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Impact of loadshedding in South Africa: A CGE analysis

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Abstract. The aim of this paper is to provide a practical contribution to the body of knowledge on the impact of loadshedding in South Africa. This study adopted a pragmatic research methodology by using a computable general equilibrium (CGE) model for empirical analysis. This study estimates that loadshedding will reduce economic growth by 2.3%, this higher than the Banks earlier prediction of a 0.6%. This study is limited to the effects of loadshedding and shed light on the South African economy that has been adversely affected by the Covid 19 pandemic and its recovery trajectory which is now stifled by persistent load shedding. Empirical analysis of the effects of loadshedding through the usage of the CGE model establishes the originality of this study.
Keywords. Loadshedding; Electricity; Energy; CGE model.
JEL. D58; L90; L94.

1. Introduction

Since the beginning of loadshedding one decade ago, the level of life of South Africans has never been the same again. Both industries and households have accepted as new normal living without electricity for several hours or days. This loadshedding has negatively affected families, firms, and the entire economy of the country. Some firms have waisted worthful working hours instead of producing goods and services due to lack of electricity. Families have experienced the pain of going without electricity and seeing their electrical appliances damaged because of the loadshedding. The economy has been the hardest hit due to loadshedding as the unemployment increased and the government revenue declined substantially.

South Africa is facing an energy crisis with further power cuts expected in 2023, which is projected to constrain GDP growth. The South African economy has been adversely affected by the Covid 19 pandemic and its recovery trajectory is now stifled by persistent load shedding. It is evident that this energy crisis will be something that will be in existence for some time in the future and it is likely to get worse. In the year 2021, there were 75 days of load shedding and in 2022 this increased to 208 days. The South Africa Reserve Bank (SARB) GDP growth forecast for 2023 is 0.3%, it estimates that loadshedding will reduce economic growth by 2 percentage points in 2023, this higher than the Banks earlier prediction of a 0.6 percentage points (SARB, 2023).

Loadshedding undoubtably impacts the economy and thus directly affects revenue collections. For example, in the mining industry revenue losses will

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impact Government's ability to earn revenue from taxes and royalties. Some firms have lost huge amount of money because of the failure to produce without electricity. In fact, the duration of the load-shedding implies that more diesel through generators should be consumed to remain operational. The Diesel Fuel Tax Refund system will be impacted by the increased reliance on diesel by industries such as agriculture, forestry, fisheries, and mining. Because loadshedding affects all industries, government could think about expanding the diesel fuel tax refund structure by incorporating strategic industries that consume the most diesel to reduce the consequences of the loadshedding. Moreover, the energy crisis has created new opportunities because the government is planning to invest in the usage of renewable energy.

In view to address the challenge of loadshedding, a wide range of reforms and policy measures were respectively announced by the President and Minister of Finance in the State of the Nation Address and Budget Speech 2023. Amongst others, this include the tax proposal aimed at enabling the growth of the renewable energy industry wherein households who are willing to use solar panels will be eligible to apply for rebate of 25% against the initial price of the panels, amounting to a maximum of R15,000 from 1st March 2023. While big firms are shifting towards self-generation of energy, this will have affirmative spin-offs for South Africa Revenue Service (SARS) through possible increased imports. Investment in renewable energy by businesses and households will contribute to increased rebate claims and thus result in refunds (SARS, 2023).

Although South Africa is not amongst the world leaders of renewable energy capacity, it is the leader in renewable energy mix capacity in the African continent followed by Egypt and Ethiopia. The country is a leader especially in both Solar and Wind energy and the third largest in Hydropower within the continent. The top 10 countries using mixed renewable energy in the world in terms of capacity are China, USA, Brazil, India, Germany, Japan, Canada, France, Italy, and Russia. These countries have made considerable improvement in converting to renewable energy as part of meeting various capacity targets and addressing concerns over air pollution.

The purpose of this paper is to provide an experimental input to the body of knowledge on the impact of loadshedding in South Africa as well as the state of South Africa's electricity industry and tax analysis of the market participants. In this paper, a Computable General Equilibrium (CGE) model is considered to analyse the impact of loadshedding on the South African economy. The model is a static CGE model applied to South Africa, using 2015 as the base year. Section 2 provides the current state of the loadshedding. Section 3 introduces the literature review. Section 4 portrays the methodology while Section 5 provides the simulation results. Last Section concludes this study.

2. Literature review

The effects of loadshedding have been severe in the livelihood of South Africans not only physically but also medically as well. For instance, there are great concerns in the hospital industry which relies heavily on cold storage as prolonged periods of loadshedding are jeopardising the viability of the industry. Patients have been traumatised by the cut of power and this has created other mental sicknesses. Even though South Africa has the highest rate of crime, prolonged load shedding has worsened the crime rate, thus causing people to live in constant fear.

The electricity sector plays an important role of input into other sectors of the economy. In fact, electrical power constitutes the basis of the digital economy which is growing with high speed and the main supplier of energy for the improvement of citizen's lives. In this respect, the citizen's reliance on electricity as basic resource is imperative as without it, they are sternly disadvantaged (Akinboarde, Niedermeier, & Sibanda, 2002).

The question inherent to the measurement of the value that is lost to the economy because of the loadshedding is not a new theory in the academic literature. In fact, the guarantee of electricity supply is a priority of energy policy across numerous countries worldwide. Concerning the energy policy for the European Union, it must be noted that the future of the energy sector depended mostly on the three important pillars that include sustainability, efficiency, and security of energy supplies. Winzer (2012) points out that the crucial meaning of energy security in this policy is not properly described while Loschel (2010) insists that the theory of security of energy supply shall be redefined accordingly. Moreover, other researchers such as Checchi, Behrens, & Egenhofer (2009) pointed out that there is no common interpretation in the security of energy supply. The main reason could be that this expression is applied in various contexts across various fields.

In 2007, it was announced that there will be shortage of electricity in the following year 2008 if precautions are not taken to generate more electricity. Consequently, the government turned a blind eye on the warning as no investment in electricity infrastructure was performed. Meantime, the price hike in electricity was repeatedly implemented as a mean to finance the investment which had a negative impact on the economy that is extremely energy dependent. Besides, the investment was non-negotiable condition to counter the negative effects of imminent loadshedding in the near future (NERSA, 2007).

Checchi, Behrens, & Egenhofer (2009) argue that no constructive measures were taken by the government although several studies including the White Paper were done to warns the government concerning the wearing out of the country's electricity infrastructure and poor management capacity in the electricity industry (DME, 1998). The worst institutional weaknesses were observed in the leadership of the major electricity supplier named ESKOM when the executive management eroded tax money with corruptions. In 2007, almost all the studies recommended that the government improves the supply capacity of the electricity to be able to meet the domestic demand (Akinbani, Oke & Bodunrin, 2021).

ESKOM's prolonged stage 6 loadshedding has already caused significant damage to the country's economy, with over R4 billion wiped from the GDP for each day it continues. If it were not for ESKOM's failings, the country's economy could be between 8% and 10% larger. But aside from the damage done to the economy in general, specific sectors are now sounding alarms over the harm caused by ESKOM's load shedding (CSIR, 2019).

The Bureau of Economic Research (2022) stated that the current round of loadshedding is likely to have a similar impact on the nation's GDP in the third quarter. The intensity of the current power cuts threatens the GDP recovery from the 0.7% quarter-on-quarter contraction experienced in 2022 quarter 2.

It also serves as another reminder of the urgency to fast-track increased private sector power generation, including securing funding for this.

Linares & Rey (2013) pointed out that various kind of impacts are linked to the costs of a power interruption. In fact, the cost is considered as loss in electricity consumption caused by the power interruption. The persistent power cuts are bound to cause anxiety and depression for many people and can be also fatal. South Africa has faced power cuts at unprecedented levels that have affected the everyday life for ordinary South Africans. Sanghvi (1991) argues that the type of costs depends on the gravity of the loadshedding based on the time and duration of outage, consequence, and notice for power cut. The real cost is measured through the determination of the related individual who suffers the consequences of the power cut.

Table 1. *Various impacts of loadshedding*

Direct economic impact	Indirect economic impact	Social impact
Loss of production	The cost of income being postponed	Uncomfortable temperature
Restart costs	The financial cost of loss of market share	Loss of leisure time
Equipment damage		Risk to health and safety
Raw material spoilage		

Source: Linares & Rey, 2013

The measurement of the economic cost triggered by the loadshedding is challenging due to the indirect impacts of power interruptions. Nonetheless, two factors such as the postponement of the cost of income and the commercial cost of loss of market share should be taken into consideration. For instance, the research conducted by the Assistant Secretary for Energy Technology (1978) for the purpose of measuring the indirect effect of the economic costs of the 1977 New York City blackout indicated that burning and looting reported for more than one-half of the entire economic costs were linked directly to power cut.

Investors are doubtful about investing in South Africa due to current continual loadshedding. Albeit investors turn blind eyes on the electricity crisis and decide to invest their funds in South Africa, the excessive risks coupled with the investment will make it very costly. The country's economy is facing an unprecedented scenario with load shedding not only impacting food security and communication networks, but business sectors and industries at large. Stats SA (2022) reported that the country's gross domestic product decreased by 0.7% in the second quarter of 2022 – much of this decline was attributed to rolling blackouts which hobbled economic output.

Loadshedding undoubtably impacts the economy and thus directly affects revenue collections. For instance, in the mining industry revenue losses will impact government's ability to earn revenue from taxes and royalties. Some industries are losing billions of rands in revenue due to the inability to operate without electricity. The more frequent loadshedding occurs and the longer it lasts, the more diesel through generators must be consumed to remain operational. In this case, the Diesel Fuel Tax Refund system will be impacted by the increased reliance on diesel by industries such as agriculture, forestry, fisheries, and mining. Because load shedding affects all industries, government should consider broadening the diesel fuel tax refund system to include critical industries that currently use higher than usual amount of diesel to counter the effects of the load-shedding. The energy crisis also provides new opportunities as government intends to bolster the use of renewable energy.

3. Loadshedding overview

South Africa seems to experience for the first time ever an unending loadshedding encounters. This recurrent phenomenon will possibly continue due to the deterioration of the country's electricity generation infrastructure which requires replacement (Findt, Scott, & Lindfeld, 2014). CSIR (2020) indicates that loadshedding negatively affected the economy by a significant loss amounted approximately to R120 billion just for the year 2019. This is due to the blackouts that continued for a total of 1,352 GWh – or 530 hours in 2019. Nonetheless, when compounding the effects of loadshedding dating back from 2007 to 2022, the overall economic effect over the period is about R338 billion. In fact, the total economic impact of loadshedding in South Africa should be more than R338 billion over the past one-decade.

As indicated earlier, South Africa is confronted with the persistent and worsening load-shedding which has become a new normal with daily power cuts that are affecting all sectors of the economy and society. These persistent electricity cuts resulted in 2022 being South Africa's most unpleasant year for load-shedding with 208 days of power cuts compared to 75 days in 2021 and has continued into 2023 with each day of the new year having load-shedding with higher stages up to stage 6. It is expected that this situation would remain for up to 24 months as announced by ESKOM (ESKOM, 2023). The average Energy Availability Factor (EAF) slumped to an average of around 58% in 2022, down from 62% in 2021 and 65% in 2020. It remains well below the utility's target of 75%. It has averaged 52% thus far and dropped to below 50% for the first time in the first week of January 2023 (Standard Bank, 2023).

The power cuts not only disrupt the functioning of the economy and households but also carry with its price effects on the cost of running business and cost of living and thus negatively impact on the growth trajectory of the economy which was recently eroded by the spread of the COVID-19 pandemic. The Monetary Policy Committee (MPC) stated in its latest statement that due to load shedding, the GDP growth is forecasted at 0.3% for 2023. Given the severity of load-shedding, the Bank projects that it will reduce growth by approximately 2 percentage points in 2023, as opposed to the earlier prediction of 0.6 percentage points (SARB, 2023).

In an attempt to address the challenge of load shedding a wide range of reforms and policy measures were respectively announced by the President and Minister of Finance in the State of the Nation Address and Budget Speech 2023. These measures included amongst others the declaration of the State of Disaster, appointment of the Minister of electricity, debt relief of R245 billion for Eskom, tax proposals that are aimed at enabling the growth of the renewable energy industry wherein households who set up rooftop solar panels will be qualified to apply for a rebate of 25% of the capital spending of the panels, up to a highest amount of R15,000 from 1st March 2023. The renewable tax breaks for businesses include a reduction of their taxable income by 125% of the cost of a capital spending in renewable energies, without limits on the generation power. The latest tax proposals indicate that, albeit not radical, the government is committed to promote the use of renewable source of energy as a substitute to the non-renewable fossil fuels such as the traditional coal fired energy source and to some degree create opportunity for households who can afford and businesses to set up rooftop solar and thus reduce pressure on the ailing power supply.

4. Empirical facts of the loadshedding

South Africa had its first widespread national electricity blackout in 2008. Fourteen years later, the problem has reached an apex with continuous rolling blackouts. It is the result of insufficient electricity generation capacity caused by, amongst other, ageing infrastructure and a lack of maintenance of the coal fleet at Eskom. Load-shedding reached a record high in January 2023.

The Energy Availability Factor (EAF) averaged around 58% in 2022, down from 62% in 2021 and 65% in 2020. It remains well below the utility's target of 75%. The EAF has averaged 52% thus far this year 2023 and dropped to below 50% for the first time this year in the first week of January 2023. This has led to load shedding being implemented daily since the beginning of 2023 and is negatively impacting on all sectors of the economy and households. Figure 1 presents the cumulative amount of electricity shed between 2018 and 2022.

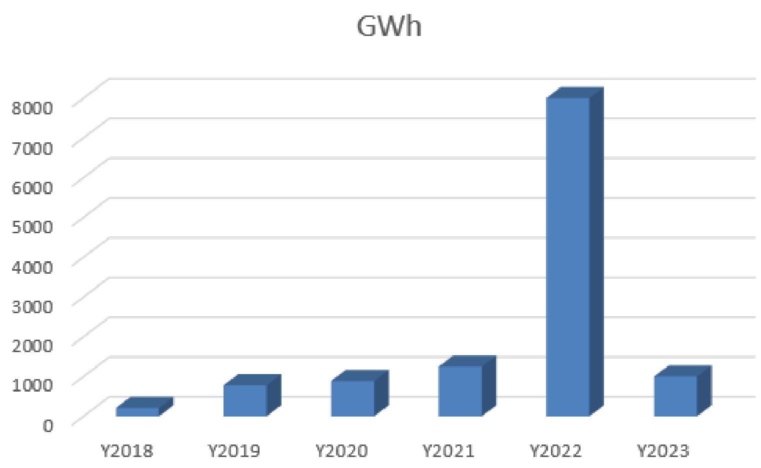

Figure 1. *Cumulative amount of electricity shed (measured in GWh) from 2018 to 2022*
Source: Eskom Data Portal, BER calculations (data for year 2023 is up to 14 January 2023)

Figure 1 indicates that a total of 8 116 GWh of electricity was shed in 2022, significantly worse than 1 775 GWh of load-shedding in 2021 as estimated by the Bureau for Economic Research (BER). There are inconveniences to households due to interruptions to daily lives and damage to appliances and perishable food items as well as access to service delivery that relies on electricity like water supply, health, critical government services like home affairs services to mention a few. Consequently, this will erode the confidence in the government's ability to discharge its mandate which in turn has led to calls for economic shutdown which will have further negative impact on the economy (BER, 2022).

The BER estimated the cost to GDP by using the Cost of Unserved Energy (COUE) to estimate the economic impact of load-shedding. The COUE is the value (in Rands per kilowatt hour) of a unit of energy not provided because of the unexpected loadshedding of short period. The latest NERSA approved estimate from Eskom for South Africa's COUE is R101.73/kWh. This means that one hour of Stage 1 load-shedding (i.e., when South Africa needs to reduce power usage by around 1 000 MW), costs the country R101.73 million.

Similarly, the SARB, BER Used the data from Eskom's research portal to calculate the volume of load-shedding per day (in GWh), They calculate the Cost of Unserved Energy (COUE) for each year since 2018. This provides a range of estimates, depending on the time of day that load-shedding took place. Table 2 presents the cost of loadshedding and cost of unserved energy.

Table 2. *Cost of load-shedding, cost of unserved energy (COUE) equivalent to R101.73/kwh*

(R billion)	All days, any time of day	Excl. weekends and public holidays	Excl. weekends and public holidays, only incl. load-shedding between 07:00 - 19:00	Excl. weekends and public holidays, only incl. load-shedding between 09:00 - 17:00
2018	22	15.9	14.4	11
2019	110.9	80.8	54.9	39.8
2020	129.1	96.2	67.6	49.8
2021	180.6	134.8	79.6	52.3
2022	825.7	618.1	383.4	254.8

Source: Eskom, BER calculations.

When considering cumulative load-shedding across all days, any time of day, power cuts are estimated to have cost the South African economy about R825bn in 2022. However, because most firms and households are impacted differently by power cuts during the night than during the day, this is most likely an overestimation of the real economic impact. In the case that weekends and public holidays are excluded, then consider conventional working hours. The economic cost of load-shedding in 2022 ranges between R255bn (for the 09:00 to 17:00 timeslot) and R383bn (for the 07:00 to 19:00 time slot). There are many unknowns, including the amount of investment and other spending foregone. If taking the average of estimates in Table 4 above, the cost of load-shedding in 2022 could have been in excess of R500 billion (equivalent to around 7-8% of GDP).

4.1. Types of impacts caused by the loadshedding

Power cuts have a pervasive effect on society and business, resulting to an economic cost. These costs can be direct and indirect as well as in varying magnitudes. At an individual level the costs of load shedding may seem insignificant but when considering the associated ripple effects, the indirect costs become increasingly significant. Some impacts do not get quantified (such as reduced investor confidence, reduced competitive advantage, supply chain disruptions) but they are extremely relevant. Table 3 lists some of the consequences of load shedding that should be noted.

Table 3. *Consequences of Load Shedding*

Direct Economic Impact	Indirect Economic Impact	Social Impacts
Loss of production and operation	Loss of corporate and personal income	Risk to health and safety
Damage of equipment and machinery	Job losses	Interrupted communication technology
Spoilage of raw material	Increased costs to source alternative energy	Disrupted evening studies
	Increased output prices	Disrupted evening entertainment

Sources: Adapted from Linares & Rey (2013)

4.2. Electricity strategy

In formulating a strategy for the energy sector of the country, the National Development Plan (NDP) refers to a 2030 vision of the country that focus on the competitiveness and growth of the energy sector. The main objective was to render consistent and inexpensive energy service at acceptable rates by considering the environment and pollution reduction.

In March 2011, the IRP 2010–2030 was endorsed and served as an electricity infrastructure development plan founded for developing the minimum price of electricity supply that should meet the demand of the consumers. Figure 6 illustrates the 2019 IRP energy mix and the 2030 futuristic targets.

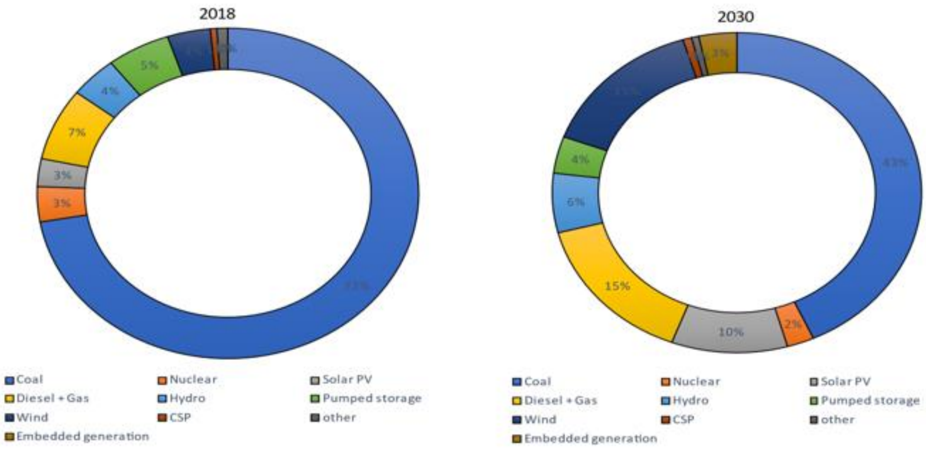

Figure 2. *Integrated Resource Plan (IRP) generation mix installed electrical capacity, 2018 and 2030*
Source: IRP 2019

The figure above shows governments commitment towards supporting the adoption of renewable energy in the energy mix and the reduction of coal generated power. The figure indicates an increased reliance from wind energy (4% in 2018 to 15% by 2030), solar PV energy (3% in 2018 to 10% by 2030) and hydro energy (4% in 2018 to 6% by 2030).

4.3. Loadshedding impact on tax

Load shedding undoubtably impacts on the economy and thus directly influences revenue collections. The discontinuous electricity distribute jeopardises the total productivity, profitability, and reduces the development of both small and large firms. Consequently, load shedding has provided new opportunities to entrepreneurs due to involvement of the government to invest in the exploitation of renewable energy. Meantime, most of big firms are practising self-generation of energy, which will have considerable spin-offs for the government by means of adjusting importation taxes.

Government has decided to arrange for tax relief of more than R20 billion and to tackle the inflation tax as both households and firms have showed the willingness to make use of renewal energy. Households will receive tax relief for the installation of solar panels while firms will get tax incentive for development of renewable energy. Besides, the diesel fuel relief will be provided to offset the harmful impact of the escalated prices of the food.

Refund System was released for the purpose of economic development. When the system was conceptualised and introduced, industries such as agriculture, forestry, fisheries, and mining were supposed to benefit first as the main reason was to protect the competitiveness of local domestic most important producers.

In the wake of the increasing levels of load-shedding, businesses are encountering more losses in revenue due to the incapacity to produce without electricity. In fact, repeated load-shedding implies that businesses must use more diesel to remain operational. Government could weigh up expanding the diesel fuel tax refund structure to stimulate strategic sectors that make use of more diesel to offset the adverse impacts of the load-shedding.

The investment in renewable energy, which will most likely be a great consideration especially by businesses and some households who can afford, will to some degree help reduce the pressure on ailing power grid. This will contribute to the increase in rebate claims and thus result in refunds.

5. Methodology

A Computable General Equilibrium (CGE) model research approach is adopted with a focus on the impact of load-shedding on the South African economy. The database of the model is composed of a social accounting matrix (SAM) constructed for the year 2015. Amongst all the economic agents captured in the SAM, particularity is given to the type of poor and non-poor households with a total of 14 households. Factors of production uses 6 types of employment classified by education levels. Factor demands are deducted from the first order conditions of companies' turnover growth while the price of every factor is deducted from value of its minimal good. Factors can be flexible with difference in prices based on the kind of activities. Portion of the Rest of the World (ROW) is based on the total assets and liabilities as captured by the South Africa Reserve Bank (SARB). The maximisation of the turnover of the companies is subject to a constant elasticity of substitution (CES) production technique by means of a linear order of factor inputs utilised to produce goods. The structure of production makes provision for each industry to generate different types of products through usage of factor of production composed of labour, land and capital. The production function uses a Leontief production function. The imports are assumed imperfect substitutes for domestic products following Armington (1969, 1970) assumption. From every product composite there is a constant elasticity of substitution (CES) function of a domestic product and the imported corresponding product. Below is the summary of the model:

5.1. Intermediate demands

In this model we first add demand for intermediate goods and services by activities, then introduce activity specific wages and unemployment, and finally allow for savings and investment. In order to accommodate intermediate demands the following new elements are added to the model:

Parameters

ica_{ca}	amount of c representing the intermediate input per unit of production in industry a

Variables

PVA_a	Net price after deductions of industry a
$QINT_{ca}$	amount of commodity c representing the intermediate input in industry a

We include two new equations inherent to the prices of value-added:

$$PVA_a = PA_a - \sum_{c \in C} P_c \cdot ica_{ca} \qquad a \in A \tag{1}$$

and intermediate demands:

$$QINT_{ca} = ica_{ca} \cdot QA_a \qquad c \in C, a \in A \tag{2}$$

Some changes in other equations are also implemented but not described here. Nonetheless, it must be noted that the payments for intermediate goods should be included where commodity rows meet the activity columns. Adding intermediates does not change the accounts in the SAM (Horridge, Parmenter, & Pearson, 1993).

5.2. Job loss and earnings by activity

In this model we assume that the minimum wage is paid for any labor performed by activity where the price of factor of production is uniform by activity as well. Although the wages in practices differ between activities, we treated this case in the model by assuming that wages are misrepresented for labor then again, the same for all activities where capital is considered with full employment for all factors of production. Furthermore, on the labor supply side, the model is calibrated by considering the quantity of labor supply as the market-clearing variable and the number of full-time equivalent employees is activity-specific,

When setting up the model, we ascribed the capital quantities by assuming that the wage (rental rate) is constant across all activities, but we consider capital to be activity specific. Thus, the time horizon of this model is of a short to medium term. In doing so, we would expect the rental rate to vary across activities when the shock is imposed on the modeled economy as opposed to the factor price equalization process of perfect competition. We assume the following when dealing with the factor behavior:

1. Description of the original levels of the factor demand variable (QF_{fa}) by activity and the factor supply parameter (qfs_f).
2. Description of the original levels of the average wage variable (WF_f) and wages (wfa_{fa}) by activity.
3. Description of the wage bias parameter ($wfdist_{fa}$) as the proportion between wfa_{fa} and WF_f.

4. The verification is done whenever there is activity-factor interaction. In this respect, the multiplication $WF_f \cdot wfdist_{fa} \cdot QF_{fa}$ should be proportional to the SAM disbursement targeting labour by industry.

Factor demand can now be written as

$$QF_{fa} = \delta_{fa}^{va} \cdot \frac{PVA_a \cdot QA_a}{WF_f \cdot WFDIST_{fa}} \qquad f \in F \quad a \in A \tag{3}$$

while factor income is defined as

$$YF_f = \sum_{a \in A} WF_f \cdot WFDIST_{fa} \cdot QF_{fa} \qquad f \in F \tag{4}$$

Each factor is assumed to transfer income to households in fixed shares:

$$YHF_{hf} = shry_{hf} \cdot YF_f \qquad h \in H, f \in F \tag{5}$$

5.3. Saving - Investment

In our model saving must be equal to investment. Nonetheless, savings can be seen as a "leakage" from the demand system. Savings are pooled to allow for investment to take place. The following modifications are necessary:

Parameters: Two important parameters are required for easy assessment of the savings. They are composed of household savings shares (mps_h) and base-year sectoral investment quantities ($\overline{qinv_c}$);

Variables: Inclusion of two important variables namely the quantities of investment demand $(QINV_c)$ and a factor establishing relative changes in investment quantities $(IADJ)$.

Equations: Introduction of important equations for the purpose of defining $QINV_c$ and checking the balance between savings and investment amounts. For instance, the equation for the investment can be portrayed as follow:

$$QINV_c = \overline{qinv_c} \cdot IADJ \tag{6}$$

While the equilibrium criteria are required between investment and savings, where savings must balance with investment, a specific variable termed WALRAS is adopted in this model to balance savings and investment. The savings – investment balance can then be written as:

$$\sum_{h \in H} mps_h \cdot YH_h = \sum_{c \in C} PQ_c \cdot QINV_c + WALRAS \tag{7}$$

In this model, to sustain the savings-investment balance the number of variables must be proportional to the number of equations as the value of WALRAS is usually set to zero. Moreover, prior to the inclusion of savings and investment, S-I is added to the components of the set AC which represents the activity account.

In this set-up we assume that the marginal propensity to save *mps* is fixed for at least one of the households. In our model we turn this around and fix investment QINV which allows us to examine the demand impact of an exogenous increase in investment demand. The income and expenditure from the household is captured in the SAM which constitutes the database for the static CGE model as depicted in equation 8.

$$Y_h\,(i) = Y_{PRIM}\,(i) + Y_{SEC}\,(i) + Y_{TERT}\,(i) + Y_{CAP}\,(i) \tag{8}$$

It is well known that the government income is always generated from various taxes composed of household tax (HHTAX), VAT and TARIFF as depicted in equation 9.

$$GR = VAT + HHTAX + TARIFF - EXPSUB \tag{9}$$

6. Results

The interpretation of the simulation results is performed based on the kind of shock occurred in the economy. Prior expectation is taken into consideration before evidencing the simulation results. We set the exogenous shock on the economy, which is the loadshedding in the electricity sector. Calculations measuring the impact of the shock are then described as percentage changes between the values in the baseline simulation and the policy simulation for every single variable in the model (Erero, 2021).

The above information provides an indication on the macroeconomic impacts of the loadshedding prior to the interpretation of the simulation results made. The policy shock related to the loadshedding will affect all the industries which are using electricity as intermediate inputs. Industries using electricity will be negatively affected while those are not will possibly benefit from the loadshedding. Nonetheless, the productivity gain should result in drop of prices of output in every industry. In this case, the impact of the loadshedding on the production function, labor, and GDP development. Table 4 includes the impact of the loadshedding in South Africa.

Table 4. *Impact on the Macroeconomic variables (base values and percentage change)*

Variables	Description	Base (2015 R billion)	Sim (% change)
ABSORP	Absorption	2687	0.1417
PRVCON	Private consumption	1586	-2.4138
FIXINV	Investment	501	0
DSTOCK	Stock	-3	0
GOVCON	Government consumption	604	0
EXPORTS	Exports	642	-3.1527
IMPORTS	Imports	-666	-2.1824
GDPMP	GDP (Market prices)	2663	-2.3043
NETITAX	Net indirect tax	287	-1.2538
EXRXY	Exchange rates	1	0.0046
YGX	Government income	679	-1.5325

Source: Shock results.

The impact of load shedding on the macroeconomic variables is already evident in the GDP figure which showed a contraction in economic growth by 2.3043% (see Table 4). The same trend is observed in other variables such as consumption (-2.4138%), exports (-3.1527%), imports (-2.1824%), and net indirect tax (-1.2538%). In fact, loadshedding has affected the production of most goods and services that relies on electricity as an essential input. South Africa's energy intensity (the amount of energy used per unit of economic output) is higher than the global average, making power outages especially costly to the economy. It is hard to put a monetary value on the cost of load-shedding. Estimates vary depending on the method and assumptions used.

The PwC recently estimated that, in the absence of loadshedding, South Africa's GDP growth rate would have been 5% points higher in 2022. According to Council for Scientific and Industrial Research's (CSIR) available data suggests that the loadshedding cost the economy R560 billion in 2022 (CSIR, 2023). Table 5 presents the industrial output from the simulation results.

Table 5. *Industrial output*

Sector	Base (2015 R billion)	sim (% change)
Agriculture	2	-4.7614
Mining	10	-4.4692
Manufacturing	14	-4.2272
Other industries	6	-2.0481
Private services	48	-3.9217
Public services	19	-1.5282

Source: Shock results.

Table 5 indicates that agriculture, mining, and manufacturing sectors have been particularly hard hit as already shown in the large contraction of the GDP. Thus, if not mitigated this contraction will have considerable repercussions on food security in the near future. In fact, current round of loadshedding affected negatively the irrigation, slaughter businesses, packaging, manufacturing and cold storage of food goods. While trying to lessen the effect of the loadshedding, farmers are experiencing substantial cost push inflation resulting from additional cost associated with additional fuel. Besides, there is rise in labour costs caused by the unproductive production time and inappropriate working hours organised around blackouts. Although primary and secondary industries are export intensive, they have poorly performed because of the loadshedding.

There are great concerns in the agriculture industry which relies heavily on cold storage as extended periods of load shedding are threatening the viability of the industry. The mining industry is heavily reliant on continuous energy supply especially in the processing, smelting and refining plants. Underground mining also requires absolute energy certainty to ensure health and safety standards are maintained. Mineworkers cannot go underground when their safety is compromised due to power cuts as this may result to fatalities. Table 6 presents the impact of loadshedding on the labour.

Table 6. *Labour*

Variables	Description	Base (2015 R billion)	sim (% change)
flab-p	Primary education	77	-5.2632
flab-m	Middle education	208	-4.1423
flab-s	Secondary education	387	-3.9811
flab-t	Tertiary education	541	-1.3184

Source: Shock results.

Table 6 indicates that loadshedding negatively impacted all labour categories where the hardest hit is employment with primary education (-5.2632%). Besides, the unemployment rate in South Africa was already high even before the resurgence of the global pandemic. It must be noted that all the industries have already had a tough moment recuperating from the previous devastation caused by the lockdown protocols. In this respect, they are forced to come with new plans to muddle through the negative effect of load-shedding in conjunction with the previous shortfall. Those industries are at risk especially for the perishable stocks which require uninterrupted power supply. More jobs have been shed as the country's economy is facing an unprecedented scenario with loadshedding not only impacting food security and mobile networks, but business sectors and industries at large. Table 7 presents the impact of loadshedding on the government revenue.

Table 7. *Impact on the government revenue*

Description	Base (2015 R billion)	Sim (% change)
Direct revenue excluding dividend tax	396	-3.6218
Activity tax revenues	38	-4.5386
Import duty revenues	23	-2.3253
Sales tax revenues	226	-5.4329
Transfers received from factors	52	-2.1052
Transfers received from ROW	-30	-1.4286

Source: Shock results.

Table 7 indicates that loadshedding negatively impacted the government tax revenue. Load shedding undoubtably impacts the economy and thus directly affects revenue collections. For example, in the mining industry revenue losses will impact Government's ability to earn revenue from taxes and royalties. Some firms are wasting billions of rands in income just because of the loadshedding. In fact, more diesel through generators must be consumed to remain operational. The Diesel Fuel Tax Refund system will be impacted by the increased reliance on diesel by industries such as agriculture, forestry, fisheries, and mining. Because load shedding affects all industries, government should revise the base of the diesel fuel tax refund by bringing in identified strategic sectors that consume more diesel to counter the consequences of the load-shedding. Table 8 presents the impact of loadshedding on the household spending.

Table 8. *Household spending*

Variables	Base (2015 R billion)	sim (% change)
POOR	273	-4.3925
hhd-0	27	-5.2836
hhd-1	47	-4.1083
hhd-2	57	-4.0985
hhd-3	65	-3.2187
hhd-4	77	-2.4278
NPOOR	1313	1.8592
hhd-5	89	-2.7342
hhd-6	108	-2.4121
hhd-7	151	-2.4001
hhd-8	287	-2.1051
HHD-9	677	-1.0263
hhd-9-1	84	-1.0141
hhd-9-21	98	0.9251
hhd-9-22	118	1.3768
hhd-9-23	144	1.4823
hhd-9-24	234	2.6245
ALLHHD	1586	1.4275

Source: Shock results.

Table 8 indicates that the household consumption is grouped according to the income sources which are poor and non-poor households. Poor households take-home pay from work only while non-poor households get earnings from other income sources such as capital, land, and labor. Usually, households own factor inputs subject to budget constraint inherent to the share of factor income, transfers from the government and other businesses. Even so, households show a discrepancy in their dynamic holdings and earnings.

Our simulation results indicate that the loadshedding pushed down the household earnings of all recipient households with exception of the top non-poor households. This substantially worsened the level of consumption expenditure and welfare of poor households. Consequently, loadshedding played a destructive role in hurting economic growth irrespective of the previous shock which caused the income loss of the households from the lockdown. The power cuts not only disrupt the functioning of the economy and households but also carry with its price effects on the cost of running business and cost of living and thus negatively impact on the growth trajectory of the economy which was recently eroded by the spread of the COVID-19 pandemic. The SARB Monetary Policy Committee (MPC) stated in its latest statement that due to load shedding, the GDP growth is forecasted at 0.3% for 2023. Given the severity of load-shedding, the Bank projects that it will reduce growth by up to 2 percentage points in 2023, as opposed to the earlier prediction of 0.6 percentage points (SARB, 2023)

7. Policy implication

It would be prudent for the government to consider the development of an industrial policy plan to support increased localisation of solar and wind energy components. Increased local production would support economic growth, employment creation and reduce the risk associated with global supply chains. The local production of most of the components would also support the rapid uptake of renewable energy sources by industry, government, and households. The renewable energy industry would also offer various economic opportunities across its value chain consisting of purchasing, producing, carriage, setting up, grid fitting, management, and preservation as well as the discharging phase.

8. Conclusion

This paper evaluated the impacts of the loadshedding in South Africa. We evaluated the general equilibrium impacts of the loadshedding by means of a CGE model adjusted to South African's social accounting matrix (SAM) for 2015. One policy simulation inherent to loadshedding is considered. The impact of load shedding on the macroeconomic variables was already evident in the GDP figure which showed a contraction in economic growth by 2.3043%. Our simulation results show that loadshedding undoubtably impacts the economy and thus directly affects revenue collections. For example, in the mining industry revenue losses will impact Government's ability to earn revenue from taxes and royalties. The application of the CGE model for analysing the impact of the loadshedding in South Africa constitutes the originality of this study.

In brief, three essential contributions are put forward in this article:

Loadshedding has been disrupting the functioning of the economy and households by carrying its price effects on the cost of running business and cost of living and thus negatively impact on the growth trajectory of the economy which was recently eroded by the spread of the COVID-19 pandemic. Given the gravity of load-shedding, the national Bank projects that it will reduce the economic expansion by approximately 2 percentage points in 2023, as opposed to the earlier prediction of 0.6 percentage points (SARB, 2023).

- Firstly, a matter-of-fact policy shock concerning the loadshedding which has developed new socio-economic behaviour in South Africa. The country's economy is dealing with an unprecedented scenario with load shedding not only affecting food guarantee and communication networks, but business sectors and industries in general. The simulation results show that loadshedding negatively impacted the GDP and welfare of citizens. This was accomplished by means of the CGE examination.
- Secondly, our research contributes to the body of knowledge on the effect of load shedding in South Africa as well as the opportunities that exist in the adoption of renewable energy sources.
- Thirdly, our research provided the country with an economic tool for policy evaluation. It would be prudent for the government to consider the development of an industrial policy plan to support increased localisation of solar and wind energy components.

Loadshedding has already caused significant damage to the country's economy, a review of respective industry impact indicates that there is an overall negative impact although the extent differs. The methods applied in this research article are appropriately documented for the elaboration of other models to be used for further studies.

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