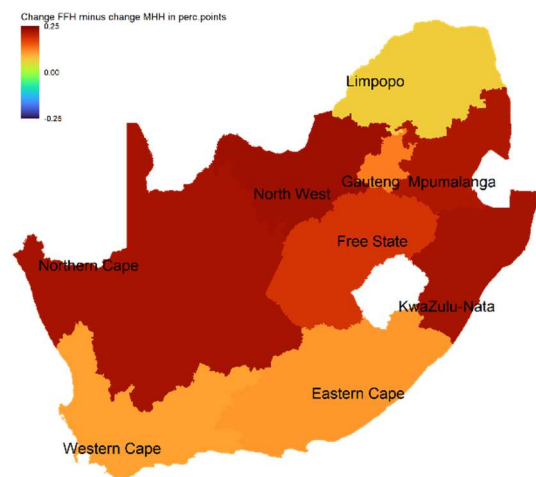


Figure 4b: Difference in the change in the poverty severity index (FGT2), computed as the change in FHHs minus the change in MHHs in the severe scenario in 2040

5. Conclusions

The nexus between climate change and gender is complex and the sector specific impacts on the socio-economic situation are difficult to understand. Designing effective and efficient counteracting policies against climate change impacts requires assessment through the gender lens, considering time allocation between work on the labour market or for domestic responsibilities. The results indicate, in a moderate scenario of climate change, a 1.9 per cent decrease in GDP. Paid labour decreases, especially for women, and unpaid labour increases for all categories of households. The nominal income increases, but a high increase in consumer prices negatively affects the consumption of all households. Therefore, at the household level, poverty increases, especially for the poorest women. the results are even more dramatic in the

severe scenario where the demand for work is reduced very sharply and the poverty of the poorest women increases very significantly.

The results support the hypothesis that climate change causes sectoral and intersectoral impacts as well as impacts on the labour markets in South Africa. These impacts are more negative for women (female-headed households) than for men (male-headed households). Based on the results, affirmative policies should compensate for the decreased household consumption of poor and vulnerable families (e.g., by a basic income grant). Specific sectoral aids could address multiple problems at the same time. Investment in climate-adapted technologies and production systems in agriculture could compensate for climate-induced losses (e.g., climate-smart agriculture). The tourism sector requires adaptation measures and investment in infrastructure to counteract the impacts of climate change and the decrease in tourism demand. In agriculture and tourism, labour market policies can strengthen women's position and reduce gender gaps (e.g., in salary). In general, many pro-gender and pro-poor policies can support the adaptive capacities of individuals and families. Providing infrastructure and services to households to overcome domestic burdens (childcare, electrification) can enhance women's economic opportunities, enrich the labour market and foster economic growth.

As an economy-wide assessment, we analyse sectors at a highly aggregated level. Information on climate-sensitive subsectors (e.g., specific crop sectors in agriculture or tourism) is required to design sector-specific policies. The CGE model simulations and results are at the country level. Regional climatic and geographic conditions and socioeconomic conditions strongly determine climate and economic impacts. Thus, an analysis considering regional heterogeneity would provide more reliable results. Finally, we derive the climate impact scenarios based on studies and combine them into moderate and severe impact scenarios. However, these scenarios represent only rough benchmarks to define a scenario space. The results can be interpreted only within this rough scenario space.

In future research, simulations and analysis should overcome these limitations. Further modelling work could provide more differentiated sectors and scenarios and consider a higher regional resolution. To obtain modelling results, the CGE model might be linked to and be extended by other models, as already applied in climate change research. Here, the consideration of the gendered dimension would be of interest, particularly for socioeconomic models. Better modelling of domestic chores helps show the direct impacts of climate change on the female labour force and women's working time. The essential requirements are a survey of more empirically founded data, which can be used to better calibrate and validate policy simulation models. Based on better empirical data, domestic chores can be better disaggregated in the model. They can be used to analyse further macro- and microeconomic aspects and gendered aspects of policy instruments and economic shocks. Thus, accompanying empirical studies can support parameter estimation and validate the model results. A research framework coordinating directly with policy stakeholders could foster the production of policy-relevant results and make the information directly accessible for policy decisions.

The pure economic model-based study presented cannot provide concrete solutions to the problem of the gendered impacts of climate change. Too many assumptions determine the results, and the model can cover only a few aspects. However, this study can contribute in a way model-based studies can do. Suspected and empirically observed problems can be simulated at a macroeconomic scale, and the economic mechanisms can be shown. Thus, the results can enter the debate for further discussion and as an incentive for the development of research to fight the impacts of climate change in a manner that addresses gender equity.

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