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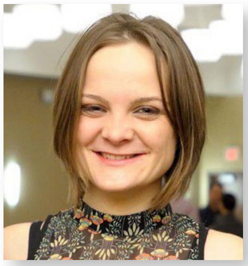

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The Risks of the Wrong Climate Policy for Developing Countries

SCENARIOS FOR SOUTH AFRICA

OZLEM OMER AND JERONIM CAPALDO[1]

ABSTRACT

In this paper, a demand-driven growth model is used to explore climate change scenarios faced by the South African economy. The focus is on key macroeconomic variables including employment, productivity, income distribution, trade and fiscal balances. Results show that emission reduction alone will not put South Africa on a sustainable and equitable growth path. Support from appropriate macroeconomic policies is necessary. We show that, under sufficient global mitigation, expansionary fiscal and monetary policies lead to faster output and productivity growth, higher employment and lower inequality. By contrast, macroeconomic tightening or "free riding" on global emission reduction leads to inferior outcomes, putting sustainable development out of reach.

[1] The authors would like to thank Duncan Foley, Lance Taylor, Kevin Gallagher and Codrina Rada for valuable discussions throughout this study.

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INTRODUCTION: SOUTH AFRICA'S CHALLENGES TO GREEN TRANSITION

In 2021, three imbalances laden with consequences have become apparent: vaccines have remained concentrated in advanced economies, the recovery has exacerbated many inequalities and the climate crisis has not been met with a global plan, leaving most developing countries on the frontline of a battle they cannot win.

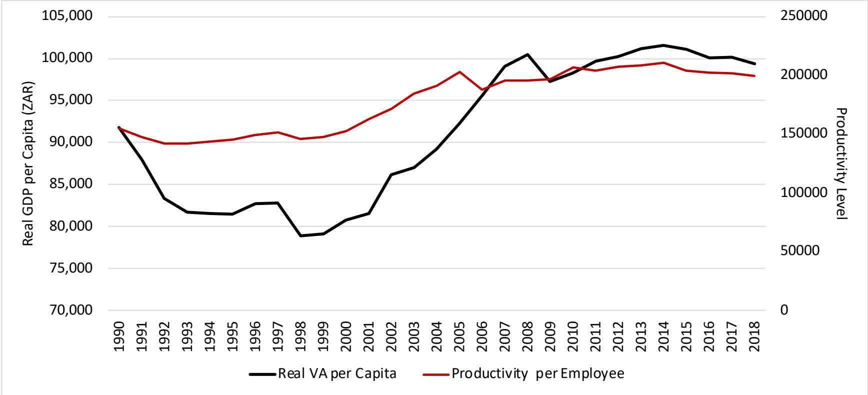
South Africa epitomizes this triple crisis. Vaccinations progress at a slow pace although the country is home to production facilities that make vaccines for developed countries. Endemic inequalities have been exacerbated by employment loss during the lockdowns, which the recovery struggles to resolve. Finally, the United Nations Conference on Climate Change (COP26) failed to deliver concrete commitments from developed countries, putting South Africa's coal dependent economy at risk of becoming a global pariah. Meanwhile, temperatures in South Africa have risen twice as fast as the world average, well above 2°C per century, causing concerns about extreme weather events becoming more frequent than elsewhere (Treasury Department of Republic of South Africa, 2020).

While no country can stop global warming alone, developed countries are not completely powerless: they can at least make the investments necessary to adapt to rising temperatures. Developing countries lack the technology, access to sufficient hard currency and the policy independence required to adapt. In South Africa, these challenges hinder not only adaptation but also the country's ability to go through the energy transition necessary to avoid backlash from developed countries.

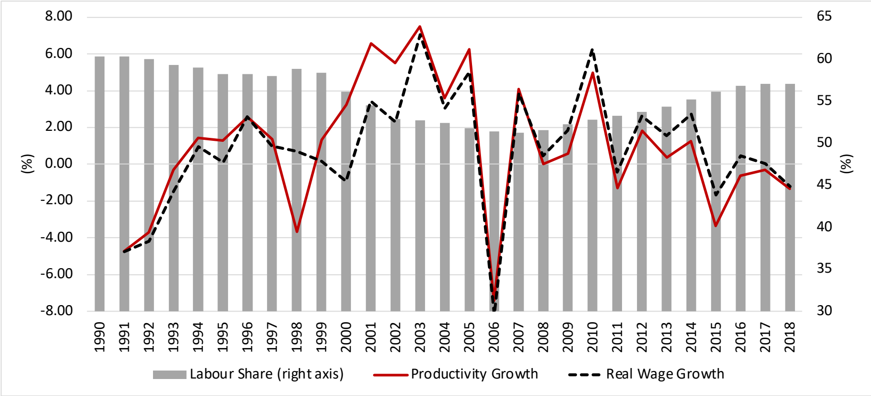
This means South Africa faces a catch-22. If the world does not drastically reduce emissions, economic growth will soon suffer, with catastrophic consequences projected to hit within a few decades. On the other hand, reducing emissions unilaterally and without an appropriate expansion of economic sectors based on renewable energy will also lead to a large loss of demand and income. In general, the stakes are much higher for low- and middle-income countries as they must go through fast economic, social and technological transformation in a highly constrained fiscal environment (Foley, 2012).

Strong, "equitable" per capita income growth, which is key to development, requires sustained labor productivity growth—particularly challenging for countries where industrialization has stalled. According to Ocampo et. al. (2009), developing countries must sustain three percent growth per capita per year just to catch-up with the advanced countries. In South Africa, between 1990 and 2018, average real GDP per capita growth and productivity growth were 0.32 percent and 0.96 percent per annum respectively, causing a visible decline in employment growth (1 percent per year on average) and stagnation since 2008. Moreover, real wage growth was far behind labor productivity growth causing a tremendous increase in inequality between 1990 and 2006, with the labor share declining approximately 10 percentage points to 50 percent in 2006, one of the lowest levels in the world. After 2006, real wages experienced a partial recovery but the downward pressure on wages has resumed, also due to the pandemic (Figure 1). Inequality in earnings of different households, high levels of unemployment and wage inequality are the main drivers of the overall inequality from which black South Africans and women suffer the most (Statistics South Africa Report, 2019). The share of public sector in total employment has increased (Table 1), indicating a loss of employment in small businesses, which according to Kerr and Wittenberg (2017) is among the main drivers of inequality.

Figure 1: South African Growth and Inequality, 1990-2018



Source: Own Calculations using **GGDC Sectoral Dataset** from https://www.rug.nl/ggdc/structuralchange/etd/



Source: Own calculation using **FRED data** from https://fred.stlouisfed.org/series/LABSHPZAA156NRUG and **GGDC data** from https://www.rug.nl/ggdc/structuralchange/etd/

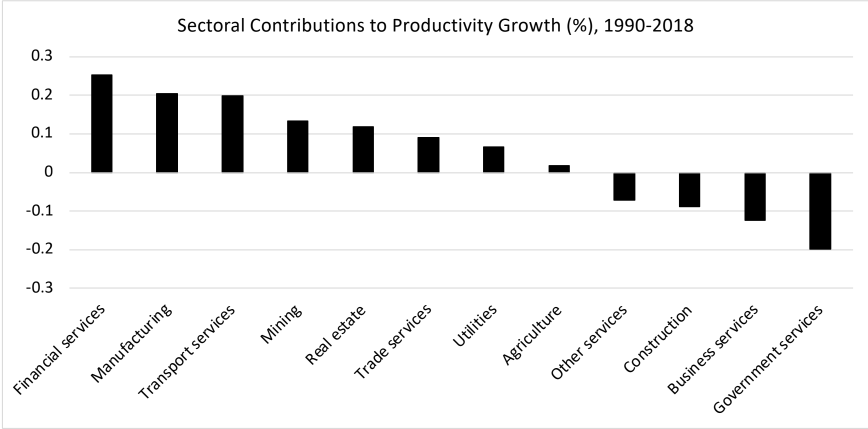
The main contributors to productivity growth are finance, manufacturing, transportation services and mining (Figure 2), which are also responsible for the largest share of CO_2 emissions in South Africa. They experienced high job losses as well. As a mineral dependent economy with high unemployment, where a large share of jobs is low-skilled and low-pay, and with widespread poverty and inequality, South Africa faces tremendous structural challenges (Nattrass, 2011).

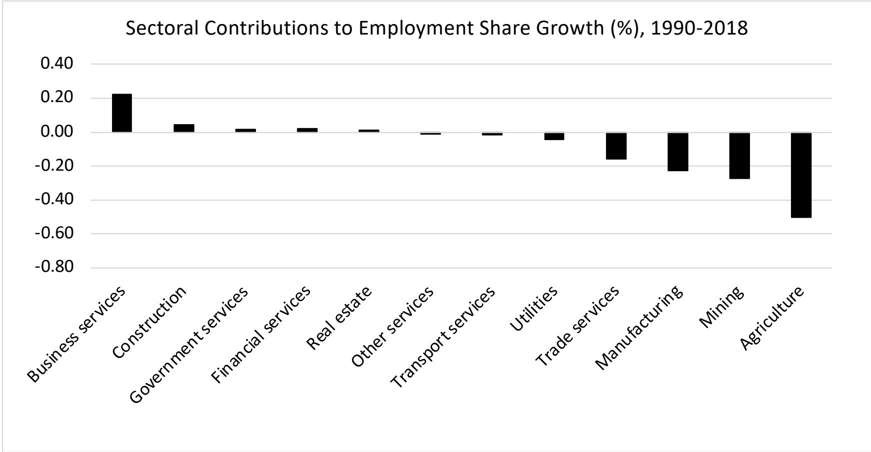
Evidence indicates premature deindustrialization with rising economic duality, more severely than many other developing countries.[2] The stagnant sectors have employed an increasing share of workers while the manufacturing sector has shrunk. Trade services and mining constitute the largest share both in total value added and total employment (Table 1). They will be the first ones to be affected as the rest of the world move away from coal and other fossil fuel-related commodities.[3]

[2] See Capaldo and Omer (2021).

[3] China, Germany, USA and UK are South Africa's biggest trade partners (Statistics South Africa, 2019), which plan to decarbonize by 2050, supporting our concerns about South African exports.

Figure 2: Sectoral contributions to productivity and employment growth





Source: Own Calculations using **GGDC Sectoral Dataset** from https://www.rug.nl/ggdc/structuralchange/etd/

Table 1: Size of the Stagnant Sector and Premature Deindustrialization, South Africa (1990-2018)

Sectors (South Africa)		Productivity Growth per employee (%)	Employment Share in Total (%)			VA Share (%)		
		AVG	1990	2018	AVG	1990	2018	AVG
DYNAMIC SECTORS	Mining	3.49	8.60	2.25	3.89	15.1	7.4	11.0
	Utilities	2.77	1.73	0.96	1.23	4.9	3.6	4.7
	Agriculture	2.50	23.22	15.71	18.15	3.1	2.4	2.6
	Transportation Services	1.91	4.55	4.90	4.72	6.1	8.4	7.9
	Manufacturing	1.45	13.51	9.33	11.89	16.9	13.3	15.0
	Trade Services	1.44	18.00	17.55	19.28	13.8	14.9	14.3
	Financial Services	1.25	1.26	2.24	2.12	5.3	9.6	7.3
	TOTAL		**70.9**	**52.9**	**61.3**	**65.2**	**59.6**	**62.8**
STAGNANT SECTORS	Construction	0.59	5.8	7.9	6.5	3.4	4.0	3.3
	Others	0.66	10.0	11.9	10.9	5.6	6.0	6.0
	Government Services	-0.49	9.0	15.2	13.0	20.8	17.4	18.1
	Business Services	-0.58	4.1	11.3	7.8	4.1	7.2	5.8
	Real Estate	-1.55	0.3	0.7	0.5	5.8	5.9	6.1
	TOTAL		**29.1**	**47.1**	**38.7**	**39.7**	**40.5**	**39.3**

Overall, key sectors such as manufacturing and information-related sectors, which historically have been drivers of structural change, have been stunted in South Africa. These sectors must expand again if development is to be revived but industrialization requires large quantities of energy, even more than the expansion of mining or services (Nielsen et. al, 2018). The question, then, becomes what prospects South Africa has for achieving its economic, social, climate and overall developmental goals. In this paper we present several modeling scenarios that help determine policy options and constraints.

GREEN STRUCTURAL CHANGE AND ENERGY DILEMMA

Transitioning to a low-carbon economy is a possible development strategy for many developing countries, but it has its own challenges. Green growth requires increasing returns to scale with energy saving technological change supported by increasing labor productivity. But evidence suggests that labor productivity growth is highly correlated with energy consumption[4] (Semieniuk et. al, 2021; Jiang & Khan, 2017; von Arnim, R., & Rada, C., 2011). If countries cannot maintain high energy productivity growth rates and transition to renewable energy, they inevitably increase their carbon energy consumption, the cheapest and most accessible option to fuel industrialization.

Studies indicate that, historically, labor productivity growth has been driven by increasing amounts of carbon energy per worker[5] (the average elasticity of the carbon energy-labor ratio with respect to labor productivity is close to one (Semieniuk 2016)). In the absence of sufficient renewable energy, carbon energy consumption can only be reduced if energy productivity grows faster than labor productivity. In the absence of the energy saving technology that gives access to this greener path, countries may be forced to reduce capital accumulation and growth (Marquetti et. al 2019). An alternative that is sometimes discussed is "leapfrogging" industrialization, betting on the service sector as the driver of economic growth (ERC Report, 2015). However, this solution ignores the key role played by manufacturing in the process of economic development.

According to the most recent Climate Change Bill (2021), South Africa's goal is to reduce its emissions to 350-510Mt Co2eq by 2050 starting in 2025.[6] Figure 3 illustrates the relationship between South Africa's labor productivity, energy productivity and energy-labor intensity given that

$$\begin{aligned} &Labor\ Productivity\ Growth\ \widehat{\left(\frac{X}{L}\right)} \\ &\qquad = Energy\ Productivity\ Growth\ \widehat{\left(\frac{X}{E}\right)} + Energy - Labor\ Intensity\ Growth\ \widehat{\left(\frac{E}{L}\right)}. \end{aligned}$$

As shown in Figure 3, a steeper linear-fitted line[7] for Energy-Labor Intensity Growth and Labor Productivity Growth rates shows that South Africa's labor productivity growth tends to be driven

[4] Given that $Labor\ Productivity\ Growth = (Energy/\ Labor)Intensity\ Growth\ + Energy\ Productivity\ Growth.$

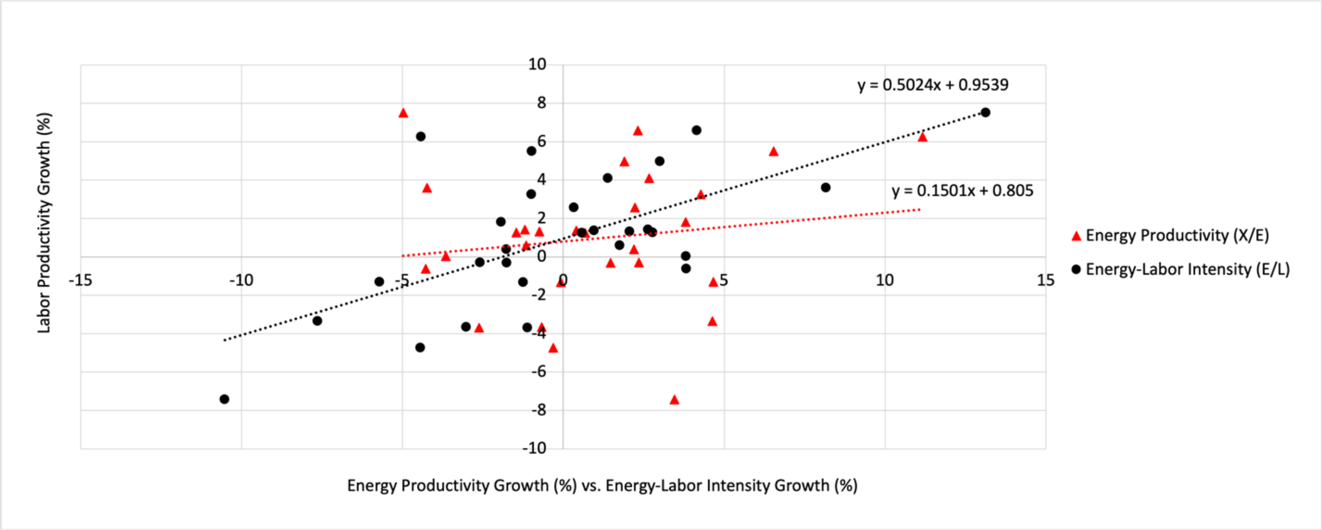
[5] Energy productivity growth rate was mostly constant at the global level.

[6] Previously, the goal was to peak emissions by 2025 before plateauing for 10 years and declining emissions to 480-614 Mt CO_2 after 2035.

[7] Namely, every 1% increase in energy-labor intensity causes 0.5% increase in labor productivity growth while 1% increase in energy productivity results in 0.15% increase in labor productivity.

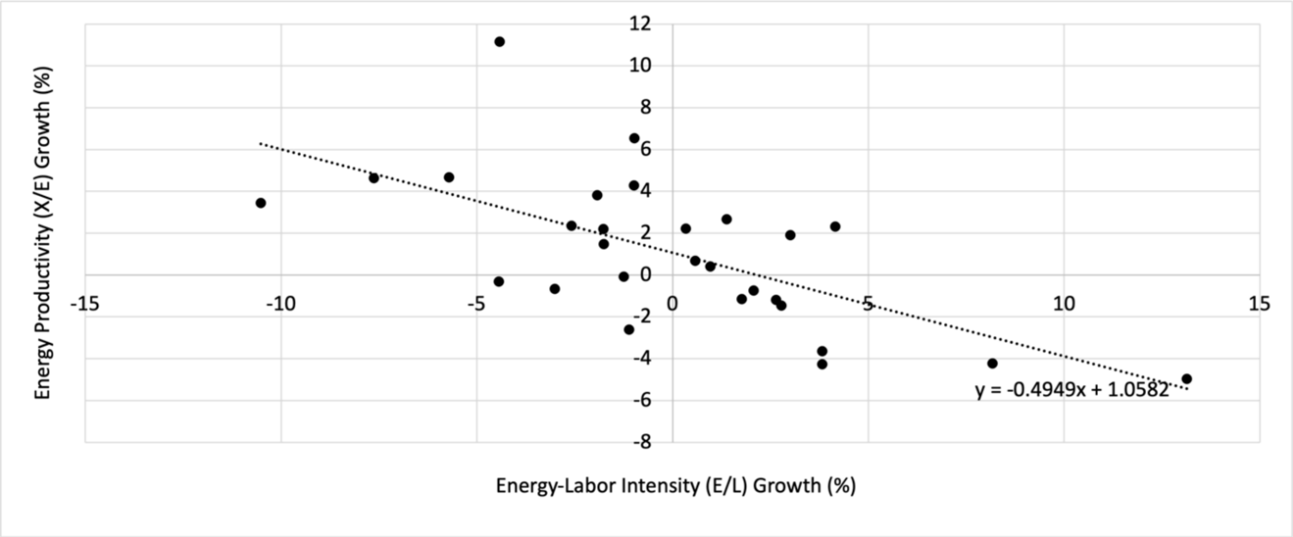
by the growth of (carbon) energy-labor intensity rather than energy productivity between 1990 and 2019.[8] Moreover, the negative relationship between energy productivity and energy-labor intensity growth rates represented in Figure 4 implies that every one percent increase in energy-labor intensity in South Africa is associated with 0.5 percent decline in energy productivity growth rate.

Figure 3: Labor productivity growth= Energy productivity growth + Energy/Labor Intensity growth



Source: Own calculation based on **energy data** from https://ourworldindata.org/energy/country/south-africa and **labor data** from **GGDC data**

Figure 4: Energy Productivity Growth vs. Energy-Labor Intensity Growth



Source: Own calculation based on **energy data** from https://ourworldindata.org/energy/country/south-africa and **labor data** from **GGDC data**

[8] Between 1990 and 2005, average labor productivity growth was 1.88% per year, while the carbon energy-to-labor ratio and energy productivity grew by 1.17% and 0.81%, respectively. After 2005, average energy productivity growth was higher managing to slow the growth of the energy-labor ratio (-1.31% per annum). However, it was not sufficient to push labor productivity up.

The energy transition necessary for green structural change requires the income elasticity of energy consumption to be less than 1. According to Zhang (2003), between 1980 and 1994, China managed to reduce its energy consumption per unit of output while industrializing, meaning that its income elasticity of energy consumption was much lower (around 0.34) than its competitors. In South Africa, between 1965 and 2018, average real GDP growth was 2.6 percent while average energy consumption was around 2.8 percent, hence income elasticity of energy consumption was 1.07. A 10 percent increase in real output corresponds to a 10.7 increase in energy consumption on average. Without an energy transition, meeting the Paris Agreement target would require South Africa to reduce its rate of capital accumulation – around -2.35 percent per year – more than the world average (Marquetti et. al, 2019).

In South Africa, 80 percent of greenhouse gas emissions originate in the coal sector[9] accounting for 7.5 percent of total value added and 2.25 percent of total employment and a coal-dependent energy sector. Beyond coal, energy related activities are the main cause of the country's CO_2 emissions: the power sector (electricity and heat) and energy used in extraction sectors constitute approximately 64 percent of overall emissions. Industrial processes come second, including manufacturing of goods, chemicals and cement (14 percent), transportation sector (12 percent) and energy use in buildings (8 percent). Transitioning out of this dependency poses massive challenges, especially in terms of labor transfer and social protection (Pollin, 2015).

Reducing carbon emissions while reaching a sustainable development path and catching-up with more advanced economies is a highly demanding task. Resource and energy requirements will have to increase as the economy grows, making cheap and abundant renewable energy and green technologies essential for a just transition in South Africa. Addressing these challenges requires coordinated fiscal, monetary and financial policies such that capital, existing resources and new financial resources can be effectively channeled towards a green recovery capable of stimulating productivity, output and employment in more equitable ways. The rest of the paper explores options for macroeconomic policy based on modeling scenarios.

A DEMAND DRIVEN GROWTH MODEL WITH CLIMATE CHANGE

We explore the options facing South Africa by estimating a macroeconomic model in which income distribution, labor productivity, investment and accumulation of greenhouse gases determine aggregate demand, which in turn determines the level of economic activity. This allows us to trace the short- and long-term impacts of climate change induced by increasing CO_2 concentration[10] in a single-open economy, reflecting the fact that South Africa's contribution to the global emission stock is irrelevant (1.06 percent of the total). The model, first introduced by Rezai et al (2018), is discussed in detail below along with the changes made on the original version for the purposes of this paper.

In the short term, we estimate that any changes that drive up aggregate demand and employment will also drive up real wages and cut into profits (a profit squeeze). Assuming, as other

[9] South Africa earned $4.2 billion from exporting coals in 2017. Moreover, 91% of electricity is produced using domestic coal resources (CPI Report, 2019).

[10] This paper focuses on concentration because it has had (and will have) the largest impact on climate change.

studies do,[11] that reduced profits have a large negative impact on investment outweighing the positive effect of wage and employment increases on consumption (i.e., the economy is profit led) the ultimate effect on economic activity is negative. But any temporary increase in economic activity drives up emissions in South Africa and elsewhere.

In the long run, without effective mitigation efforts, increasing atmospheric greenhouse gas (GHG) accumulation pushes down profitability, and causes faster capital depreciation such that investment declines and the economy stabilizes at undesirably low levels of output and investment. As shown below, this poses an existential threat to developing countries.

Global mitigation efforts, including technology transfer, are key to reducing GHG levels and preventing disaster (Taylor and Foley, 2014; Gregor et. al. 2021, Rezai et. al., 2018). If they take place, South Africa could achieve faster growth of output and employment as well as achieving a just transition with the help of appropriate fiscal and monetary policies.

MODEL DESCRIPTION

Macro Balance and Short Run Economic Activity & Distribution

In the model, short to medium term economic activity and distribution are represented by capacity utilization, $u[t] = \frac{Output}{Total\ capital\ Stock} = \frac{X[t]}{K[t]}$ and profit share, $\pi[t] = \frac{Profits}{Output} = \frac{P[t]}{X[t]}$, respectively while long run trajectories are shaped by the dynamics of endogenous capital stock per capita $\frac{K[t]}{Population}$, labor productivity $\xi[t] = \frac{Output}{Labor} = \frac{X[t]}{L[t]}$ and exogenously determined global greenhouse gas GHG accumulation.

Let X be real GDP (output), C consumption, I investment, G non-mitigation government spending, T taxes, EX exports, IM imports and M mitigation expenditures on GHG mitigation efforts.[12] $C = (1 - s[t] - \tau)X[t]$ where saving ratio $s[t]$ is an increasing function of profit share ($\pi[t]$). The model introduces different classes with different saving propensities—s_p, as saving propensity of capitalist class and s_w, as the saving propensity of workers; therefore, total saving rate is $s[t] = s_p\, \pi[t] + (1 - \pi[t])\, s_w$, where $s_p > s_w$.[13]

As a result, the macro balance can be represented as:

$$X[t] = (1 - s[t] - \tau)X[t] + I[t] + M[t] + G[t] + (EX[t] - IM[t])$$

Following Kalecki (1971) and the structuralist tradition (Taylor et.al, 2015; 2018, 2020), we assume that gross fixed capital formation (investment), I, is driven by profit rate $r = \pi\, u$, animal spirits $(g_o - g_i r)$ and economic activity $u[t]$ so that

$$I[t] = ((g_o - g_i r) + \alpha \pi[t] u[t] + g_u u[t])K[t]$$

where $(g_o - g_i r)$ represents animal spirit and takes the changes in real interest rate r into account.[14]

[11] According to Onaran and Galanis (2012), South African economy is profit-led. However, if the economy is wage-led, it might cause a further increase in economic activity.

[12] All the variables are treated as "flows" per unit of time.

[13] Namely, redistribution towards capitalists which earn profit income leads to higher savings.

[14] For the purpose of assessing the monetary policies in our simulations, real interest rate r, is introduced as a jump parameter, where $\frac{\partial I}{\partial r} < 0$.

Exports are assumed to be driven by an exogenous real exchange rate, z,[15] and capital stock-GHG concentration ratio ($K[t]/G[t]$):

$$EX[t] = \epsilon \left(\frac{K[t]}{G[t]}\right)^f z[t]^\gamma \text{ where } f \text{ and } \gamma > 0.$$

Exports are assumed to be proportional to GHG accumulation because the impacts of climate change and/or a transition to a zero-carbon economy by the rest of the world, will reduce the demand for South African export commodities first via declining income of the rest of the world, and second through declining incentives of consuming fossil-fuel base South African commodities, i.e., coal and commodities that are produced using carbon-energy.

Similarly, imports are

$$IM[t] = a\frac{X[t]}{z[t]^c} \text{ where } a = \text{ import ratio and } c > 0$$

Mitigation expenditures ($M = m\,X[t]$) and the leakages (i.e., taxes, savings and imports) are set proportional to output while the injections (i.e., exports, investments and non-mitigation government spending) are proportional to capital stock (K). Therefore, macro balance becomes:

$$X[t] = (1 - s - \tau)X[t] + (g_o + \alpha\pi[t]u[t] + g_u u[t])K[t] + \beta\,K[t] + mX[t]$$

$$+ \epsilon\left(\frac{K[t]}{G[t]}\right)^f z[t]^\gamma - a\,z[t]^{-c}\,X[t]$$

As mentioned earlier, profit share represents short to medium term distributional dynamics. In the model, savings and investments are positively related to profit share (profit-led economy). If the increase in investments is strong enough, output, employment and capital stock can go up. Global GHG accumulation, taken exogenous,[16] also affects the profits by reducing profitability and investment demand. If global emissions can be reduced by higher global mitigation efforts, the system may stabilize at a lower GHG concentration—our simulations will be set to produce different paths for different potential GHG concentration scenarios that, in turn, will have exogenous effects on South African economy via profits, capital accumulation and exports.

In the labor market, when the employment is higher (labor market is tighter) due to increasing economic activity, profit share will tend to decline such that increased economic activity will be partially offset by profit-squeeze (à la Marx and Goodwin). In the meantime, labor productivity may rise with a higher level of investment[17] and lower employment while higher GHG concentration can reduce the productivity. Overtime, capital accumulation will be driven by investments as the size of the economy expands.

[15] Real exchange rate $z[t]$ is introduced as an exogenous jump variable where $\frac{z\prime[t]}{z[t]} = \sigma\,(1 - z[t]/2)$. It is assumed to be stable initially. In some simulations, it is allowed to depreciate or appreciate for policy purposes. An increase in $z[t]$ means depreciation of local currency—ZAR weakens.

[16] It is exogenous because South Africa plays a negligible role in affecting the atmospheric GHG concentration. Therefore, GHG accumulation is set as a "shift" variable using an exogenous dynamic equation to represent potential global responses to climate change and their impacts on South African economy. On the contrary, it is an endogenous state variable in the original "global climate" model, where its dynamics are driven by global emissions, natural abatement rate, mitigation rate, energy intensity and energy productivity.

[17] It can also increase as a result of an increase in energy intensity (energy/labor ratio) but they are not included explicitly in this version of the model. See Rezai et al. (2018) for the "global" version of the model.

In the model, any increase in GHG accumulation has an impact on profit share through a damage function, affecting profitability. It also has a direct impact on capital stock through increasing depreciation. Increasing GHG accumulation could also diminish productivity, which is endogenously determined by a "technical change function." Capital stock per capita is determined by capital accumulation, population growth and depreciation caused by the global GHG accumulation.

Overall, profit share is represented as a function of GHG concentration ($G[t]$) via damage function $Z[G]$ and employment-population ratio, $\lambda = \frac{\kappa\, u}{\xi}$, such that

$$\pi_{[t]} = f(G, \lambda) = f\left(Z(G), \frac{\kappa\, u}{\xi}\right) = \frac{(\phi\, Z[t])^A}{\lambda[t]^B}$$

where κ is capital stock per capita, u is capacity utilization and ξ is labor productivity.

$A, B > 0$, $\eta = 0.5$ so the damage function, $Z[t]$ is

$$Z[t] = \left(1 - \left(\frac{G[t] - G_{(Preindustrial)}}{G_{Max} - G_{(Preindustrial)}}\right)^{\frac{1}{\eta}}\right)^{\eta}$$

$G_{(Preindustrial)}$ represents the preindustrial level of atmospheric CO_2 concentration, which is equal to 280 ppmv (parts per million per volume) while G_{Max} is 780 ppmv. As mentioned above, GHG accumulation and tighter labor market cut into profit share (profit-squeeze) so that partial derivatives of both G and λ are negative $\left(\frac{\partial f}{\partial\, G}\ and\ \frac{\partial f}{\partial\, \lambda} < 0\right)$.

Long Run Equations

Our first endogenous, dynamic "state variable" represents the dynamics of the capital stock per capita $\kappa[t]$, hence growth rate of capital stock per capita $\hat{\kappa}[t]$ is

$$\frac{\dot{\kappa}[t]}{\kappa[t]} = g[t] - \delta - Pop[t] - \delta_1 G[t]$$

where $g[t] = \frac{I[t]}{K[t]} = ((g_o - g_i r) + \alpha\pi[t]u[t] + g_u u[t])$, $g_i * r$, represents the impact of real interest rate on real investments and initially set to be constant,[18] δ is capital stock depreciation, δ_1 is the depreciation caused by GHG accumulation $G[t]$ and $Pop[t]$ is population growth rate.[19]

Our second long run equation is labor productivity growth, represented as "a technical progress function" (Kaldor 1957; 1978). It shows that faster output growth and/or higher investments result in increasing returns to scale with decreasing cost and leads to use of more advanced technologies. Therefore, growth rate of labor productivity is

$$\hat{\xi}[t] = \frac{\dot{\xi}[t]}{\xi[t]} = \gamma_0 + \gamma_1\hat{\kappa}[t] - \gamma_2(\lambda[t] - \bar{\lambda})$$

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[18] It will be used as a jump variable to implement expansionary vs. contractionary monetary policy impacts in different scenarios.

[19] An exogenous dynamic equation is introduced to determine the long-term population dynamics. Assuming South African population will reach to 100 million and stabilize in the long run, population growth is $\frac{P\dot{o}p[t]}{Pop[t]} = n\left(1 - \frac{Pop[t]}{100}\right)$.

where employment-population ratio equals to $\lambda[t] = \frac{\kappa[t]u[t]}{\xi[t]}$. $\gamma_0 > 0$ is the exogenous rate of productivity growth, $\gamma_1 > 0$ represents the capital deepening affect caused by capital accumulation, and γ_2 captures the labor market dynamics—tighter labor market (lower unemployment) has a negative effect on productivity growth.

Finally, an "exogenous" GHG accumulation equation, representing the changes in atmospheric CO_2 concentration is introduced in order to trace potential future climate change dynamics, and their impacts on South African economy. $G[t]$ is exogenously set to generate different global climate scenarios i.e., Global and South African Business as Usual scenario, which CO_2 concentration reaches to catastrophic levels (780 ppmv) by 2100, and global mitigation scenarios which lead to lower CO_2 concentration levels i.e., 425 ppmv and 350 ppmv.

$$\hat{G}[t] = \frac{\dot{G}[t]}{G[t]} = a\left(1 - \frac{G[t]}{\bar{G}}\right) - \frac{\Omega(1-e^{-\varphi t})}{\varphi}.$$

SIMULATIONS

In the absence of ambitious global climate policies, the world economy may go through "boom-bust cycles" and stabilize around a lower level of economic activity (Rezai et al., 2018). We show that the results could be even more devastating for low-and middle-income countries. The simulations from our parameterized model, calibrated to South Africa, using available data[20] provide a valid case.

Our simulations are built upon different "global" baseline scenarios[21] (IPCC Technical Report, 2001; IPCC Technical Paper III, 1997; IPCC-AR5, 2014) as we aim to capture the impacts of different climate change scenarios on the South African economy.[22] The first global baseline (red line) represents the "global business-as-usual" (BAU) case in which there is no mitigation effort at the global level. Therefore, atmospheric CO_2 concentration reaches 724 ppmv by 2100 and stabilizes at 780 ppmv in the longer term—temperature increases well above 3°C. In the second global baseline (black line), atmospheric CO_2 concentration rises to 425 ppmv by 2100 and stabilizes—thanks to mitigations, temperature remains around 1.8 °C above the pre-industrial level. Finally, in the third global baseline (blue-dashed line), more ambitious global mitigation efforts reduce atmospheric CO_2 levels to 350 ppmv by 2100. This scenario represents the net negative CO_2 emissions—temperature rise remains between 1.2-1.5 °C pre-industrial level (DDPP, 2019).[23]

Simulation I: Global Business-as-Usual (Global BAU-Red line)

The first set of simulations focuses on demonstrating severity of the global warming and its implications for the future of the South African economy in the absence of effective global

[20] Based on a social accounting matrix (SAM) of South Africa, generated Seventer and Davies (2019).

[21] For more details on climate change scenarios, visit https://www.ipcc.ch/report/ar3/wg1/the-carbon-cycle-and-atmospheric-carbon-dioxide/ and https://c-roads.climateinteractive.org/

[22] The impacts of South African emissions or mitigation efforts are too small to cause any visible impacts on global GHG accumulation. Therefore, modeling single economy dynamics in a model that considers the impacts of global warming on the local economy is more realistic.

[23] According to Hansen et al. (2016, 2017) in order to avoid the most catastrophic climate change impacts, CO_2 concentrations must be reduced to 350 ppm or less by the end of the 21st century (Hansen et al. 2016; Hansen et al. 2017)

mitigation. In this business-as-usual scenario, atmospheric CO_2 concentration will stabilize at around 780 ppmv in the long run with catastrophic outcomes.

At the global level, growth will continue for a few decades before the environment breaks down. Growing capital-labor ratios drive up output until rising CO_2 concentration cuts into existing capital. The engine of global growth will idle, polluting without moving.

South Africa's prospects in this scenario are shown in Figure 5. Initially, the economy will grow at around two percent per year and continue growing until 2060 when the environmental breakdown is projected to take place. High CO_2 concentration will lead to capital destruction to an extent that will make economic recovery impossible, eventually pushing the economy into a "bad" equilibrium where per capita levels of output and capital will be well below 2016 levels. Profitability will diminish, resulting in a sharp decline in profit share and capital accumulation. Real output will peak by 2060 (at R 6,168 billion) then it will begin shrinking (Table 2). More than a hundred years of economic growth will be wiped out.

In the expansion phase, projected to last until 2060, labor's energy use will increase pushing labor productivity to a peak around 2060.[24] Since renewable energy is a small portion of overall energy generation—only around six percent of total energy mix[25] in South Africa, higher carbon-energy use will drive emissions up too.[26] After the peak, arrested capital accumulation will cause the employment rate (the ratio of employed workers to total population) to fall stabilizing around 15 percent in the long run, or half its current level. Conversely, the number of people dependent on each job, directly or indirectly (through formal social protection systems), will soar.

Since the profit share declines in the expansion phase and productivity grows, real wages will rise until 2060 and then decline, dragged down by the collapse of the labor productivity.[27] Given the structure of the South African economy, climate-related damage will especially impact sectors that employ large shares of workers by destroying capital and constraining exports. This includes mining, agriculture, utilities, manufacturing and trade services.

Imports and exports are also projected to increase in the expansion phase until 2060. In recent years, South Africa's exports and imports have tended to balance each other out, but this is likely to change. In our estimates, exports will be more severely affected than imports leading to deficits in the order of 8 percent of the GDP, which will make it even harder for the country to purchase the inputs and technology it needs to respond to the crisis. Fiscal deficit will almost double, reaching 15 percent by 2100.

In the business-as-usual scenario, inaction proves catastrophic, leading South Africa into a deep and prolonged depression. In the very long run (over 200 years), real GDP per capita will contract as much as 4.3 percent per year while capacity utilization will shrink over 10 percentage points only to recover as capacity (the capital stock) is destroyed by the environmental breakdown.

[24] As mentioned earlier, based on the available data and the literature on energy use and productivity, there assumed to be a one-to-one relationship between the energy use per labor and labor productivity.

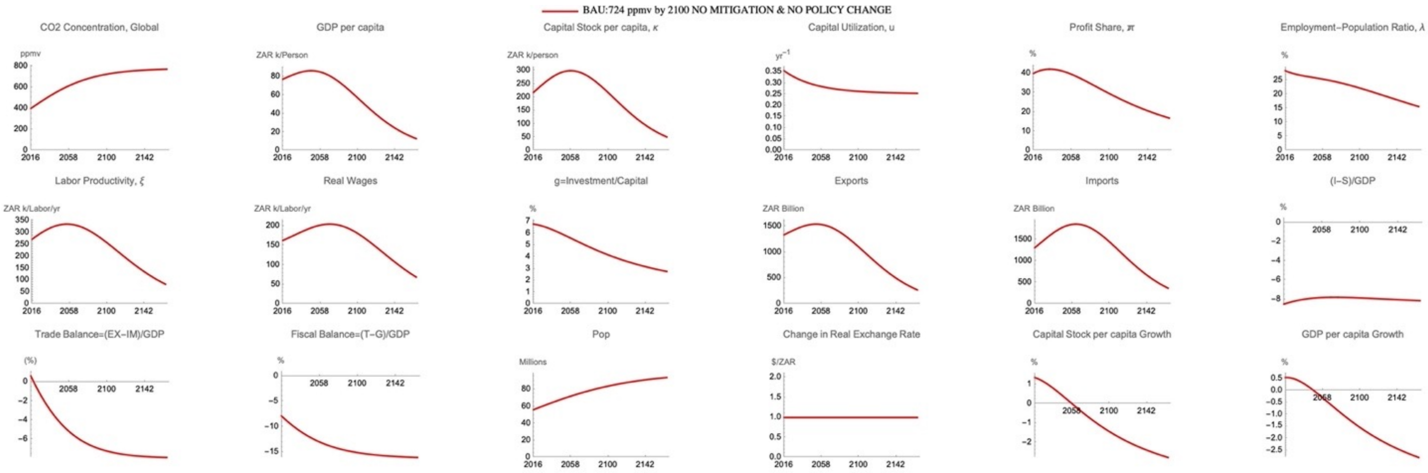
[25] See https://www.climate-transparency.org/wp-content/uploads/2020/11/South-Africa-CT-2020-Web.pdf .

[26] See the report by IRENA (2021) for a more detailed discussion on the potential of renewable energy sources in South Africa.

[27] This follows as accounting identity from measuring aggregate output at factor cost.

Employment, productivity and income distribution will deteriorate greatly. Society and the macroeconomy might breakdown long before these extreme losses occur.

Figure 5: Effects of Climate Change on SA: Global and South African Business as Usual



Source: Author calculations.

Simulation II: Global and South African BAU (red line) vs. South African Mitigation Scenario with Expansionary Policies under different atmospheric CO_2 concentration pathways (i.e., 425 ppmv with expansionary policies in South Africa (black line) vs. 350 ppmv with expansionary policies in South Africa (blue-dashed line))

In this section, we contrast the global BAU scenario from the previous section (reproduced in Figure 6, red line) with two new scenarios in which mitigation policies are adopted worldwide—including South Africa. In the mitigation scenarios, South Africa also adopts expansionary macroeconomic policies to support its mitigation efforts—every financial (and investment) decision is assumed to take climate change into account. The two new scenarios differ by the strength of mitigation efforts (the black line reflects weaker mitigation, the blue dashed line stronger mitigation), meaning that the atmospheric CO_2 concentration stabilizes around 425 ppmv (black line) and 350 ppmv (blue dashed line), respectively.

As mentioned, in the BAU scenario, output's energy intensity in South Africa is constant as renewables and more efficient technologies are of limited use–only six percent of total energy production (accessible). Although solar and wind power is easily accessible, and renewable technologies exist at a declining cost, phasing out of coal seems to be politically challenging. As a result, changes in the energy-labor ration imply equal changes in labor productivity (in jargon, the relationship between the two ratios is unit-elastic). By contrast, in the mitigation scenarios, mitigation efforts drive an energy transition that allow higher energy productivity. Therefore, labor productivity can increase without increasing energy use by each worker. Decoupling is possible.[28] To simplify, the mitigation scenarios "assume" that the energy labor ratio remains constant.

[28] Since atmospheric GHG accumulation is exogenous, and South African emissions have a negligible effect on global GHG levels, South Africa's energy productivity and energy-labor ratio are not included in the model. Therefore, energy-labor ratio and energy productivity plots are only for demonstrative purposes, representing the data and findings in the literature.

Total investment needed to achieve South Africa's National Development Plans (NDPs) is estimated to amount to R 8.9 trillion over 15 years (IFC, 2016). This means that South Africa should spend R 595 billion per year until 2030. However, financing options fall short of expectations. According to Cassim et al. (2021), annual climate finance totaled around R62.2 billion between 2017 and 2018, of which R12 billion provided by the government.

Global mitigation would free up policy space, but sustainable structural change requires appropriate macroeconomic policies, too. In the second (black line) and the third (blue-dashed line) scenarios, this is reflected in government spending of 2.5 percent of GDP per year on mitigation,[29] amounting to R8 trillion and R9 trillion by 2060 respectively.[30] Government mitigation (and adaptation) spending are assumed to be used only in green transition related activities, such as investing in green and renewable energy technologies, subsidizing green manufacturing technologies, reducing motor vehicle use, increasing energy efficiency of buildings and ending deforestation. As a result, government mitigation spending aims at increasing productive capacity of the economy, by attracting and facilitating green private investments.

Coal dependence poses a challenge to the balance of payments. As the world phases out of fossil fuels, South African exports are assumed to suffer until the country progresses in its energy transition. Taking this into account, we assume that South Africa's exports decline by 15 percent, initially, and then may recover depending on the interaction of GHG concentration and investment in energy transition.

As spending on mitigation increases, fiscal space is ensured in these scenarios by the positive effects of investment on growth, employment and tax revenues (Kaldor, 1978). However, developing countries are financially and technologically more constrained when it comes to implementing expansionary policies. If green technologies and financing options are either unavailable or unaffordable to developing countries, their commitment to combat climate change will not materialize. Therefore, expansionary and progressive policies are introduced under the assumption that the necessary technologies and financing options are made available at low cost.[31]

During the "green" transition South African firms with undersized infrastructure will have large working capital commitments. If interest rates rise, financing costs will increase, putting an upward pressure on prices. This, in turn, might cut into output and raise inflation in some sectors where supply constraints are tighter. As government mitigation spending can stimulate private investment, relatively lower and stable interest rates can help the process. We, therefore, let real interest rate decline by 1.5 percentage point from its initial level—from 2.5 percent to one percent. This, of course, may not be possible due to the pressure faced by South Africa and most developing countries to attract capital flows through higher interest rates, but expansion of domestic financing vehicles, including national development banks, can help provide the necessary cheap funding. So long as the mitigation efforts are channeled into "appropriate," "green" real investment, the economy will move from "brown" sectors to more productive, higher paying

[29] Mitigation and adaptation spending can be used to invest green and renewable energy technologies, subsidize green manufacturing technologies, reduce motor vehicle use, increase energy efficiency of buildings, end deforestation, etc.

[30] As explained in the model section, mitigation spending (m) is proportional to GDP—m X[t], so annual mitigation spending will vary with economic activity.

[31] This assumption in fact, emphasizes the necessity of well-governed international institutions that are willing to facilitate financial and technology transfers between developed and developing world.

dynamic sectors, pushing up the long-term trajectory of economic growth. As a result, total productivity, employment and real wages will increase while inequality will be alleviated, without leading to unsustainable debt levels.

Under such circumstances, the real exchange rate will be affected by changes in real interest rates. Developing countries' exchange rates tend to depreciate when interest rates are cut, as fund managers reallocate their portfolios to seek higher returns abroad (Frenkel, 2004).[32] Whether this has a positive impact on trade balance depends on income and price elasticities of imports and exports—in jargon, the Marshall-Lerner conditions (Barbosa Filho, 2001). In South Africa, demand for imports is mostly determined by domestic economic activity rather than relative prices (Gumede, 2000). The same is also true for South African exports, meaning that the exports are mostly determined by its trade partners' economic prosperity (Olofin and Babatunde, 2018). This means that South Africa's trade balance is not very sensitive to small variations of the exchange rate. But larger swings will affect the economy through other channels that may well reverberate on the balance of payments. For example, a strong depreciation may not lead to a large fall of imports if these are of critical inputs, but it will likely drive-up producer prices, as experienced by many developing countries in the 1980s.

Knowing that South Africa's green transition will inevitably depend on imports of intermediate and capital goods, means that exchange rate management, also through multilateral cooperation, will be critical. That's because some costs (as imported inputs) may increase but also because some others, such as wages, may not. If money wages are not tied to price increases, inflation will be weaker, but inequality will be exacerbated, with negative consequences on aggregated demand and, ultimately, economic activity.

If exchange rate stability is generally desirable, exchange rates' levels matter, too. A relatively weak exchange rate can be desirable for developmental purposes under certain conditions (Frenkel and Taylor, 2006) including "a monetary authority willing and able to maintain a competitive rate" with the help of "necessary capital market interventions, and a political will to face potentially higher initial costs of weaker currency,[33] inflation and output contraction." Capital controls, international grants and debt relief are all factors that can help loosen the balance of payments constraint.

Based on this, in the following mitigation scenarios, the South African Rand (ZAR) is assumed to depreciate slowly – around six percent by 2100 and 15 percent in 200 years.[34] As long as the real exchange rate remains *stable* at *relatively weak* levels, external deficits remain limited and inflation under control.[35] Along with sensible industrial and commercial policies, such exchange rate policy can be instrumental to green economic development.

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32 Standard arbitrage argument on the other hand, argues that lower interest rates should cause appreciation of local currency (Frenkel, and Taylor, 2006).

33 In this line, exchange rates should not be used for inflation targeting purposes (Taylor and Rada, 2006).

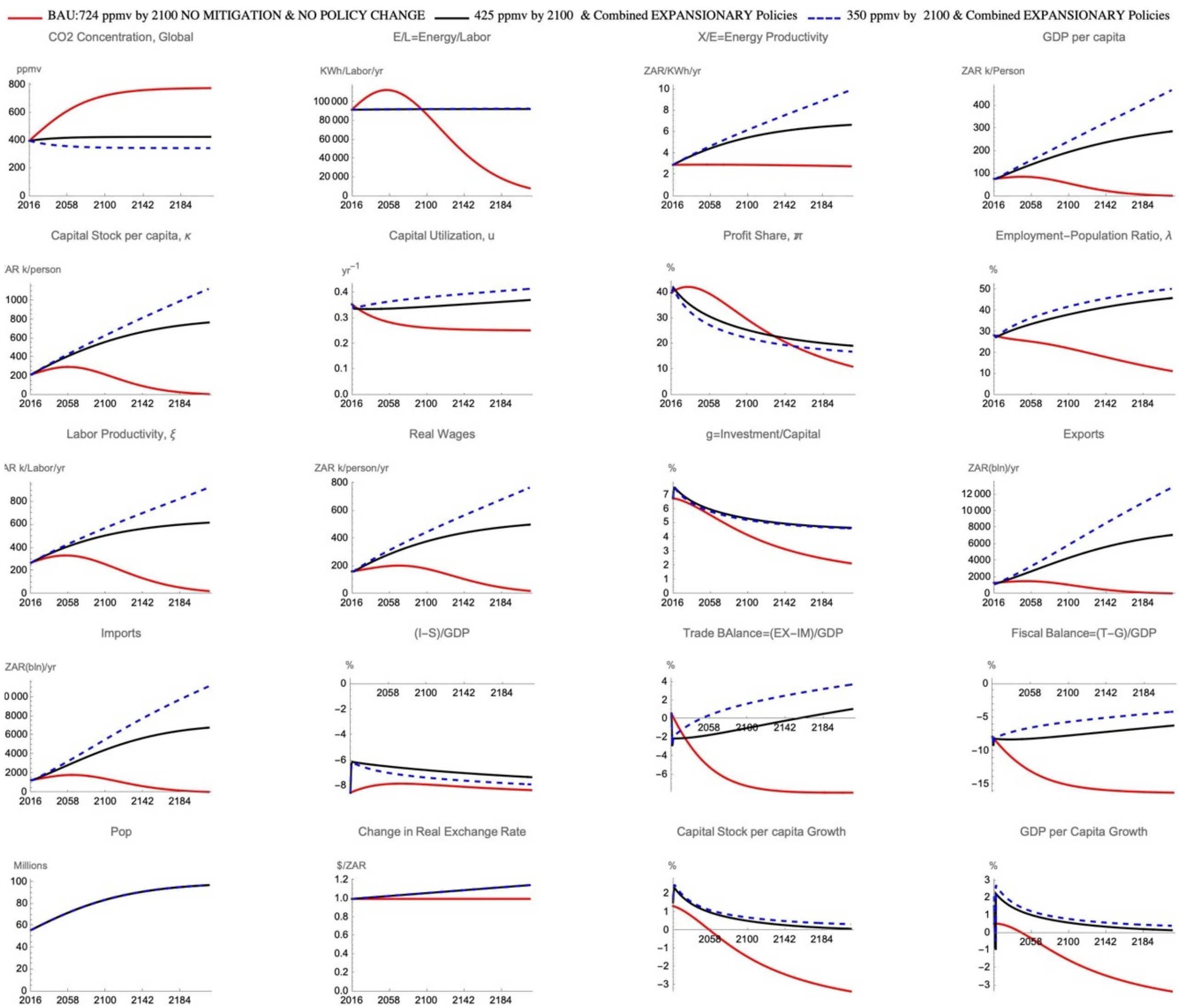
34 It is a fact that long-lasting weakening of local currency can lead to cost driven inflation dynamics and reduce real purchasing power of workers, especially if the economy is highly depended on imported intermediates and capital. The effect would be even stronger if imports exceed exports (Taylor, 1982). That is why we assumed a stable and manageable depreciation of the real exchange rate.

35 However, the trajectories of the system can be easily disturbed by many different channels such as suddenly imposed austerity measures, political conflicts, or natural disasters. For example, large capital outflows could cause large depreciation of exchange rates, so that inflation and debt burdens would reach to unsustainable levels.

Finally, public spending on mitigation will crowd in private investment but financing remains a major concern for all developing economies. Progressive taxation can help by mobilizing private savings held by the wealthy and loosening the budgets for households with higher propensity to spend. In these scenarios, the tax rate on the richest 10 percent of households is increased so that the average tax rate increases by 15 percent, and carbon taxes are increased too, helping the government address distributional issues and climate change mitigation.

Results indicate that this set of domestic fiscal, monetary and exchange rate policies can effectively reflate the South African economy (Figure 6 and Table 3), leading to an equitable and sustained structural change. Income and employment are projected to return to a sustained growth path, with real GDP reaching to ZAR 20 trillion by 2100 leading to much higher productivity and higher wage and employment levels. Output growth reaches 3.3 percent per year in the short-term converging to around 0.5 percent per year in the very long term.

Figure 6: Global BAU (780 ppmv) vs. Mitigation Scenario I (425 ppmv) vs. Mitigation Scenario II (350 ppmv) with South African Expansionary Policy Changes



Source: Author calculations.

As a result of increased economic activity, the employment-population ratio almost doubles, reaching 42 percent by 2100, allowing to absorb the workers made redundant by the winding down of the "brown" sectors. Faster growth of GDP, wages and employment are projected to reduce the imbalance in income distribution, which is a fundamental cause of inequality.[36]

Sustained growth of global demand implies that exports recover faster than imports, resulting in improving trade balances for South Africa. As a result, the balance of payments constraint is alleviated. The fiscal deficit improves and stabilizes at a much lower level thanks to the positive effect of growth and employment creation on government revenue.

The policy response explored in the mitigation scenario is projected to generate higher productive investment, which will increase productive capacity but also aggregate demand driving up economic activity, employment and wages. With capacity increasing, neither import costs nor wage growth create excessive inflationary pressures.

Our results show that industrial policies and appropriate macroeconomic demand management are critical to the green transition in South Africa, although the real-life picture is certainly more complicated than in the model. Successful experiences of industrialization, such as those of China and South Korea are clear main examples. As emphasized by Cimoli et. al (2020), industrial policies in China and Korea from 1970 to the 2000s, enabled by competitive exchange rates and capital controls strategies, allowed those countries to catch up with and get ahead of many advanced economies, in terms of technological capabilities and industrial capacity (Rodrik and Subramanian, 2009). However, their economic success, which allowed them to lift tens of millions of people out of poverty, came at the cost of massive carbon emissions.

Simulation III: Expansionary Policies (blue-dashed line) vs. Stricter Policies (gray line) vs. Free Riding by South Africa (green-line) under 350 ppmv pathway[37]

What happens if the world meets the climate challenge, but South Africa does not adopt the policies of the previous section? Here, we present two more scenarios: one in which South Africa adopts a more contractionary mix of fiscal and monetary policies, dictated by fear of deficit spending and inflation; and a scenario in which South Africa carries on business-as-usual, essentially trying to take a free ride on global growth.

In the first scenario (Gray line), the government is assumed to spend 1.5 percent of GDP per year on mitigation efforts (as opposed to 2.5 percent in the previous section), or R 6 - 6.6 trillion by 2060. As in the previous mitigation scenarios, exports fall by 15 percent. In contrast, the real interest rate is assumed to increase by 1.5 percentage point from 2.5 percent to four percent due to difficulties in obtaining multilateral financing and fears of inflation. As a result, the real exchange rate is assumed to *appreciate* gradually to 15 percent. Finally, taxes are raised by 15 percent as in the previous mitigation scenarios. The goal is to highlight the potential impacts of austerity measures South Africa might take if fear of deficit takes hold.

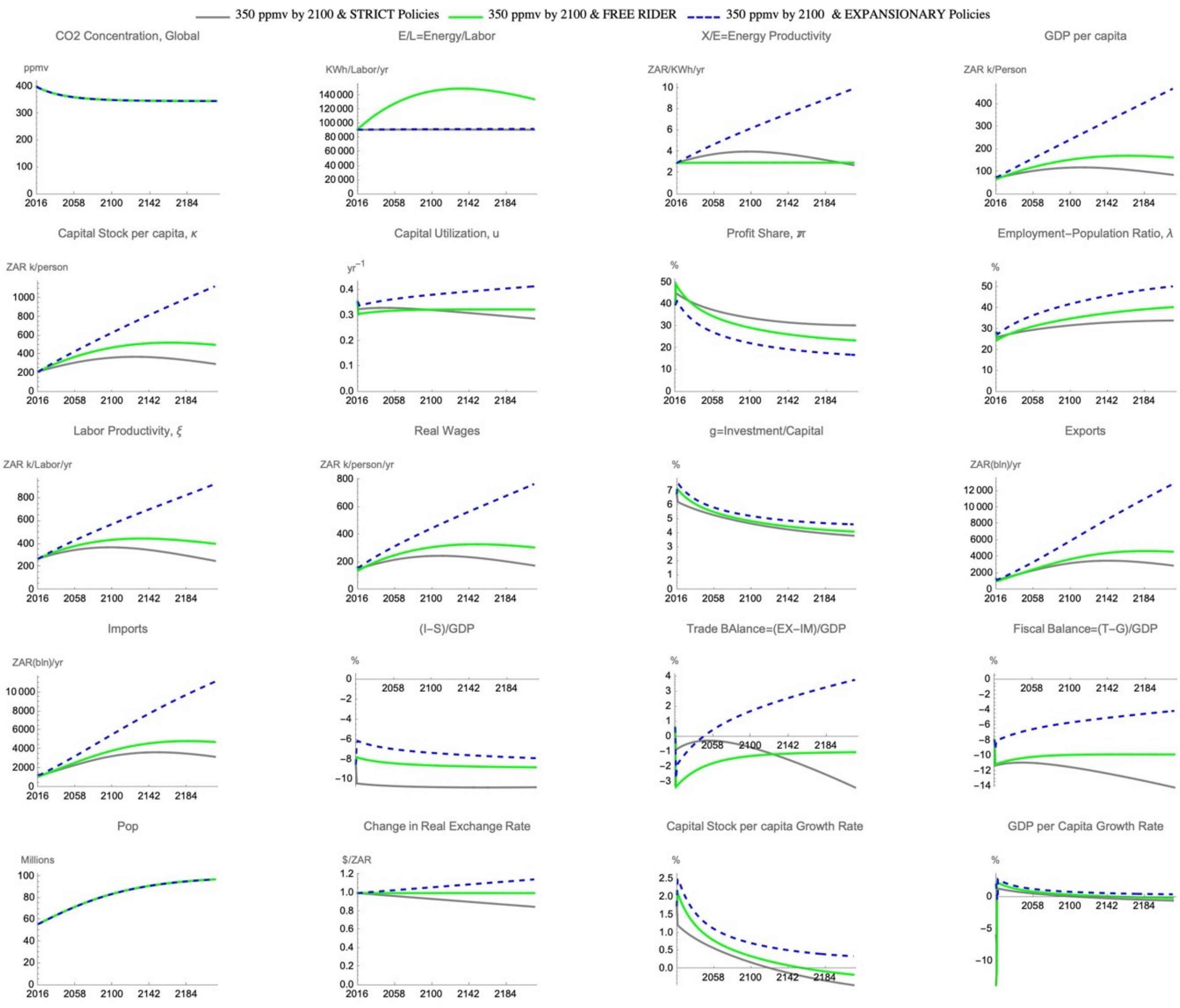
[36] One can argue that low interest rate can feedback into increasing asset prices, causing higher wealth inequality due to rising capital gains. However, in our scenarios, lower interest rates are channeled to create real investments. In order to reach to this outcome, policy makers must introduce necessary regulations to make sure that any fiscal and monetary policy will serve the purpose of generating real "green" investments. Moreover, any deterioration in distribution should be prevented via stronger progressive taxation and transfer policies.

[37] Results under other concentration pathways are provided in the Appendix.

In the second scenario (Green line), real interest and real exchange rates remain unchanged.[38] As discussed above, the current sectoral structure in South Africa is not sustainable and may lead to stagnation due to declining productivity and growth as well as rising inequality. Exports are assumed to fall more than in the previous scenarios – *25 percent* as the rest of the world will move away from coal-related products,[39] and South Africa loses its export share.

Results are shown in Figure 7. The expansionary policies (Blue-dashed line) discussed in the previous section produce the most desirable results by far. On the other hand, outcomes of the contractionary policy (Gray line) and of free riding (Green line) are similar, with the economy performing slightly better in the free riding scenario. In both scenarios, output, productivity and real wages stabilize at much lower levels than in the expansionary policy scenario (Tables 4-6).

Figure 7: Atmospheric Concentration pathway is 350 ppmv: Strict vs. Expansionary Policies vs. Free Riding



Source: Author calculations.

[38] This is an oversimplification, but we only want to focus on the best possible "free rider" scenario although it is the least possible one given South Africa's fiscal and financial fragilities along with its highly problematic productive structure.

[39] Carbon Border Adjustment Mechanism (CBAM), introduced by the EU, is an example supporting this assumption.

Expansionary policies also outperform alternatives in terms of trade and fiscal balances. While both fiscal and trade deficits widen under a contractionary scenario, they are slightly lower in the free riding scenario. In the contractionary scenario, a relatively higher real interest rate, a stronger real exchange rate and relatively lower mitigation spending undermine the crowding-in effect by cutting into investment and growth, as found in earlier studies (Aghazadeh and Evans, 1985)

Additionally, although taxes are raised by the same amount, and mitigation spending is lower than in the expansionary policy scenario, fiscal deficit worsens under the contractionary scenario, as weaker economic activity leads to smaller tax revenues. In this scenario, the employment-population ratio goes up from 28 percent to 31 percent, reaching 35 percent in the free riding scenario. Both labor productivity and real wages increase more in the free riding scenario than the contractionary scenario.

DISCUSSION

South Africa's current economic structure has led to massive inequalities, generated insufficient development dynamics and latched onto an energy supply based on carbon-intensive sources. In other words, the economy has grown unsustainable from economic, social and environmental perspectives. The shares of high value-added manufacturing and information-related sectors have been declining while labor has been pushed into less productive, lower-wage service sectors. This increase in sectoral duality enabled by premature deindustrialization has resulted in a severe deterioration of output and productivity growth since the early 2000s. Policy-related phenomena, including regressive distribution, weak labor institutions, wage repression and declining bargaining power of labor have further depressed aggregate demand by driving up inequalities. As a result, South Africa finds itself in deep stagnation and must urgently revive its industrialization process in order to relaunch it economic development. However, expanding the industrial sector requires higher energy inputs per labor than expanding any other sectors. Transitioning to a greener, more sustainable economic structure offers a promising way out of the current impasse, but this path requires broad policy changes, at home and abroad, and exposed to high uncertainty.

Our scenarios underline three important points. First, inaction would be catastrophic because the climate crisis will push the world economy into a bad equilibrium, in which humanity will face an irreversible existential threat. Second, achieving the sustainable development goals (SDGs) and combatting climate change simultaneously would require at four conditions:

- Global emissions are reduced so that atmospheric temperature remains around 1.5°C to 2°C above pre-industrial levels;
- Largely expansionary domestic fiscal and monetary policies, coordinated across countries, are adopted;
- International financial institutions take action to ease developing countries' policy constraints by providing sufficient finance and enabling technology transfer, in order to promote full employment in developed countries and industrialization in developing ones; and
- The green technologies needed to prevent climate collapse are made affordable to all countries.

Third, similarity in outcomes between a scenario with contractionary policies and a scenario of free riding raises a crucial strategic point: if mitigation policies in developed countries force developing countries to adopt policies that cut into output and productivity, and drive-up inequality in the long run, they face a perverse incentive to free ride. This is why avoiding a climate catastrophe and its macroeconomic impacts will require unorthodox measures at home and abroad. Low- or zero-carbon targets can be reached through timely collective action but only if the growth and developmental objectives of the developing world are supported globally.

When countries pursue expansionary policies, fiscal sustainability looms large. Many economists argue that high spending inevitably leads to higher borrowing costs and growing debt ratios, and history is full of examples of developing countries in debt distress. However, as our simulations indicate, unsustainable debt does not inevitably follow from fiscal spending. Rather, it can be the result of a mismatch between macroeconomic and industrial policies, exacerbated by multilateral rules that force countries into a race to the bottom. Our simulations indicate that in South Africa, any turn toward austerity can easily trigger a boundless increase in the debt-to-GDP ratio and lead to a deep recession.

In order to accomplish the green transition, South Africa will require large *government-led* investment in mitigation and adaptation, as a key driver of private sector investment. This is because green technologies are capital intensive, and the cost of capital is much higher in developing countries. Government policies can have direct and indirect effects on investments, i.e., governments can invest in green transformation directly, and shape private investors' decisions (and consumers' behaviors) towards low carbon resilient activities by subsidizing green investments, building necessary infrastructure, providing cheap credit options and using carbon-tax/price mechanisms. As shown above, public spending on mitigation and adaptation, combined with progressive redistribution, a stable and competitive real exchange rate, and a relatively low real interest rate can be instrumental in restructuring the economy and improving its prospects for a greener development.

Despite fear mongering over debt, capital flight and inflation, our simulations suggest that austerity measures bear the real risk (McKibbin et. al, 2017; Dunz et. al, 2021). As mentioned earlier, expansionary macroeconomic policies are politically challenging as they involve public (and private) borrowing—raising concerns about sovereign debt sustainability, but they are essential to decarbonizing economic activities. This, in turn, limits the governments' willingness to take expansionary and regulatory measures. In this case, access to regional and international borrowing facilities, i.e., national and multilateral development banks (NDBs and MDBs), development finance institutions, and green investment banks plays a critical role in improving developing countries' fiscal space for the necessary expansionary policies. The new sustainable financial system, which promotes green investments and financing, has the potential to amplify the effectiveness of the governments' climate policies by providing financing options, only if the governments have "credible, time consistent and committed" policy frameworks that focus on decarbonization (Carney, 2021).

The question is, then, how to improve the credibility of expansionary government policies in South Africa? After determining the main causes of emissions, governments must have a plan (involving private sector) on how to change the structure of the economy such that emissions can be reduced in high-carbon-sectors, while output and employment continue to grow. In South

Africa, energy related activities are the largest emitters[40] of CO_2; power sector (electricity and heat) and energy used in extraction sectors constitute approximately 64 percent of overall emissions, followed by industrial processes, such as production of manufacturing goods, chemicals and cement (14 percent), transportation sector (12 percent) and energy use in buildings (8 percent), meaning that South Africa's decarbonization plan must include mining, energy, manufacturing and transportation services sectors. Therefore, government's mitigation efforts must be channeled into timely investments in transforming coal-dependent-energy sector to renewable energy sector, decarbonizing industrial processes by replacing existing equipment with the best available options, shifting from petrol to electric powered transportation and increasing the energy efficiency in buildings.

Besides being key to decarbonization, along with information related sectors, energy, mining, manufacturing and transportation services sectors are also at the center of South Africa's output, productivity and employment dynamics. As shown (Figure 2), manufacturing and transportation services are the main drivers of productivity growth in South Africa. Once the coal-dependent energy sector is transformed toward renewables, and premature deindustrialization is reversed using up-to-date green technologies, they can lead more rapid output growth and create higher paying jobs. The construction sector suffers from low productivity growth, but its share in total value added has been increasing. As constructing energy efficient buildings requires higher skills and will be a key policy change, construction sector can generate more and "higher" paying jobs. According to Garrett-Peltier (2017), each $1 million public and private spending shifted from brown to renewable and energy efficiency related investments creates five more jobs on average, than spending on the brown energy related activities.

The global financial system has the potential to increase the financial capacity to help developing countries, by financing investments in sustainable infrastructures. According to Carney (2021), emerging and developing countries are expected to constitute two-thirds of future global investments. This means that these countries private and public sectors' commitments and how fast they act in combatting climate change will determine who gets a larger share of global investments and finance (Carney, 2021). South African government must have a well-designed decarbonization plan for three reasons: to reach the best possible outcome from decarbonization policies by setting "the green structure" to attract private investments, to justify the use of expansionary policies by explaining how and where they will be used and finally, to increase the credibility of the government's policies, which will facilitate access to borrowing from domestic and international institutions. Once this is accomplished, South Africa will be one of the most attractive candidates for strong financial support in global markets. In fact, "Just Energy Partnership" launched by the European Union, United Kingdom, United States, Germany and France to support South Africa's transition from coal is an encouraging example.[41]

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[40] See https://www.climate-transparency.org/wp-content/uploads/2020/11/South-Africa-CT-2020-Web.pdf.

[41] See https://www.climatepolicylab.org/climatesmart/2021/12/20/the-best-agreement-out-of-glasgow

CONCLUSION

South Africa must overcome a long-lasting recession enabled by its economic structure. A green transition is viable way forward but bears special challenges for developing countries. The transition may prove prohibitively costly without proper multilateral support and support from developed countries. Since no country can achieve mitigation alone, there is a strong incentive toward providing such support. But global mitigation policy could also include measures, such as carbon border adjusted taxes, that make it harder for developing countries to achieve the transition.

Energy demand is bound to increase as economies grow, making affordable renewable energy, and related green technologies, essential for a green economic transformation. Addressing those challenges in South Africa will require coordinated fiscal, monetary and financial policies such that capital, existing resources and new financial resources are effectively channeled towards green growth that stimulates productivity, output and employment in more equitable way.

Three different modeling scenarios (from a demand-driven growth model describing South Africa and the rest of the world) help better understand the potential consequences of global warming and climate action in South Africa and other developing countries we project. Atmospheric CO_2 concentration is adjusted to hit three different targets: 780 ppmv, 425 ppmv and 350 ppmv. Then, different economic policies are implemented, simulated and discussed.

Results show that inaction is catastrophic as the climate crisis will push the world economy to a bad equilibrium and humanity will face irreversible consequences. Moreover, achieving the SDGs and combatting climate change at the same time will require broad policy changes and massive investment in both South Africa and the rest of the world. Global emissions must be reduced so that the atmospheric temperature remains around 1.5°C to 2°C above pre-industrial levels. But this is only possible if developing countries' access to green technology improves. Otherwise, they will have no choice but to rely on carbon-intensive energy. South Africa in particular, as a coal-dependent economy, will face a hard choice unless technology transfer is improved at the multilateral level.

Fiscal and monetary policies are critical to green industrialization, by supporting growth in an equitable way. International financial institutions have an important role to play in creating all necessary policy space for developing countries. Our simulations show that domestic policies, which are at the core of a green structural transformation, must be necessarily expansionary to make sure mitigation policies lead to real investment. In order to achieve this goal and keep public finances sustainable, complementary monetary and distributional policies are required.

A relatively low and stable real interest can encourage and fortify real investment by containing borrowing costs but may lead to real exchange rate depreciation. A sustainable, competitive and "stable" real exchange rate is essential. Ensuring it can be maintained in the face of financial market pressures requires both an effective international financial safety net and domestic capital account regulation.

Our results chart a possible path for developing countries to survive the climate crisis, based on policies that create the necessary fiscal space. But this path requires global coordination toward a common goal. Who should contribute, how much and how remains as the major stumbling blocks, but our results clearly indicate the payoff can be persuasive for all.

TABLES

Table 2: Global BAU Scenario: 780 ppmv without Policy Change (Red Line)

Levels

	Year:2016	Year:2100
Real GDP (X)	4349.76	4814.91
Capacity Utilization (u)	0.354624	0.263199
Capital Stock per capita (κ)	218.253	217.793
Population	56.2	83.9963
Profit Share (π)	0.4	0.295494
Profit Rate (r)	0.14185	0.0777738
GHG Concentration (G)	400.	724.613
Employment-Population Ratio (λ)	0.284682	0.222675
Exports (EX)	1335.68	1099.67
Imports (IM)	1308.	1447.87
Labor Productivity (ξ)	271.875	257.428
Energy-Labor Ratio (KWh per labor per year)	92 005.1	87 211.3
Energy Productivity (ZAR/KWh)	2.955	2.95177

Growth Rates (percent)

	Year=2016	Year=2100
Real GDP Growth (%)	2.08307	-1.2749
Capital Stock per Capita Growth(%)	1.34855	-1.43997
Population Growth(%)	1.46154	0.213027
Labor Productivity Growth(%)	1.02832	-1.12207
Energy/Labor Ratio Growth (%)	1.00775	-1.09963
Energy Productivity Growth(%)	0.0205664	-0.0224408

Table 3: 425 ppmv with Expansionary Policies Scenario I (Black Line):

Levels

	Year:2016	Year:2100
Real GDP (X)	4349.76	16 434.1
Capacity Utilization (u)	0.354624	0.345518
Capital Stock per capita (κ)	218.253	566.259
Population	56.2	83.9963
Profit Share (π)	0.4	0.254327
Profit Rate (r)	0.14185	0.0878748
GHG Concentration (G)	400.	426.631
Employment-Population Ratio (λ)	0.284682	0.383737
Exports (EX)	1335.68	4355.68
Imports (IM)	1308.	4509.62
Labor Productivity (ξ)	271.875	509.861
Energy-Labor Ratio (KWh per labor per year)	92 005.1	92 585.4
Energy Productivity (ZAR/KWh)	2.955	5.50693

Growth Rates (percent)

	Year=2016	Year=2100
Real GDP Growth (%)	2.28307	0.865411
Capital Stock per Capita Growth(%)	1.54855	0.536823
Population Growth(%)	0.73452	0.26838
GHG Concentration Growth(%)	0.234414	0.0124863
Labor Productivity Growth(%)	1.12832	0.349512
Energy/Labor Ratio Growth (%)	0.0112832	0.00349512
Energy Productivity Growth(%)	1.11704	0.346017

Table 4: 350 ppmv with Expansionary Policies Scenario II (Blue dashed line):

Levels

	Year:2016	Year:2100
Real GDP (X)	4349.76	20 405.2
Capacity Utilization (u)	0.354624	0.382195
Capital Stock per capita (κ)	218.253	635.618
Population	56.2	83.9963
Profit Share (π)	0.4	0.22298
Profit Rate (r)	0.14185	0.0852216
GHG Concentration (G)	400.	350.791
Employment-Population Ratio (λ)	0.284682	0.4215
Exports (EX)	1335.68	5946.22
Imports (IM)	1308.	5599.31
Labor Productivity (ξ)	271.875	576.346
Energy-Labor Ratio (KWh per labor per year)	92 005.1	92 699.
Energy Productivity (ZAR/KWh)	2.955	6.21739

Growth Rates (percent)

	Year=2016	Year=2100
Real GDP Growth (%)	2.48307	1.07789
Capital Stock per Capita Growth(%)	1.74855	0.722145
Population Growth(%)	0.73452	0.26838
GHG Concentration Growth(%)	-0.44721	-0.0339835
Labor Productivity Growth(%)	1.22832	0.555462
Energy/Labor Ratio Growth (%)	0.0122832	0.00555462
Energy Productivity Growth(%)	1.21604	0.549908

Table 5: 350 ppmv with Austerity Policies Scenario (Gray Line):

Levels

	Year:2016	Year:2100
Real GDP (X)	4349.76	9970.95
Capacity Utilization (u)	0.354624	0.322377
Capital Stock per capita (κ)	218.253	368.224
Population	56.2	83.9963
Profit Share (π)	0.4	0.338467
Profit Rate (r)	0.14185	0.109114
GHG Concentration (G)	400.	350.791
Employment-Population Ratio (λ)	0.284682	0.319127
Exports (EX)	1335.68	3234.42
Imports (IM)	1308.	3305.31
Labor Productivity (ξ)	271.875	371.974
Energy-Labor Ratio (KWh per labor per year)	92 005.1	92 293.9
Energy Productivity (ZAR/KWh)	2.955	4.03032

Growth Rates (percent)

	Year=2016	Year=2100
Real GDP Growth (%)	2.48307	0.374867
Capital Stock per Capita Growth(%)	1.74855	0.184257
Population Growth(%)	0.73452	0.26838
GHG Concentration Growth(%)	-0.44721	-0.033984
Labor Productivity Growth(%)	1.22832	-0.0206013
Energy/Labor Ratio Growth (%)	0.0122832	-0.000206014
Energy Productivity Growth(%)	1.21604	-0.0203953

Table 6: 350 ppmv with South Africa as Free Rider (Green Line):

Levels

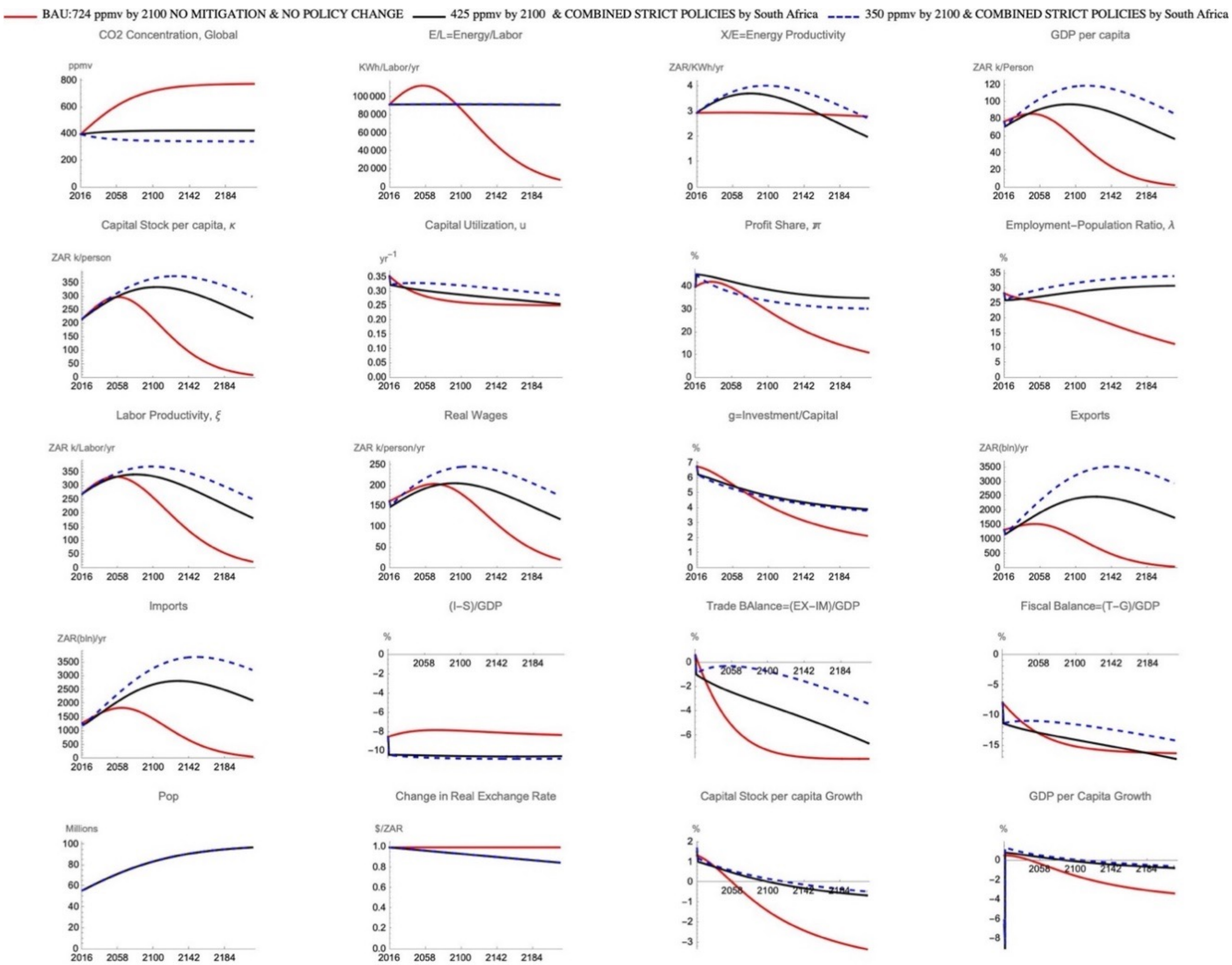
	Year:2016	Year:2100
Real GDP (X)	4349.76	12914.6
Capacity Utilization (u)	0.354624	0.323543
Capital Stock per capita (κ)	218.253	475.212
Population	56.2	83.9963
Profit Share (π)	0.4	0.293129
Profit Rate (r)	0.14185	0.09484
GHG Concentration (G)	400.	350.791
Employment-Population Ratio (λ)	0.284682	0.351238
Exports (EX)	1335.68	3717.27
Imports (IM)	1308.	3883.49
Labor Productivity (ξ)	271.875	437.741
Energy-Labor Ratio (KWh per labor per year)	92005.1	146731.
Energy Productivity (ZAR/KWh)	2.955	2.98328

Growth Rates (percent)

	Year=2016	Year=2100
Real GDP Growth (%)	2.48307	0.636893
Capital Stock per Capita Growth(%)	1.74855	0.356005
Population Growth(%)	0.73452	0.26838
GHG Concentration Growth(%)	-0.44721	-0.0339834
Labor Productivity Growth(%)	1.22832	0.161607
Energy/Labor Ratio Growth (%)	1.20375	0.158374
Energy Productivity Growth(%)	0.0245664	0.0032322

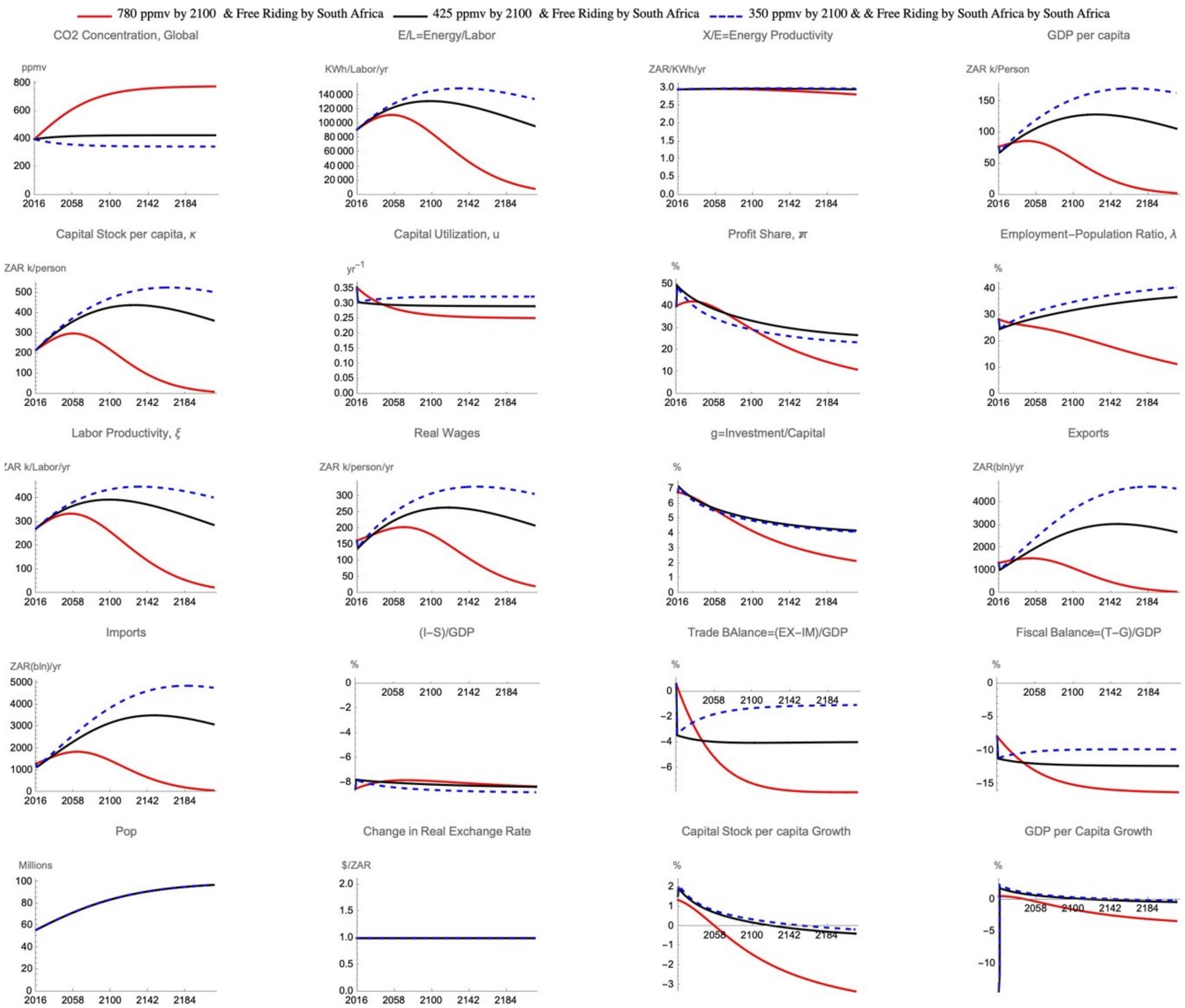
APPENDIX: ADDITIONAL SIMULATIONS

Figure 8: Global & South African BAU under 780 ppmv pathway (Red line) vs. "Strict Policies" under 425 ppmv pathway (Black line) vs. "Strict Policies" under 350 ppmv pathway (Blue dashed line)



Source: Author calculations.

Figure 9: Global & South African BAU under 780 ppmv pathway (Red line) vs. "South Africa as Free Rider" under 425 ppmv pathway (Black line) vs. "South Africa as Free Rider" under 350 ppmv pathway (Blue dashed line)



Source: Author calculations.

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