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Interactions between recovery and energy policy in South Africa

Bence Kiss-Dobronyi [a,b,*], Margaret Chitiga-Mabugu [c], Richard Lewney [b], Nokulunga Mbona [a]

[a] *Corvinus University of Budapest, Budapest, Hungary*
[b] *Cambridge Econometrics, Cambridge, UK*
[c] *University of Pretoria, Pretoria, South Africa*

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ABSTRACT

The COVID-19 pandemic caused a severe economic shock to which governments responded by announcing large-scale recovery packages with magnitudes unseen before. While some of these policies have been expected to have positive environmental outcomes ("green" policies), most of them have not been designed to address those challenges ("colourless"). Focusing on the economic recovery program announced in South Africa, a country still heavily reliant on fossil-fuels, this paper shows how colourless recovery policy can increase environmental harm, whereas green elements in recovery packages can enhance the decarbonisation effects of energy policy and promote positive economic outcomes. The analysis uses the energy-environment-economy model E3ME to simulate effects of different kinds of recovery policies and quantify the combined impact of a package of measures.

1. Introduction

The COVID-19 pandemic has been one of the most significant public health events in the modern world, which also triggered a severe economic recession [1] and substantial employment losses [2]. Impacts were felt in shocks to international trade, supply chain bottlenecks and a decline in tourism [3–5]. Meanwhile, the economic slowdown also produced a pause in environmental degradation. In 2020 emissions of greenhouse gases (GHG) fell by an estimated 5% [6] exceeding the estimated reductions during World War II and the 2007-10 global financial crisis [7].

Post-pandemic economic recovery was expected to create a strong rebound in emissions [6,8], and this could be exacerbated by large-scale government stimulus policies if the *status quo* economic and energy structure based on fossil fuels is maintained [2,6,8]. Hence, economy recovery plans could be in direct contradiction with countries' climate ambitions [9].

This paper analyses the interaction between recovery policies, including *colourless* policies, and energy- and climate policy in the case of South Africa. South Africa offers a particularly important case for analysis because its economy was adversely affected by the pandemic, the government has announced large-scale recovery plans, and the goal of reducing GHG emissions requires a major transition in its coal-based energy system [10–12]. The novelty of the paper is to showcase, through the integrated modelling exercise and the case of South Africa, how environmental outcome of recovery policies is closely interlinked with long-term energy policy and how without long-term energy policy transformation even *colourless* recovery policies can have adverse environmental impacts.

The paper describes the situation in South Africa both in terms of recovery and in terms of energy challenges. It then applies integrated-environment-economy (E3) macro-sectoral modelling to analyse potential future pathways and policy interactions. The paper's first section describes interactions between energy and recovery policy; the second examines South Africa's recovery policies and energy system challenges; the third focuses on the modelling, noting relevant literature and then presenting the results of new modelling. Limitations are noted before the final section, which draws conclusions from the analysis.

2. South Africa and the pandemic

South Africa imposed strict lockdown measures after the start of the pandemic [12–14]. These measures were deemed necessary to curb the pandemic, but have negatively impacted an economy that was already under substantial strain and was already dealing with high levels of unemployment [13], high public debt [15] and high levels of inequality [14]. During COVID-19, GDP fell by more than 6% in 2020, with investment falling by 15% [16]. Unemployment increased to 30% in 2020

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* Corresponding author. Fővám tér 8, Budapest, 1093, Hungary.
E-mail address: bence.kiss-dobronyi@uni-corvinus.hu (B. Kiss-Dobronyi).

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Q1 and employment in 2020 Q2 fell by more than 13% [10]. Lost jobs, deferred investment and electricity supply shortages were key features of the crisis [12].

While the country saw a strong economic rebound in 2021, with GDP growth of 5% and projected further growth rates of 1–2% for 2022–2023 [17]; National Treasury, 2022; [16], there are still concerns about longer-term consequences of the pandemic. There are worries about the "scarring" of the economy, i.e., that medium-term economic growth will stay below pre-pandemic expectations – this is sometimes called a *hysteresis* effect. This notion is supported by the fact that GDP rebound was not matched by a similar increase in employment and investment. In 2021 Q3 there were still 2.1 million fewer jobs than in 2019 Q4, resulting in an all-time high unemployment rate of nearly 35%. Despite increases in government investment, the overall level of investment remains below pre-pandemic levels, due to low private investment [12].

2.1. *Recovery policies*

This economic rebound has already been supported by rescue and recovery policies adopted by the state. Public investments and household consumption, supported by COVID relief measures, have been the principal drivers of growth [16]. At the time of writing, COVID social relief measures have been extended to March 2023, with additional COVID-related budget allocations of R109 billion[1] in the next 3 years [12].

The plans that have been announced are on even larger scale: the large-scale public infrastructure investment program announced by President Ramaphosa in 2020 is expected to unlock investments amounting to R1 trillion in the decade. Other, smaller programs are also intended to support recovery: the Tourism Recovery Plan is intended to add R15 billion over three years for selected sectors, while food vouchers amounting to R50 billion are expected to help vulnerable groups. Strategic localisation,[2] through local content requirements, are expected to direct more of the impact of additional spending toward domestic production. Meanwhile, the Expanded Public Works Program is creating temporary job opportunities in the fields of environment, health and social care, safety and food security, with an expected 800,000 new jobs [10].

2.2. *Challenges of energy supply in South Africa*

Energy supply shortages, particularly in electricity generation and distribution, are a long-standing issue, at least since 2007 [11]. Load-shedding, the practice of using planned power outages to reduce demand, has been often applied by ESKOM, the main power operator, to manage supply shortages [19,20]. The practice is not only expected to continue, but actually reached its highest levels during the pandemic [12].

Inadequate power supply has reflected insufficient investment in generation capacity over more than a decade, resulting in declining stability and capacity. Heavily subsidised ESKOM capacity has crowded out private sector investment in electricity generation, resulting in today's aging, coal-dominant energy mix, intermittent power outages, and unreliable electricity supply [11,21].

The obvious consequence of reliance on coal-based power generation has been major environmental concerns about emissions. The country relies on coal for over 70–90% of its electricity supply [11,19,21,22] and is the 13th largest global GHG emitter [23], despite being only the 33rd largest economy,[3] making the country a "disproportionate contributor to climate change" [19]; p. 238).

Policy has already been moving to address this. The 2019 Integrated Resource Plan (IRP) anticipates major additions to renewable based power generation [10,11,19]. It is expected that Independent Power Producers (IPP), companies with power generation capacities different from those of ESKOM, will play a large role. Legislation to support IPPs has been announced, including the full removal of licensing thresholds for embedded generation [24]. But government plans still suggest that coal will retain a significant role in the energy mix and non-green investments will continue, tapping into the countries' oil and gas reserves [10,21]. This reaction has some resemblance to behaviour by other fossil fuel exporters and users. Many of these countries have promoted a 'grey' recovery, which – in addition to its environmental effects – could create false sense of recovery leading to even more investment into fossil assets [25].

3. Interactions between energy policy and recovery policy

Following COVID-19 induced crisis policy makers have recognised the importance of "building back better", i.e. using the recovery to build economic structures that are environmentally less harmful (Cambridge Econometrics et al., 2022; [2,26]. Recovery measures can be grouped according to their contribution to climate goals: 'green' measures expected to have positive impacts and 'grey' measures likely to contribute directly to environmental harm, [10,26–28].

However, most adopted measures fall into another category: 'colourless' policies [2,27,28]. These policies are thought to "have a neutral effect on *status quo* environmental harm (meaning that they do not *worsen* the environmental harm linked to economic growth)" [2]; p. 12). This means that their effect depends on the existing economic and energy structure. For example, if we consider a policy that introduces a cut in taxes on consumer spending to counter sharp, pandemic-induced falls, the environmental effect clearly depends on the carbon and material intensity of consumption in the economy in which the policy is implemented. Hence, it is not only the content of the recovery package that determines environmental impacts, but also the nature of the energy system and any concurrent energy policy. This highlights the importance of analysing the *interaction* of climate, energy and recovery policies, as highlighted in a recent report for the G20 presidency [29].

3.1. *Climate and recovery in South Africa*

South Africa represents a particularly relevant case for this kind of analysis. The economic effects of the pandemic still hang over the country [12]; the government has announced a substantial package with many of its recovery policies can be categorised as 'colourless' [10]. Furthermore, the country was facing an energy crisis, even before COVID [11], it has substantial surplus labour (involuntary unemployment) and it is highly dependent on fossil fuels for energy supply. And the same modelling framework that we apply in this paper has already been used for modelling the macroeconomic effects of the announced recovery package [10].

South Africa has recently reached an agreement with the UK, the US, France, Germany, and the EU to receive support for its Just Transition and the phasing-out of coal [19]. Some US$8.5 billion (R 150 bn) has been pledged by the countries to support the energy transition [23]. But while the amount pledged for the next three to five years is substantial, it is small[4] compared to both the initially announced COVID stimulus of R 500 bn and to the broader recovery program estimated to amount to about R 1120 bn in the coming decade [10]. It is also small in the context of previous estimates of the overall price of an energy transition in South Africa: between R 25 bn and R 250 bn over the next three decades [23].

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[1] South African rand.

[2] *Strategic localisation* refers to the practice of procurement of and investment in locally produced goods [18].

[3] World Bank estimate, nominal GDP, 2021.

[4] About R 153 bn using current exchange rate (18.06 ZAR/USD) as of 27 Sept 2022.

3.2. Existing evidence of the interactions between energy and recovery policy

Building on the experience of the recovery after the Global Financial Crisis [30], argues that sustained economic recovery requires more than short-term fiscal stimulus. He argues for long-term reforms such as the removal of fossil-fuel subsidies and raising the price of carbon and other pollutants can generate revenue while accelerating the transition to the green economy post-COVID-19 [31]. argue that the decline in prices of renewable energy technologies versus other energy sources over the past decade make green energy stimulus an attractive policy for COVID-19 recovery [31].

Studies have also investigated the impacts of green recovery scenarios [32]. have analysed simplified recovery scenarios with substantial green elements in four European countries and have concluded that results of the same policies can be rather different due to economic and energy structure. Studies have also compared green recovery and non-green recovery, for example [33], applied E3 macroeconomic modelling to compare a consumption driven recovery and a 'green' recovery. They find better environmental, employment and GDP impacts in the 'green' case. [34]; undertook a similar analysis using three well-established global models (E3ME, GEM-E3 and IMAGE). They found that a Green Recovery scenario that assumes 1% of global GDP directed consistently towards climate mitigation measures can reduce emissions by over 10–15% *and* bring lasting benefits to the global economy [1]. compared global recovery scenarios with high emission and low emission intensity investments. In their work ongoing stimulus packages will increase emissions unless the transition to low-carbon technologies is kick-started [35]. applied a Computable General Equilibrium (CGE) model for Belgium to simulate the impacts of a demand-side, environmentally sustainable recovery. The study finds both positive economic growth impacts and reductions in CO_2 from sustainable investment policies [35].

4. Modelling the interaction between recovery and energy policies

To better understand the interactions between long-term energy policy and recovery policy this paper uses the E3ME macro-econometric model and develops three "baselines", representing long-term energy policy, and three policy packages, representing recovery measures. E3ME, combined with the FTT:Power [36,37], is able to represent detailed policies through its simulation approach. These policies can focus on environmental and climate policy but can come from other areas as well (i.e., standard recovery policies). E3ME has detailed coverage for South Africa and an earlier modelling exercise [10], commissioned by UN PAGE and ILO has focused on simulating post-COVID recovery measures for the country. Importantly, E3ME, being a non-equilibrium, demand-led model can simulate policies in an economy where there is a considerable output gap and there are under-used resources [33,37], which, given its unemployment situation, is very relevant in South Africa.

In this section first, the E3ME model is introduced, then energy policy pathways are discussed and finally, recovery policies modelled are described.

4.1. The E3ME-FTT model

The E3ME model is founded on post-Keynesian theory and ideas emphasised in complexity economics such as bounded rationality and non-equilibrium economic modelling. The full model manual and detailed description of the model are maintained by Ref. [38]; while the full set of equations that comprise the model mechanics can be found in Ref. [37]. Importantly, the model allows involuntary unemployment and accepts the potential of spare capacity in the economy – both of which are realistic in the South African context. E3ME is a global model, distinguishing over 70 countries or groups of countries, and one of the countries distinguished is South Africa.

The model is structured around an input-output model of the economy, which links individual sectors together. Demand for goods produced by those sectors is derived from aggregated consumption and a disaggregation of that to consumption categories (products). Industrial sectors then use input factors to produce the demanded goods and services. In this process they interact with the labour market as well as with the energy system, while the structure of intermediate goods used is determined by the input-output tables. Unit costs and prior investments determine prices, while employment and energy use are determined by the level of supplied demand and, again, prior investments. Trade is handled through bilateral linkages [33,38,39].

Most of these relationships are represented at the product/industry level, with econometrically estimated equations. Parameters are estimated on historical data, using the concepts of cointegration and the error-correction method, following a two-stage process put forward by Refs. [40,41]. The process therefore captures both short-term and long-term economic responses.

The nature of the equation structure can be demonstrated through the example of the equation for agricultural employment and investment in South Africa. The employment equations, long- and short-term, are specified as shown in equations Eq 1 and Eq 2.

Eq 1 Co-integrating long-term equation

$$\begin{aligned}\ln\left(YRE_{t,i}\right) = \alpha + \beta_1 \ln\left(QR_{t,i}\right) + \beta_2 \ln\left(YRWC_{t,i}\right) + \beta_3 \ln\left(YRH_{t,i}\right) \\ + \beta_4 \ln\left(PQRM^{oil}_{t,i}\right) + \beta_5 \ln\left(YKNO_{t,i} + YCAP_{t,i}\right) + ECM\end{aligned}$$

Eq 2 Dynamic equation

$$\begin{aligned}\Delta\ln\left(YRE_{t,i}\right) = \gamma + \lambda_1 \Delta\ln\left(QR_{t,i}\right) + \lambda_2 \Delta\ln\left(YRWC_{t,i}\right) + \lambda_3 \Delta\ln\left(YRH_{t,i}\right) \\ + \lambda_4 \Delta\ln\left(PQRM^{oil}_{t,i}\right) + \lambda_5 \Delta\ln\left(YKNO_{t,i} + YCAP_{t,i}\right) \\ + \lambda_6 \Delta\ln\left(YRE_{t-1,i}\right) + \lambda_7 ECM_{t-1,i}\end{aligned}$$

where.

- α and β_1 to β_5 are estimated long-term parameters,
- γ and λ_1 to λ_7 are estimated dynamic parameters,
- *YRE* is total employment in thousands of persons,
- *QR* is real output in million EUR 2010 prices,
- *YRWC* real average labour cost, which is real wage costs divided by employees,
- *YRH* is average hours worked per week,
- $PQRM_{oil}$ effect of real oil price (import prices in local currency, 2010 = 1.0),
- $YKNO + YCAP$ is the stock of knowledge and capital aggregated in million EUR 2010 prices,
- YRE_{t-1} is the lagged change in employment,
- *ECM* is the error term in the long-run equation and ECM_{t-1} is the lagged error correction term
- Indexes *t* and *i* refer to the year and the region (e.g., South Africa) of the observation

These equations are estimated on historical data; in the case of South Africa this means using UN National Accounts, OECD Labour Force Survey and ILO modelled estimates of employment as well as IEA energy balances. All available data between 1970 and 2018 is used for the estimation of the parameters [38]. To account for COVID related economic shocks, data have been updated as described in Ref. [33]. The estimated parameters are restricted by theory driven economic assumptions.[5] This yields the final equations, e.g., in the case of the above equations:

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[5] These are described in detail in the E3ME Technical Manual [38].

Eq 3 Co-integrating long-term equation, with parameters estimated for South Africa agricultural sector

$$\ln\left(YRE_{t,i}\right) = 9.133 - 0.264 \times \ln\left(YKNO_{t,i} + YCAP_{t,i}\right) + ECM_{t,i}$$

Eq 4 Dynamic equation, with parameters estimated for South Africa agricultural sector

$$\begin{aligned}\Delta\log\left(YRE_{t,i}\right) = {} & 0.039 + 0.113 \times \Delta\ln\left(QR_{t,i}\right) - 3.044 \times \Delta\ln\left(YRH_{t,i}\right) \\ & - 1.2 \times \Delta\ln\left(YKNO_{t,i} + YCAP_{t,i}\right) - 0.2 \times \Delta\ln\left(YRE_{t-1,i}\right) \\ & - 0.453 \times ECM_{t-1,i}\end{aligned}$$

These stochastic equations are sequentially connected and solved through a simple iteration method. The model iterates until it converges for key variables.

Energy use and emissions are linked to the economic system; energy is modelled both in physical and in monetary terms. Energy use in physical units is determined by econometric equations at a sectoral level, by fuel used, with a bottom-up representation of available technologies for key sectors (see FTT below) [33]. Energy use generally decreases in response to investments in industrial sectors, i.e., increasing energy efficiency is assumed as technologies develop [38]. Emissions of various gases are then determined by energy use: once energy use by fuel is determined, fixed coefficients are applied to the consumption of each energy carrier to derive the level of greenhouse gas emissions [39].

Given its reliance on econometric methodology, the model could be vulnerable to the 'Lucas Critique' [33]. Partly to address this issue, and partly to accommodate explicit representation of the adoption of key new technologies, the econometric equations are integrated with the Future Technology Transformation (FTT) suite of models, in particular a bottom-up technology diffusion model of the power sector [36]. Technology and fuel-use choices are based in part on the levelized cost of electricity (LCOE). To represent bounded rationality in decision making under uncertainty, the LCOE for the various available technologies is defined as a distribution. Take-up is influenced by the existing market share of each technology, with a penalty for less familiar technologies. The model also assumes path dependency and learning-by-doing in technology adaptation. A detailed description of the model can be found in Ref. [36]; while its integration with E3ME is described in Ref. [42].

The model's economic and energy linkages and its determination of emissions are shown on Fig. 1, while a more detailed representation of the model is presented in the Annex. The model is frequently used for the analysis of socio-economic impacts of climate and energy policy. Recently it has been used for investigating effects of net-zero transition in Japan [43], assessing global consequences of stranded assets [44] and exploring strategic and economic implications of the new energy geography shaped by climate mitigation [45].

The analysis here briefly compares the long-term outcomes, until 2040 of each of the energy policy scenarios (or "baselines"), but the primary focus is on the interaction between the recovery policies and the long-term energy policies.

4.2. Long-term energy policy: the integrated resources plan (IRP) of South Africa

The IRP has been drafted in 2018 [21] and an update to it has been published in 2019 [19]. This document sets out the government's energy strategy [19,21], discussing new planned capacities and regulatory measures for the development of the energy system in the country. Nevertheless, there has been delays in the implementation of the IRP [19], it is currently undergoing a revision that expected to be completed in 2023 [46] and it only set energy system capacity goals up until 2030.

Since it is not clear exactly how objectives in South Africa's Integrated Resource Plan (IRP) will be achieved the modelling includes a range of alternative ways of projecting forward the power generation fuel mix under 'baseline' (i.e., no recovery policies) conditions. These different "baselines" also represent different approaches to long-term energy policy.

- **BA1 Endogenous**: in the endogenous case, the model's FTT:Power module determines South Africa's power generation energy-mix profile, given the prospective costs of technology and fossil fuels: this is the *main* or *default* baseline case. In this case no carbon pricing is included in the baseline. While in *reality* there is a carbon tax already in place in the country, considering various uncertainties around climate policy in South Africa, we still feel relevant to consider this case kind of a *counterfactual, no-policy* option.
- **BA2 IRP Regulated fossil, market-based renewables**: in this case nuclear-based generation is exogenously fixed,[6] while coal-based power generation is regulated[7] to levels prescribed in the IRP until 2030 and then phased out over 2030-40.[8] The scale of power generation from other sources (including wind, solar and gas) is left for the model to determine endogenously. This case also considers a carbon tax, that is already in effect in the country, covering power generation and industry, with prices starting around US$9 and increasing to US$30 by 2030 and US$120 by 2050.[9]
- **BA3 IRP Fixed investment:** in this case the scale of the key power generation technology types is set exogenously, in line with the IRP's targets (which extend to 2030). This includes nuclear, coal, gas, and renewables. The scale of investment and the resulting generation capacity are fixed to follow the IRP until 2030. Thereafter, the exogenous treatment is continued to 2040 in the case of nuclear and coal, but for the other technologies the outcomes are formed endogenously. The same carbon tax is applied as in the BA2 case.

Differences across these 'baseline' scenarios are considered in the Annex. This paper uses the 'baseline' scenarios to test the extent to which the impact of different recovery policies varies according to which long-term energy policy is adopted. Fig. 2 shows the power generation mix of different baseline scenarios. In BA1 coal is not phased out from the mix: there is no carbon tax to discourage its use and there is no IRP that would force it out of the power-mix. In contrast, BA2 phases out coal and the capacity are replaced by renewables. BA3 follows the IRP's projected mix more closely, keeping coal-based generation for longer than BA2, but still has renewable capacity increasing substantially by 2040.

It needs to be noted, that the BA1 scenario is somewhat more pessimistic from a climate perspective than what is expected in reality: the scenario does not consider some regulatory measures, that could lead to "organic" phasing-out of coal-based capacities: e.g., minimum emission standards.

While what happens *outside* of South Africa might also have a bearing on results within the country, analysing this is outside of this paper's scope. Therefore, for the rest of the world the modelling assumes no change in policies or a business-*as*-usual case, which builds on assumptions and projections built into E3ME's standard baseline, which in turn is based on [47] current policies scenario [47].

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[6] Fixed level of capacities was set based on the IRP, see detailed scenario assumptions in the Annex.

[7] Regulation in this case means setting a maximum capacity, this means that the model will basically put a cap on possible coal-based generation.

[8] Based on: https://carbontracker.org/south-africa-needs-significantly-more-money-to-help-phase-out-coal/.

[9] Based on these sources: https://theconversation.com/south-africas-carbon-tax-rate-goes-up-but-emitters-get-more-time-to-clean-up-177834; https://carbonpricingdashboard.worldbank.org/map_data; note that carbon tax revenues are not directly recycled in any of the scenarios, however they can be used for financing required investments, which are discussed in section 5.

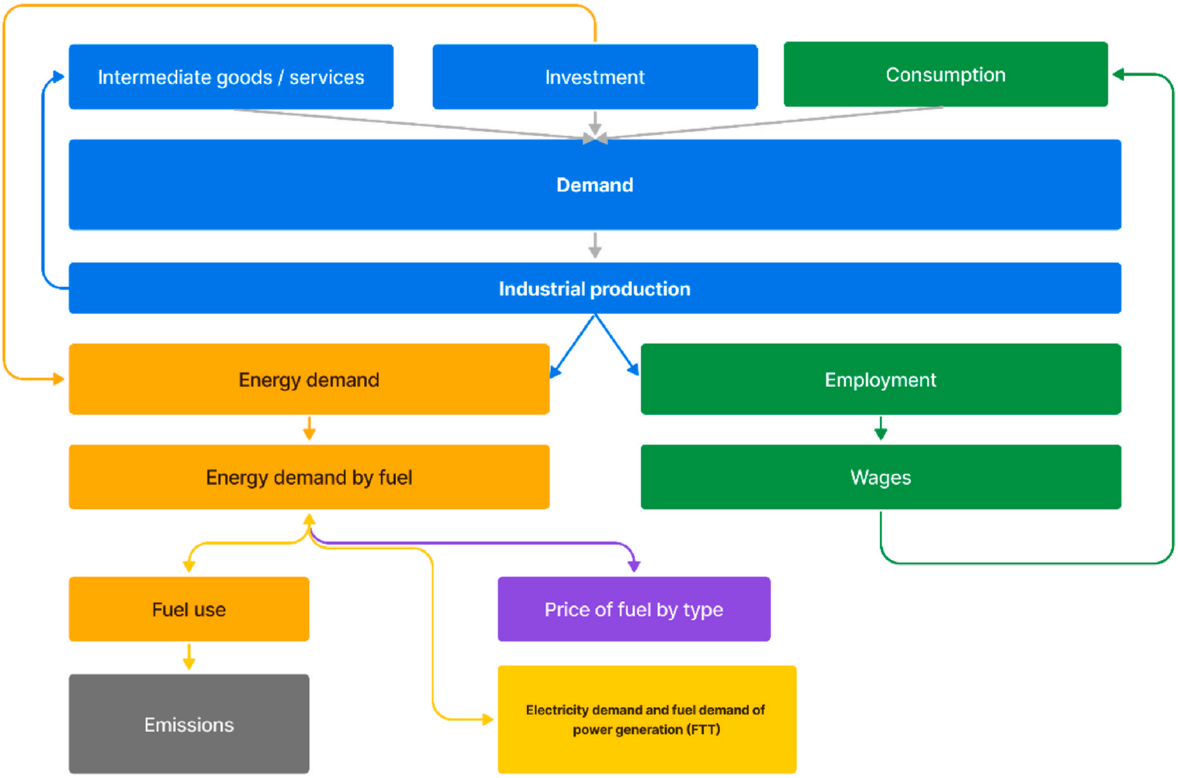

Fig. 1. Simplified overview of linkages in the E3ME-FTT model, a more detailed overview of the model linkages can be found in the Annex, this representation excludes trade linkages.

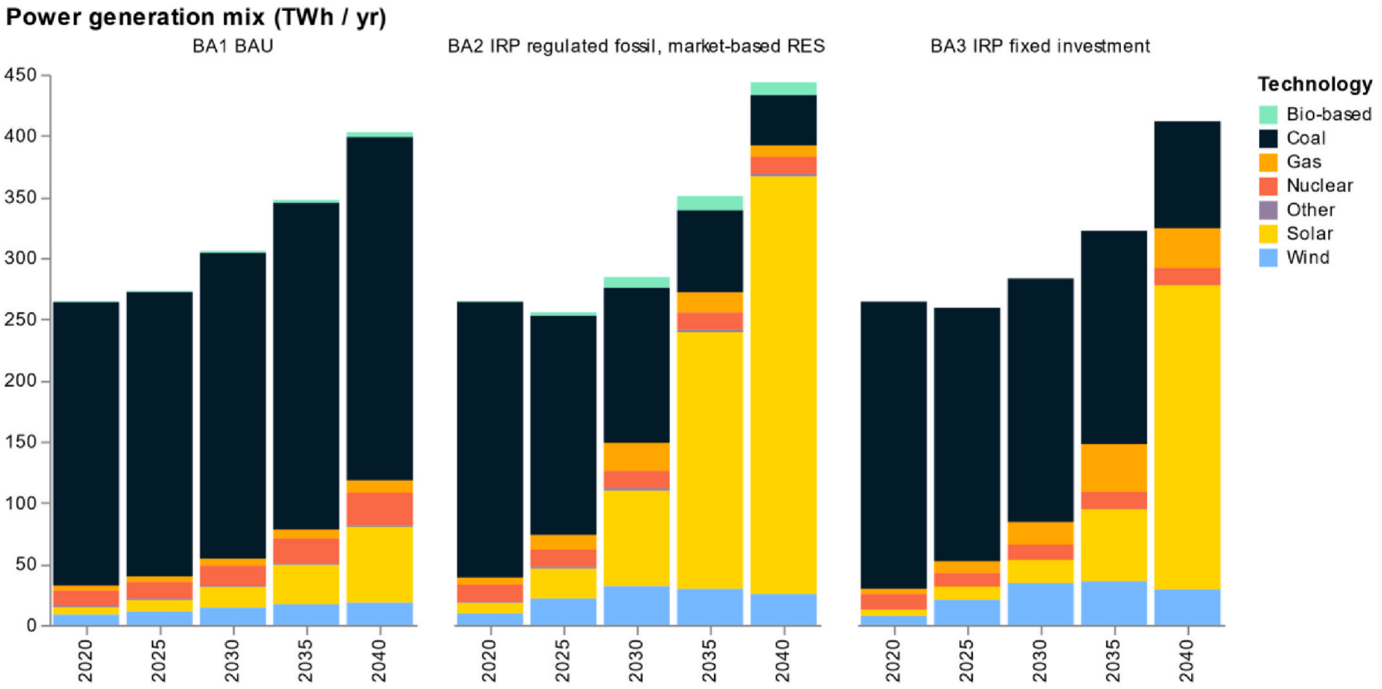

Fig. 2. Power generation mix developments in the 'baseline' scenarios, TWh/yr 2020–2040.
Source: E3ME simulation results

4.3. Recovery policies and scenario setup

The recovery policies considered in the modelling are based on announced government plans and follow the treatment in a previous modelling exercise [10]. Recovery policy measures are grouped into three categories: (A) conventional economic recovery measures (which have no green elements), (B) a public works job-creation policy, and (C) green energy-system related policies. Each group is modelled separately (3 scenarios) and building up A, (A + B) and (A + B + C) (a further 3 scenarios). Table 4 in the Annex shows the combinations of all 18 modelled scenarios (6 scenarios for each of 3 baselines).

The three policy packages differ in their scale of spending, reflecting the Government's announcements. The overall magnitude of conventional policies (A) is R 836 billion over 10 years, that of public works (B) R 68 billion, and that of green policies (C) R 200 billion. Table 7 in the Annex gives a detailed overview of the policy packages.

5. Discussion of the results

The discussion presented here focuses on the differences from baseline projections for key indicators for emissions, employment, and economic activity (GDP), as these are treated as the key outcomes by which the success of the policies is to be judged. Discussion of the results is organised as follows: the impact of *colourless* recovery policies (A + B) given the different long-term pathways is analysed first, while the second part considers the situation if recovery policies also include 'green' elements.

5.1. Impacts of colourless recovery measures

Fig. 3 shows headline employment and emission results for the *"colourless"* part of recovery policies. Panel (A) shows the result of the scenario simulations for A + B recovery policies, compared to the three baselines. Panel (B) shows the combined effect of energy policies and recovery policies shown as differences from the BA1 case with no recovery programme. In the latter case we consider what the energy and recovery policies can achieve compared to a business-*as*-usual case with no recovery and no set energy policy goals.

5.1.1. Marginal impacts of recovery policies considering long-term energy policy

Panel (A) of the figure shows that cumulated employment gains increase over the years, compared to no recovery, while emissions grow substantially up until 2030, only to shrink somewhat and then gradually increase again until 2040. The magnitude of emissions resulting from the colourless recovery policies varies considerably across the energy policy scenarios, illustrating that the impact of economic recovery on emissions depends on the extent to which transition policies are put into place in power generation. The impacts on employment are similar, regardless of the assumed energy mix.

Detailed results are shown in the Annex, highlighting the marginal impacts of the recovery policies given the different energy policy assumptions. The average annual employment addition of the recovery policies is between 233 and 239,000 jobs, depending on the energy policy pathway, while the boost to economic activity (GDP) increase is about 5.5% compared with the 2018 level[10]).

The range of additional emissions from the recovery policies is much greater. Additional emissions are the highest in the BA1 case: about 84 $MtCO_2$ over the 20 years. They are somewhat lower in the IRP fixed investment case (BA3) (about 62 $MtCO_2$) and lowest in the IRP regulated fossil, market-based RES case (BA2) (about 46 $MtCO_2$).

This shows that recovery policies can add substantial emissions: 84 $MtCO_2$ is equal to about 2.5 months' worth of CO_2 emissions from the overall South African economy.[11] However, if energy policy is working towards transitioning the country's energy system (as in BA2 and BA3), the additional emissions can be substantially reduced: IRP with fixed investments reduces additional emissions from recovery policies by 26%, while IRP with regulated fossil and market-based RES can cut recovery related emissions by 45%.

The Annex also details economic activity and investment impacts.

Table 1
Policy measures in the modelled scenarios.

Group	Measure	Description
A - Conventional policies	Infrastructure investment	New private and public investment into infrastructure projects, public financing is assumed to be ~10% of overall investment, financing is assumed to be international aid and FDI
	Localisation measures	Import reduction and increased FDI due to localisation measures
	Relief provided to selected sectors	Government subsidy provided to tourism, transport, service sectors
	Food vouchers	Subsidised food consumption for low-income households
B – Public works	Public works programme	Government financed public works in certain sectors (e.g., education, healthcare, etc.)
C – Green policies	Energy efficiency	Energy demand reduction in households
	Capital subsidy for renewables	Capital subsidies for wind and solar PV projects
	Early coal phase-out in power generation	Phase-out in power generation, meaning no new capacity built after 2030

Focusing on the investment, it is notable that the impact of the recovery policies on investment decreases from BA1 to BA2 and BA3. This reflects the fact that implementation of the long-term energy policy (IRP) incorporates additional investment in the baseline, and so there is a lower investment cost for the recovery policies. Investment in the scenarios grows by about 27% compared to 2018 levels; this is partially fuelled by exogenous investment assumed in the 'A' component of the recovery policies (see Table 1).

5.1.2. Overall impact of recovery and energy policies

As noted earlier, Panel (B) shows the combined effects of recovery policies and long-term energy policy compared to a business-*as*-usual case with no recovery (BA1, no recovery). The Y-axis of the figure is the difference in cumulated employment for each energy and recovery package compared with that baseline, and the x-axis is the difference in the cumulated emissions impact. Table 2 shows the detailed impacts of the analysis: covering employment, emissions, GDP, and investments. These impacts combine effects from long-term energy policy (i.e., investment needed for transitioning the energy system) and recovery policies (e.g., public works, large-scale investment stimulus).

The BA1 case in this comparison essentially shows the effects of the recovery policies since no long-term energy policy is included. These effects have been discussed in the previous section.

Employment and GDP impacts are strongest in the IRP regulated fossils, market-based RES (BA2) case. This scenario also brings the largest emission reductions, resulting in about 2310 $MtCO_2$ reductions by 2040. However, the scenario requires (assumes) substantial mobilisation of private sector investment: recovery and energy policy together result in investment levels (compared to 2018 investment levels) increasing by over 40%.[12]

Finally, the BA3 IRP with fixed investment case results in outcomes that lie between the recovery only (BA1, with B+A) and the BA2+A+B scenario. Employment impacts are slightly lower (about 10% lower) than in the BA2+A+B case, as are GDP impacts (about 15% lower). But the reduction in emissions is much less ambitious in this case: 55% less by 2040 than in the case of BA2+A+B. The required investment is only about 6% lower overall than in the BA2+A+B case and 39% higher than in the only recovery no energy policy (BA1+A+B) case.

All three scenarios (even the BA1 with no energy policy) produce

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[10] Results are presented in percentage terms as share of 2018 values to avoid calculating with figures from outlier years (i.e., 2020 or 2021 because of COVID impacts).

[11] Considering energy-related emissions in 2018.

[12] Not discounted.

Table 2
Key outcomes of the combined energy and recovery policy impacts.

Cumulated impact by 2040 of the A + B recovery policies and long-term energy policy (IRP) compared to BA1 without recovery	BA1 energy: BAU recovery: A + B	BA2 energy: IRP regulated fossil, market-based RES recovery: A + B	BA3 energy: IRP fixed investment recovery: A + B
Employment			
(A1) Employment impact (FTE-years, thousand), over 20 years, 2021–2040	4655	6892	6219
(A2) Employment (annual average additional jobs, thousand)	232.8	344.6	310.9
(A3) Annual average employment addition [A2] as % of 2018 employment level	+1.39%	+2.05%	+1.85%
Emissions			
(B1) Emissions impact ($MtCO_2$), over 20 years	83.9	−2309.8	−1047.5
(B2) Average annual addition	4.2	−115.5	−52.4
(B3) Annual average emission addition [B2] as % of 2018 emission level	+0.91%	−25.15%	−11.40%
Economic activity (GDP)			
(C1) Economic activity (GDP, bn ZAR 2010 prices), over 20 years	3495	4602	3912
(C2) Economic activity (annual addition, bn ZAR 2010 prices)	174.7	230.1	195.6
(C3) Annual average GDP addition [C2] as % of 2018 levels	+5.52%	+7.27%	+6.18%
Investment[15]			
(D1) Investment (bn ZAR 2010 prices), over 20 years	3344	4986	4664
(D2) Assumed exogenous investment (average annual, bn ZAR 2010)	31.6	31.6	31.6
(D3) investment (annual addition, bn ZAR 2010 prices)	167.2	249.3	233.2
(D4) Annual average investment addition [D3] as % of 2018 levels	+27.27%	+40.67%	+38.04%

emissions consistent with the Copenhagen Accord in the short term (by 2025), that is within the targets of 315–455 $MtCO_2$.[13] However, going forward, by 2040 only BA2+A+B is below the target range (with about 292 $MtCO_2$ annual energy related emissions). Emissions in BA3+A+B amount to about 354 $MtCO_2$ annually by 2040 (in the 2025 target range), while emission in BA1+A+B increase above the 2025 target, reaching 518 $MtCO_2$. BA3+A+B is also within the NDC target range for 2030, while BA1+A+B is about 35% over it.[14]

5.2. Green recovery policies and coal phase-out

This section considers the impact of 'green' recovery policies ('C' component) on top of the A+B recovery policies, taking account of the different long-term energy policy options. Fig. 4 shows estimated employment and emission impacts for the combined A+B+C recovery policies. Panel (A) on the left shows impacts compared to each of the three energy policy baselines (i.e., the marginal impact of the recovery policies), while Panel (B) shows the combined effect of the recovery and energy policies compared to the BA1 case with no recovery and no energy policy. Results tables for both marginal and overall impacts can be found in the Annex.

Panel (A) of Fig. 4 shows the impacts of the recovery policies. Much of the emissions abatement in the simulated scenarios happens after 2030, which is when the 'green' recovery policies assume an early coal phase-out.

Comparison with Fig. 3 shows that the emissions results are the opposite of what is shown there. Emissions reductions from the 'green' recovery policies are highest in the case of the BA1+A+B+C case (amounting to an overall 1564 $MtCO_2$ reduction), while in the BA1+A+B case the reduction was the lowest compared to the other cases. The explanation for this is that green policies can achieve reductions more easily in this case, because there is no ongoing large-scale energy policy that is already phasing out fossil-based power generation. In the case of the IRP scenarios, the energy policy side already achieves high emission reductions, therefore the additional impact of the green policies is less. The employment impact of the recovery policies (including green elements) is substantially higher in the BA1 energy policy case than in the other cases. But this is due to the fact that here the green recovery policies are inducing the energy system transition because that is promoted through long-term energy policy.

This idea is illustrated by Table 3, where both marginal and total emissions impacts are shown. Total impacts can be disaggregated into direct recovery policy impacts and impacts energy policy (due to potential interactions it is labelled "non-recovery"). The idea, that the place for emission abatement is shifted to green recovery policies in the case of BA1, is clearly illustrated here.

Nevertheless, the table also shows that the marginal emission reduction of the green elements in recovery policies is still considerable across all simulations. Even in the BA2+A+B+C case they add about 411 $MtCO_2$[15] cumulated emission reductions, which is equal to over 94% of the country's annual emissions.[16]

Employment and economic activity increase as well. In the case of BA1+A+B+C this means an average 70,000 additional jobs over the two decades compared to BA1+A+B. Impacts are smaller in the case of BA2+A+B+C and BA3+A+B+C, for the reasons discussed above, but still substantial: about 39,000 additional jobs on average for BA3 and 12,000 additional jobs on average for BA2 (compared to recovery without green elements).

Crucially, the green elements also result in higher GDP in all simulations. The increase is between 0.1 and 0.4% (compared with 2018 GDP) across the scenarios. This is linked to investment needs: while in the A + B case the magnitude of investment was about 27% of 2018 investment levels annually (without energy policy investment), or about R 3 trillion, the investment figure is necessarily higher if the green elements are considered. Estimated investment levels for the scenarios are between R 3.7 and R 4.8 trillion or a 30–40% increase on the 2018 level. If we consider the investment need of energy policies as well, the figures rise to R4.9 to R5.5 trillion, or a 40–45% increase compared to 2018.

6. Some limitations of the analysis

There are various limitations of the analysis, this section is not going to be able to provide a comprehensive list, only some of the most important ones are summarized here. First, as it is noted in Ref. [10] modelling of recovery plans in South Africa takes the planned

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[13] About 24% reduction by 2025 from 2020 targets of 414–599 $MtCO_2$ excluding LULUCF. Based on [48].

[14] NDC target by 2030 is 3–23% increase from 1990 emission levels [48].

[15] Calculated as emissions from recovery that are avoided (46 $MtCO_2$) and actual abatement of recovery (365 $MtCO_2$).

[16] Based on 2021 data.

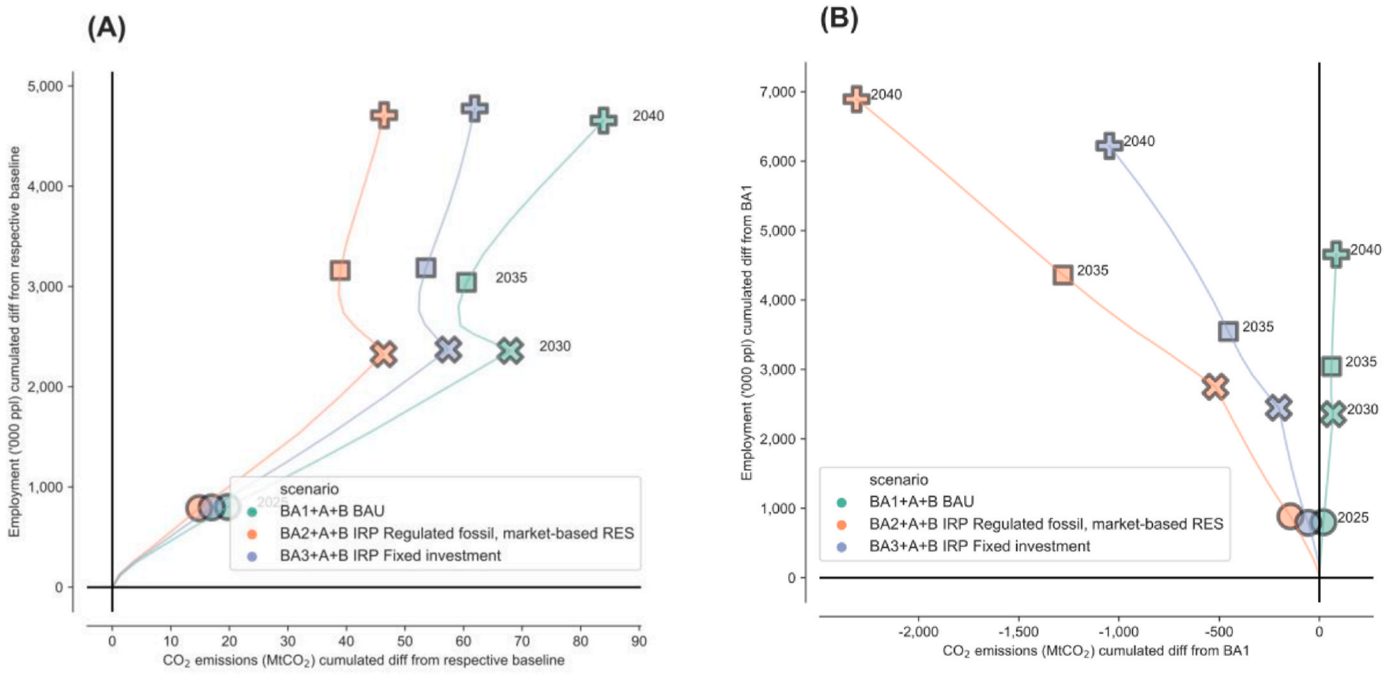

Fig. 3. Panel (A) Difference from respective baseline scenario without recovery policies, combined A + B recovery effects; Panel (B) Difference from BA1 baseline scenario without recovery policies, combined A + B recovery effects.
Source: E3ME simulation results; Note: see also Fig. 1 in the Annex

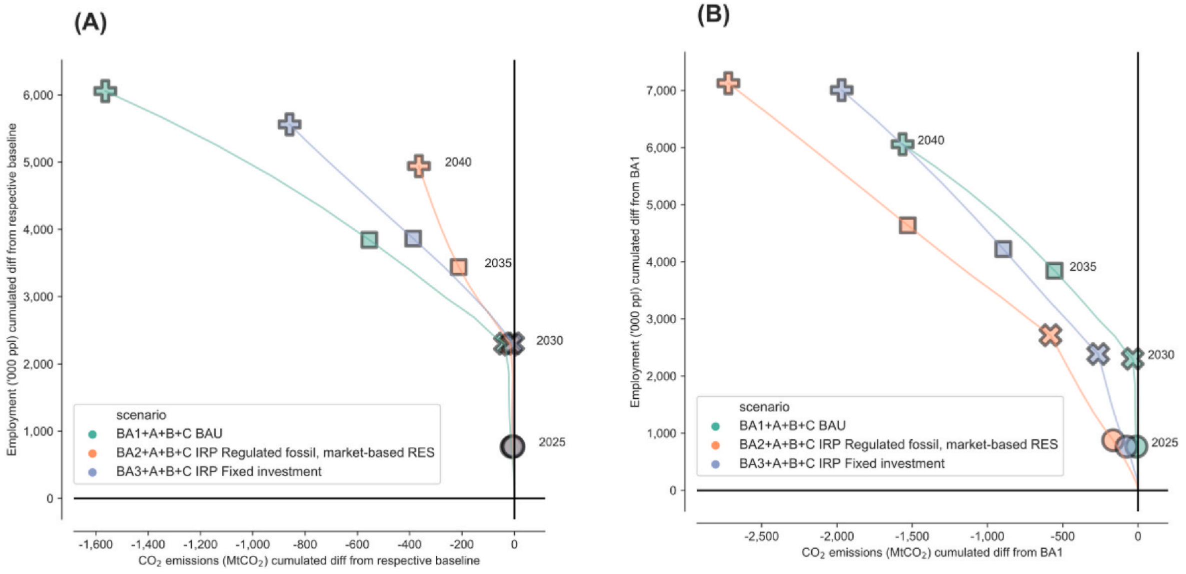

Fig. 4. Panel (A) Difference from respective baseline scenario without recovery policies, combined A + B + C recovery effects; Panel (B) Difference from BA1 baseline scenario without recovery policies, combined A + B + C recovery effects.
Source: E3ME simulation results; Note: see also Fig. 2 in the Annex

investments as exogenous. This means that the source of capital for those investments are not assessed in this exercise. Recovery plans have been talking about both an increasing domestic as well as increasing foreign investment that can support the required capital. Second, similarly the modelling is not able to assess the actual implementation, in terms of efficiency and efficacy, of the modelled policies. The government may fail to efficiently implement a policy or corruption might decrease the actual observable outcomes [49,50]. Hence, in the case of government polices this can be understood as a "best possible" outcome.

More on the technical level, the modelling itself is also constrained. An important limitation of any macroeconomic modelling that uses econometrically estimated parameters is its inability to sufficiently represent structural change. Nevertheless, section 4.1 discusses how this issue, also known as the Lucas-critique [33] is partially avoided by the usage of FTT models.

Finally, this exercise focuses on South Africa and investigates effects of energy and economic policy mostly in a domestic context. However, global developments might also change domestic impacts and outcomes, especially in the medium- and long-term. What this analysis does not consider is whether these effects would be different if the policies would be happening in a world that is committed towards mitigating climate change and would made sure to achieve NDCs and limit global warming.

Table 3
Marginal and total impact of the policies by type of policy Note: values in brackets compare the impact to total emissions in 2021.

Cumulated impact by 2040 of the policies						
Recovery policy	A + B			A + B + C (incl. green)		
Energy policy	**BA1 BAU**	**BA2 IRP regulated fossil, market-based RES**	**BA3 IRP fixed investment**	**BA1 BAU**	**BA2 IRP regulated fossil, market-based RES**	**BA3 IRP fixed investment**
Marginal impact of policies (compared to respective energy policy baseline)						
(A1) Recovery emissions impact ($MtCO_2$)	84 (19%)	46 (11%)	62 (14%)	−1564 (−359%)	−365 (−84%)	−860 (−197%)
Marginal impact of energy policies						
(A2) Energy policy impacts ($MtCO_2$) as [B1]-[A1]	0 (0%)	−2356 (−540%)	−1110 (−255%)	0 (0%)	−2356 (−540%)	−1109 (−254%)
Total impact of recovery and energy policy (compared to BA1 no recovery)						
(B1) Emissions impact ($MtCO_2$)	84 (19%)	−2310 (−530%)	−1048 (−240%)	−1564 (−359%)	−2721 (−624%)	−1969 (−452%)

Then the economy and energy system might react somewhat differently to these polices because of renewable prices might see an even steeper decrease, but also because this could significantly impact fossil fuel and energy transition metals trade of South Africa. These question would merit a separate, future analysis.

7. Conclusion and policy implications

The devastating effects of COVID-19 throughout the world have prompted many countries to implement stimulus packages that could expedite economic recovery. Many countries have been emphasising the integration of green recovery policy measures in order to gain both socio-economic and environmental benefits. However, most of the announced recovery plans have been “colourless”, policies that are thought to have no direct environmental impact.

This paper examines the case of South Africa, which has announced a large-scale and comprehensive stimulus package that is dominated by colourless policies. The paper shows that the environmental impact of “colourless” policies depends on the underlying economic and energy structure. Without a long-term energy policy, colourless recovery policies in South Africa are expected to lead to increasing emissions. But the modelling also shows that if long-term energy policy is successfully implemented, achieving the goals and targets set out in the IRP, then the marginal emission impacts of recovery policies can be cut from 84 $MtCO_2$ to 46 $MtCO_2$. Therefore, while recovery policies have an unquestionable importance for the overall economy, for the purposes of environmental and climate considerations energy policy and the transformation of the energy system is still the major question, especially in countries with high fossil dependence.

Nevertheless, if the implementation of the green elements of the recovery package, especially the phasing-out of coal and the construction of infrastructure for the energy transition, both emissions savings and further positive socio-economic outcomes (jobs and economic activity) can be achieved. The modelling finds that recovery plans, including green elements, combined with IRP, can result in on average + 2.1% more jobs, +8.1% higher GDP and −29.6% less annual emissions over the next twenty years (compared to 2018 levels). Meanwhile, recovery policy, without long-term energy policy and green elements would achieve +1.4% jobs, +5.5% more GDP, but would also increase CO_2 emissions by about +1% annually (again compared to 2018 levels).

The modelling also shows that substantial increases in investment will be needed both for economic recovery plans and for carrying out the energy transition. The total amount of investment estimated ranges between R 3.3 trillion and R 5.5 trillion until 2040. This encompasses both direct (i.e., stimulus) investment and additional investment stimulated by higher economic activity. To put this figure into context, on some estimates the energy transition itself could cost about R 4.5 trillion in the coming three decades [23]. The infrastructure part of the recovery plans could amount to about R 1 trillion additional investment in the next 10 years [10], while overall consolidated government spending is expected to be R 6.62 trillion in the next 3 years in South Africa [12]. Therefore, based on these numbers, it is reasonable to say that the country will need to raise investment equal to about 7–13% of its national budget in the next 20 years to be able to achieve both recovery and energy policy goals.

The recently pledged Just Transition support from other countries amounts only to about R 150 bn over the next 3 years [23], which would therefore cover required investments for only about one year. The analysis therefore emphasises the need for further international support and foreign investments as well as domestic investments to move towards these policy goals. It is also important to note, that if available investment is lacking, this will call into question the achievement of long-term energy policy goals. This will result in continued environmentally damaging emissions and will increase the damage associated with colourless recovery policies.

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CRediT authorship contribution statement

Bence Kiss-Dobronyi: Conceptualization, Methodology, Software, Formal analysis, Investigation, Writing – original draft, Visualization, Project administration. **Margaret Chitiga-Mabugu:** Conceptualization, Writing – review & editing, Resources. **Richard Lewney:** Conceptualization, Writing – review & editing. **Nokulunga Mbona:** Writing – original draft, Investigation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Annex.

Further result tables

Table 1
Cumulated impact by 2040 of the A + B recovery policies compared to respective baselines

Cumulated impact by 2040 of the A + B recovery policies compared to respective baselines	BA1 energy: BAU recovery: A + B	BA2 energy: IRP regulated fossil, market-based RES recovery: A + B	BA3 energy: IRP fixed investment recovery: A + B
Employment			
(A1) Employment impact (FTE-years, thousand), over 20 years, 2021–2040	4655	4708	4776
(A2) Employment (annual average additional jobs, thousand)	232.8	235.4	238.8
(A3) Annual average employment addition [A2] as % of 2018 employment level	+1.39%	+1.40%	+1.42%
Emissions			
(B1) Emissions impact ($MtCO_2$), over 20 years	83.9	46.4	61.9
1(B2) Average annual addition	4.2	2.3	3.1
(B3) Annual average emission addition [B2] as % of 2018 emission level	+0.91%	+0.51%	+0.67%
Economic activity (GDP)[15]			
(C1) Economic activity (GDP, bn ZAR 2010 prices), over 20 years	3495	3528	3526
(C2) Economic activity (annual addition, bn ZAR 2010 prices)	174.8	176.4	176.3
(C3) Annual average GDP addition [C2] as % of 2018 levels	+5.52%	+5.57%	+5.57%
Investment[15]			
(D1) Investment (bn ZAR 2010 prices), over 20 years	3344	3301	3303
(D2) Assumed exogenous investment (average annual, bn ZAR 2010)	31.6	31.6	31.6
(D3) investment (annual addition, bn ZAR 2010 prices)	167.2	165.1	165.2
(D4) Annual average investment addition [D3] as % of 2018 levels	+27.2%	+26.9%	+26.9%

Table 2
Cumulated impact by 2040 of the A + B + C recovery policies compared to respective baselines

Cumulated impact by 2040 of the A + B + C recovery policies compared to respective baselines	BA1 energy: BAU recovery: A + B + C	BA2 energy: IRP regulated fossil, market-based RES recovery: A + B + C	BA3 energy: IRP fixed investment recovery: A + B + C
Employment			
(A1) Employment impact (FTE-years, thousand), over 20 years, 2021–2040	6058	4942	5562
(A2) Employment (annual average additional jobs, thousand)	302.9	247.1	278.1
(A3) Annual average employment addition [A2] as % of 2018 employment level	+1.8%	+1.5%	+1.7%
Emissions			
(B1) Emissions impact ($MtCO_2$), over 20 years	−1564	−365	−860
1(B2) Average annual addition	−78.2	−18.2	−43.0
(B3) Annual average emission addition [B2] as % of 2018 emission level	−17.0%	−4.0%	−9.4%
Economic activity (GDP)[15]			
(C1) Economic activity (GDP, bn ZAR 2010 prices), over 20 years	5350	4021	4569
(C2) Economic activity (annual addition, bn ZAR 2010 prices)	267.5	201.1	228.4
(C3) Annual average GDP addition [C2] as % of 2018 levels	+8.5%	+6.4%	+7.2%
Investment[15]			
(D1) Investment (bn ZAR 2010 prices), over 20 years	4862	3676	4145
(D2) investment (annual addition, bn ZAR 2010 prices)	243.1	183.8	207.3
(D3) Annual average investment addition [D2] as % of 2018 levels	+39.7%	+30.0%	+33.8%

Table 3
Cumulated impact by 2040 of the A + B + C recovery policies and long-term energy policy (IRP) compared to BA1 without recovery

Cumulated impact by 2040 of the A + B + C recovery policies and long-term energy policy (IRP) compared to BA1 without recovery	BA1 energy: BAU recovery: A + B + C	BA2 energy: IRP regulated fossil, market-based RES recovery: A + B + C	BA3 energy: IRP fixed investment recovery: A + B + C
	Employment		
(A1) Employment impact (FTE-years, thousand), over 20 years, 2021–2040	6058	7126	7005
(A2) Employment (annual average additional jobs, thousand)	302.9	356.3	350.3
(A3) Annual average employment addition [A2] as % of 2018 employment level	+1.8%	+2.1%	+2.1%
	Emissions		
(B1) Emissions impact (MtCO_2), over 20 years	−1564	−2721	−1969
1(B2) Average annual addition	−78.2	−136.0	−98.5
(B3) Annual average emission addition [B2] as % of 2018 emission level	−17.0%	−29.6%	−21.4%
	Economic activity (GDP)[15]		
(C1) Economic activity (GDP, bn ZAR 2010 prices), over 20 years	5350	5096	4955
(C2) Economic activity (annual addition, bn ZAR 2010 prices)	267.5	254.8	247.7
(C3) Annual average GDP addition [C2] as % of 2018 levels	+8.5%	+8.1%	+7.8%
	Investment[15]		
(D1) Investment (bn ZAR 2010 prices), over 20 years	4862	5362	5507
(D2) investment (annual addition, bn ZAR 2010 prices)	243.1	268.1	275.3
(D3) Annual average investment addition [D2] as % of 2018 levels	+39.7%	+43.7%	+44.9%

Further result figures

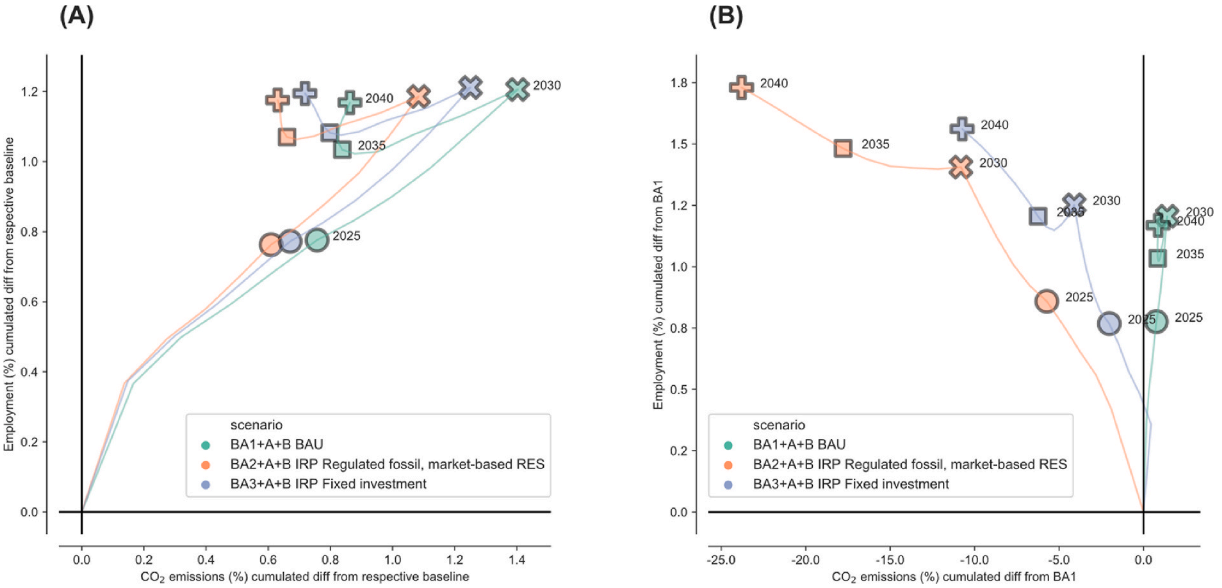


Fig. 1. Panel (A) Difference from respective baseline scenario without recovery policies, combined A + B recovery effects; Panel (B) Difference from BA1 baseline scenario without recovery policies, combined A + B recovery effects
Source: E3ME simulation results

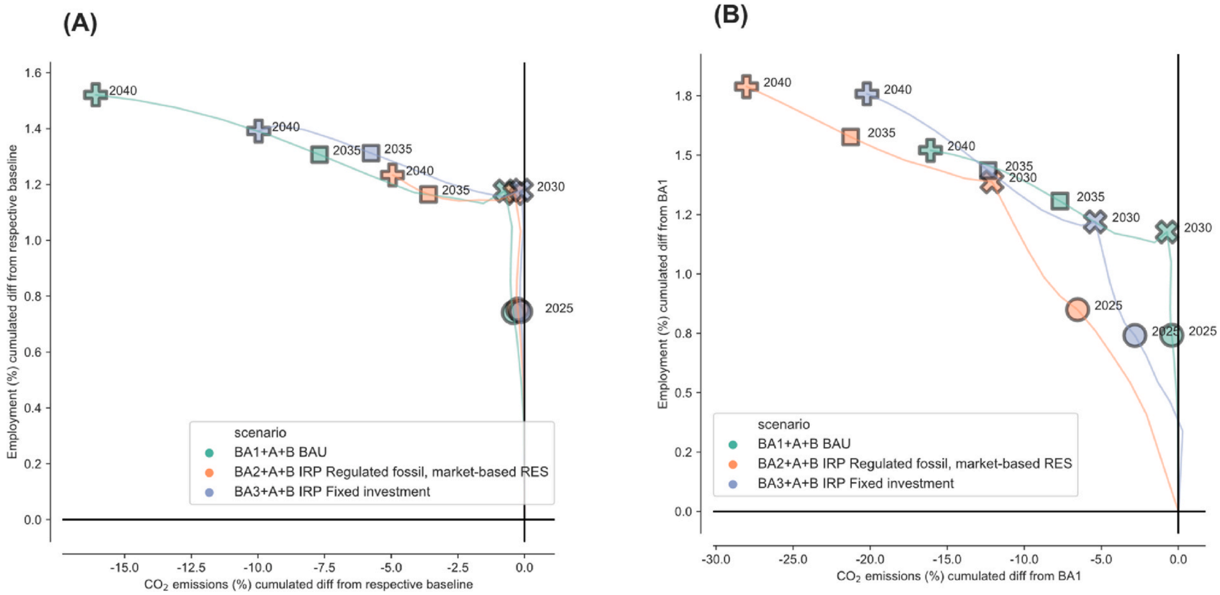


Fig. 2. Panel (A) Difference from respective baseline scenario without recovery policies, combined A + B + C recovery effects; Panel (B) Difference from BA1 baseline scenario without recovery policies, combined A + B + C recovery effects
Source: E3ME simulation results

Socio-economic impacts of the IRP baselines (BA2, BA3) no recovery compared to endogenous baseline (BA1 no recovery)

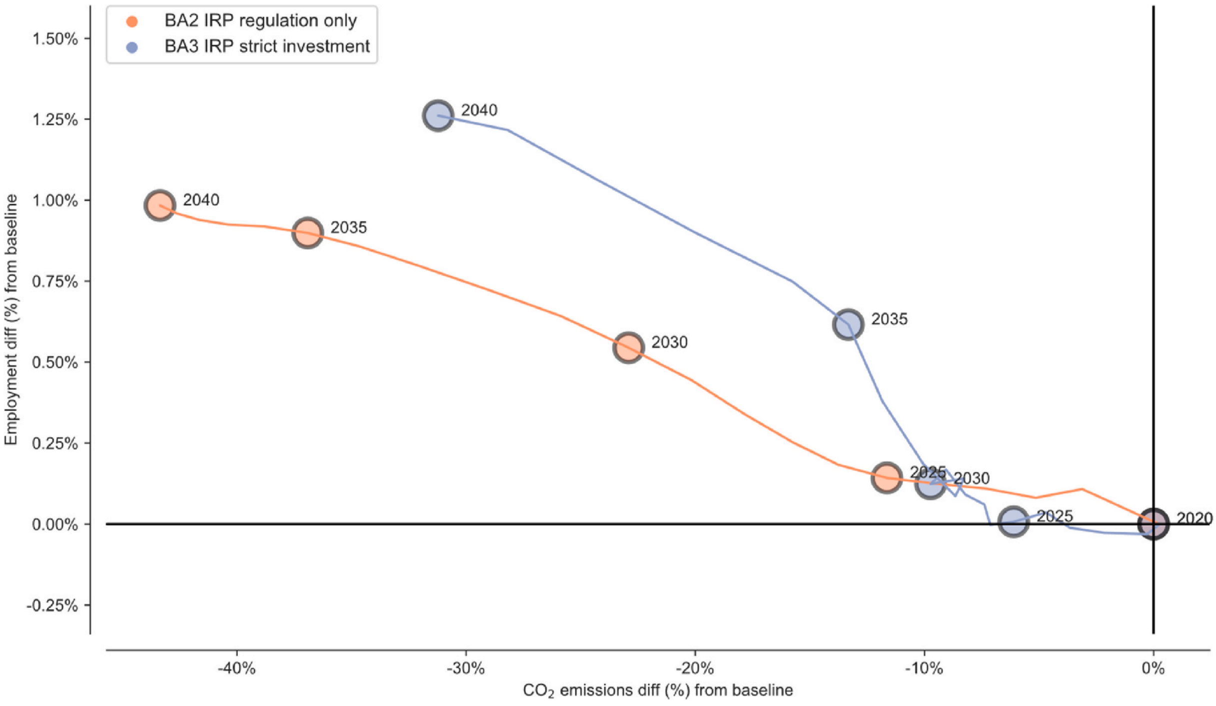


Fig. 3. Employment and CO$_2$ emission impacts in the IRP baselines (BA2-BA3) compared to the endogenous baseline (BA1)
Source: E3ME Simulation Results

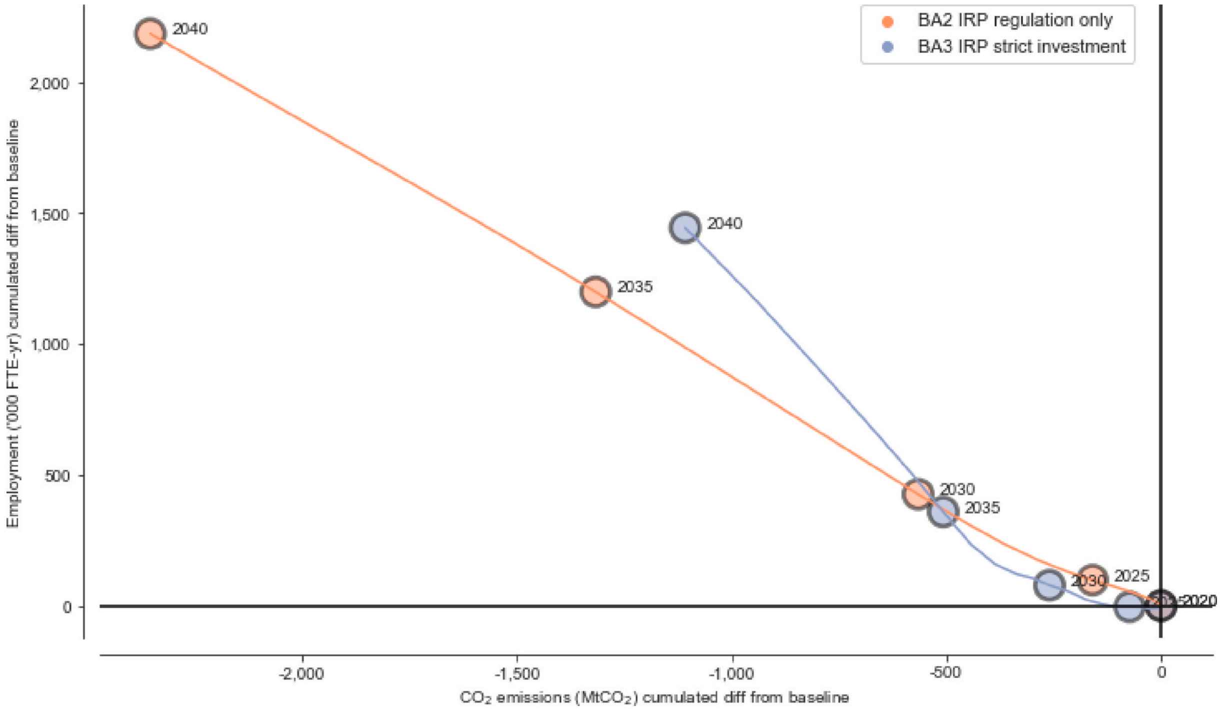


Fig. 4. Employment and CO_2 emission impacts in the IRP baselines (BA2-BA3) compared to the endogenous baseline (BA1) **cumulated**
Source: E3ME Simulation Results

All modelled scenarios

Table 4
All scenarios modelled, with baseline used and recovery policies used indicated

Scenario code	Long-term energy policy baseline used	Recovery policies used
BA1	BA1	None
BA1+A	BA1	A
BA1+B	BA1	B
BA1+C	BA1	C
BA1+A + B	BA1	A + B
BA1+A + B + C	BA1	A + B + C
BA2	BA2	None
BA2+A	BA2	A
BA2+B	BA2	B
BA2+C	BA2	C
BA2+A + B	BA2	A + B
BA2+A + B + C	BA2	A + B + C
BA3	BA3	None
BA3+A	BA3	A
BA3+B	BA3	B
BA3+C	BA3	C
BA3+A + B	BA3	A + B
BA3+A + B + C	BA3	A + B + C

Energy system development assumptions

Table 5
Installed power generation capacity (MW), defined based on IRP, BA3 Fixed investment case

Year	Nuclear	Coal	Gas	Hydro	Wind	PV	CSP
	If value specified, then set by assumption						
2019	1.86	36.9	3.83	2.1	2.22	1.47	0.6
2020	1.86	37.8	3.83	2.1	2.52	1.59	Endogenously determined by FTT:Power
2021	1.86	37.8	3.83	2.1	3.34	1.89	
2022	1.86	37.7	3.83	2.1	4.94	3.29	
2023	1.86	37.9	3.83	2.1	6.54	4.29	
2024	1.86	37.9	4.83	2.1	8.14	4.29	
2025	1.86	37.9	4.83	2.1	9.74	5.29	
2026	1.86	36.7	4.83	2.1	11.34	5.29	

(*continued on next page*)

Table 5 (*continued*)

Year	Nuclear	Coal	Gas	Hydro	Wind	PV	CSP
	If value specified, then set by assumption						
2027	1.86	36.6	6.83	2.1	12.94	5.29	
2028	1.86	36.1	6.83	2.1	14.54	6.29	
2029	1.86	34.4	6.83	2.1	16.14	7.29	
2030	1.86	33.4	6.83	4.6	17.74	8.29	
2031	1.86	33.1	Endogenously determined by FTT:Power	Endogenously determined by FTT:Power	Endogenously determined by FTT:Power	Endogenously determined by FTT:Power	
2032	1.86	32.7					
2033	1.86	30.8					
2034	1.86	29.5					
2035	1.86	28.9					
2036	1.86	27.7					
2037	1.86	25.1					
2038	1.86	23.2					
2039	1.86	21.3					
2040	1.86	20.0					

Table 6

Installed power generation capacity (MW), defined based on IRP, BA2 Regulated fossil, market-based renewables case

Year	Nuclear	Coal	Gas	Hydro	Wind	PV	CSP
	Set by assumption	*Maximum capacity regulated*					
2019	1.86	36.9	3.83	2.1	2.22	1.47	0.6
2020	1.86	37.8	Endogenously determined by FTT:Power				
2021	1.86	37.8					
2022	1.86	37.7					
2023	1.86	37.9					
2024	1.86	37.9					
2025	1.86	37.9					
2026	1.86	36.7					
2027	1.86	36.6					
2028	1.86	36.1					
2029	1.86	34.4					
2030	1.86	33.4					
2031	1.86	33.1					
2032	1.86	32.7					
2033	1.86	30.8					
2034	1.86	29.5					
2035	1.86	28.9					
2036	1.86	27.7					
2037	1.86	25.1					
2038	1.86	23.2					
2039	1.86	21.3					
2040	1.86	20.0					

Elements of recovery policies

Table 7

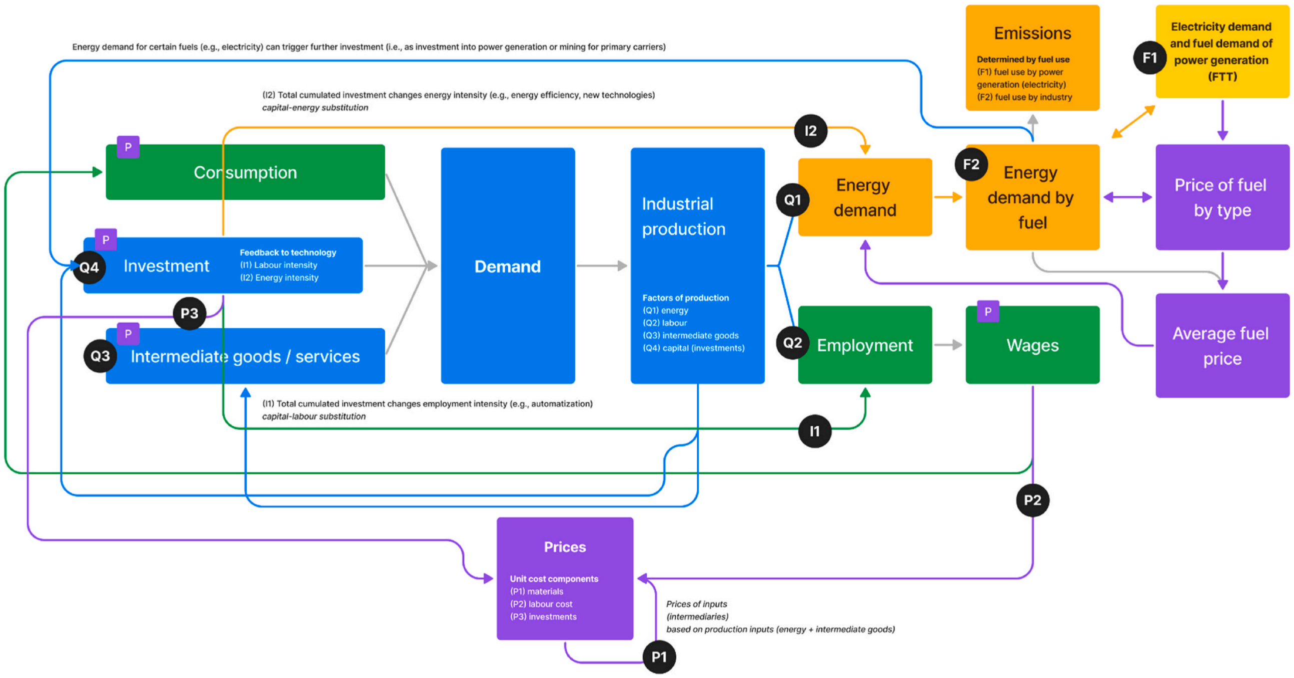
Components of modelled policy packages and magnitudes, monetary measures are in R bn (2020 price) unless otherwise stated (continued on next page)

Scenario component	Measure	Modelling instrument	Target sectors	Comment	Total over 10 years
(A) Conventional policies	Infrastructure investment	Net additional investment in the economy (exogenous + endogenous response)	Agriculture, road transport, construction, water transport, water supply, public admin & defence, telecommunications		760.4
		Government spending on investment (reallocated from baseline government spending)		Slightly over 10% due to model dynamics	85.9
	Localisation measures	Assumed FDI investment due to localisation (exogenous investment)	Mining, textiles, wood products, pharmaceuticals, rubber & plastics, metal goods, electronics, vehicles, other transport equipment		10.5
		Reduction of imports (by value) in the target sectors		In % of import value	10.0
	Relief to selected sectors	Government subsidy to selected sectors (negative taxation)	Hotels & catering, land transport, water transport, air transport, miscellaneous services	Modelled through negative taxation, government tax revenues drop	15.0
	Food vouchers	Exogenous food consumption boost	Food household consumption		50.0

Table 8
Components of modelled policy packages and magnitudes, monetary measures are in R bn (2020 price) unless otherwise stated (continued from previous page)

Scenario component	Measure	Modelling instrument	Target sectors	Comment	Total over 10 years
(B) Public works	Public works programme	Exogenous employment increase in selected sectors	Agriculture, forestry, water supply, construction, land transport, professional services, public administration & defence, education, health & social work, miscellaneous services	In additional FTE employment in the given year	1531.0
				In additional "work opportunities" created	4593.0
		Government financing to selected sectors (e.g., government pays for job creation in these sectors)			67.7
(C) Green policies	Energy efficiency improvement	Energy demand reduction	Electricity, natural gas, oil in households and other final-use (commercial)	Compared to baseline, not cumulative	10%
		Government investment to energy efficiency	Public administration, construction		11.7
		Government investment to grid improvement	Electricity	Assumed to be grid improvement and energy storage solutions	42.3
	Capital subsidies for RES	Capital subsidy for wind and solar power	Solar and wind technology	In % of capital costs, not cumulative	20%
		Government subsidy amount			10.1
		Total RES investment public + private (not assumption!)			217.2
		Total new RES investment public + private (result not assumption!)			152.1

More detailed representation of linkages in the E3ME model



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