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Climate change, monetary policy and price stability in South Africa

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Abstract

Climate change affects the effectiveness of monetary policy, particularly in maintaining price stability. In a two-period theoretical model with heterogeneous agents, monetary policy and climate externalities, we establish that a trade-off exists between climate change and inflation. In addition, lower interest rates for green investments enhance economic growth and aggregate social welfare when carbon tax is not at the optimal level. Our analysis suggests that green monetary policy and carbon emission taxes are complementary rather than substitutes. Our findings provide policy implications for balancing climate change mitigation and economic stability for the South African Reserve Bank.

JEL classification

E31, E42, E58, Q54

Keywords

Climate change, climate risk, green monetary policy, carbon tax

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1. Introduction

Climate change has emerged as a significant macrofinancial concern for central banks (Schnabel 2021a), including the South African Reserve Bank (SARB). South Africa's power system remains dominated by coal, which supplies about 70% of installed generation capacity and more than 80% of electricity output (International Energy Agency 2025). This carbon-intensive structure leaves the economy exposed to both physical climate shocks – such as drought-driven food-price surges – and transition risks linked to the government's move towards net-zero emissions.

Physical shocks already threaten price stability. Recent literature highlights the negative impact of physical risks on price stability globally (Faccia, Parker and Stracca 2021; Kotz et al. 2023; Ciccarelli and Marotta 2024). In South Africa, the 2023/24 El Niño drought, an extreme climate-driven shock, is expected to cut national maize yields by roughly 17%, intensifying cereal price pressures (Glauber and Anderson 2024). South Africa's policy response to climate risks is anchored by the Carbon Tax Act 15 of 2019. The Act's Phase 2 path raises the headline rate from R159 per tonne of carbon dioxide (tCO_2) in 2023 to R462 per tCO_2 by 2030 (National Treasury 2024), which introduces a transition risk as proposed by Schnabel (2022).

While the carbon tax aims to reduce carbon emissions, its implications for consumer prices, production costs and monetary policy raise critical questions for central bankers. Dynamic computable general equilibrium simulations suggest that, when revenues are recycled, the macroeconomic costs of the carbon tax in South Africa are modest (Van Heerden et al. 2016; Ward and Batista 2016). Cross-country evidence indicates that carbon pricing raises retail energy prices without materially shifting aggregate consumer price index (CPI) inflation (Konradt, McGregor and Toscani 2024). Nevertheless, large, persistent changes in relative prices can widen the wedge between headline and core measures (Schnabel 2022). Given the high CPI weight of regulated electricity tariffs, this wedge poses a particular challenge for the SARB. The best ways of incorporating climate change into the policy framework and designing the optimal monetary policy remain open questions.

A further issue is the principle of market neutrality of central bank policy. Conventional doctrine holds that central bank operations should not distort sectoral credit allocation

(Schnabel 2021b). The SARB reiterates this stance in its collateral and open-market frameworks, stressing that instruments must remain "as non-distortionary as possible" (South African Reserve Bank, April 2024). At the same time, SARB stress tests reveal that transition risks are concentrated in bank exposures to the coal value chain and could become systemic under a disorderly policy path (Monnin, Sikhosana and Singh 2024). Amid these challenges, central banks must still determine how best to adjust monetary policy to maintain price stability in the face of climate-related risks.

This paper tackles that question by asking whether a targeted green credit facility – offering concessional funding to low-carbon firms – can be justified when the carbon tax is set below its Ramsey (first-best) level, a gap linked to the 'tragedy of the horizon' (Carney 2015). We develop a two-period general equilibrium model, building on Tan, Tsomocos and Wang (2025), with heterogeneous agents, endogenous money creation and climate externalities. In our model, the government sets the carbon tax path and the central bank chooses the policy rate and, optionally, a green credit discount.

We begin by analysing a baseline in which the central bank adheres to market neutrality – no credit tilting – and show that climate change affects the central bank's inflation target primarily through a supply shock. Even under an optimal (Pigouvian) carbon tax, inflation remains above its no-damage benchmark because long-run climate losses feed back into current price setting. Moreover, the relationship between expected inflation and the carbon tax rate is non-monotonic: a moderate tax curbs climate damage and therefore lowers inflationary pressure, but once the rate approaches its Pigouvian level, further increases raise energy costs and dampen investment sufficiently to push future prices up again. Optimal monetary policy must therefore set a higher policy rate to achieve the same inflation target as in a world without climate change.

Second, we evaluate the trade-off created by a green credit policy in the presence of a carbon tax. A green credit policy offers lower interest rates to green firms to encourage green investment. Our numerical analysis suggests that such a policy can complement the carbon tax by reducing carbon emissions without increasing inflation when the tax itself is not stringent. However, when combined with a strict carbon tax, the effectiveness of the green credit policy diminishes and may even induce unexpected inflation. Policymakers must therefore calibrate green credit facilities to the prevailing level of the carbon tax to avoid destabilising prices.

The key results imply that departures from neutrality can play a useful – yet policy-space-dependent – role in South Africa's policy mix. A green credit facility enhances social welfare only while carbon pricing is demonstrably insufficient; it should be wound down once fiscal policy closes the tax gap. Effective deployment therefore requires clear ex-ante criteria that link the size and duration of the credit discount to measurable shortfalls in the carbon tax path, alongside transparent communication to preserve the SARB's credibility and legal mandate. The findings urge a state-contingent approach to monetary policy. Climate metrics – effective carbon price, emissions intensity, transition risk exposures – should join inflation and output in the SARB's reaction function. Clear coordination with fiscal authorities can reduce the need for credit tilting. A transparent exit plan for any green credit tool safeguards neutrality and keeps expectations anchored.

The remainder of the paper is organised as follows. Section 2 sets out the model and timeline. Section 3 derives the competitive equilibrium and states the key propositions. Sections 4 and 5 present numerical simulations. Section 6 discusses policy implications for the SARB. Section 7 concludes.

2. Model

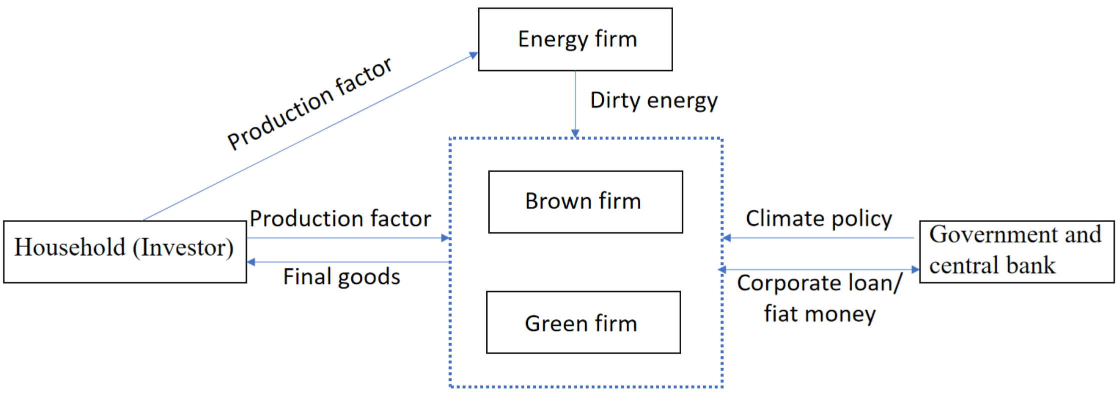
In this section, we present the theoretical model that serves as the foundation of our analysis. The model incorporates the key features in Tan, Tsomocos and Wang (2025) and an energy-economics framework that draws on the works of Acemoglu et al. (2012), Acemoglu et al. (2016), Golosov et al. (2014) and Barrage (2020). We also incorporate interest rates and fiat money into the model.

2.1 Model environment

The model environment, sketched in Figure 1 and sequenced in Figure 2, features four representative agents: households, a competitive energy firm, two production sectors (brown and green) and a consolidated policy block that includes both the government and the central bank. To keep the analysis analytically tractable, we assume that the central bank lends directly to firms, thereby abstracting from frictions in the banking sector (see e.g. Lucas (2016); Pfister (2024); Li and Li (2025)).[1]

Households supply capital, buy the final good and hold outside money. The model distinguishes between two types of firms: brown firms and green firms. Brown firms rely on dirty energy as a production input, resulting in carbon emissions – a negative externality that contributes to climate change. The energy firm converts production factors into dirty energy, which it sells exclusively to brown firms. Green firms are similar to brown firms, except that they are assumed not to rely on dirty energy in producing final goods.

Figure 1: Model structure



The timeline of our two-period model is shown in Figure 2. At $t = 0$ the government announces the carbon tax schedule, while the central bank sets the policy rate and decides whether to grant a green credit discount. Immediately afterwards ($t = 0^+$) firms obtain inter-period loans; if the discount is active, green firms borrow at a lower rate than brown firms. The energy firm produces dirty energy, brown and green firms manufacture goods, emissions occur and carbon accumulates in the atmosphere. At $t = 1$ loans are repaid, households consume, production takes place subject to climate damage and all market conditions clear.

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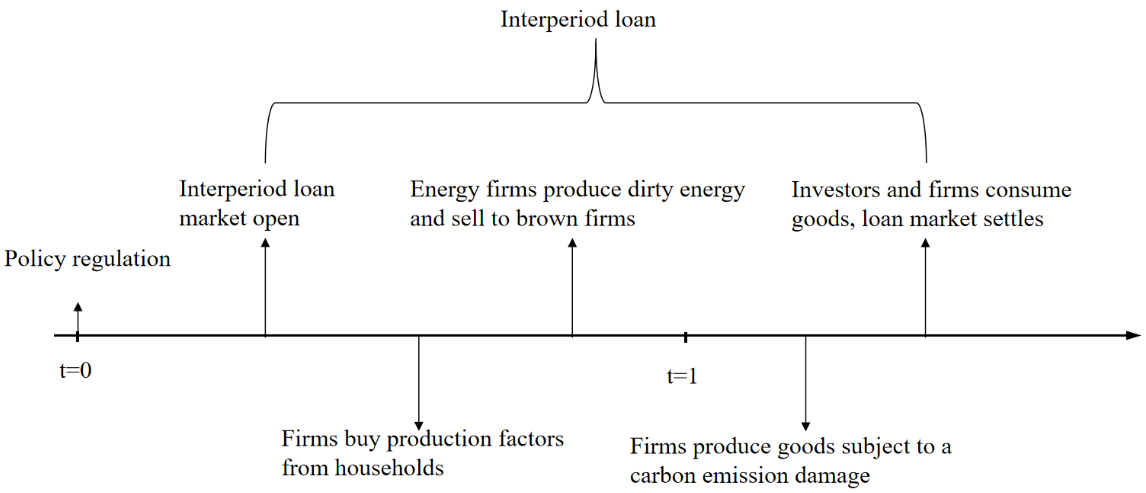
[1] This stylisation isolates the macro-welfare effects of a 'green' discount without the additional frictions that arise inside the banking system. Section 6 discusses how a similar dual rate could be approximated in practice – through targeted refinancing, collateral policy or fiscal backstops – while considering the SARB's institutional constraints.

Figure 2: Timeline



Because central bank money enters the economy through bank lending, the framework captures the joint transmission of carbon pricing, green credit policy and climate shocks to inflation, output and welfare, allowing us to assess when credit tilting enhances or undermines the SARB's price stability mandate.

Our main innovation is to introduce explicit money creation into this climate transition setting, allowing us to trace how green monetary policy, carbon taxation and climate damage interact. The framework therefore illuminates both the mitigation benefits and potential price stability risks that arise when monetary policy supports the shift from brown to green capital.

2.2 Investors

The economy comprises a unit continuum of identical investor households, indexed by $i \in [0, 1]$. Each investor starts period 0 with an endowment $e > 0$ of a perishable good. A share c_0 is consumed immediately, while the remainder $q \equiv e - c_0$ is sold to firms as a capital input. At $t = 1$, households buy the final good for consumption c_1 using the sales revenue and any money endowment m.

$$U_i = \ln c_0 + \beta\big[\ln c_1 - \phi^I(\Delta)\big] \tag{1}$$

where $\beta \in (0, 1)$ denotes the subjective discount factor and $\phi^{i}(\cdot)$ is a damage function of using dirty energy Δ. The budget constraints of investors are:

$$p_1 c_1 = p_0 q_c + m \quad (2)$$

$$c_0 = k - q_c \quad (3)$$

where p_0 and p_1 are the prices of the consumption good in periods 0 and 1, respectively, and m is the monetary endowment. Equation 3 states that households consume the portion c_0 of their endowment k after selling q_c units to firms. The second-period consumption c_1, as shown in equation 2, is financed by the sales proceeds $p_0 q_c$ together with the revenue carried over from the initial date. Maximising utility (1) subject to (2)–(3) yields the Euler condition:

$$\frac{U_i(c_0)}{U_i(c_1)} = \beta \frac{p_0}{p_1} \quad (4)$$

which is standard except for the climate damage term in utility.

2.3 Final goods firms

There are two firm types, indexed by h, represented by b for brown firms and g for green firms. In South Africa's coal-dependent economy, brown firms correspond to high-carbon activities – such as coal-fired power generation, coal mining and energy-intensive heavy industry – whereas green firms represent low-carbon producers in renewables, services and lighter manufacturing.

In the first period, both types of firms issue bonds Q_h, with an interest rate r_h, to buy non-consumable capital goods k_h. In addition to capital, brown firms require dirty energy, denoted by δ, as an additional input. Following Golosov et al. (2014), the production and use of dirty energy serve as the sole source of carbon emissions within the model, directly linking firm activities to climate change. Carbon emissions generate negative externalities by intensifying climate-induced economic damage, thus reducing productivity across both sectors. The magnitude of productivity loss attributable to climate change is captured by a damage function $\phi(\Delta)$, which increases with total emissions Δ. Aggregate emissions Δ are defined as the sum of emissions generated by all brown firms. Furthermore, consistent with the framework proposed by Acemoglu et al. (2012), productivity levels A_h differ between brown and green firms, reflecting heterogeneous technological capabilities across sectors.

2.3.1 Brown firms

Brown firms maximise the following utility function:

$$\max_{B_b,\delta,k_b,c_b,q_b} \quad \ln c_b$$

We assume identical utility preferences across investors and firms. At $t = 0$, brown firms finance their purchase of capital goods k_b at price p_0 from investors and dirty energy δ at price p_δ from energy sector firms through loans from the central bank. Loans have a nominal face value B_b and an interest rate r_b, making total borrowing equal to $\frac{B_b}{1+r_b}$.[2] Thus, the liquidity constraint of brown firms at the beginning of the first period is:

$$p_\delta \delta + p_0 k_b \leq \frac{B_b}{1+r_b} + T \tag{5}$$

where T represents a lump sum transfer from the government. In the second period, brown firms use these inputs to produce output y_b, according to the following production technology:

$$y_b = A_b(1-\phi(\Delta))\left(k_b^\gamma \delta^{1-\gamma}\right)^\alpha \tag{6}$$

where A_b is the total factor productivity (TFP) of brown firms. The production function exhibits decreasing returns to scale, where γ is the share parameter for capital input, and $\alpha \in (0, 1)$ scales the overall production function. The term $\gamma\alpha$ represents the output elasticity of capital. The climate damage function $\phi(\Delta)$ represents the scale of production loss attributable to the total carbon emissions Δ of the entire economy. The brown firms then sell a fraction of the final goods q_b to investors and use the remaining

2 To maintain analytical simplicity, we abstract from commercial banking activities and assume direct lending by the central bank.

portion c_b for their own consumption. The revenue from the sale of goods is used to pay off the loans, expressed as:

$$q_b = y_b - c_b \tag{7}$$

$$B_b = p_1 q_b \tag{8}$$

The maximisation problem of brown firms using dirty energy implies:

$$\frac{\gamma\delta}{(1-\gamma)k_b} = \frac{p_1}{p_\delta} \tag{9}$$

where the proportions of dirty energy are determined by the shared parameter and the relative price of capital goods. Combined with equation 6, we derive the output of brown firms as a function of prices and capital goods:

$$y_b = \left(\frac{(1-\gamma)p_1}{\gamma p_\delta}\right)^{(1-\gamma)\alpha} A_b(1-\phi(\Delta))k_b^\alpha \tag{10}$$

The first order condition (FOC) with respect to debt further determines the level of capital goods:

$$\frac{p_0(1+r_b)}{p_1} = \frac{\alpha y_b}{k_b} \tag{11}$$

where $\frac{\propto y_b}{k_b}$ captures the real return on capital goods k_b. Equation 11 implies that the real return to capital by brown firms is equal to the loan rate minus nominal inflation.

2.3.2 Green firms

Green firms are analogous to brown firms, except we assume green firms do not require dirty energy to produce final goods. We assume green firms have a different TFP A_g. The production function is outlined as follows:[3]

$$y_g = A_g(1-\phi(\Delta))k_g^\alpha \tag{12}$$

[3] The details of the green firm's functions are shown in Annexure A.

The optimal level of capital input, similar to the conditions for brown firms, is determined by the loan rate, the inflation rate and the output elasticity parameter of capital, where:

$$\frac{p_0(1+r_g)}{p_1} = \frac{\alpha y_g}{k_g} \tag{13}$$

The loan rate r_g for green firms can differ from the loan rate r_b for brown firms. The central bank can implement a green credit policy to provide a discount ϵ to the loan rate for green firms, making r_g lower than the policy rate. In this case, $1 + r_g = \epsilon(1 + r)$. This green credit policy is designed to incentivise investment in green firms by reducing their cost of capital.

2.4 Energy sector

There is a competitive energy sector producing dirty energy Δ with a risk-neutral utility function. The sector maximises its profit π_δ by producing and selling energy. At $t = 0$, it purchases capital goods k_e from investors as production input. At $t = 1$, it produces energy using a linear production function with TFP ξ and sells it to brown firms at price p_δ. The government can impose an income carbon tax during the sale of the energy:

$$p_0 k_e + \pi_e = p_\delta(1-\tau)\Delta \tag{14}$$

$$\Delta = \xi k_e \tag{15}$$

where τ is a carbon tax on energy sales.

2.5 Emissions and climate damage

Climate damage is modelled as a direct function of cumulative carbon emissions, denoted by Δ. These emissions drive increases in global temperature, resulting in economic losses. Rather than explicitly modelling temperature dynamics, we use a simplified reduced-form damage function, $\phi(\Delta)$, which captures the relationship between total carbon emissions and resulting climate impacts. The damage function satisfies the following standard monotonicity condition:

$$\frac{\partial \phi(\Delta)}{\partial \Delta} > 0 \tag{16}$$

implying that higher levels of emissions always amplify economic damage from climate change.

2.6 Central bank and government

The central bank issues reserves M and sets the policy rate r to maximise aggregate social welfare. Social welfare is formally expressed as a weighted sum of individual utilities:

$$W = w_i U_i + w_b U_b + w_g U_g \tag{17}$$

where w_s denotes the predetermined welfare weight for agent s, and U_s represents the utility of agent s, with $s \in \{i, b, g\}$.

To address climate-related externalities, two distinct policy instruments are available to South African policymakers. First, in line with South Africa's Carbon Tax Act, the government can levy a carbon tax τ on emissions-intensive energy sources to internalise environmental externalities and curb emissions. Second, the SARB can introduce a climate-oriented monetary policy at the start of the first period, providing a loan rate discount ϵ to green firms. Such a targeted green credit policy would imply that green firms borrow at a lower interest rate than their brown counterparts, mirroring emerging international practices aimed at accelerating low-carbon transitions in carbon-intensive economies like South Africa.

3. Competitive equilibrium: South African context

The model's key insights are derived within a decentralised environment representative of South Africa's unique economic structure, notably its reliance on coal-based energy and industrial sectors vulnerable to climate risks.

3.1 Definition of equilibrium

The competitive equilibrium is defined by allocations (c_1, c_b, c_g, k_b, k_g, k_e, Δ, δ, q_c, q_b, q_g, Q_b, Q_g) and prices (p_0, p_1, p_e), given policy tools (r, τ), ensuring utility maximisation, budget constraints and market clearing conditions consistent with South African economic realities:

- Goods market: $q_g + q_b = c_1$
- Factor market: $q_c = k_g + k_b + k_e$
- Energy market: $\Delta = \delta$
- Money market: $1 + r = \frac{Q_g + Q_b}{M}$

3.2 Analytical characterisation of equilibrium

In equilibrium, the investment level equals:[4]

$$k_b = \frac{k\gamma}{((1 - \tau(1-\gamma)) + f(\tau)\gamma)(2 + r)} \tag{18}$$

$$k_g = f(\tau)k_b \tag{19}$$

where the function $f(\tau)$ is defined as:

$$f(\tau) = \left(\gamma \frac{A_b}{A_g}\right)^{\frac{1}{\alpha-1}} \left((1-\tau)\xi \frac{1-\gamma}{\gamma}\right)^{\frac{(1-\gamma)\alpha}{\alpha-1}} \tag{20}$$

indicating capital reallocation from brown (coal-intensive) to green sectors driven by the carbon tax τ. The function $f(\tau)$ is a monotonically increasing function of the carbon tax τ. According to equation 19, in South Africa, a higher carbon tax incentivises a shift away from fossil fuels towards renewable energy, reflecting ongoing efforts such as South Africa's Integrated Resource Plan and the Carbon Tax Act.

Production of dirty energy, closely tied to South Africa's heavy reliance on coal (about 80% of energy generation), in equilibrium equals:

$$\Delta = (1-\tau)\xi \frac{1-\gamma}{\gamma} k_b \tag{21}$$

This expression indicates that the responsiveness of carbon fuel usage to changes in the carbon tax depends on the capital share in the production function and the relative

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[4] For detailed derivatives about the competitive equilibrium, please refer to Tan, Tsomocos and Wang (2025).

share of capital in brown firm technology. In addition, equilibrium outputs reflect South Africa's economic vulnerability to carbon taxation, emissions and climate damages:

$$y_b = A_b(1-\phi(\Delta))\left((1-\tau)\xi\frac{1-\gamma}{\gamma}\right)^{(1-\gamma)\alpha}(k_b)^\alpha \tag{22}$$

$$y_g = A_g(1-\phi(\Delta))(k_g)^\alpha \tag{23}$$

highlighting that coal-dependent and energy-intensive sectors, prominent in South Africa's economy, face substantial productivity and output risks due to climate policies and associated damages.

Investors allocate consumption across two periods. First-period consumption is given by:

$$c_0 \;=\; \frac{k\,(1+r)}{2+r} \tag{24}$$

An increase in the policy rate *r*, as determined by the SARB's inflation targeting (3%–6%), reduces c_0 by raising the denominator (2 + *r*), thereby shrinking current household expenditure. In South Africa, this effect is amplified because many households hold variable rate debt, so even modest hikes in *r* directly reduce disposable income. Second-period consumption is given by:

$$c_1 \;=\; \frac{k\,\alpha\,A_g\,[1-\phi(\Delta)]\,(f(\tau)\,k_b)^{\alpha-1}}{2+r} \tag{25}$$

In equation 25, as the carbon tax τ increases, dirty energy usage Δ falls, driving down $\phi(\Delta)$ and raising green sector capital k_g, as shown in equation 19. Hence, a higher τ bolsters c_1 by improving future returns – especially relevant for climate-sensitive South African households in agriculture or mining. However, if the SARB concurrently raises *r* to contain inflationary pressures, the term (2 + *r*) grows, partially offsetting the gains in c_1.

Regarding price dynamics, the prices are characterised by the following equations:

$$p_0 \;=\; \frac{(2+r)\,m}{r\,k} \tag{26}$$

$$p_1 = \frac{(1+r)\, p_0\, k_g}{\alpha\, y_g} \tag{27}$$

$$p_\delta = \frac{p_0\, k_e}{(1-\tau)\, \Delta} \tag{28}$$

From equation 26 to 28, inflation is defined as:

$$\pi = \frac{p_1}{p_0} \tag{29}$$

An increase in r raises the denominator in equation 26, thereby reducing the current-period price level p_0. The term p_δ in equation 28 reflects the price of energy usage. Since Δ denotes dirty energy usage, a larger Δ (indicating greater efficiency) reduces p_δ, whereas a higher carbon tax increases the energy price p_δ, widening the divergence between the consumption-goods price p_0 and the energy price p_δ. This elevation in energy costs contributes to higher production expenses and intensifies inflationary pressures. In the second period, if climate damages $\phi(\Delta)$ are severe due to high carbon fuel usage Δ, aggregate output $y_g + y_b$ declines and p_1 increases, exerting upward pressure on π. Conversely, a higher carbon tax τ lowers Δ, which mitigates $\phi(\Delta)$ and increases green output y_g. The resultant rise in y_g reduces the second-period price p_1, thereby helping to contain inflation. However, a very high carbon tax would increase the energy price p_δ, reduce the capacity of brown firms in the current period and lower y_b, which could offset the benefits of reduced climate damages by imposing a substantial transition cost.

In summary, a well-calibrated carbon tax τ can reduce climate damages $\phi(\Delta)$, increase output from green sector y_g and lower p_1, thereby supporting lower inflation in period 1. However, if renewable capacity expansion lags or if the SARB raises r sharply, the short-run effect can be higher energy prices (p_δ) and lower aggregate demand (c_0 and c_1), presenting a complex trade-off between climate mitigation and price stability in South Africa.

3.3 Optimal interest rate and carbon pricing

In this policy-oriented paper, based on the analytical solution of the competitive equilibrium, we summarise the main results of jointly determining the optimal interest rate r^* and carbon tax τ^* in a heterogeneous-agent setting with climate externalities. Detailed derivations and proofs are in Tan, Tsomocos and Wang (2025); here, we present only the essential propositions.

Proposition 1 (baseline interest rate rule)

When climate damages are absent ($\Phi(\cdot) = 0$) and no carbon tax is imposed ($\tau = 0$), the welfare-maximising policy rate r^*_{base} satisfies:

$$1 + r^*_{\text{base}} = \frac{w_I}{\gamma}$$

Although the Friedman rule would prescribe $r^* = 0$, the presence of production heterogeneity and credit-market imperfections implies $r^*_{base} > 0$ (see Tan, Tsomocos and Wang (2025), Proposition 1).

Proposition 2 (climate-adjusted interest rate rule)

Once climate damages $\phi(\Theta) > 0$ are introduced while the carbon tax remains zero ($\tau = 0$), the optimal interest rate $r^*_{\tau=0}$ strictly exceeds its baseline value:

$$1 + r^*_{\tau=0} > \frac{w_I}{\gamma}$$

Raising r in this case diminishes dirty energy use Δ, mitigates $D(\Theta)$ and thereby enhances social welfare, so that the optimal r exceeds r^*_{base} (see Tan, Tsomocos and Wang (2025), Proposition 2 and Lemma 1).

Proposition 3 (joint optimality with positive carbon tax)

Suppose $D(\Theta) > 0$ and a non-negative carbon tax $\tau > 0$ is available. Then the optimal interest rate $r^*_{\tau\geq 0}$ lies between its baseline and no-tax climate values:

$$r^*_{\text{base}} \leq r^*_{\tau\geq 0} \leq r^*_{\tau=0}$$

The lower bound is attained when τ is sufficiently large to eliminate dirty energy use, whereas the upper bound corresponds to τ = 0. For intermediate τ, a positive but partial tax reduces the marginal benefit of raising *r*, so $r^*_{\tau \geq 0}$ declines monotonically as τ increases from 0 (see Tan, Tsomocos and Wang (2025), Proposition 3).

Proposition 4 (non-monotonic inflation response)

Under D(Θ) > 0 and τ ≥ 0, there exists a $\bar{\tau} > 0$ threshold such that the equilibrium inflation rate rate $\pi(\tau)$ satisfies:

$$\frac{\partial \pi(\tau)}{\partial \tau} < 0 \quad \text{for } \tau \leq \bar{\tau}, \qquad \frac{\partial \pi(\tau)}{\partial \tau} > 0 \quad \text{for } \tau > \bar{\tau}$$

This proposition indicates that a small increase in τ reduces inflation by lowering climate damages, but once τ surpasses $\bar{\tau}$, further increases shrink aggregate output sufficiently that inflation begins to rise (see Tan, Tsomocos and Wang (2025), Proposition 4).

4. Quantitative example

To investigate the macroeconomic and welfare implications of green credit policy in South Africa, we calibrate our two-period general equilibrium model using parameter values informed by established international literature and South African economic features. The climate damage parameter is set at *d* = 0.71, which results in an output loss of about 8% under a projected temperature increase of 6°C – consistent with South Africa’s vulnerability to climate-induced productivity shocks due to its coal-intensive energy sector.

The subjective discount factor $\beta = 0.96^{10}$ corresponds to an annual discount rate of 4%, which is at the upper end of typical values in climate–macroeconomic models (Golosov et al. 2014). Such a rate is particularly suitable for emerging markets like South Africa, where higher effective discounting is often applied to reflect elevated macroeconomic uncertainty, capital market imperfections and shorter policy horizons (Hassler, Krusell and Olovsson 2016; Buera and Shin 2011). The productivity parameters draw from Acemoglu et al. (2012), assigning a higher TFP to brown firms

(A_b = 1.2) relative to green firms (A_g = 1), while maintaining standardised productivity in the energy sector (ξ = 1).

Production elasticities are selected to reflect South African structural conditions. The energy share parameter ($1 - \alpha = 0.1$) is taken from Steenkamp and Naudé (2018), capturing the relatively high energy intensity of domestic production. The capital elasticity is set to $\gamma = 0.4$, consistent with calibration practices in climate–fiscal policy models such as Barrage (2020).

On the monetary side, the nominal money supply is normalised to m = 100, which yields an annualised inflation rate of about 4.5%, aligning with the midpoint of the SARB's inflation-targeting band. Utility weights are calibrated to generate a baseline policy rate of 7% annually, with W_I = 0.65 for investors, $W_{l,b}$ = 0.28 for brown firm agents and $W_{l,g}$ = 0.07 for green firm agents. These weights broadly mirror the current structure of the South African economy, where fossil fuels account for roughly 80% of primary energy production.

This calibration establishes a South African baseline against which to evaluate distributional and inflationary impacts of green credit initiatives under different carbon tax regimes (see Table 1).

Table 1: Parameter calibration for South African baseline scenario

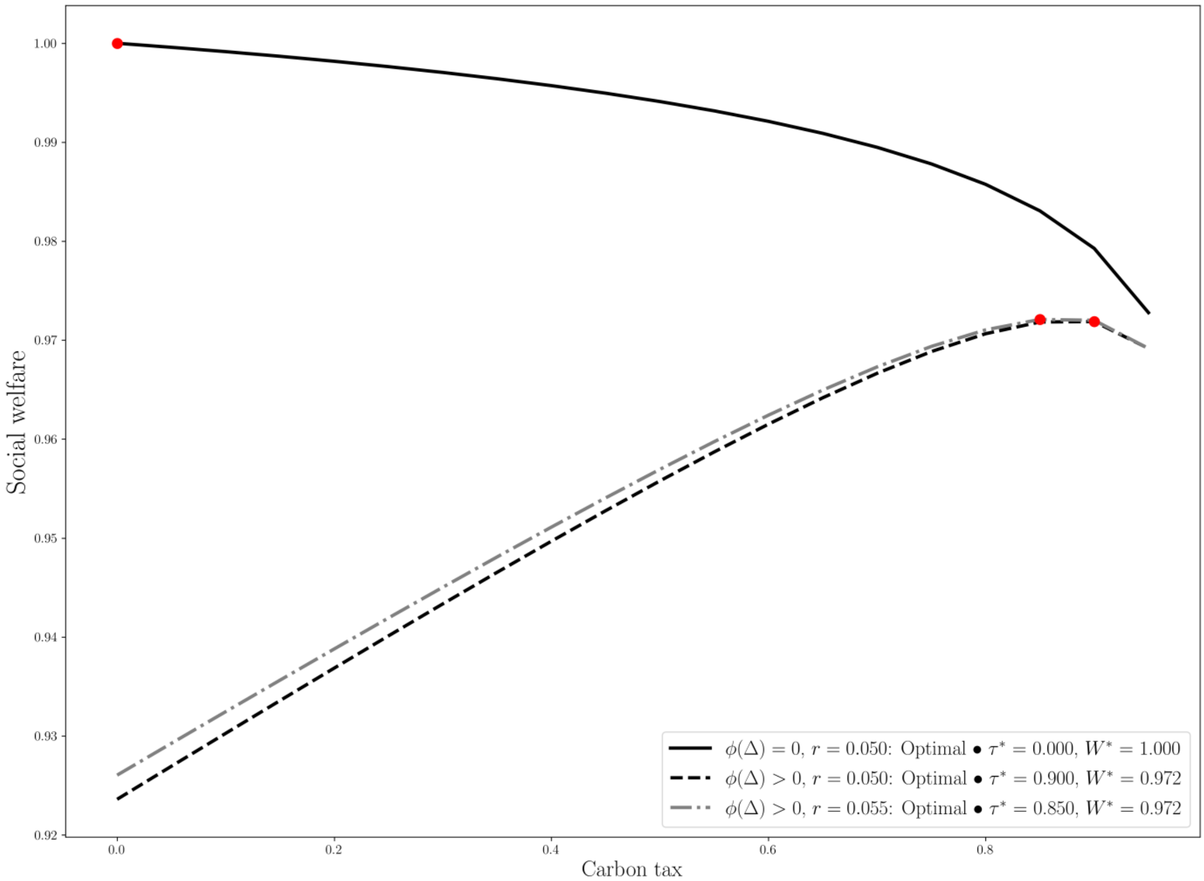
Parameter	Calibrated value	Target or data source
Preferences		
Climate damage parameter	$d = 0.71$	Output loss of 8% at a temperature rise of 6°C
Subjective discount factor	$\beta = 0.96^{10}$	Annual discount rate of 4% over a 10-year horizon
Productivity		
Brown firm TFP	$A_b = 1.2$	Acemoglu et al. (2012)
Green firm TFP	$A_g = 1$	Standardised
Energy sector TFP	$\xi = 1$	Standardised
Production elasticities		
Energy input share	$1 - \alpha = 0.1$	Steenkamp and Naudé (2018)
Capital elasticity	$\gamma = 0.4$	Barrage (2020)
Monetary parameters		
Nominal money supply	$m = 100$	4.5% annualised inflation rate
Utility weights	$W_I = 0.65$	Annualised policy rate of 7%
	$W_{l,b} = 0.28$, $W_{l,g} = 0.07$	80% share of the dirty energy sector in South Africa

We first investigate the interaction between the carbon tax τ and the policy rate *r*. In Figure 3, the horizontal axis denotes the carbon tax rate $\tau \in [0, 1]$, while the vertical axis shows social utility normalised by the optimal welfare absent climate damages. The solid black line corresponds to the case $\phi(\Theta) = 0$, $\tau = 0$. The optimal carbon tax for this case, indicated by the red dot, is 0, as expected. The dashed black line illustrates the scenario $\phi(\Theta) > 0$, with *r* held at its baseline value. According to Figure 3, the absence of a carbon tax in an environment with a 6°C temperature increase leads to a welfare loss of over 8% due to climate damage. Introducing τ initially yields large marginal welfare gains – reflecting substantial reductions in Δ and $D(\Theta)$ – but these gains disappear once τ exceeds 90%,[5] beyond which further increases harm welfare due to excessive investment crowd-out.

Moreover, the dashed grey line captures a scenario in which the SARB raises the policy rate above its baseline level to control the inflation pressure from climate change. This reflects an approach in which the central bank, in pursuit of market neutrality, incorporates climate risks into its policy framework by using a higher interest rate to discourage brown sector investment. However, the figure demonstrates that even when monetary policy is adjusted to account for climate risks – thereby reducing coal-based capital – the resulting welfare gains are marginal relative to maintaining the baseline rate. In South Africa, where the SARB's mandate prioritises price stability and the inflation target, these results underscore the limited effectiveness of conventional interest rate interventions in addressing climate externalities.

5 Expressing carbon taxes in relative terms: a 90% tax on coal (priced at roughly US$75 per tonne, carbon content 71%) equates to approximately US$104 per tonne of CO_2. Thus, a 50%–150% rate corresponds to US$50–US$150 per tonne.

Figure 3: Social welfare as a function of carbon taxes and the policy rate

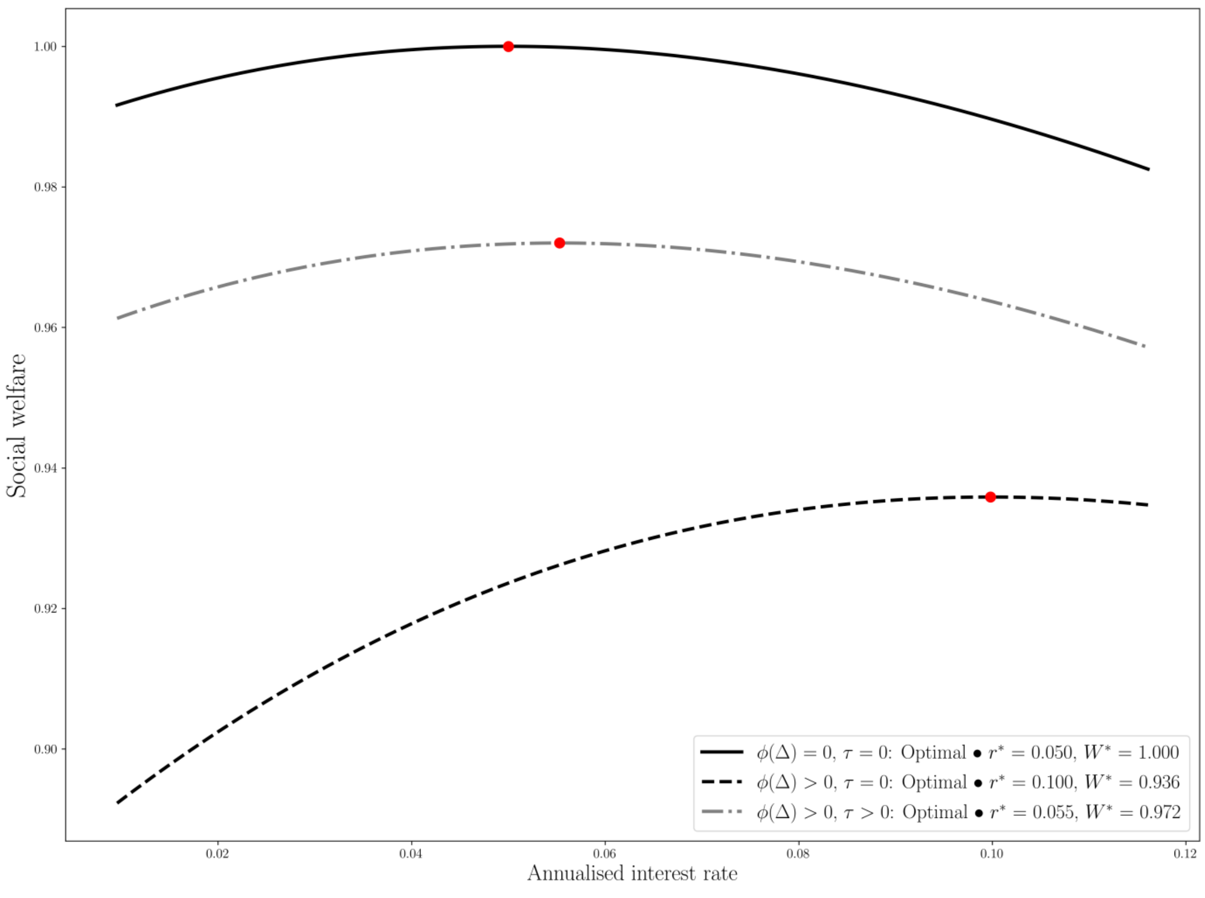


Note: The figure plots social welfare as a function of the carbon tax rate under different monetary policy assumptions. The x-axis reports the carbon tax rate ranging from 0 to 1, while the y-axis shows social welfare normalised by the optimal social welfare without climate damage. The solid black line denotes the baseline case with no climate damage. The dashed black line shows the case with climate damage and the baseline annualised policy rate. The dashed grey line represents the case with climate damage and a higher annualised policy rate. The red dot marks the welfare-maximising carbon tax level in each case.

Figure 4 illustrates the social welfare associated with different policy rates *r*, normalised to the welfare level when there is no climate damage $\phi(.) = 0$. The solid black line is the baseline ($\phi = 0$, $\tau = 0$), with an annualised optimal *r* = 5%. When climate damage is introduced and $\tau = 0$, the dashed black line shows that the welfare-maximising *r* jumps to around 10%, but welfare remains more than 7.4% below the no-damage benchmark, indicating limited efficacy of monetary policy alone. By contrast, the dashed grey line (holding a positive τ) shows that the optimal *r* falls much closer to the baseline level. This underscores that carbon taxation is substantially more effective in mitigating climate damage than raising *r*. It also reveals that while the optimal τ is relatively insensitive to *r*, the optimal *r* is highly sensitive to τ.

However, as illustrated by the dashed grey line, if there is a reasonable level of carbon tax, the optimal policy rate is now much lower than in the second case, but much closer to the baseline case. This suggests that carbon taxation is the more effective tool to address carbon emissions compared to monetary policy. When there is a reasonable level of carbon tax, the increase in the policy rate to maximise social welfare and stabilise prices does not need to be substantial, unlike the previous case with no carbon taxes. Comparing this result with that in Figure 3, we also find the optimal tax level is not sensitive to the interest rate, but the optimal policy rate is very sensitive to the carbon tax rate. This underscores the central role of carbon taxation in climate mitigation, highlighting its relative effectiveness over conventional monetary policy.

Figure 4: Social welfare as a function of policy rates in three cases



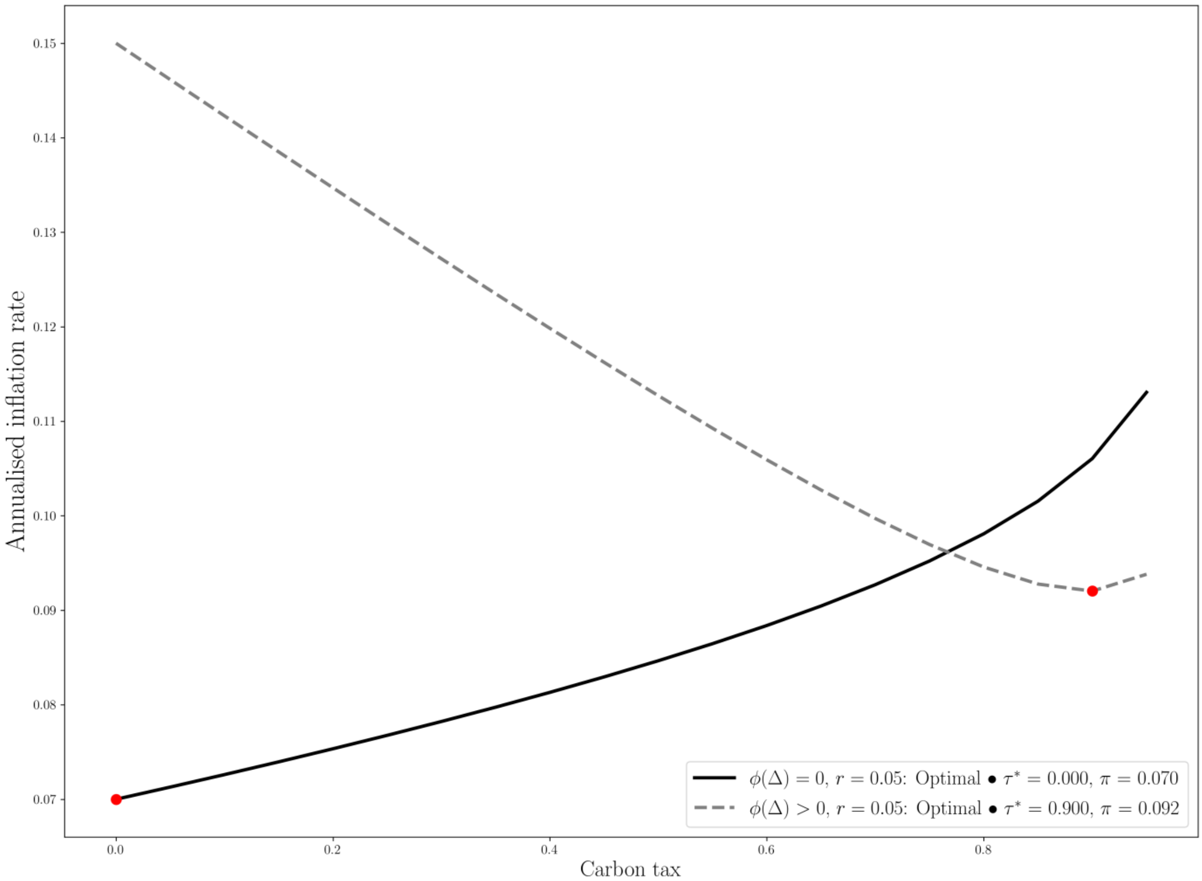
Note: The figure plots social welfare as a function of the policy rate across three cases. The x-axis shows the policy rate and the y-axis presents normalised social welfare. The solid black line represents the baseline case with no climate damage. The dashed black line incorporates climate damage with optimised monetary policy and no carbon tax. The dashed grey line shows the case with climate damage and a fixed carbon tax. The red dot marks the welfare-maximising annualised policy rate in each case.

In the South African context, the SARB operates within a 3%–6% inflation-targeting framework and faces constraints in adjusting r by large amounts without risking financial stability. A jump from 5% to 10% would not be feasible given current debt levels, currency volatility and economic growth considerations. Hence, the finding that a positive τ allows the SARB to maintain r near its baseline – while still achieving significant climate mitigation benefits – aligns with the SARB's mandate to remain market neutral and avoid destabilising the domestic economy. In practice, this suggests that coordinated fiscal policy (i.e. carbon taxation) is necessary to complement monetary policy, enabling the SARB to fulfil its price stability objectives without shouldering the full burden of climate mitigation through interest rate adjustments alone.

Next, we illustrate how carbon taxes affect future inflation and price stability. Figure 5 shows the relationship between τ (horizontal axis) and the annualised inflation rate (vertical axis). The solid line represents the case without climate damage: when $\tau = 0$, the annualised inflation rate is 7%. As τ increases, higher taxes reduce investment and create a second-period supply shortfall, raising inflation. When $\phi > 0$ (dashed line), an initial increase in τ lowers inflation – via improved second-period output from reduced climate damages – until a critical tax rate (around 90%), beyond which further increases reduce output sufficiently to raise inflation, consistent with Proposition 4.

In South Africa, where energy costs and electricity shortages frequently drive headline inflation, a moderate carbon tax can help the SARB achieve its inflation target by improving future supply through reduced $\phi(\Delta)$. However, if τ surpasses a threshold, the resulting contraction in output exacerbates existing supply constraints – such as load-shedding and transport bottlenecks – leading to higher inflation. Thus, the SARB must consider the non-monotonic inflation response to τ when evaluating policy coordination with National Treasury, ensuring that carbon taxation supports price stability rather than undermining it.

Figure 5: Inflation as a function of tax in two cases



Note: The figure plots the impact of carbon taxes on inflation. The x-axis displays the carbon tax rate and the y-axis shows the annualised inflation rate. The solid line represents the case without climate damage. The dashed line includes climate damage. The red dot marks the inflation rate level when the carbon tax is set at the optimal level.

5. Green credit policy

In this section we extend the model by allowing the central bank to implement a green credit policy to mitigate climate change. This green credit policy offers a discount of $\in (\frac{1}{1+r}, 1)$ to the borrowing cost of green firms. That is, their borrowing cost r_g satisfies $r_g = (1 + r)\epsilon$. Now the central bank can choose both the policy rate r and the green credit policy ϵ to maximise social welfare and stabilise prices.

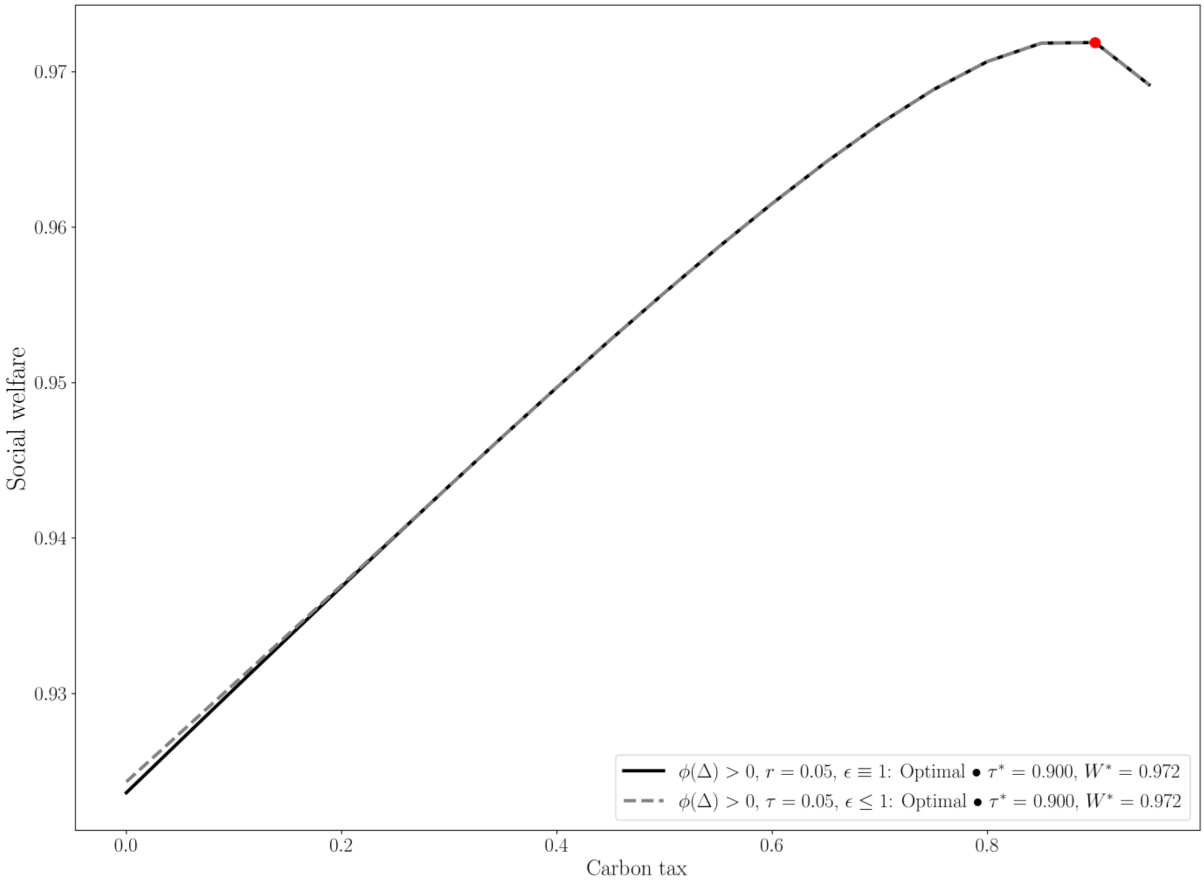
This green credit policy could incentivise green firms to invest more, assist in shifting capital allocation from brown producers to green producers and reduce carbon emissions. However, this policy may come at the cost of raising price levels for a given policy rate. This is because the effective interest rate of the firm sectors, taken as the weighted average of the borrowing costs of green firms r_g and of brown firms r, will be lower than the policy rate without the green credit policy. The price functions (26) to

(28) indicate that a lower effective interest rate will increase the price level in both periods, raising concerns about inflation.

To quantify the impact and trade-offs associated with the green credit policy, we conduct a numerical simulation based on the parameterisation in Table 1. The discount ϵ ranges from 0 (indicating a free loan) to 1 (indicating no discount). We run the following numerical simulation to test whether this green credit policy could mitigate climate damage contingent on the carbon tax level and whether it has a negative effect on inflation as discussed.

We test the effect of the green credit policy on social welfare with different carbon tax rates. In Figure 6, the x-axis represents the carbon tax rate while the y-axis shows the corresponding equilibrium social utility. The black line represents the benchmark results shown in Figure 3, where the conventional monetary policy rate and the carbon tax rate are at their best possible combinations. The grey line assumes that the policy rate remains the same but that the green credit policy is implemented to address the climate change issue. The differences between these lines allow us to evaluate how the green credit policy increases social welfare with the same level of carbon tax and monetary policy rate.

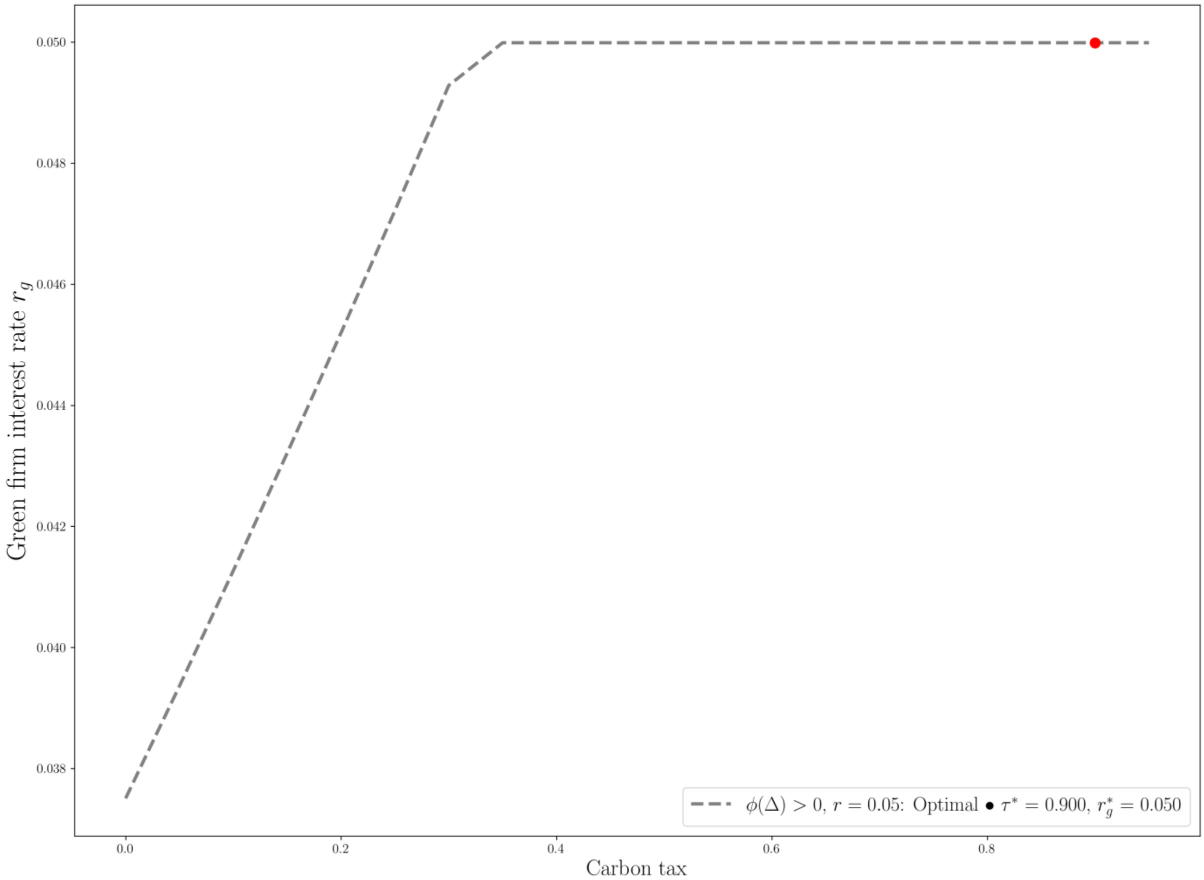
Figure 6: Simulation results for the green credit policy case – social welfare



Note: The figure compares social welfare under different green credit policy scenarios. The x-axis shows the carbon tax rate and the y-axis shows social welfare in equilibrium. The black line shows benchmark results without green credit. The grey line incorporates a green credit policy. The gap between the lines reflects the welfare gains from implementing green credit when carbon taxes are below optimal.

Figure 7 shows the optimal annualised interest rate for green firms in equilibrium. The interest rate for green firms is bounded by the zero lower bound and cannot exceed the policy rate level of 0.05.

Figure 7: Simulation results for the green credit policy case – discount



Note: The x-axis denotes the carbon tax rate and the y-axis shows the annualised interest rate for green firms. The results show that the green interest rate hits the zero lower bound when carbon taxes are low but converges to the policy rate when taxes are high.

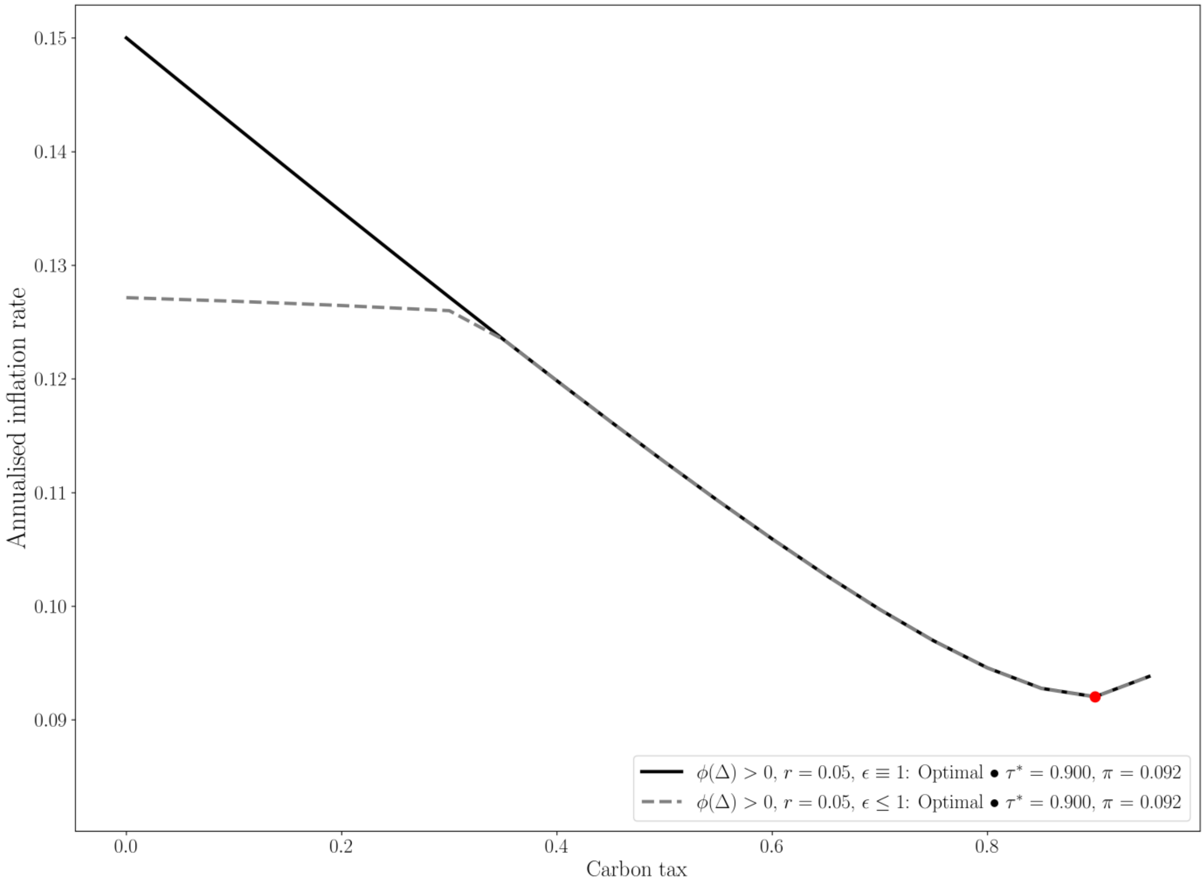
When the carbon tax is significantly below the optimal level, a lower interest rate for green firms is the optimal choice for the green credit policy. This policy has a substantial effect on social welfare when the carbon tax is insufficient. For example, when the carbon tax is below 0.1, the lower green credit policy can improve social welfare by 0.2%. A lower cost of capital for green firms shifts investment from brown to green sectors, thereby decreasing carbon emissions and mitigating climate damage. This finding has significant policy implications, as scholars have argued that the current carbon tax policy is far below the optimal level due to the 'tragedy of the horizon' and political issues (Carney 2015; Hansen 2022). Implementing a green credit policy with a lower loan rate for green firms can help mitigate these challenges by directly incentivising environmentally friendly investments, reducing carbon emissions and enhancing social welfare. These welfare gains are especially relevant given that South Africa's current carbon tax (R150 per tCO_2) remains well below optimal level, owing to political constraints and concerns about competitiveness (Winkler and Marquard 2016;

Sterner and Robertson 2020). A temporary green credit subsidy can thus help overcome short-run underinvestment in renewables, raise green output and partially compensate for the low carbon tax.

The advantages of the green credit policy diminish to zero when the carbon tax is high. As the tax increases, the marginal cost of dirty energy decreases, and the marginal benefits of the interest rate discount for green firms diminish significantly. Conversely, inflation and the high marginal investment value for brown firms cause the marginal cost of a lower rate for green firms to increase. After the tax surpasses a threshold, the optimal green firm rate converges to the policy rate. This indicates that the green credit policy cannot provide additional value to the economy when the carbon tax is at a sufficiently elevated level. This underscores the fact that green credit policies are only useful when the carbon tax is not at the optimal level and can only serve as an auxiliary policy to address climate issues. In South Africa, these results suggest that green credit is most useful during the early transition phase, when τ is below the efficient tax level: it can accelerate investment in renewables (e.g. wind and solar under the Renewable Energy Independent Power Producer Procurement Programme) without requiring the SARB to adjust r substantially.

A primary concern is whether subsidising green finance undermines the SARB's inflation-targeting mandate. Figure 8 shows equilibrium inflation under (i) benchmark policy (black line) and (ii) benchmark plus green credit (grey line) as τ varies. When τ is low, green credit lowers inflation relative to the benchmark by expanding green output, which eases second-period supply constraints and offsets the reduced effective interest rate. During this phase, South Africa's chronic load-shedding and high electricity prices make supply enhancements especially valuable for stabilising inflation. However, as τ increases, the marginal supply benefit of green credit falls, and if ϵ remains excessively generous at high τ, inflation may rise above the benchmark – contravening the SARB's market neutrality and price stability objectives.

Figure 8: Simulation results for the green credit policy case – inflation



Note: The figure shows the inflation response to the green credit policy across varying carbon tax levels. The x-axis indicates the carbon tax rate and the y-axis presents the annualised inflation rate. The black line is the benchmark without green credit and the grey line includes green credit. The figure shows that green credit helps reduce inflation when carbon taxes are low, but the effect diminishes as the tax increases.

In summary, while the SARB's market neutrality principle ordinarily discourages sector-specific credit concessions, our results indicate that a time-limited green credit policy can improve welfare and even alleviate inflationary pressures when τ is below its optimal level. This aligns with South African policy debates – where the current carbon tax is widely viewed as too low to drive the energy transition – by showing that green credit can serve as a targeted, temporary complement to carbon taxation. Once τ reaches a sufficiently high level (e.g. exceeding R250 per tCO_2), the welfare gains from green credit vanish, along with any subsidy risks exerting upward pressure on prices. Consequently, South African policymakers should deploy green credit only as an auxiliary tool – coordinated with National Treasury's carbon tax – to advance the transition without undermining the SARB's commitment to price stability and market neutrality.

6. Policy implementation: feasibility for the SARB

The green credit policy in our model assumes that the central bank can lend directly to green firms at a lower rate. In practice, however, the SARB operates a single-rate repo framework and does not provide selective credit to firms. As a result, any preferential funding for low-carbon activities would need to be intermediated through the banking sector or other financial institutions. To assess the feasibility of the differentiated policy between green and brown firms proposed in our paper, we discuss three operational channels through which the SARB could approximate a green credit policy, highlighting both their potential and limitations.

One possible approach involves targeted refinancing operations. A climate-linked facility could offer term funding at a discounted rate, ϵr, to banks that meet verifiable green-lending benchmarks. This would mirror programmes such as the Bank of Japan's zero-interest Fund-Provisioning Measure for Climate Response (Bank of Japan 2021) or the People's Bank of China's 1.75% Carbon Emission Reduction Facility (People's Bank of China 2021; Bank for International Settlements 2022). Within the South African context, the Prudential Authority could be tasked with overseeing eligibility audits, while a well-defined sunset clause would help safeguard the SARB's market neutrality mandate.

A second option would be to tilt the collateral framework. Without altering the policy rate, the SARB could adjust collateral haircuts – reducing them for green assets and increasing them for carbon-intensive instruments – consistent with proposals to 'green' central bank collateral policies (McConnell, Yanovski and Lessmann 2022). Empirical evidence suggests that such differentiated haircuts can shift financial flows towards green assets without imposing significant balance sheet risks (Krusell and Smith 2024). The SARB's existing legal and operational framework may accommodate such differentiated haircuts, although incorporating explicit climate-related criteria could require further regulatory or legislative clarification.

A third and more ambitious channel involves collaboration with fiscal and development finance institutions. Even a well-designed central bank refinancing tool would fall short of mobilising the approximately R500 billion in green capital needed per decade, as suggested by our welfare calculations. To bridge this gap, National Treasury could assume first-loss risk through vehicles such as the Infrastructure Fund or the Development Bank of Southern Africa, drawing inspiration from Germany's KfW green bond model (Griffith-Jones 2016). While such blended finance arrangements blur the boundary between monetary and fiscal policy, they would help limit direct credit exposure on the SARB's balance sheet.

Taken together, these instruments suggest that a green monetary policy in South Africa could only be implemented indirectly – through targeted refinancing schemes, collateral policy adjustments or co-financing arrangements with National Treasury – rather than via direct lending by the central bank. Consequently, the welfare gains presented in our model should be interpreted as upper bounds, premised on perfect pass-through of monetary support. Translating these theoretical gains into practice would require several institutional safeguards: well-defined green taxonomies to ensure consistency and credibility; formalised risk-sharing mechanisms with National Treasury; and clearly articulated exit strategies, to be enacted once the carbon tax trajectory converges to its Ramsey-efficient level. Without these features, a dual-rate system risks drifting into quasi-fiscal territory, ultimately compromising the SARB's primary mandate of price stability (Pfister 2024; Campiglio 2016).

Although the dual-rate policy proposed in our model is difficult to replicate exactly, treating the green discount ϵ as a proxy for any instrument that lowers the cost of capital for clean projects allows us to isolate and quantify the key trade-off: cheaper green finance reduces climate damage and future inflation via the supply side, but it can raise current money demand and hence near-term prices. By abstracting from banking intermediation, the model provides an upper bound on welfare gains and a clean mapping from 'policy spread' to macroeconomic outcomes. Policymakers can use these elasticities to gauge the size and duration of any real-world intervention – be it a targeted refinancing window, softer collateral haircuts or a fiscal guarantee – without committing the SARB to permanent credit allocation. In this sense, the dual rate becomes a convenient synthetic variable: once calibrated to match the subsidy embedded in an actual scheme, the model's quantitative results give a first-pass assessment of (i) how large the concession can be before it jeopardises price stability, and (ii) how quickly it should be tapered as the carbon tax approaches its social optimum. Even if the operational route is indirect, the theoretical spread helps translate complex, multi-agency arrangements into familiar monetary policy metrics, thereby offering transparent guidance on sequencing and scale.

7. Conclusion

This paper demonstrates that climate change fundamentally changes the transmission and effectiveness of monetary policy in maintaining price stability. By incorporating endogenous central bank credit creation into a general equilibrium model featuring heterogeneous firms, we find that both the direct physical impacts of climate change and the dynamics of transitioning to a low-carbon economy create novel challenges for central banks. In particular, inflation exhibits greater responsiveness to changes in the policy rate when climate risks are present, and even with optimal carbon taxation in place, future inflation remains elevated – requiring a higher interest rate than in an economy without climate damage.

Our results confirm that carbon taxation is the single most powerful tool for curbing climate damages. Nevertheless, its capacity to stabilise prices is constrained by ongoing supply-side shocks. In South Africa – where the carbon tax is perceived as politically constrained and set well below levels recommended by economists – green credit policy can act as a valuable complement. By offering subsidised lending to renewable energy firms, a targeted green credit facility can boost clean investment and ease supply bottlenecks, thereby improving welfare and dampening inflation when τ is below its socially optimal rate. However, as the carbon tax approaches higher, more effective levels (for example, above R250 per tCO_2), the incremental gains from green credit diminish and may even become inflationary.

These findings carry important implications for the SARB, which operates under a market neutrality principle. While the SARB's mandate emphasises price stability without favouring specific sectors, our analysis suggests that a time-limited green credit policy – designed to work in tandem with National Treasury's carbon tax – can be implemented without breaching neutrality if it is carefully calibrated. In practice, the SARB could provide concessional funding to green firms only until the carbon tax rises to a level that ensures sufficient private-sector investment in renewables. Thereafter, any continued subsidy risks distorting financial markets and undermining the SARB's core objective of maintaining inflation within its 3%–6% target range.

In summary, South Africa's policymakers should adopt an integrated approach that aligns fiscal and monetary instruments: carbon taxation must be strengthened to address supply-side disruptions, and green credit can be deployed as a temporary, state-contingent measure. Such coordination will enable the SARB to uphold its market neutrality commitment and price stability mandate while supporting the economy's transition to a low-carbon future.

Annexures

A. The model structure for green firms

The green firms maximise the following objective function:

$$\max_{Q_g, k_g, c_g} \quad \frac{c_g^{1-\sigma} - 1}{1 - \sigma}$$

subject to the following budget constraints:

$$p_0 k_g = \frac{Q_g}{1 + r_g}$$

$$Q_g = p_1 q_g$$

$$q_g = (y_g - c_g)$$

$$y_g = A_g(1 - \phi(\Delta)) k_g^{\gamma}$$

where

Q_g ≡ Face value of green firm's bond

k_g ≡ Capital input of green firm

q_g ≡ Goods sold by the green firm to investors

c_g ≡ Consumption of green firm

y_g ≡ Goods produced by green firm

γ ≡ Output elasticity of capital input

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