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The impact on the South African economy of alternative regulatory arrangements in the petroleum sector

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The collaboration is between the United Nations University World Institute for Development Economics Research (UNU-WIDER), the National Treasury of South Africa, the International Food Policy Research Institute (IFPRI), the Department of Monitoring, Planning, and Evaluation, the Department of Trade and Industry, South African Revenue Services, Trade and Industrial Policy Strategies, and other universities and institutes. It is funded by the National Treasury of South Africa, the Department of Trade and Industry of South Africa, the Delegation of the European Union to South Africa, IFPRI, and UNU-WIDER through the Institute's contributions from Finland, Sweden, and the United Kingdom to its research programme.

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The impact on the South African economy of alternative regulatory arrangements in the petroleum sector

Heinrich Bohlmann[1] and Rod Crompton[2]

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Abstract: This paper adds quantitative analysis to the study by Crompton et al. (2020), in which various alternative regulatory arrangements regarding the petrol price in South Africa were explored. We use a multi-sector dynamic computable general equilibrium model for South Africa to conduct our economic impact analysis. Five scenarios are modelled, first individually to correctly calibrate the shocks, and then cumulatively to find the overall economy-wide effects of the proposed reforms. Under the most comprehensive set of reforms to the determination of petrol prices, which seeks to emulate market forces, the South African economy is seeing substantial benefits. GDP is expected to rise by 0.67 per cent and real wages by over 1.1 per cent relative to the baseline. Refineries are assumed to shrug off reforms targeted at removing pure profits earned via the import parity price (Basic Fuel Price) methodology by accepting a slightly lower rate of return, enabling them to meet the expected increase in demand for petrol on the back of the lower consumer prices achieved via the reforms. Whilst job losses at fuel service stations may be expected as a result of reduced revenues and margins, increased activity and job opportunities in the rest of the economy, facilitated through cheaper trade and transport margins, will more than offset those losses.

Key words: computable general equilibrium, economic impact, petrol price, South Africa

JEL classification: C68, K23, L59, D40

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1 Introduction

1.1 Background

The South African Government has intervened in and/or regulated markets involved in the manufacture, distribution, and retailing of liquid fuels in various ways since the 1930s. Since the Second World War the retail price of petrol has been a target of these interventions and its price has been regulated for most of the period since that time. Interventions in the diesel, paraffin, and LPG markets have followed patterns set by petrol price regulation.

Since the advent of democracy in 1994 the government of South Africa has been concerned by above-inflation increases in 'administered prices'. Transport fuels are an important driver of living costs for many black South Africans, who suffer from the legacy of apartheid town planning that had them reside far from their workplaces. This is one of the ways in which the regulated or 'administered' petrol price acts as a key intermediate input in the economy. The National Development Plan 2030 called for better regulation of petroleum product prices (RSA 2012: 164) and the National Treasury believes that 'fuel price regulation should be reviewed in its entirety' (RSA 2019: 33).

This paper is the second in a series of Working Papers commissioned by UNU-WIDER that are concerned with the nature of petrol price regulation, the policy informing it, and the impact on the economy of regulated petrol prices. The first paper, entitled 'Petrol Price Regulation in South Africa: Is it Meeting its Intended Objectives?' set out the regulatory background and history of petrol price regulation (Crompton et al. 2020). It found that 'Government policy in the petrol market over about 90 years appears to have been consistently driven by import substitution industrialization objectives and the desire to support profitability for investors along the downstream value chain rather than the protection of consumers against excessive pricing'. (Crompton et al. 2020: 44). It pointed out that, although formal government policy adopted in 1998 required the petrol price to be deregulated (RSA 1998), this had not yet happened.

Crompton et al. (2020) examined the key elements in petrol price regulation in South Africa: the import parity pricing methodology known as the Basic Fuel Price (BFP) and the wholesale, retail, and distribution elements encompassed within the Regulatory Accounting System (RAS). It found that the BFP was not updated regularly as local and global markets changed, and that the RAS contains methodological errors and apparently over-generous margins, leading to the misallocation of capital in the economy. The paper also raised concerns about the institutional design of petrol price regulation, resting as it does in the hands of the Minister of Energy rather than a modern independent regulator or commission. Moreover, social policy objectives have become intertwined with petrol price regulation over the last 20 years. They include the protection of low-value-adding jobs (forecourt attendants) and the protection or promotion of small businesses in the retail or service station sector as well as black economic empowerment. These social policy objectives, together with the institutional design of petrol price regulation, may account for the lack of progress towards prices determined by market forces.

This paper seeks to build upon the analysis in Crompton et al. (2020) by measuring the impact on the economy of various petrol pricing scenarios based on information provided in that paper. The scenarios range from modest tweaking of the existing regulatory instruments to one that seeks to emulate competitive market pricing.

Petrol price regulation is the most detailed and all-encompassing of all liquid fuel regulations in South Africa. Diesel retail prices are not regulated at all, although the government publishes guideline prices. Paraffin and LPG have regulated price caps, all following patterns of regulation led by petrol price regulation. Thus, although this paper focuses on the impact on the economy of petrol pricing, it is our view that if petrol prices were deregulated, this would also be the case for other fuels, as it would be much more difficult for government to defend its market interventions in that case. Consequently, the economic impacts would be more substantial than those caused by just the petrol price changes modelled in this study.

1.2 Scenarios

This paper examines the economy-wide impact of several petrol pricing scenarios based on the analysis in Crompton et al. (2020). They are based on the distinctive elements of the regulated petrol price (Table 1).

Table 1: Elements of the regulated petrol price

Generic term	Regulatory term	Acronym	Petrol (93 ULP) cpl in Feb 2020 (Gauteng)	%	Notes
Import parity price	Basic fuel price	BFP	665.0	42.3%	
Regulatory accounting system					
Wholesaling, distribution and retailing	Regulatory Accounting System	RAS			
Wholesale margin	Wholesale margin		35.7	2.3%	
Secondary storage	Secondary storage		23.0	1.5%	
Road and rail transport costs	Secondary distribution		15.2	1.0%	
Retail margin	Retail margin		211.6	13.5%	
Cost to transport inland	Zone differential in Gauteng		57.4	3.7%	Based on pipeline tariff regulated by NERSA
Rounding of fractions	Pump rounding		-0.2	0.0%	Regulated prices are rounded to the nearest cent.
Taxes and levies					
Fuel tax	Fuel levy	GFL	361.0	23.0%	
Customs & excise duty	Customs & excise duty		4.0	0.3%	
Road accident insurance	Road Accident Fund levy	RAF levy	198.0	12.6%	
Regulator's revenue	NERSA levy	NERSA levy	0.3	0.0%	Levy on fuel transported in petroleum pipelines for benefit of NERSA
Retail price	Retail price		1571.0	100.0%	

Note: cpl = cents (ZAR) per litre; NERSA = National Energy Regulator of South Africa.

Source: authors' calculations based on data from Department of Mineral Resources and Energy, Media Statement, 31 January 2020.

In assembling the scenarios certain elements of the petrol price were excluded, as follows:

- Taxes and levies, which are imposed on the petrol price by the Minister of Finance and are not within the purview of the petrol price regulator.
- Transport costs from the coast to Gauteng, which are based on the pipeline tariff set by NERSA, a separate and independent regulator. Pipelines are natural monopolies and are likely to remain regulated even in a price-deregulated market.
- Pump rounding, as it concerns only a fraction of 1 cent per litre and is not material as a proportion of the retail price.

The elements for which prices were changed in the scenarios modelled were confined to those of the BFP and the RAS, as set out in Table 2 and Table 3.

Table 2: BFP elements

Element	**Clarification**	**Changed for scenario modelling**
Free on board	Cost of petrol delivered to vessel at port of lading	✓
Freight costs	Shipping cost	✓
Insurance	Insurance of petrol cargo	-
Demurrage	Demurrage	✓
Product loss / Ocean loss	Loss of product through evaporation whilst at sea	✓
Stock financing	Working capital costs in financing purchase of petrol	-
Cargo dues	Wharfage charges at South African ports	-
Coastal storage	Cost of storing petrol discharged from vessels in South African ports	✓

Source: authors' elaboration derived from RSA (2008).

Table 3: RAS elements[1]

Element	**Clarification**	**Changed for scenario modelling**
WACC	Weighted average cost of capital	✓
CAPM	Capital asset pricing model	✓
Gearing	Debt:equity ratio	✓
Entrepreneurial compensation	Additional return to investor	✓
Benchmark service station operating costs	Benchmark service station operating costs	✓

Source: authors' elaboration derived from RSA (2020).

The scenarios modelled and the BFP and RAS elements affected in each scenario are set out in detail in Appendix A. A summary of each scenario is given below for quick reference. It should be noted that no changes to the rather substantial tax component of fuel are considered. That is, taxes such as the General Fuel Levy and Road Accident Fund remain exogenous in the modelling of the various scenarios. Scenarios 1 to 4 emulate possible cumulative modifications to the regulatory methodologies used, whilst Scenario 5, building on the previous four scenarios, ultimately seeks to emulate prices determined by market forces.

[1] See Crompton et al. (2020) for details.

Scenario 0 assumes no change to the petrol price regulatory methodologies in force as of February 2020. This scenario may be interpreted as the business-as-usual baseline scenario of the computable general equilibrium (CGE) model.

Scenario 1 assumes that the changes to the BFP advocated by the DoE in its discussion paper (RSA 2018) were implemented. These changes concern shipping and delivery costs rather than the FOB price at the port of lading. Consequently, Scenario 1 models a 9 cents per litre (cpl) total reduction in the BFP component of the final purchase price of fuel. Relative to the February 2020 benchmark price, this equates to a 0.57 per cent reduction in the price of fuel at the pump.

Scenario 2 makes the same assumptions as Scenario 1 and further assumes that the source of petrol is shifted 100 per cent to the Arabian Gulf. Consequently, Scenario 2 models an 18 cpl total reduction in the BFP component of the final purchase price of fuel. Relative to the February 2020 benchmark price, this equates to a cumulative 1.15 per cent reduction in the price of fuel at the pump.

Scenario 3 makes the same assumptions as Scenario 2 and further assumes that the errors in the RAS methodology are corrected. Consequently, Scenario 3 models an 18 cpl total reduction in the BFP and a 8.57 cpl reduction in the RAS component of the final purchase price of fuel. The final purchase price of fuel is therefore reduced by 26.57 cpl. Relative to the February 2020 benchmark price, this equates to a cumulative 1.69 per cent reduction in the price of fuel at the pump.

Scenario 4 makes the same assumptions as Scenario 3 and further assumes reduced RAS operating costs and a more realistic RAS weighted average cost of capital (WACC) with 50 per cent debt. Consequently, Scenario 4 models an 18 cpl total reduction in the BFP and a 50.29 cpl reduction in the RAS component of the final purchase price of fuel. The final purchase price of fuel is therefore reduced by 68.29 cpl. Relative to the February 2020 benchmark price, this equates to a cumulative 4.35 per cent reduction in the price of fuel at the pump.

Scenario 5 makes the same assumptions as Scenario 4 except that the RAS gearing is set at 70 per cent debt and RAS staffing costs are reduced by 30 cpl (Crompton et al. 2020: 17) by using a low estimate of the number of forecourt staff. This scenario seeks to emulate prices determined by market forces. Consequently, Scenario 5 models an 18 cpl total reduction in the BFP and an 85.82 cpl reduction in the RAS component of the final purchase price of fuel. The final purchase price of fuel is therefore reduced by 103.82 cpl. Relative to the February 2020 benchmark price, this equates to a cumulative 6.61 per cent reduction in the price of fuel at the pump.

2 CGE methodology

2.1 Overview

CGE models have become an indispensable tool in quantifying the economy-wide impacts of an exogenous shock or policy change. The combination of a rigorous theoretical specification describing the optimizing behaviour of agents in the economy and a multi-sector database that describes the structure of the economy permits a credible and detailed impact analysis. Given the very specific regulatory changes to the fuel pricing formula proposed in this study and its potential for far-reaching general equilibrium effects, CGE modelling is an appropriate choice of methodology to quantify and analyse the various scenarios developed in Crompton et al. (2020).

For readers unfamiliar with the CGE methodology, a good starting point is to think of a detailed snapshot of the economy that describes all the inter-linkages between buyers and sellers in a typical year. This picture of the structure of the economy—represented by the model's core database—is based on large and suitably detailed datasets such as input–output tables, supply–use tables, or a social accounting matrix. CGE models are not simply big databases, though. In order to credibly analyse the effects of exogenous shocks on the economy, theory describing the behaviour of all agents recognized in the model database is specified through a comprehensive system of equations in combination with a valid model closure. It follows that the impact of resource constraints and relative price changes on behaviour are explicitly modelled and accounted for.

A CGE model is therefore a tool that allows us to analyse how the structure or unperturbed baseline path of the economy will change over time in response to a shock. Technically, two simulations are required to achieve this. The first is the baseline run, in which a business-as-usual path for the economy is specified on the basis of available forecasts from specialist institutions. The second is the policy run, which adds the exogenous shock to be investigated. Simulation results are then typically reported as the percentage change deviation in the underlying value of variables between the unperturbed baseline run and perturbed policy run. When explaining the results of CGE simulations, modellers consider only the database, theory, and closure of the model.

We use the University of Pretoria General Equilibrium Model (UPGEM) to simulate the economy-wide effects of the alternative fuel pricing scenarios developed in Crompton et al. (2020) and briefly described again in the previous section. The version of UPGEM used in this study is a CoPS-style dynamic CGE model for South Africa solved using the GEMPACK platform.[2] The database that underpins the model's theoretical specification is for the base year 2017. Original data from the supply and use tables for 2017 published by Statistics South Africa were used to build the model's core database (StatsSA 2019). Additional detail for occupation groups, multiple households, and different direct and indirect tax types were also incorporated in the master database using various data sources (SARB 2019; StatsSA 2016a, 2016b, 2019).

For this study, the master database was aggregated to 56 industries and commodities and a single representative household.[3] The aggregated version of the database preserves key industry-level detail without encumbering users and readers with unnecessary detail. The methods used to build the database largely follow those described in Roos et al. (2015).

2.2 Theoretical specification of UPGEM

Based on the MONASH model described in Dixon and Rimmer (2002), the system of equations that make up UPGEM describes the theory underlying the behaviour of participants in the economy. It contains equations describing (i) industry demands for primary factors and intermediate inputs; (ii) final household, investment, government, and foreign demand for commodities; (iii) pricing in the economy which sets pure profits from all activities to zero; (iv) market clearing equations for various primary factors and commodities; and (v) miscellaneous or

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[2] The Centre of Policy Studies (CoPS) is a leading research unit in Melbourne, Australia, that specializes in the development and application of CGE models and accompanying GEMPACK solution software. The theoretical specification of UPGEM is based on the MONASH model developed at CoPS and described in Dixon and Rimmer (2002) and Dixon et al. (2013). The GEMPACK solution software is described in Horridge et al. (2013).

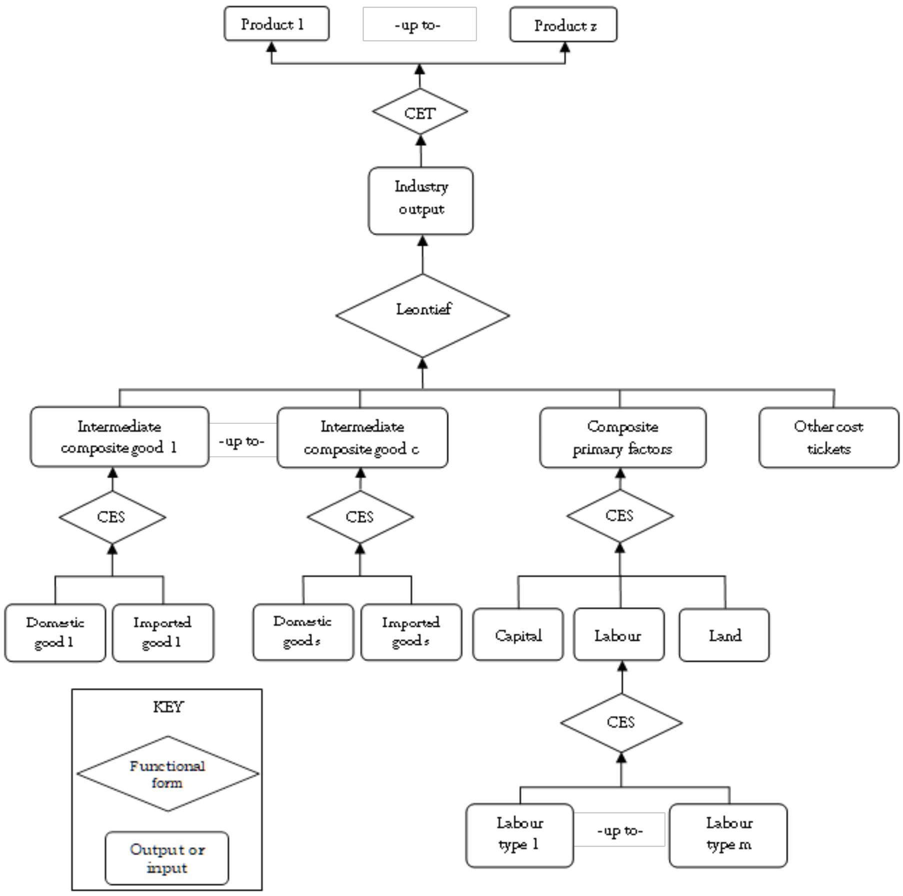
[3] See Appendices B and C for a detailed description of the structure and dimensions of the model database.

definitional items such as GDP, aggregate employment, consumer price index (CPI), and the current account deficit.

UPGEM allows each industry to produce several commodities, using as inputs combinations of domestic and imported commodities, and different types of labour, capital, and land. The multi-input, multi-output production specification is kept manageable by a series of separability assumptions, illustrated by the nesting shown in Figure 1. This nested production structure reduces the number of estimated parameters required by the model.

Optimizing equations determining the commodity composition of industry output are derived subject to a CET function, while functions determining industry inputs are determined by a series of nests. At the top level, intermediate commodity composites and a primary-factor composite are combined using a Leontief or fixed proportions production function. Consequently, they are all demanded in direct proportion to industry output or activity. Each commodity composite is a CES function of a domestic good and its imported equivalent. This incorporates Armington's assumption of imperfect substitutability for goods by place of production (Armington 1969). The primary-factor composite is a CES aggregate of composite labour, capital, and land, with composite labour itself a CES aggregate of different labour types. Although all industries share this common production structure, input proportions and behavioural parameters may vary between industries.

Figure 1: Structure of production for a representative industry in UPGEM



Source: authors' elaboration based on Dixon and Rimmer (2002: 191).

Demand and supply equations for industries and households are derived from the solutions to the optimization problems which are assumed to underlie the behaviour of private sector agents in conventional neo-classical microeconomics. Each industry minimizes costs subject to given input prices and a constant returns-to-scale production function. Households maximize a Klein-Rubin utility function subject to their budget constraints. Units of new industry-specific capital are determined as cost-minimizing combinations of domestic and imported commodities. Imperfect substitutability between sources of commodities is modelled using the Armington CES assumptions. The export demand for any local commodity is inversely related to its foreign-currency price. The price of imports is exogenously determined, consistent with the assumption of South Africa being a small open economy. Government consumption and the details of direct and indirect taxation are also recognized in the model. In the standard model, markets are assumed to be competitive, which implies that zero pure profits are captured in any sector or activity.

Variations to the typical structure of the model as just described can be implemented relatively easily based on the requirements of the simulation. For example, it is common in the energy literature to include a separate nest for energy alongside capital and labour in the primary-factor composite nest. However, for the purposes of this study, the standard theoretical structure of the model was adequate given our choice of simulation design and implementation strategies. Only minor additions to the model code were necessary to capture the details of each policy simulation.

An important feature of UPGEM relevant to this study is that it models the different price components of goods and services individually. Final purchase prices are determined as the sum of the basic price, indirect sales taxes, and trade and transport margins. In principle, the basic price distinguishes the amount received by the producer from the amount paid by the final consumer. The balance is made up of a set of sales taxes payable to government, and trade and transport margins payable to the providers of those services. This allows policy shocks to affect only a specific component of the final price or the decomposition of simulation results of commodity prices between these three components.

The dynamic elements of UPGEM permit inter-temporal links describing (i) physical capital accumulation; (ii) financial asset/liability accumulation; and (iii) lagged adjustment processes for labour. Capital accumulation is specified separately for each industry and linked to industry-specific net investment. Investment in each industry is positively related to its expected rate of return on capital. An industry's end-of-year capital stock is therefore calculated as the sum of start-of-year capital stock plus investments during the year minus depreciation. End-of-year *t* capital stock then determines start-of-year *t+1* capital stock. Thus, investment in this period affects only capital stock in the next period. A similar mechanism for financial asset/liability accumulation is specified. Adjustments to the national net foreign liability position of households are related to the annual investment/savings imbalance, revaluations of assets and liabilities, and remittance flows during the year. Changes in the public sector debt are related to the public sector deficit incurred during the year. In policy simulations, the labour market follows a lagged adjustment path where wage rates are allowed to respond over time to gaps between demand and supply for labour. The speed of adjustment parameter in the wage adjustment equation is useful as it implicitly permits more accurate modelling of scarce skilled workers versus abundant lower-skilled workers.

Containing thousands of lines of computer code describing many equations and variables, UPGEM is too large to be fully documented in this study. In the following section we give a stylized 'back-of-the-envelope' representation of the theoretical structure of the core model. This allows us to describe the most important macroeconomic relationships and basic functioning of the model without burdening the reader with too much detail for an understanding of the full model. A more detailed exposition and discussion of the capital and labour market theory in UPGEM is also provided after the BOTE model.

2.3 Stylized representation of UPGEM

Equations (EQ1–EQ21), shown in Table 4, describe the key macroeconomic relationships in UPGEM. This system of equations will hereafter be referred to as the BOTE model. Miniature models such as BOTE have become a popular method for presenting and explaining the core elements in CGE models. The BOTE model's simple and compact nature is also useful when interpreting simulation results produced by the full model.

Table 4: The BOTE model: a stylized representation of UPGEM

Equation	LHS		RHS
BOTE static component			
EQ1	GDP	=	C + I + **G** + (X-M)
EQ2	GDP	=	**A***f(**K**, L)
EQ3	C	=	**APC***HINC
EQ4	HINC	=	GDP*f(TofT)*(1-**TQ**) – (**BTRW**.L)***TL** – (**NFLH***R**)
EQ5	GINC	=	GDP*f(TofT)***TQ** + (**BTRW**.L)***TL** – **NFLG***R**
EQ6	GNDI	=	HINC + GINC
EQ7	M	=	f(GDP, TofT, **TWS**)
EQ8	TofT	=	PX/**PM**
EQ9	PX	=	f(X, **F_X**)
EQ10	PY	=	f(**CPI**, TofT)
EQ11	I/**K**	=	R_IK
EQ12	I	=	f(RoR, **F_I**)
EQ13	RoR	=	f(**K**/L, TofT, **A**)
EQ14	**BTRW**	=	f(**K**/L, TofT, **A**)
EQ15	ATRW	=	**BTRW** *(1-**TL**)
EQ16	L	=	L_S – **U**
BOTE dynamic component			
EQ17	ΔK	=	I – **DEP***K**
EQ18	ΔNFLG	=	**G** – GINC
EQ19	ΔNFLH	=	I – (1-**APC**)*HINC
EQ20	ΔATRW	=	f(L, L_S)
EQ21	L_S	=	f(ATRW, **ΔL_PREF**)

Note: exogenous variables in bold.

Source: authors' elaboration.

In BOTE, equations (EQ1–EQ16) describe variables within any given year of a dynamic simulation. Equations (EQ17–EQ19) describe how key stock variables move through time and hold between any two successive years of a dynamic simulation. Equations (EQ20–EQ21) describe the real wage adjustment mechanism applicable to policy simulations.

Equation (EQ1) is the well known identity describing real gross domestic product (GDP) from the expenditure side. In South Africa, private households contribute around 60 per cent to GDP, with investment and government expenditure each contributing roughly 20 per cent. The balance of trade (X–M) typically shows a deficit, but for the model's 2017 base year South Africa achieved a slight trade surplus. Equation (EQ2) describes an economy-wide constant returns-to-scale production function, relating real GDP from the supply side to inputs of capital, labour, and primary-factor-augmenting technical change. In South Africa, compensation of employees carries a slightly larger share of GDP at factor cost than gross operating surplus.

Equation (EQ3) relates private household expenditure (C) to household disposable income via the average propensity to consume. Equations (EQ4) and (EQ5) define real household disposable income (HINC) and government revenue (GINC), respectively. HINC is defined as total income available for household expenditure after taking into account tax and net foreign liability payments. GINC is defined as the sum of all production and labour taxes collected minus any interest payments by government on its foreign liabilities. The first term in both these equations describes the value of real GDP, which could be expressed as [(GDP*PY)/CPI]. PY (the price of economy-wide output) measures the average price level of GDP and as such contains no information on import prices. PY does, however, incorporate prices of domestically produced exports. In contrast, the CPI contains no information on export prices, but does include import prices. We can therefore interpret [PY/CPI] as a function of the terms of trade (TofT) and write this component as GDP*f(TofT). Equation (EQ6) confirms that (EQ4) and (EQ5) exhaust all claims on gross national disposable income (GNDI).

Equation (EQ7) relates imports (M) to the level of GDP, TofT, and an import/domestic preferences twist variable. TofT is defined in (EQ8) as the foreign-currency price of domestically produced exports relative to the price of imports. Commodity exports in UPGEM are inversely related to foreign-currency prices via constant elasticity demand functions. This is summarized by (EQ9), which relates the foreign-currency price of exports (PX) to the volume of exports and an export-demand shift variable. This is consistent with the assumption of South Africa being an open economy facing downward-sloping demand curves for its exports. This allows us to incorporate appropriate export demand elasticities for South African commodities in UPGEM. Import prices are exogenous as South Africa is considered a price-taker in the global import market.

In our determination of (EQ10) we write the percentage change of the economy-wide output price as $P_Y = [S_A P_A + S_X(P_X – P_M)]$. Following the notation employed by many CoPS-style CGE modellers, S_A and S_X reflect the share of absorption and exports in the economy, while P_Y, P_A, P_X, and P_M represent the percentage change in the price of their respective upper-case variables. For BOTE we assume that the price of absorption is reflected in the CPI, and that trade is balanced. From here we are able to write equation (EQ10), which relates PY to the CPI and TofT. PY may also be interpreted as the GDP deflator.

Equation (EQ11) defines the investment capital ratio (R_IK), whilst equation (EQ12) relates investment expenditure (I) to the rate of return on capital (RoR) and an investment demand shift variable. In (EQ11), R_IK may also be used to determine the gross capital growth rate. Since the production function in (EQ2) is constant returns to scale, marginal product functions are homogenous of degree zero and can thus be expressed as functions of the capital:labour (K/L) ratio and technical change (A). In our description of the capital and labour markets, we recognize that the marginal product of capital (MPK) is negatively related to the K/L ratio and the marginal product of labour (MPL) positively related to the K/L ratio. In determining (EQ13) we assume that the RoR can be expressed as [Q/PI] with Q the factor payment to capital and PI the price index for new investments. We then assume that Q is determined by the value of the marginal product of capital, written as [MPK*PY]. With MPK a function of the K/L ratio and technical change, and [PY/PI] a function of TofT, we are able to summarize this relationship through equation (EQ13).

In determining (EQ14) we assume that the before-tax real wage of consumers (BTRW) can be expressed as [W/CPI] with W the factor payment to labour and CPI the consumer price index. We assume that W is determined by the value of the marginal product of labour, written as [MPL*PY]. In similar fashion to (EQ13) we are then able to write equation (EQ14) linking the BTRW to the K/L ratio, technical change, and TofT effect. The next section elaborates on these key equations determining the rate of return and real wage in UPGEM. Equation (EQ15) defines the after-tax real wage (ATRW) and equation (EQ16) permits unemployment (U).

Equations (EQ17–EQ19) relate movements in three key stock variables to relevant flow variables. Equation (EQ17) shows that changes in capital stock (ΔK) are calculated as the sum of new capital investments minus depreciation of old capital stock. Equation (EQ18) relates changes in the government's net foreign liability position (ΔNFLG) to the public sector deficit incurred during the year. Equation (EQ19) relates changes in the net foreign liability position of households (ΔNFLH) to the excess of investment over savings.

Equations (EQ20) and (EQ21) capture the real-wage adjustment and labour supply mechanism in policy simulations. Where a policy has elevated labour demand relative to labour supply, the after-tax real wage (ΔATRW) will increase over time relative to its baseline value. Under this specification, the local labour market does not clear in the short-run perturbed scenario. An appropriate parameter in the wage adjustment equation governs the lagged wage response to gaps between labour demand and supply. Labour demand (L) is determined as a function of the before-tax real wage in (EQ14), and labour supply (L_S) is determined in (EQ21) as a function of the after-tax real wage and any change in labour supply preferences of workers.

To complete our description of the BOTE model we have to consider an appropriate closure for the system of equations in Table 4. In doing so we must distinguish between equations that describe economic relationships within any given year (EQ1–EQ16), equations that describe movements in stock variables between years (EQ17–EQ19), and equations describing the real-wage adjustment mechanism (EQ20–EQ21). In our exposition of BOTE we consider a typical short-run recursive-dynamic modelling environment.

Within any given year, K, NFLH, and NFLG can be considered exogenous, with movements between years dependent on their respective flow variables. Similarly, our 'sticky' real wage (RW) adjustment mechanism allows us in effect to treat BTRW, and therefore ATRW, as fixed within any given year, with movement between years dependent on the interaction between labour demand and supply. Reflecting changes in policy or economic conditions that are considered extraneous to the model, we also set DEP and ΔL_PREF as exogenous.

Recognizing that (EQ17–EQ21) govern dynamics across years, our task of finding a suitable model closure narrows to evaluating (EQ1–EQ16). We assume that the labour market clears within this set of equations and that the unemployment level is fixed or exogenous within any given year. These 16 equations contain 31 unknown variables. As the number of endogenous variables must correspond to the number of equations, 15 variables must therefore be treated as exogenous in order to close the model. In Table 4 we provide a quick reference to our choice of model closure by highlighting exogenous variables in bold. Table 5 summarizes what a conventional year-on-year short-run closure would look like for the core (EQ1–EQ16) system of equations, and Table 6 summarizes all the variables contained in BOTE.

Table 5: The BOTE model: example of policy closure for static component

Equation	Endogenously determined	Exogenous variables	Determined elsewhere
EQ1	X	G	GDP, C, I, M
EQ2	GDP	K, A	L_S
EQ3	C	APC	HINC
EQ4	HINC	TQ, BTRW, TL, NFLH, R	GDP, TofT
EQ5	GINC	TQ, BTRW, TL, NFLG, R	GDP, TofT
EQ6	GNDI		HINC, GINC
EQ7	M	TWS	GDP, TofT
EQ8	TofT	PM	PX
EQ9	PX	F_X	X
EQ10	PY	CPI (numeraire)	TofT
EQ11	R_IK	K	I
EQ12	I	F_I	RoR
EQ13	RoR	K, A	L, TofT
EQ14	L_S	BTRW, K, A	L, TofT
EQ15	ATRW	BTRW, TL	
EQ16	L	U	L_S

Source: authors' elaboration.

The short-run closure applied to (EQ1–EQ16) via our choice of exogenous variables reflects the standard macro assumptions of 'sticky' real wages and fixed capital stocks in primary-factor markets. Although ATRW is endogenous in our model closure, it can effectively be seen as fixed within any given year since both BTRW and TL are exogenous in the short run. To simplify our analysis, we assume that labour markets clear within this set of equations. Hence, with BTRW and K fixed, and A, TQ, and TL also exogenous, (EQ14) can be identified with the determination of L_S. Since U is exogenous, this allows (EQ16) to determine L.

With K and A exogenous, (EQ2) then determines GDP. With GDP now determined, (EQ4–EQ6) calculate GNDI and its distribution between HINC and GINC. With HINC determined by (EQ4) and APC exogenous, (EQ3) determines C. Ignoring any movements in the TofT, (EQ7) determines M with GDP already determined and TWS exogenous. With L_S determined by (EQ14), and K and A exogenous, (EQ13) determines the RoR via the marginal product of capital. This determines I via (EQ12), which allows R_IK to be calculated via (EQ11).

With GDP, C, I, G, and M explained, (EQ1) determines X. With PM exogenous, this determines PX and TofT via (EQ8) and (EQ9), respectively. With BTRW and TL fixed in the short run, (EQ15) simply determines ATRW. To allow the absolute price level to be determined, the CPI acts as the numeraire in our BOTE system of equations. With the CPI exogenous and TofT already determined, (EQ10) determines PY.

Table 6: The BOTE model: list and description of variables

Variable	Description
A	Primary-factor-augmenting technical change
APC	Average propensity to consume
ATRW	After-tax real wage
BTRW	Before-tax real wage
C	Real household consumption expenditure
CPI	Consumer price index
DEP	Depreciation rate on fixed capital stock
F_I	Shift variable, investment demand curve
F_X	Shift variables, export demand curve
G	Real government expenditure
GDP	Real gross domestic product
GINC	Real government income
GNDI	Real gross national disposable income
HINC	Real household income
I	Real investment expenditure (gross fixed capital formation)
K	Capital stock
L, L_S	Labour demand, Labour supply
L_PREF	Labour supply preferences
M	Import volumes
NFLG	Net foreign liabilities of government
NFLH	Net foreign liabilities of households
PM	Foreign-currency import price
PX	Foreign-currency export price
PY	GDP deflator
R	Interest rate on net foreign liabilities
R_IK	Ratio of Investment/Capital
TL	Labour income tax rate
TofT	Terms of trade
TQ	Production tax rate
TWS	Cost-neutral import/domestic preference twist
U	Unemployment
X	Export volumes

Source: authors' elaboration.

This exposition of the BOTE model broadly describes the key macroeconomic relationships in UPGEM under a typical short-run recursive-dynamic environment, with every equation linked to the determination of a specific endogenous variable. Variations to BOTE and the model closure shown here can easily be made to highlight other relationships, if needed. BOTE is useful as a quick general reference to UPGEM and provides insight for the interpretation of simulation results.

2.4 Marginal products of capital and labour

Following the description of BOTE and the theory behind rates of return and real wages in UPGEM, this section elaborates on the various relationships governing these variables. For this purpose, we return to (EQ13) and (EQ14) in BOTE.

$$RoR = f(\frac{K}{L}, TofT, A) \quad \text{(EQ13)}$$

$$RW = f(\frac{K}{L}, TofT, A) \qquad \text{(EQ14)}$$

In our description of the capital and labour markets, we recognize that the marginal product of capital (MPK) is negatively related to the K/L ratio and the marginal product of labour (MPL) positively related to the K/L ratio. In determining (EQ13) we assume that the RoR can be expressed as [Q/PI] with Q the factor payment to capital and PI the price index for new investments. We then assume that Q is determined by the value of the marginal product of capital, written as [MPK*PY]. With MPK a function of the K/L ratio and technical change (A), and [PY/PI] a function of TofT, we are able to summarize this relationship through equation (EQ13). In determining (EQ14) we assume that the RW can be expressed as [W/CPI] with W the nominal factor payment to labour and CPI the consumer price index. We then assume that W is determined by the value of the marginal product of labour, written as [MPL*PY]. In similar fashion to (EQ13), we are then able to write equation (EQ14) linking the RW to the K/L ratio, technical change (A), and TofT effect.

In (EQ13) and (EQ14) we assume that domestic production is via a constant returns-to-scale production function of capital and labour inputs, and that the costs of employing capital and labour equal the values of the marginal products of capital and labour, respectively. This enables us to derive the 'back-of-the-envelope' equations shown in (EQ13K) and (EQ14L) to better interpret movements in capital and labour markets, and subsequently the K/L ratio, for UPGEM policy simulations.[4]

$$\frac{\partial GDP}{\partial K} = MPK \approx \frac{1}{A} * \frac{Q}{P_y} \quad \rightarrow \frac{\partial GDP}{\partial K} = MPK \approx \frac{1}{A} * \frac{Q}{P_i} * \frac{P_i}{P_y} \qquad \text{(EQ13K)}$$

$$\frac{\partial GDP}{\partial L} = MPL \approx \frac{1}{A} * \frac{W}{P_y} \quad \rightarrow \frac{\partial GDP}{\partial L} = MPL \approx \frac{1}{A} * \frac{W}{P_c} * \frac{P_c}{P_y} \qquad \text{(EQ14L)}$$

In the capital (EQ13K) and labour (EQ14L) equations, Q and W are factor payments to capital and labour; P_i and P_c the price indexes for new investment and consumption goods; P_y the price index for domestically produced goods; and MPK and MPL the marginal products of capital and labour, respectively. In this exposition, the term P_c is equivalent to the CPI.

In equation (EQ13K), the (Q/P_y) term can be split into two components or effects to enhance our analysis. The first term, (Q/P_i), can be interpreted as the RoR. The second term, (P_i/P_y), similar to the (P_c/P_y) term in (EQ14L), can be interpreted as a decreasing function of the TofT. This is because both P_i and P_c include imports but not exports, whilst P_y includes exports but not imports. The TofT effect is especially important in economies for which X and M are relatively large values. In equation (EQ14L), the (W/P_y) term can be interpreted as the real producer wage or cost of employing a unit of labour. To enhance our analysis, we again split this term into two effects. The first term, (W/P_c), can be interpreted as the real consumer wage, and the second, (P_c/P_y), as the TofT effect.

Recognizing that the MPK is negatively related to the K/L ratio, equation (EQ13K) can then be used to show that the K/L ratio in (EQ13) is negatively related to the RoR, and positively related to the TofT and A. That is, as the relative amount of capital in the economy increases, and the MPK falls, we can expect a decline in the RoR on capital investments. Similarly, with the MPL positively related to the K/L ratio, equation (EQ14L) can be used to show that the K/L ratio in (EQ14) is positively related to the RW.

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[4] The two 'back-of-the-envelope' equations (EQ13K) and (EQ14L) are easily derived by maximizing economy-wide profits, PY.Y – (W.L + Q.K), subject to a Cobb-Douglas production function where Y = A[Lβ.K(1-β)].

2.5 Capital accumulation mechanism in UPGEM

Recursive-dynamic modelling requires that an economy's capital stock be allowed to adjust over time according to the level of net investment. Given an initial level of capital [$K_t(j)$] and a mechanism for determining investment [$I_t(j)$], equation (EQ22) can be used to trace out the path of industry *j*'s capital stock. The rate of growth in industry *j*'s capital stock [$K\_GR_t(j)$] is defined by (EQ23) and linked to expected rates of return [$ERoR_t(j)$] in (EQ24). Equation (EQ24) defines an investment-supply curve showing that the rate of return investors require depends on the rate of growth in industry *j*'s capital stock. This physical capital accumulation mechanism in UPGEM is summarized below with a definition of all variables provided in Table 7.

$$K_{t+1}(j) = K_t(j) * [1 - DEP_t(j)] + I_t(j) \tag{EQ22}$$

$$K\_GR_t(j) = \frac{K_{t+1}(j)}{K_t(j)} - 1 \tag{EQ23}$$

$$ERoR_t(j) = \psi[K\_GR_t(j)] \tag{EQ24}$$

Table 7: Capital accumulation mechanism: list and description of variables

Variable	Description
$K_t(j)$	Capital stock available for use in industry *j* at the start of year *t*
$K_{t+1}(j)$	Capital stock available for use in industry *j* at the end of year *t*
$I_t(j)$	New investment in industry *j* during year *t*
$DEP_t(j)$	Rate of depreciation on capital stock of industry *j*
$ERoR_t(j)$	Expected rate of return on capital of industry *j*
$RoRN_t(j)$	Historically normal rate of return on capital of industry *j*
$F\_ERoR_t(j)$	Industry-specific vertical shift in the capital-supply curve
F_ERoR_t	Uniform vertical shift in the capital-supply curve
$K\_GR_t(j)$	Rate of growth in the capital stock of industry *j* during year *t*
$TREND\_K_t(j)$	Historically normal rate of growth in the capital stock of industry *j*
$K\_GR\_MIN_t(j)$	Minimum possible rate of growth in the capital stock of industry *j* typically set at the negative of the rate of depreciation in industry *j*
$K\_GR\_MAX_t(j)$	Maximum feasible rate of growth in the capital stock of industry *j* defined as $TREND\_K_t(j)$ plus $DIFF_t(j)$ with $DIFF_t(j)$ set at a value of 0.10 to prevent large simulated capital growth rates
$C_t(j)$	Positive parameter that controls the sensitivity of industry *j*'s capital growth to variations in its expected rate of return
$S\_KGR\_ERoR_t$	Estimate of the average value over all industries of the sensitivity of capital growth to variations in expected rates of return
$ARoR_t(j)$	Actual rate of return on capital for industry *j*
$NPV_t(j)$	Net present value of purchasing a unit of capital for use in industry *j* in year *t*
$PINV_t(j)$	Cost of buying or constructing a new unit of capital for use in industry *j* in year *t*
$PCAP_t(j)$	Rental rate on industry *j*'s capital in year *t*, i.e. the user cost of a unit of capital in year *t*
R_t	Nominal rate of interest for all industries in year *t*
INF_t	Rate of inflation in year *t*

Source: authors' elaboration.

Equation (EQ22) shows that the amount of capital available for use in industry *j* at the end of year *t* is calculated as start-of-year *t* capital stock minus depreciation, plus new capital investments during year *t*. End-of-year *t* capital stock then determines start-of-year *t+1* capital stock. In UPGEM, the capital-supply function for industry *j*, equivalent to ψ in (EQ24), describes the relationship between *j*'s expected rate of return and the proportionate growth in *j*'s capital stock between successive years. A complete exposition of the capital-supply function and determination of rates of return for industry *j* is given below.

$$ERoR_t(j) = \{RoRN_t(j) + F\_ERoR_t(j) + F\_ERoR_t\} + [1/C_t(j)] \; * \\ [ln\{K\_GR_t(j) - K\_GR\_MIN(j)\} - ln\{K\_GR\_MAX(j) - K\_GR_t(j)\} \\ - ln\{TREND\_K(j) - K\_GR\_MIN(j)\} + ln\{K\_GR\_MAX(j) - TREND\_K(j)\}] \qquad \text{(EQ25)}$$

$$C_t(j) = \left[\frac{\partial ERoR_t(j)}{\partial K\_GR_t(j)}\bigg|_{K\_GR_t(j)=TREND\_K_t(j)}\right]^{-1} * \\ \left[\frac{K\_GR\_MAX_t(j) - K\_GR\_MIN_t(j)}{\{K\_GR\_MAX_t(j) - TREND\_K_j(j)\}\{TREND\_K_t(j) - K\_GR\_MIN_t(j)\}}\right] \qquad \text{(EQ26)}$$

$$\left[\frac{\partial ERoR_t(j)}{\partial K\_GR_t(j)}\bigg|_{K\_GR_t(j)=TREND\_K_t(j)}\right]^{-1} = S\_KGR\_ERoR_t \qquad \text{(EQ27)}$$

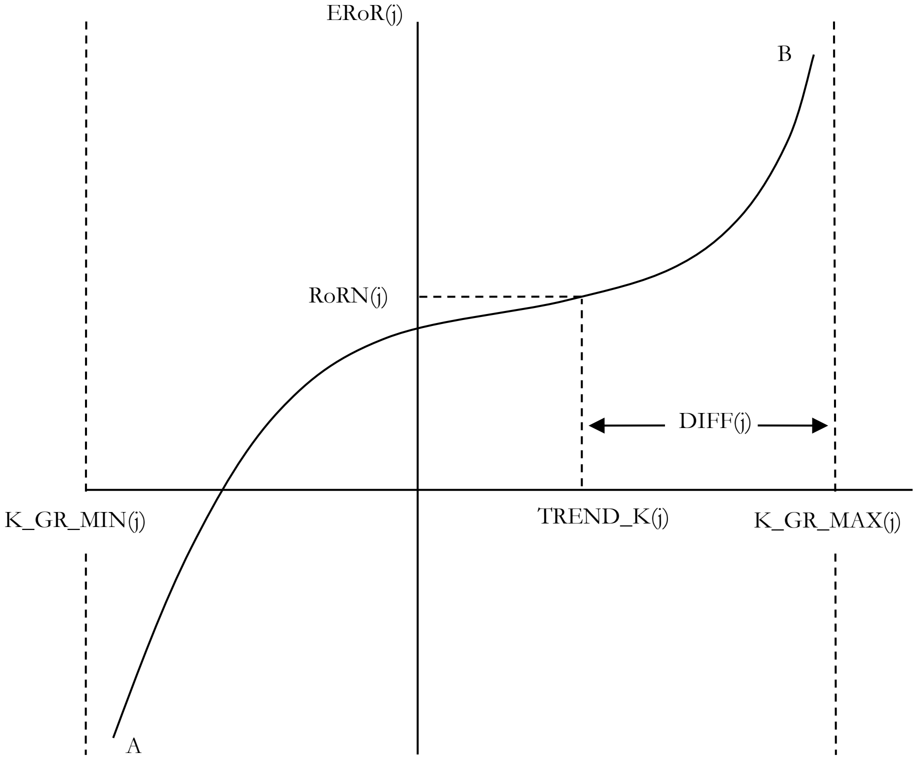
For readers familiar with GEMPACK, equation (EQ28) shows the linearized form of (EQ25) as it appears in the actual UPGEM code. We include (EQ28) here since the BFP simulations conducted in this study include a shock to the shift variable d_f_eeqror(j). A quick reference to this section may be helpful to readers wanting to understand the implementation of those scenarios in UPGEM.

$$del\_eror_t(j) = [1/C_t(j)] * [1/\{K\_GR_t(j) - K\_GR\_MIN_t(j)\} \; + \; 1/ \\ \{K\_GR\_MAX_t(j) - K\_GR_t(j)\}] * del\_k\_gr_t(j) \; + \; d\_f\_eeqror(j) \; + \; d\_f\_eeqror_t \qquad \text{(EQ28)}$$

Under the expected rates of return specification in equation (EQ25) we can interpret the equilibrium expected RoR in industry *j* as an inverse logistic function of the proportionate growth in *j*'s capital stock. This relationship is illustrated by the AB curve in Figure 2. With the F_ERoR terms exogenous and set to zero, it shows that if industry *j* is to attract sufficient investment in year *t* to achieve a capital growth rate of $TREND\_K_t(j)$, it must have an $ERoR_t(j)$ equal to $RoRN_t(j)$. An increase (or decrease) in industry *j*'s capital growth beyond its $TREND\_K_t(j)$ must therefore be accompanied by an $ERoR_t(j)$ in excess of (or below) its $RoRN_t(j)$ level.

Evaluation of the parameter $C_t(j)$ becomes important in simulations where (EQ25) plays an active role. In choosing appropriate values for $C_t(j)$ we note its derivation from (EQ25) in equation (EQ26). We can therefore estimate $C_t(j)$ if we assign a value to the reciprocal of the slope of the AB curve in the region of $K\_GR_t(j)=TREND\_K_t(j)$. Since no reliable data exist which will enable us to complete this task, we follow a similar approach to that adopted in the MONASH model. An average value over all industries for the sensitivity of capital growth to variations in expected rates of return is used as a proxy, denoted by the term $S\_KGR\_ERoR_t$ in (EQ27). We base our estimates for these parameters on those used in Roos et al. (2020).

Figure 2: Capital-supply logistic curve



Source: authors' elaboration based on Dixon and Rimmer (2002: 191).

Equations (EQ29–EQ33) briefly describe how actual rates of return in UPGEM are determined and used to form expected values. To find the actual rates of return for industries we start by defining the net present value of purchasing a unit of capital for use in industry *j* as the discounted rental value of an extra unit of capital in year *t+1*, plus the discounted resale value of the asset in year *t+1* taking into account depreciation, minus the immediate outlay cost of the new capital. This relationship, ignoring the role of taxes, is given by (EQ29). To derive a rate of return formula we divide both sides of (EQ29) by $PINV_t$(j), as shown in (EQ30). This yields the expression for actual rates of return on capital for industry *j* as shown in (EQ31). As noted, the determination of capital growth and investment in UPGEM requires use of expected rather than actual rates of return. $ERoR_t$(j) is subsequently formed by generating expectations held in year *t* about $ARoR_t$(j). Under static expectations this is achieved by assuming that rental rates and asset prices will increase by the current rate of inflation, as shown in (EQ32) and (EQ33) (Dixon and Rimmer, 2002: 190–94).

$$NPV_t(j) = \frac{PCAP_{t+1}(j)}{1+R_t} + \frac{PINV_{t+1}(j)[1-DEP_t(j)]}{1+R_t} - PINV_t(j) \quad \text{(EQ29)}$$

$$\frac{NPV_t(j)}{PINV_t(j)} = \frac{PCAP_{t+1}(j)}{(1+R_t)*PINV_t(j)} + \frac{PINV_{t+1}(j)[1-DEP_t(j)]}{(1+R_t)*PINV_t(j)} - \frac{PINV_t(j)}{PINV_t(j)} \quad \text{(EQ30)}$$

$$ARoR_t(j) = \frac{PCAP_{t+1}(j)}{(1+R_t)*PINV_t(j)} + \frac{PINV_{t+1}(j)[1-DEP_t(j)]}{(1+R_t)*PINV_t(j)} - 1 \quad \text{(EQ31)}$$

$$PCAP_{t+1}(j) = PCAP_t(j) * [1 + INF_t] \quad \text{(EQ32)}$$

$$PINV_{t+1}(j) = PINV_t(j) * [1 + INF_t] \quad \text{(EQ33)}$$

2.6 Wage adjustment mechanism in UPGEM

Following the wage adjustment process described for policy simulations in MONASH, we assume that after-tax real wages for all occupations in UPGEM adjust according to equation (EQ52) with after-tax real wages defined as before-tax real wages net of taxes on labour as per equation (EQ53).

$$\left(\frac{ATRW_t{}^{policy}(o)}{ATRW_t{}^{base}(o)}\right) - \left(\frac{ATRW_{t-1}{}^{policy}(o)}{ATRW_{t-1}{}^{base}(o)}\right) = \beta(o)\left(\frac{D_t{}^{policy}(o)}{D_t{}^{base}(o)} - \frac{L_t{}^{policy}(o)}{L_t{}^{base}(o)}\right) \qquad \text{(EQ52)}$$

$$ATRW_t(o) = BTRW_t(o) * [1 - TL_t] \qquad \text{(EQ53)}$$

In the baseline forecast, after-tax real wages $\left(ATRW_t{}^{base}\right)$ and labour demand $\left(D_t{}^{base}\right)$ are typically set according to available projections. Labour supply $\left(L_t{}^{base}\right)$ evolves naturally according to initial settings in the base year data. Equation (EQ52) implies that if a policy causes the demand for occupation-specific labour to increase relative to its supply, then after-tax real wages between years *t-1* and *t* would increase relative to their baseline values. Similarly, if a policy causes the supply of labour to decrease relative to demand, after-tax real wages may be expected to rise for the particular type of labour under investigation. The positive parameter $\beta(o)$ reflects the speed of adjustment in the labour market, that is, it controls the response of after-tax real wage rates to gaps between labour demand and supply for each occupation group. The speed of adjustment parameter is useful as it implicitly permits a distinction in how scarce skilled workers are modelled versus abundant lower-skilled workers. In UPGEM, equation (EQ52) therefore has the role of determining after-tax real wage rates for local occupations. Before-tax real wage rates for all occupations are then determined by applying the appropriate labour tax rates net of social benefits received according to (EQ53).

From these equations, it is important to note that any reductions in the implied unemployment rate in the long run will be driven by exogenous projections in the baseline. The wage adjustment mechanism in the policy run is designed for employment to return to its baseline value in the long run, facilitated by an appropriate change in the real wage. This corresponds to typical labour market theory found in macroeconomics, which assumes sticky real wages alongside flexible employment outcomes in the short run, compared with full or baseline employment alongside flexible real wages in the long run. The wage adjustment mechanism in UPGEM essentially describes the dynamics of the labour market between these two points in time.

3 Simulation design

3.1 Overview

Two key aspects determine the credibility of policy simulation design in CGE modelling. First is the identification of the relevant variable to be shocked combined with the magnitude of the shock for the given scenario. That is, the first-round impact must affect the appropriate variable(s) in the model with an appropriately sized shock(s). Second is running the policy simulation under modelling assumptions that are compatible with the economic environment under which the scenario occurs in the real world. That is, the choice of endogenous versus exogenous variables in the model closure must impose appropriate assumptions and behaviour. For the policy simulations conducted in this report, we mainly use standard policy simulation closures, as described in Dixon and Rimmer (2002), with only minor simulation-specific adjustments.

In designing the simulations within the UPGEM framework, careful consideration was given to the methodologies behind the petrol price savings described in Crompton et al. (2020). As noted in Section 1, the five scenarios to be modelled can effectively be categorized into two groups according to the component of the fuel price they affect. The first two scenarios directly affect the BFP component, and the last three the RAS. Subsequently, the simulation design differs between the two groups of simulations in terms of the variables that are shocked and the choice of model closure, which indirectly allows the source of saving between the different scenarios to be distinguished. The shocks for all BFP and RAS scenarios were calibrated to achieve the desired reduction in the consumer price of fuel at the pump as described in Crompton et al. (2020) and Appendix A.

3.2 The BFP scenarios

The BFP scenarios model the removal of implicit pure profit earned by refineries in the current pricing formula. The first BFP scenario (S1) cuts 9 cpl attributed to shipping and handling costs and the second BFP scenario (S2) cuts a further 9 cpl by changing the source of petrol used in the formula to 100 per cent Arabian Gulf. To implement the BFP scenarios in UPGEM, we impose a shock to the investment logistic curve that lowers the required rate of return for refineries. That is, the logistic curve described in (EQ28) is shifted down via a negative shock to d_f_eeqror(j) for the refinery industry. The supply of investable funds to the refinery industry is thus not affected for any given rate of required capital growth at the lower price.

The shocks to the logistic curve are calibrated to achieve the desired reductions of 9 cpl for S1 and 18 cpl for S2. Relative to the February 2020 benchmark, this implies a targeted cumulative reduction of 0.57 per cent under S1 and 1.15 per cent under S2 in the final purchase price of fuel.

The calibrated reduction in the required rate of return by refineries under S2 amounts to 0.018 per cent. That is, if the refineries were willing to supply capital at, for example, an RoR of 10 per cent under business-as-usual conditions, the shock now implies that they will be willing to supply the same required amount of capital at 9.982 per cent. This strategy allows refineries to be willing to satisfy higher future demand for their outputs of refined petroleum despite receiving 18 cpl less at a lower RoR on capital investment. The subsequent drop in the final purchase price of petrol, which will increase demand over time, will therefore not lead to an excess demand situation.

The standard UPGEM does not explicitly account for the foreign ownership of capital, but instead assumes that all capital is owned by South Africans, with any investment requirements in excess of domestic savings financed through foreign debt. Subsequent interest payments on foreign debt are then modelled to affect the current account deficit. Whilst this mechanism is adequate to capture the basic macroeconomic implications of foreign capital ownership, debt, and subsequent interest payments, it not sufficiently nuanced to capture the benefit to South Africa's GNP of cutting the pure profits of local refineries when there is a substantial foreign ownership share. Foreign ownership of petrol refineries in South Africa stands at roughly 50 per cent based on available information.

We calculate this benefit accruing from the reduction of pure profits earned by refineries as:

$$RBenefit(t) = -FP2021 * DF(t) * \left(\frac{LP1CAP\_PR(t)}{LP1CAP\_PRold(t)} - 1\right) \quad \text{(EQ54)}$$

where

$$FP2021 = SHF\_PR(2021) * V1CAP\_PRold(2021) \quad \text{(EQ55)}$$

and

$$DF(t) = (1 - DEP)^{t-2021} \qquad \text{(EQ56)}$$

The benefit then enters the modified current account deficit equation in UPGEM as:

$$CADEF = IMPORTS - EXPORTS + INTFD - RBenefit \qquad \text{(EQ57)}$$

Whilst this benefit is expected to be relatively small in overall GNP terms, it will help raise the performance of GNP relative to GDP in the short to medium term. In the longer term, the depreciation factor (DF) will contribute to a shrinking benefit generated relative to the baseline.

Alternative approaches to modelling changes to the BFP component of the fuel price were initially considered. These included a direct shock to the basic price component of refined petroleum products and modelling the removal of an artificially created phantom tax on petrol collected by the refinery industry. Various challenges presented themselves with these approaches, including difficulties in finding an appropriate model closure and controlling for investment behaviour of refineries. Ultimately, our strategy of exogenously shifting the logistic curve to generate the required fall in the price of fuel ticked all the boxes in terms of simulation design for our BFP scenarios.

3.3 The RAS scenarios

In the system of national accounts (SNA), the output of retailers is measured by the value of the trade margins realized on the goods they sell, that is, the difference between the sale value of products sold and the cost of purchasing these products. Fuel service stations (or the retail trade of automotive fuel) are captured within the broader trade sector in South Africa's supply and use tables (StatsSA 2019). As detailed in Appendix C, the overall trade sector includes all wholesale and commission trade (SIC 61), retail trade (SIC 62), and sale of motor vehicles and fuel (SIC 63). In the model's 2017 base year, the total supply of trade margin services produced by the trade sector (SIC 61–63) in South Africa amounted to just over R857 billion. The sub-sector under which the activities of services stations fall—the sale, maintenance, and repair of motor vehicles and retail trade of automotive fuel (SIC 63)—accounts for R151 billion or around 18 per cent of this total. This implies that, within the context of the SNA definition, trade margins generated by service stations alone will be some share of this. No reliable estimates of the exact share are available, but the more detailed 2010 supply and use tables (StatsSA 2016b) suggest it to be around 20 per cent of the SIC 63 sub-total, or R30 billion in 2017 terms.

The RAS scenarios model a reduction in the amount of trade margins per unit of sale attributed to the final purchase price of fuel, weighted for the appropriate share of fuel trade within the overall trade sector. We first model these scenarios separately to ensure correct calibration of the model before modelling them in a cumulative manner alongside the BFP scenarios. The first RAS scenario (S3) cuts the required amount of trade margins by 8.57 cpl via a correction in the pricing methodology as described in Crompton et al. (2020). The second RAS scenario (S4), building on S3, cuts the required amount of trade margins by a cumulative 50.29 cpl via additional adjustments to the WACC in the formula. Finally, the fifth RAS scenario (S5), building on S4, cuts the required amount of trade margins by a cumulative 85.82 cpl via additional adjustment to the WACC in the formula and using a low estimate of forecourt staff.

The shocks to the trade margin component only of delivering fuel to final consumers are calibrated to achieve the desired reductions of 8.57 cpl for S3, 50.29 cpl for S4, and 85.82 cpl for S5. Relative to the February 2020 benchmark, and including the total reduction in the BFP component of 18 cpl under S2, this implies a targeted cumulative reduction of 26.57 cpl or 1.69 per cent under S3, 68.29 cpl or 4.35 per cent under S4, and 103.82 cpl or 6.61 per cent under S5 in the final purchase price of fuel.

In order to model the RAS scenarios, we only add a technical change shift variable that specifically permits an exogenous change to the trade margin cost of delivering refined petroleum products. No other changes are required to the standard UPGEM to implement the RAS scenarios.

4 Simulation results

Simulation results shown for the various policy scenarios should all be interpreted as cumulative percentage change deviations in the underlying value of the variable, relative to its baseline projection, unless otherwise stated. Our focus will be on the most important variables and indicators, including common macro variables such as GDP, household consumption, and trade, and industry-specific variables for the directly affected refined petroleum and trade industries. The refined petroleum industry produces fuel which is effectively sold at the BFP or basic refinery gate price plus other transport and storage (RAS) margins to service stations, and ultimately to final consumers after the relevant tax and retail margin charges are added. The performance of the trade sector is a key indicator of how petrol service stations will be affected, as retail trade in automotive fuel is included in this industry group.

Table 8 summarizes the key policy simulation results for all scenarios.

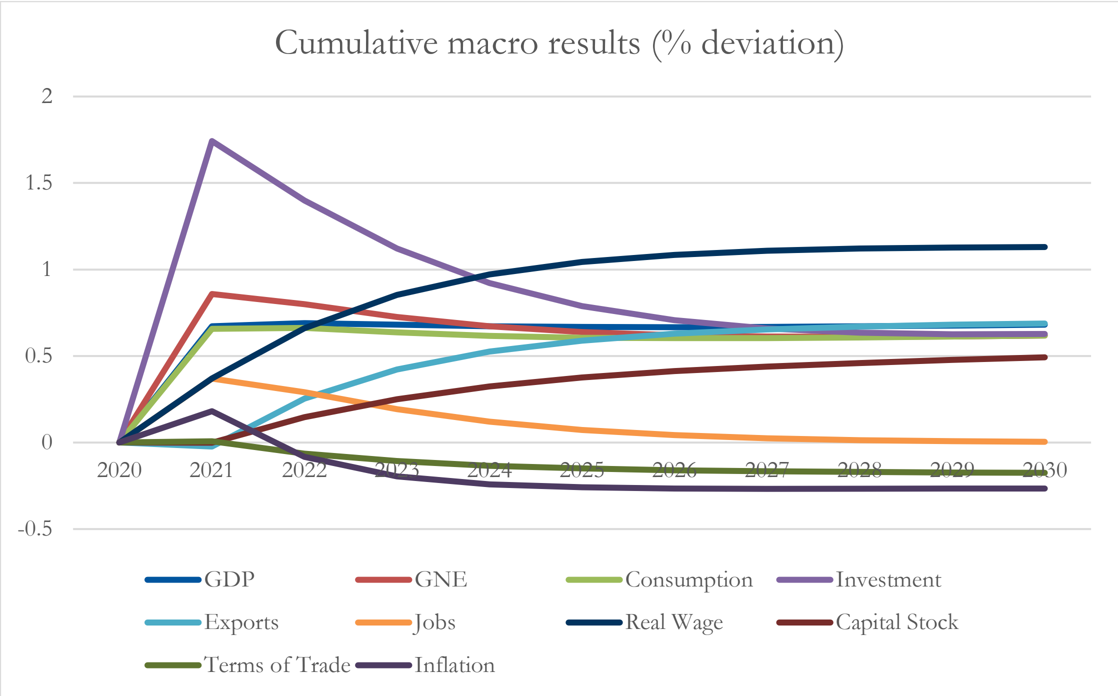
Table 8. Policy simulation results for S1–S5 combined in 2028 (only year *t*+7)

Policy simulation results	**S1**	**S2**	**S3**	**S4**	**S5**
Macro variables					
Gross domestic product (x0gdpexp)	0.03	0.06	0.12	0.42	0.67
Household consumption (x3tot)	0.02	0.05	0.10	0.37	0.60
Investment expenditure (x2tot_i)	0.11	0.23	0.27	0.48	0.66
Exports (x4tot)	0.07	0.15	0.20	0.44	0.65
Jobs (employ_io)	0.01	0.01	0.01	0.02	0.02
Real wages (real_wage_c)	0.09	0.18	0.27	0.72	1.11
Capital stock (x1cap)	0.06	0.12	0.15	0.31	0.44
Terms of trade (p0toft)	–0.02	–0.04	–0.05	–0.11	–0.17
Refined petroleum sector					
Final consumer prices (p3_s)	–0.57	–1.15	–1.69	–4.35	–6.61
Industry output (x0ind)	0.85	1.71	1.82	2.32	2.76
Household demand (x3_s)	0.26	0.51	0.80	2.19	3.51
Jobs (x1lab_o)	–1.12	–2.29	–2.23	–1.89	–1.60
Investment (x2tot)	1.44	2.99	3.13	3.74	4.28
Capital stock (x1cap)	1.36	2.80	2.91	3.46	3.94
Trade sector					
Industry output (x0ind)	0.07	0.14	–0.05	–1.00	–1.80
Jobs (x1lab_o)	0.06	0.11	–0.10	–1.16	–2.08
Investment (x2tot)	0.15	0.31	0.09	–1.00	–1.95
Capital stock (x1cap)	0.08	0.16	0.01	–0.81	–1.51

Source: authors' elaboration.

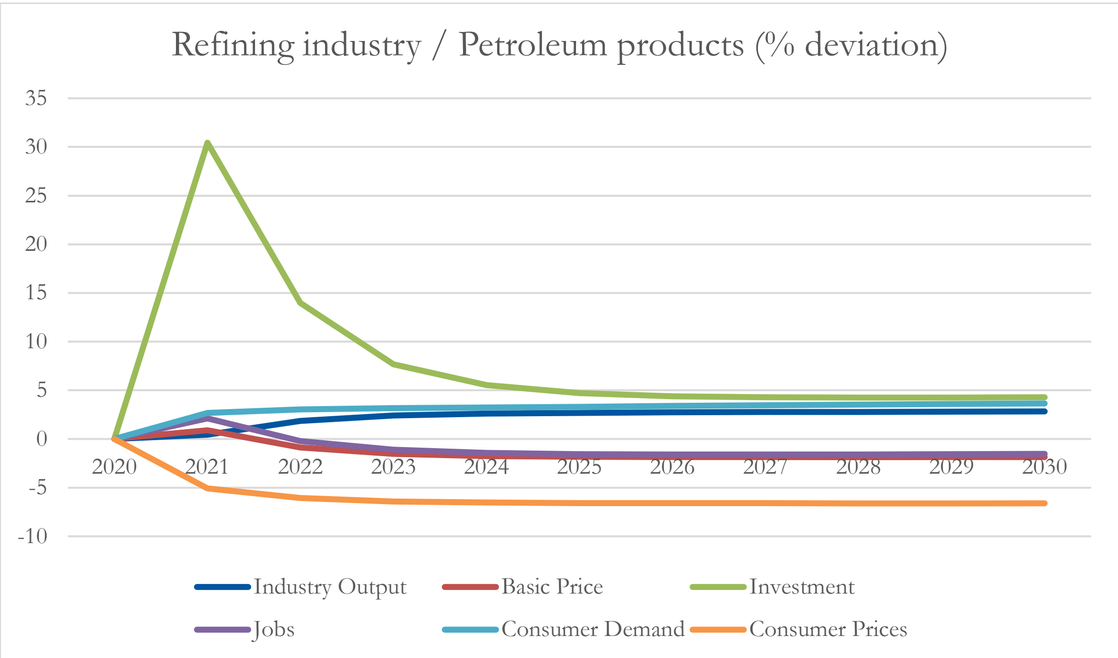
In Table 8, we choose to display comparative results for year *t*+7 (2028) only. As can be seen in Figure 3 and Figure 4, which display results across the entire simulation period, all results stabilize beyond year *t*+4 (2025). Results for year *t*+7 (2028) can thus be viewed as a reliable benchmark to compare the impact of the different scenarios. All exogenous shocks for the different scenarios were calibrated to achieve the desired reductions in the final consumer price of fuel, as confirmed by results shown below.

Figure 3: Policy simulation results for S5 combined, 2021–30 (macros)



Source: authors' calculations.

Figure 4: Policy simulation results for S5 combined, 2021–30 (refining industry)



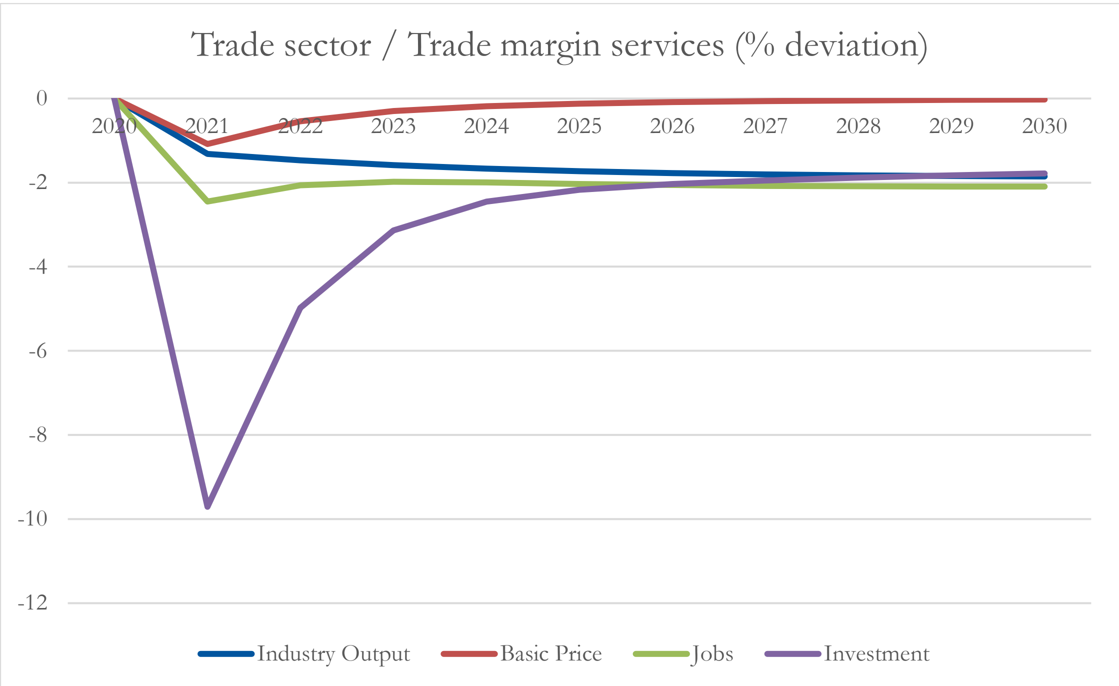
Source: authors' calculations.

Since S1 and S2 are essentially the same simulation—both reduce the price of fuel by 9 cpl—we start our assessment of the results with S2. Scenario S2 models a reduction in the required rate of return by refineries calibrated for an 18 cpl reduction in the price of fuel. Our modelling strategy allows the final consumer price reduction to be achieved via the basic refinery gate price of fuel, leaving tax and margin components unaffected. In percentage change terms, the drop in the basic price of fuel must therefore be larger than the drop in the final consumer price, which includes additional taxes and margins.

The results for S2 highlight the implementation of the simulation. The reduction in the basic price of fuel does not diminish the appetite of refineries to increase investment and output to meet the increase in demand from final consumers of 0.51 per cent as a result of the drop in retail prices of 1.15 per cent. The lower rate of return of around 0.018 percentage points accepted by refineries accounts for this. The trade sector, which includes service stations, also benefits from the increase in demand from consumers. Since the trade margin allowed on fuel is not affected under S2—only the basic price charged by refineries—the trade sector is also willing to increase investment and output to meet the higher demand. On a macro level, the results are relatively small, as may be expected given the magnitude of the shock in S2. All macro indicators show minor gains on the back of a more competitive economy. Real GDP is up by 0.06 per cent and exports by 0.20 per cent relative to the baseline under S2.

Once scenarios S3–S5 are added on top of S2, the picture changes drastically for service stations captured within the trade sector. With the remaining reductions in the pump price coming from trade margins, fuel service stations are directly affected. With final consumer demand rising by 3.51 per cent on the back of the overall drop in the pump price of 6.61 per cent under S5, refinery investment and output continue to grow in order to meet demand. However, service stations are put under pressure as their revenues are reduced. Key variables such as industry output, jobs, and investment all fall relative to the baseline, as shown in Figure 5. In reality, this may be interpreted as a consolidation of trade margin services provided by service stations. The fact that South Africa has an abundance of service stations is perhaps an indicator that there is room for consolidation in this regard.

Figure 5: Policy simulation results for S5 combined, 2021–30 (trade sector)



Source: authors' calculations.

The technical change in S3–S5 that permits a saving in the amount of trade margins required per unit of sale of petrol to final consumers is the largest contributor to the overall gains seen in the macroeconomy. Given the relatively small saving in the fuel price under S1/2—the BFP-only scenarios—the muted impacts on a macroeconomic level are to be expected. Under S5, the combined and cumulative effect of all regulatory adjustments results in a significant impact of key macro variables. GDP rises by 0.67 per cent relative to the baseline. Consumption, investment, and exports are up by similar margins. The small gain in employment relative to the baseline is to be expected, as in the long run the model's labour market and wage adjustment mechanisms ensure that wages adjust to return employment back to baseline. The rise of over 1.1 per cent in real wages is indicative of the positive overall labour market impacts generated under S5.

Whilst the model produces robust percentage change deviation results, stakeholders are often interested to know what the impacts are in levels terms, that is, in terms of actual rands or number of jobs. We advise caution when converting the results to levels terms, as they then become dependent on uncertain medium- to long-term forecasts about the economy. Nonetheless, such interpretations are necessary to communicate the results broadly and effectively. We can therefore proceed to interpret our percentage change deviation results in nominal or levels terms under the disclaimer that, despite using the best available forecast data, the underlying baseline projections for the economy remain highly uncertain due to the ongoing COVID-19 pandemic and its subsequent impact on the global economy.

The results shown in Table 8 are positioned as a reliable medium-term estimate of the real impact of the proposed reforms. We will, for the purposes of our explanation in this section, simply assume that the impacts of the COVID-19 recession will be offset by the subsequent recovery anticipated over the said medium term in our business-as-usual baseline forecast. This assumption is in line with recent macro forecasts in World Bank (2020) and IMF (2020). The increase in real GDP of 0.67 per cent relative to the baseline under S5 is therefore expected to generate an additional R31.2 billion (in 2017 rands) in value added to the economy. Real household consumption is similarly expected to rise by R16.5 billion (in 2017 rands) over the medium term.

On an industry level, the modest loss of jobs in the refined petroleum sector is driven by a change in the relative real costs of capital to labour. With rising real wages in general, substitution towards a slightly more capital-intensive structure is to be expected, relative to the baseline. The trade sector, and more specifically service stations, faces a policy-induced recession caused by the reduction in value of sales for their trade margin services under S3–S5. The cumulative fall in fuel prices of 6.61 per cent under S5—of which 5.46 per cent is due to the individual trade margin reforms in S3–S5 alone—increases consumer demand by only 3.51 per cent.

In Crompton et al. (2020), an estimate of around 100,000 forecourt workers employed at the more than 4,600 fuel service stations around South Africa was given. Since the 2.08 per cent loss in trade sector jobs under S5 is expected to be concentrated in the SIC 63 sub-sector, which accounts for only 18 per cent of overall trade services. This implies a rather substantial loss of jobs at service stations. Given the relative weights, we estimate a loss of around 15 per cent of forecourt workers employed at service stations under the harshest scenario, S5, which equates to a minimum of 15,000 workers. Job losses under S4 are expected to be around half of those under S5, whilst job losses in the trade sector under S3 will be negligible. Whilst the overall demand for fuel by consumers is expected to increase, the lower margins allowed will hurt individual service stations on average. It follows that service stations that are already in a vulnerable financial position—perhaps as a result of their location or poor management—may be under threat. To survive, these stations will have to generate an upward shift in their demand curve, which may be hard to achieve given the difficulties and costs involved in changing location or management. A consolidation in the number of service stations in South Africa is therefore to be expected given that investment in new service stations is expected to drop by around 15 per cent relative to the baseline under S5. Forecasting the exact number of service stations that will close is not possible, but what can be said with certainty is that under S5 there will be fewer service stations than in the business-as-usual baseline scenario.

The good news for workers is that the general boom created in the economy, on the back of the positive technical changes achieved via the proposed fuel price reforms, will allow workers who may have lost their jobs in 'losing' industries to be absorbed in 'winning' industries. Virtually all industries, outside of refineries and the fuel trade, show a gain in output and employment relative to the baseline. With a slight overall increase in jobs over the medium term combined with higher real wages, it can be concluded that even the most comprehensive reforms proposed under S5 will be beneficial for the labour market as a whole, despite the short-term adjustment costs associated with moving between jobs.

5 Further research

Future research should be targeted towards further refinements of the database and simulation design aspects. A more detailed database in which petrol is fully disaggregated from the other refined petroleum products would provide more insights, as would a more detailed knowledge of the intermediate use structure and capital–labour shares of petrol refineries relative to the overall refined petroleum sector. Further refinements to the UPGEM database to improve allocation of margins on imported goods and allocation of indirect sales taxes (outside of import tariffs) on imported goods can also be achieved.

Proposals to mitigate job losses of forecourt workers at service stations under S5 need to take account of the legal prohibition on self-service at service stations prescribed by Section 2A(5)(b) of the Petroleum Products Act 1977 (Act 120 of 1977). In other words, motorists are not currently permitted to fill their own vehicles with fuel at service stations; a service station attendant must be employed to do so. The reduction in trade margins related to forecourt staff at service stations as modelled assumes that consumers are willing to give up some forecourt services in exchange for paying less for their fuel at the pump. Future research will need to consider more closely to what extent this will be possible, taking into account the aforementioned prohibition, and consumers' willingness to pay for forecourt services.

6 Conclusions

The proposed changes to the regulatory framework that determines petrol prices in South Africa as set out in Crompton et al. (2020) are shown to generate substantial benefits across the board at both macro and industry levels. Apart from fuel service stations, captured within the broader trade sector, virtually all industries emerge as winners relative to the baseline under the cumulative and combined S5. Under the assumption that refineries are willing to forgo existing pure profits calculated in S2 and accept a slightly lower rate of return, continued growth in supply of fuel from local refineries in line with increased consumer demand is assured.

The anticipated loss of forecourt workers at service stations is one of the few genuine negative outcomes under S5. However, with almost all other industries growing faster relative to the baseline in the longer term, the model shows that employment opportunities lost in the service stations will be more than compensated for by growth in employment opportunities in other economic activities. The implied demand elasticity for fuel leads to reduced revenues for stations, as the percentage change drop in prices exceeds the percentage change increase in consumer demand. It is expected that some financially vulnerable service stations may close down or consolidate. Legal limitations on self-service at service stations and consumer preferences regarding forecourt services vis-a-vis fuel prices at the pump may influence these outcomes as modelled under the market-oriented S5. If we regard the prohibition on self-service at service stations as in effect a subsidized job creation programme (paid for by motorists), the transfer of subsidized jobs to unsubsidized jobs in the 'real' economy reduces the overall tax burden on motorists directly and on the rest of the economy indirectly.

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Appendix

A Summary table of policy simulation scenarios

Table A1

Scenario number	S0	S1	S2	S3	S4	S5
Scenario title	BAU Baseline	DME 2018	100% Arab Gulf	RAS (a)	RAS (b)	RAS (d)
Short description	All elements & methodology as at August 2019	Based on DoE 2018 discussion paper.[1] BFP proposed changes only	BFP 100% Arab Gulf. Contract & spot price shares as per Crompton et al. (2020)	Corrected errors in methodology & 20% debt	Corrected errors in methodology + more appropriate margin & 50% debt	Corrected methodology + more appropriate margin & 70% debt + reduced staffing costs
BFP ELEMENTS, sum of	status quo[2]	DOE 2018 paper	100% Arab Gulf as per Crompton et al. (2020)	100% Arab Gulf as per Crompton et al. (2020)	100% Arab Gulf as per Crompton et al. (2020)	100% Arab Gulf as per Crompton et al. (2020)
RAS ELEMENTS	status quo	status quo	status quo	Corrected methodology, no other adjustments	Corrected methodology + more appropriate margin [50% debt]	Corrected methodology + more appropriate margin [70% debt] + reduced staffing costs

BFP Elements (ZAR cpl)	683.2	-9[3]	-18[4]	-18	-18	-18
RAS Elements (ZAR cpl)	338.8	0	0	-8.57	-50.29	-85.82
Total	1 022.00	-9	-18	-26.57	-68.29	-103.82

PETROL ('total')	1 572.00	1 563.00	1 554.00	1 545.43	1 503.71	1 468.18
% decrease		0.57	1.15	1.69	4.35	6.61
Saving p.a. ZAR/mil petrol only (2019 volumes)[5]		ZAR96 959	ZAR193 918	ZAR286 244	ZAR735 702	ZAR1 118 474
Saving p.a. ZAR/mil 3 main fuels (2019 volumes)[6]		ZAR218 715	ZAR437 430	ZAR645 696	ZAR1 659 563	ZARR2 523 002

Notes:

[1] RSA (2018).

[2] Status quo means DoE practice as at the reference month. Reference month for BFP elements is August 2019 and for RAS elements is February 2020.

[3] The -9cpl is based on prices shipping costs of -10cpl + an increase in the FOB price of 1cpl. Data for the period from September 2017 to August 2019.

[4] The -18cpl is the sum of the -9cpl referred to in note 3 + a decrease in the FOB price of -9cpl. FOB data for the period March 2019 to August 2019.

[5] 2019 fuel volumes from Department of Mineral Resources and Energy http://www.energy.gov.za/files/energyStats_frame.html (accessed 17 July 2020).

[6] Petrol, diesel, and paraffin, assuming the impact on diesel and paraffin prices is the same as the impact on the petrol price.

Source: derived from Crompton et al. (2020) and authors' calculations.

B UPGEM database

This study introduces a new 2017 base year database for the national version of UPGEM. The master database recognises 71 industries and commodities, four household groups, and a central government. No further provincial or regional detail is included in this version of the database, since the policies simulated in this study are all implemented uniformly at a national level. The methods used to build the database largely follow those described in Roos et al. (2015). As has been the norm in other publications using UPGEM, this appendix contains a brief description of the structure of the model's core database.

Table B1: Database structure

		Absorption Matrix (Use Table)						
		1	2	3	4	5	6	7
		Producers	Investors	Household	Export	GenGov	Stocks	Total
	Size	IND	IND	HOU	1	1	1	All Users
Basic Flows	COMxSRC	V1BAS	V2BAS	V3BAS	V4BAS	V5BAS	V6BAS	V0BAS Basic
Margins	COMx SRCxMAR	V1MAR	V2MAR	V3MAR	V4MAR	V5MAR	N/A	V0MAR Margins
Indirect Taxes	COMxSRC	V1TAX	V2TAX	V3TAX	V4TAX	V5TAX	N/A	V0TAX TLSP
BAS + MAR + TAX = PUR Values	COM	V1PUR Intermed Use	V2PUR Investment	V3PUR Priv Cons	V4PUR Exports	V5PUR Pub Cons	V6BAS Stocks	Total COM Demand
Labour Costs	OCC	V1LAB						
Production Taxes	1	V1PTX						
Capital Rentals	1	V1CAP						
V1PUR + V1PRIM = Total Cost	1	Total IND Costs						

	Production Matrix (Supply Table)				
Size	IND	1	1	1	All Sources
COM	MAKE Supply Table	V0IMP Imports	V0MAR Margins	V0TAX TLSP	Total COM Supply
1	Total IND Sales				

Source: authors' elaboration based on Dixon et al. (2013)

As described in Bohlmann et al. (2015), the UPGEM database structure presented above has two main parts: an absorption matrix and a joint-production matrix. The absorption matrix simultaneously shows total industry costs and total commodity demand across all users. The production matrix simultaneously shows total industry sales and total commodity supply. The main data sources for the core UPGEM database are the supply-use tables published by Statistics South Africa.

The first row in the absorption matrix, V1BAS,…, V6BAS, shows flows in the base year of commodities to producers, investors, households, exports, government consumption, and inventory accumulation. Each of these matrices has COMxSRC rows, one for each of COM commodities from SRC sources.

V1BAS and V2BAS each have IND columns where IND is the number of industries. The typical component of V1BAS is the value of good i from source s used by industry j as an input to current production, and the typical component of V2BAS is the value of (i,s) used to create capital for industry j. V3BAS to V6BAS typically each have one column, which refers to one representative household, one foreign buyer, one category of public demand and one category of inventory demand. These dimensions can be extended if necessary; for example, the single representative household may be split according to HOU number of household categories based on detailed income or ethnic group information found in social accounting matrices.

All of the flows in V1BAS,…, V6BAS are valued at basic prices. The basic price of a domestically produced good is the price received by the producer (that is the price paid by users excluding sales taxes, transport costs, and other margin costs). The basic price of an imported good is the landed-duty-paid price, i.e. the price at the port of entry just after the commodity has cleared customs.

Costs separating producers or ports of entry from users appear in the input-output data in the margin matrices and in the row of sales-tax matrices. The margin matrices, V1MAR,…, V5MAR, show the values of MAR margin commodities, typically trade and transport services, used in facilitating the flows identified in V1BAS,…, V5BAS. The sales tax matrices V1TAX,…, V5TAX show collections of indirect taxes (positive) or payments of subsidies (negative) associated with each of the flows in V1BAS,…, V5BAS.

Payments by industries for labour by skill or occupation group (OCC) are recorded in the matrix V1LAB, whilst payments by industries for the use of capital and land are recorded in the vectors V1CAP. The vector V1PTX shows collections of net taxes on production. We may also include a vector V1OCT (not shown) to capture other industry costs not elsewhere classified, where appropriate.

The remaining data items are MAKE and V0TAR (not shown). V0TAR is a vector showing tariff revenue by imported commodity. The joint-product matrix, MAKE, has dimensions COMxIND and its typical component is the output of commodity c by industry i, valued in basic prices. The content of the MAKE matrix is equivalent to the supply table's domestic industry output at basic prices component.

Together, the absorption and joint-production matrices satisfy two balancing conditions. First, the column sums of MAKE (values of industry outputs) are identical to the values of industry inputs. Hence, the j-th column sum of MAKE equals the j-th column sum of V1BAS, V1MAR, V1TAX, V1LAB, V1CAP, and V1PTX. Second, the row sums of MAKE (basic values of outputs of domestic commodities) are identical to basic values of demands for domestic commodities. If i is a non-margin commodity, then the i-th row sum of MAKE is equal to the sum across the (i,'dom')-rows of V1BAS to V6BAS.

The presentation of the matrices also highlights certain national accounting conventions. The green cells indicate the value of total industry costs across all categories and total industry sales of domestically produced commodities. As noted previously, the column totals for each industry in both the cost and sales matrices should match. This also reflects the zero pure profit condition. Similarly, the blue cells indicate the value of total commodity demand across all users and total commodity supply from all sources, at purchasers' prices. As a balancing condition, the row totals for each commodity in both the demand and supply matrices should match. This represents the market clearing condition.

One more cell deserves some explanation. The V1CAP cell is commonly interpreted as the cost of capital rentals, including land, to industries in the production process. Within the system of national accounting (SNA), this cell represents the gross operating surplus (including mixed income) of an industry. Gross operating surplus (GOS) is defined in the context of national accounting as the balancing item in the generation of income account. GOS differs from profits shown in industry accounts for several reasons. Only a subset of total costs is subtracted from total sales to calculate GOS. Essentially, GOS is the value of gross output or sales less the cost of intermediate goods and services to give gross value added, and less compensation of employees. It is gross because it makes no allowance for depreciation or consumption of fixed capital (CFC). By deducting CFC from GOS, one calculates net operating surplus (NOS).

When adapted to the structure of the UPGEM database, the gross operating surplus (V1CAP) can be calculated as the value of total sales (MAKE) less intermediate input costs (V1PUR), less labour input costs (V1LAB), less production taxes (V1PTX). V1CAP therefore represents the value of capital rentals—the gross profit earned by and payable to investors as compensation for the provision and maintenance of capital stock. In a 'normal' year, capital rental flows in each industry should reflect the normal risk-adjusted rate of return expected by investors based on the value of the underlying capital. Annual capital rental flows, reflected by V1CAP, in combination with normal required rates of return, are often used to estimate underlying industry capital stock values in UPGEM.

A summary of the national income and production accounts for the model's 2017 base year is shown in tables below.

Table B2

GDP at market prices from the income side (Rm)	2017	Share
Compensation of employees	2,225,800	47.83
Gross operating surplus	1,865,105	40.08
Other taxes on production	92,075	
less Other subsidies on production	9,653	
Gross value added at basic prices	4,173,328	89.68
Taxes on products	497,335	
less Subsidies on products	17,084	
Gross domestic product at market prices	4,653,579	100.0

Source: authors' elaboration based on South African Reserve Bank's (SARB) Quarterly Bulletin, March 2020 (SARB 2020).

Table B3

GDP at market prices from the expenditure side (Rm)	2017	Share
Final consumption expenditure by households	2,756,540	59.24
Final consumption expenditure by general government	967,898	20.80
Gross fixed capital formation	873,223	18.76
Exports of goods and services	1,378,747	29.63
less Imports of goods and services	1,319,114	(28.35)
Change in inventories and residual item	-3,716	(0.08)
Gross domestic product at market prices	4,653,579	100.0

Source: authors' elaboration based on SARB Quarterly Bulletin, March 2020 (SARB 2020).

A summary of the contribution to national gross value added at basic prices by sector or kind of economic activity for 2017 is shown in the table below.

Table B4

GVA at basic prices by sector (Rm)	**2017**	**Share**
Primary sector	453,554	10.87
Agriculture, forestry, and fishing (SIC 1)	109,882	
Mining and quarrying (SIC 2)	343,672	
Secondary sector	879,900	21.08
Manufacturing (SIC 3)	558,957	
of which the petroleum industry (SIC 331-332) contributes	42,737	
Electricity, gas, and water (SIC 4)	157,781	
Construction (SIC 5)	163,162	
Tertiary sector	2,839,874	68.05
Trade, catering, and accommodation (SIC 6)	625,147	
Transport and communication (SIC 7)	410,824	
Business services (SIC 8)	826,776	
General government services (SIC 91)	734,072	
Other community, social, and personal services (SIC 92-99)	243,055	
Gross value added at basic prices	4,173,328	100.0

Source: authors' elaboration based on SARB Quarterly Bulletin, March 2020 (SARB 2020).

C Description of industries in the UPGEM database

Table C1

Nr	IND56	Description of economic activity from standard industrial classification 3.0
1	I1_fieldcrop	I0101: Growing of cereal grains incl rice, wheat, maize and sugar cane, and other field crops [SIC 1111]
2	I1_fruitveg	I0102: Growing of vegetables, horticultural and nursery products [SIC 1112]; Growing of fruit, nuts, beverage and spice crops incl growing of grapes and manufacture of wine at the same location [SIC 1113]
3	I1_livestock	I0103: Farming of live animals incl dairy farming [SIC 112]; Mixed farming [SIC 113]; Other agricultural services [SIC 114]; Hunting and related services [SIC 115]; Production of organic fertilizer such as compost [SIC 116]
4	I1_forestry	I0104: Forestry, logging and related services [SIC 12]
5	I1_fishing	I0105: Fishing, operation of fish hatcheries and fish farms [SIC 13]
6	I2_coal	I0206: Mining of coal and lignite [SIC 21]
7	I2_metalore	I0207: Mining of gold and uranium ore [SIC 23]; Mining of iron ore and other non-ferrous metals incl platinum [SIC 24]
8	I2_othmining	I0208: Extraction of crude petroleum and natural gas [SIC 22]; Other mining and quarrying incl diamonds [SIC 25]; Service activities incidental to mining of minerals [SIC 29]
9	I3_meat	I0309: Manufacture of meat and meat products incl beef and poultry, operation of slaughterhouses and preservation of meat [SIC 3011]
10	I3_fish	I0310: Manufacture of fish and fish products [SIC 3012]
11	I3_fruitveg	I0311: Manufacture of fruit and vegetables [SIC 3013]
12	I3_oilsfats	I0312: Manufacture of oils and fats from vegetable or animal materials [SIC 3014]
13	I3_dairy	I0313: Manufacture of dairy products incl milk, butter, cheese and yoghurt [SIC 302]
14	I3_grain	I0314: Manufacture of grain mill products, starches and starch products and prepared animal feeds [SIC 303]
15	I3_bakery	I0315: Manufacture of bakery products incl bread, cakes, pastries and biscuits [SIC 3041]
16	I3_sugar	I0316: Manufacture of sugar incl raw sugar cane and syrup [SIC 3042]
17	I3_cocoa	I0317: Manufacture of cocoa, chocolate products and sugar confectionary [SIC 3043]
18	I3_othfood	I0318: Manufacture of other food products nec incl pastas and coffee [SIC 3044-3049]
19	I3_beverage	I0319: Manufacture of alcoholic beverages [SIC 3051-3052]
20	I3_softdrink	I0320: Manufacture of soft drinks and mineral water [SIC 3053]

21	I3_tobacco	I0321: Manufacture of tobacco products [SIC 306]
22	I3_textiles	I0322: Manufacture of textiles and clothing apparel [SIC 311-315]
23	I3_leather	I0323: Manufacture of leather and leather goods incl tanning and dressing of leather [SIC 316]
24	I3_footwear	I0324: Manufacture of footwear products of any material incl leather, rubber, plastics or textile materials [SIC 317]
25	I3_wood	I0325: Manufacture of wood and wood products [SIC 321-322]
26	I3_paperpub	I0326: Manufacture of paper and paper products [SIC 323]; Publishing [SIC 324]; Printing and services related to printing [SIC 325]; Reproduction of recorded media [SIC 326]
27	I3_petroref	I0327: Manufacture of coke oven products incl asphalt materials for road building [SIC 331]; Manufacture of refined petroleum products incl liquid or gaseous fuels, lubricating oils and petroleum jelly [SIC 332]
28	I3_othchem	I0328: Manufacture of nuclear fuel and other radioactive elements [SIC 333]; Manufacture of basic chemicals and other chemical products incl pesticides, paints and pharmaceuticals [SIC 334-335]; Manufacture of man-made fibres [SIC 336]
29	I3_rubber	I0329: Manufacture of rubber products incl tyres and tubes [SIC 337]
30	I3_plastic	I0330: Manufacture of plastic products [SIC 338]
31	I3_glass	I0331: Manufacture of glass and glass products [SIC 341]
32	I3_nonmetal	I0332: Manufacture of other non-metallic mineral products incl ceramic and cement [SIC 342]
33	I3_ironsteel	I0333: Manufacture of basic iron and steel (SIC 351]; Casting of iron and steel and other non-ferrous metals [SIC 353]
34	I3_nonfmetal	I0334: Manufacture of basic precious and non-ferrous metals incl gold, silver, PGMs and alumina [SIC 352]
35	I3_othmetal	I0335: Manufacture of structural and fabricated metal products [SIC 354-355]; Manufacture of general and special purpose machinery [SIC 356-357]; Manufacture of household appliances and office and computing machinery [SIC 358-359]
36	I3_elecmach	I0336: Manufacture of electrical machinery and apparatus incl electric motors, insulated wire and cables, primary batteries and lighting equipment [SIC 36]
37	I3_radtvins	I0337: Manufacture of radio, TV and communication equipment, medical appliances, optical instruments, photographic equipment, watches and clocks [SIC 37]
38	I3_transeqp	I0338: Manufacture of transport equipment incl motor vehicles, parts, trailers, boats, trains and aircraft [SIC 38]
39	I3_othmanuf	I0339: Manufacture of furniture and other product groups nec incl jewellery, sporting goods and toys, recycling of metal and non-metal waste and scrap [SIC 39]
40	I4_elecgas	I0440: Generation and distribution of grid-based electricity, manufacture and distribution of gas, steam and hot water supply [SIC 41]
41	I4_water	I0441: Collection, purification and distribution of water [SIC 42]
42	I5_construc	I0542: Construction and construction related services [SIC 50]

43	I6_trade	I0643: Wholesale and commission trade [SIC 61]; Retail trade [SIC 62]; Sale, maintenance and repair of motor vehicles and retail trade in automotive fuel [SIC 63]
44	I6_accom	I0644: Hotels, other short-stay accommodation, restaurants and bars [SIC 64]
45	I7_landtrns	I0745: Land transport incl passenger and freight services via road and rail [SIC 71]
46	I7_airtrns	I0746: Air transport incl passenger and freight services [SIC 73]
47	I7_othtrns	I0747: Water transport services [SIC 72]; Supporting transport activities incl cargo handling, storage and warehousing, activities of travel agencies [SIC 74]
48	I7_postcomm	I0748: Post and telecommunication services [SIC 75]
49	I8_finance	I0849: Financial intermediation services [SIC 81]; Insurance, medical aid and pension funding services [SIC 82]; Other financial intermediation services [SIC 83]
50	I8_realest	I0850: Real estate activities incl buying, selling, renting, managing and developing of residential dwellings and non-residential buildings [SIC 84]
51	I8_rentmach	I0851: Renting of machinery and equipment incl agricultural, construction, transport and personal equipment [SIC 85]
52	I8_othbus	I0852: Computer and related IT activities [SIC 86]; Research and development [SIC 87]; Other business service activities [SIC 88]
53	I9_gengov	I0953: Public administration and defense activities by general government [SIC 91]; Sanitation activities, sewage and refuse disposal [SIC 94]
54	I9_educat	I1054: Private education services [SIC 92]
55	I9_health	I1055: Private health and social work services incl medical activities and day care centres [SIC 93]
56	I9_othsrv	I1056: Other service activities incl professional organisations and sporting activities [SIC 95-99]

Source: authors' elaboration based on StatsSA (2016b).