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Electricity Shortages and the South African Economy: Reflections Based on an Economy-Wide Analysis

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Electricity Shortages and the South African economy: reflections based on an economy-wide analysis[1]

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1. Introduction

In the beginning of 2008, South Africa faced shortages of electricity, with an apparent suddenness and after many years of excess supply. It is anticipated that these shortages will continue for several years. Their economic impact will depend in large measure on how they are managed. In general, when there is a shortage, something has to bring the total quantity all users would like into line with available supply: the economy cannot use more electricity than is available.

This paper looks at the impact the shortage might have on the economy as a whole, depending on how use is adjusted to the shortage. We begin by stating the nature of the problem in order to set out what it is we attempt to analyse. We then look briefly at the use of electricity in the South African economy and some of the data problems involved in getting a clear picture. This is followed by a consideration of how impacts are affected by the time over which they take place. We then discuss some basic issues related to rationing. Finally, we use an economy-wide model to look at the impact of an electricity price increase and of rationing that is distributed differently according to sectors.

1.1 The nature of the problem(s)

There are three dimensions to the electricity problem faced by South Africa (DME 2008). While they are related, they have different prime causes and may require different responses.

First, there is a **capacity problem,** caused primarily by the gap between the installed (or operational) generating capacity and peak demand. The solutions are, on the supply side, to increase capacity by new investment and, on the demand side, to reduce peak demand. This can be done by shifting the timing of peaks of different users as well as by reducing those peaks through technical interventions.

Second, there is a **supply problem**, caused by a gap between consumption levels and ability to supply power. The latter is determined by a combination of operational capacity and the ability to run it over sustained periods. This depends in part upon technical requirements for maintenance and in part upon availability of complementary inputs, primarily coal. In South Africa there seems to be a constraint on production caused by quality and quantity of coal supplies.

Finally, there is a **reserve margin problem**, in which the margin between capacity and demand is below what is safely required to allow routine maintenance, to meet unanticipated surges in demand and to cope with unanticipated down time. In South Africa, this has been caused by demand rising faster than operational capacity. It results in less time for maintenance, in equipment being run harder and longer than is optimal, and it reduces the buffer for unplanned down time, so that any such time leads to disruptions of supplies.[2] The problem can be addressed in the longer run by increasing capacity. With given capacity in the short run, the ability to meet unanticipated increases in demand depends in part on the ready availability of inputs such as coal. When stocks have been depleted, they can only be rebuilt if coal purchases exceed usage. This can be achieved in part by reducing electricity consumption.

All three problems can thus be solved by various combinations of increased supply capacity and reduced use. The scope for the former in the short run is limited but not non-existent, placing much of the burden of adjustment on the demand side. In broad terms, users need to be either induced or instructed to use less electricity. Inducements could be targeted incentives to cut use – for example, subsidies for installing less electricity-intensive equipment – or price increases that persuade users to conserve electricity in whatever way they can. "Instructions" covers all forms of rationing. Rationing can be direct – some explicit administrative rule which decides which users will cut back and by how much – or indirect – some process which is not based on

[2] One can think of this as equivalent to carrying stocks of materials and finished product as a precaution against unanticipated disruption of supply and production. Since electricity cannot easily be stored, reserve capacity is the only way the industry can take such precautions.

targeting specific users but employs other criteria such as geographical area or time, such as load-shedding.

The policy problem is to find ways of reducing use that impose least cost on the economy in terms of foregone output, reduced employment and increased social disruption. While it is natural to focus attention in the short run on lost output and jobs, the greater cost is probably foregone growth. Lack of electricity constrains South Africa's ability to benefit from an international commodity boom. It probably also exacerbates negative influences on the economy – such as rising oil prices. While these consequences may not be completely avoidable, it is important that they are minimised as far as possible.

Both demand and consumption can be affected by price. However, they are not necessarily affected in the same way. Consumption is affected by cost to the user, although this is not the only determinant. The specifics of some uses may limit users' ability to respond to price increases. For example, the possibility of switching to other sources of energy varies across users. However, within these structural constraints, raising the price will reduce consumption. But peak demand depends not only on the **level** of consumption but also on its **pattern**. It is feasible for the level of consumption to be reduced without peak demand falling. One can think of a production process requiring two different electricity inputs, one related to starting up the process and the other to running it. In mining, for example, the start and end of a shift, in which lift gear is heavily used, has a higher demand than the rest of the shift. It may well be that the best way for mines to reduce electricity consumption in response to a price increase is to reduce other consumption, but to maintain the peak demand. A general price rise may accentuate the difference between peak and 'normal' demand, but not necessarily reduce the peak. To be certain to reduce demand through a price increase requires a time-dependent tariff structure.

The same considerations apply to using rationing to affect consumption and demand. Even when rationing reduces consumption, it may not reduce demand, and vice versa. To affect demand, the rationing instrument has to focus on a particular time of day or particular seasonal use.

The above discussion is intended to highlight the importance of understanding the specific problem we wish to address and the appropriate instruments for doing so. It should not be taken as suggesting that these varied instruments do not already exist in South Africa. Eskom already has mechanisms specifically aimed at peak demand. For example, large users are charged tariffs based on agreed peak usage and pay penalty prices if they exceed these limits. In most instances such users have installed equipment to monitor peak use and automatically switch use if they are approaching the limit.[3]

The modelling we use focuses on consumption not demand. We assume that there is a relationship between the amount of electricity a sector consumes and the output it produces over the year. While this is a reasonable assumption, it could be invalid for sectors where production processes have fixed peak demand requirements. It is possible that such an industry reduces output, because capacity cannot meet its peak, even though the supply of energy to it is not cut. Our models do not capture this possibility.[4]

It is useful to distinguish three possible phases in the output response of a sector, taken in isolation, as its electricity consumption is reduced (see Figure 1). Initially, there may be no reduction in output (Phase I). Continued reductions beyond this phase cause output to fall, possibly in steps, possibly at an accelerating rate (Phase II). Finally we reach some point when everything shuts down, even though some electricity may still be available (Phase III). The length of these phases (in terms of the amount of electricity cut) will differ from sector to sector.

[3] These provide excellent illustrations of the effectiveness of price-based mechanims for inducing desired responses from users.

[4] We could be interpreted as assuming a fixed relationship between peak demand and consumption. The figures in Table 1 suggest that this is not totally unreasonable. Between 1991 and 2008, differences in the ratio of peak MW to consumed GWh show up only in the third decimal place (although this constancy is dependent on the units of measurement).

The existence of Phase I need not imply that electricity is being "wasted". The electricity used by a firm or sector includes electricity purchased not only for a narrowly defined production process, but for all uses by the firm or sector. Thus, for example, electricity inputs into mining include electricity used by hostels at mines. Similarly, a manufacturing firm might purchase electricity not only to run its plant, but also to provide air-conditioning in its offices. Reducing these purchases may cause discomfort and require adaptation, but will not necessarily cause output to decline.

In the modelling we focus on phase II effects. The production relationships in the model do not incorporate any 'waste' or slack in electricity use. In any case, there is little problem if sectors are able to reduce electricity purchases without reducing output. We also assume that the Phase II curve is linear, so that there is a proportional relationship between electricity use and output.

1.2 An overview of electricity as an input into the South African economy

The most detailed publicly available data on patterns of electricity use are provided in the Supply Use Tables (SUTs) published by StatsSA. The latest SUT published is for 2002 (Statistics South Africa, 2005). Although this is now dated, we are concerned mainly with the structure they depict, rather than their levels. Experience elsewhere suggests that structure changes slowly. The 2002 Use Table shows the use of 153 products by 94 sectors.

In principle there are two questions we would like to answer if we were to examine shortages from a sectoral, rather than an economy-wide, perspective: how dependent are sectors on electricity and how much electricity do sectors use? The answer to the first would tell us how output would be affected by any cuts, giving us a first take on the impact of the reductions. The second would tell us how much electricity could be released from the sector, a particularly important piece of information if we are trying to meet some targeted reduction in overall electricity consumption. From this point of view, out ideal target would be a sector that consumes a high proportion of total electricity consumption, but that has either a low dependence on electricity, produces a small proportion of national output or contributes little to national employment. Table 2, Table 3 and Table 4 present data relevant to these questions.

The share of electricity in the cost structure of an industry might give some indication of its direct vulnerability to electricity shortages. Table 2 shows industries ranked according to their 'dependence' on electricity, i.e. the share of electricity in their cost structure (for convenience we present only the top and bottom parts of the distribution. We would ideally like to target the sectors at the lower end of this table, i.e. the least dependent sectors. But we can see from the second column that these sectors consume very little of South Africa's electricity (together, the bottom 11 sectors account for only 1.3% of total industrial consumption). We have to target sectors that are relatively dependent on electricity (in this sense) in order to make any significant reduction in electricity consumption.

We would also ideally try to avoid sectors that make a high contribution to GDP (or to employment or to exports – whatever criterion we think is important). Table 2 also shows contributions of the sectors to gross output and to value added. There is no correlation between dependence on electricity and contribution to value added (the simple correlation coefficient between the two is -0.05). We can see how this shows up with the top two sectors in the table, "Non-ferrous Metals" and "Gold". Although electricity is a high proportion of input costs for both, and they both account for a high proportion of industrial consumption of electricity, "Non-ferrous Metals" (which includes most of smelters) produces only 0.8% of GDP, whereas "Gold" contributes 2.6%. Other things equal, we would prefer to make cuts to the former.

Table 3 and Table 4 give similar information. 75% of spending on electricity by industry was accounted for by the top 15 purchasers, which produce 45.9% of GDP (value added). Table 4 presents complete data on dependence and use.

We should note the limitations of cost share as a measure of dependence. It would be appropriate if there was a fixed (proportional) relationship between input of electricity and output of a sector. We would ideally like to know what flexibility a sector has in responding to reduced electricity supply. Is it in Phase I or Phase II? What is the shape of its Phase II? We do not have information that allows us to answer these questions.

Table 2, Table 3 and Table 4 provide information that helps to understand the direct impacts of electricity cuts. However, sectors consume electricity indirectly as well, through the inputs they purchase from other electricity consuming sectors. These inter-industry effects will also determine the impact on GDP that the sector has. We can note from Table 2 that although the contribution of "Non-ferrous Metals" to value added is low, its contribution to gross output (which includes intermediate purchases) is high. It is likely therefore to have high knock on effects, which may increase the impact that reduced output has on national electricity consumption and simultaneously make the output and employment consequences worse. To analyse these we need to move away from a sector focus and look at the economy-wide impact.

While the SUT data are useful for understanding electricity use in South Africa, and form the basis for most of the modelling we undertake later, there are some shortcomings which need to be noted.

Differential pricing: Most importantly, these data show expenditure on electricity, rather than physical use (i.e. KwH). Since users are charged different prices, physical use and expenditure are not perfectly correlated. However, to the extent that there is a tendency for big users to be charged lower prices, the figures in Table 3 will understate relative use at the top and over state it at the bottom.

Unfortunately detailed data on physical use by user are not publicly available. Eskom does have confidential data on usage classified at a 5-digit SIC level. However, electricity supplied by municipalities is classified only at the very broadest level – residential, commercial and industrial. It is therefore not possible to collate the two sources of data to provide a detailed picture of physical consumption by user.[5]

Based only on the Eskom data, the biggest anomaly the price differentials cause is for residential and prepaid users. They consume about 10% of Eskom's sales measured by expenditure, but only about 4% measured by kilowatt hours.

Peak demand: we have no data on peak demands by users. This is not a problem for the modelling since we model consumption not demand. However, such data would be useful for more rigorous modelling of production processes.

Consumption of self-generated electricity: the SUT does not record use of electricity generated by users. SUTs measure market transactions, not intra-firm activities. Where electricity is generated inside the firm using purchased inputs, we would see high purchases of (say) diesel which is then transformed into electricity. This is no different from any other inputs that are transformed in the production process, and does not pose problems. However, when we consider changing technologies induced by the shortages and the possibilities of co-generation by private producers, we would probably wish to be able to identify the extent of own use.

1.3 Impacts and time

The size of any impact of a shock to the economy will depend in part on the period over which it is measured, for several obvious reasons. First, any cumulative impact will be bigger over longer periods simply because it is cumulative. Second, (and importantly for economy-wide assessments) the impact will be greater the more time there is for it to have knock on effects – for the shock waves to be felt through the economy. Third, responses – whether ameliorating or aggravating – will be more significant the more time they have to be put into place.

The same shock may have different time profiles, depending on the specific measure of its impact. We are interested in the impact of the electricity shortages on, *inter alia*, output and employment. When we assess the output response, we should be more precise in specifying the

[5] We would like to thank Eskom and EDI for supplying us with these data.

period to which we refer. Obviously, we would expect the aggregate output lost to rise as time passes, allowing losses to accumulate. However, we would expect the impact on the industry's ability to produce within a given period of time, say a week, to be bigger immediately after the cuts than later, when producers have had time to respond with actions that ameliorate the impact. Indeed, there may be no discernible effect on output per week after sufficient time has passed.

However, this may not be true when we measure the impact on employment. Even if firms wish to reduce their labour force in response to the shortages, they may not be able to do so in the very short run because of contractual obligations. In this case, employment may decline only after some time has lapsed. It may then never recover to its former level if the ameliorating response is to move to less labour intensive technologies.

Impacts can be usefully classified according to the period in which they take effect:[6]

- ***Very short run***: no supply response is possible and demand responses are limited to adjustments within existing technology (e.g., switching off lights, air conditioning, hot-water geysers, etc.);
- ***Short run:*** no supply response is possible, but a wider range of demand responses are possible, including some minor technical changes (e.g. using CFLs: A possible way of distinguishing between these demand responses and those in the very short run is that there is now some kind of 'capital' cost involved in making the change);
- ***Medium run:*** some supply responses are possible (e.g. co-generation from existing capacity); demand responses include making 'easy' switches in technology ;
- ***Long run:*** the full range of supply and demand responses is possible.

These periods lie on a continuum, and will differ from industry to industry, and probably from firm to firm within any industry. Nonetheless it is useful to analyse impacts within this periodisation.

In the shortest run, when supply/capacity is fixed, some form of demand management is required. In principle, this can be done ***through the market*** (allowing prices to change and letting users respond as best they can) or by ***rationing*** (some administrative allocation) or a ***combination of the two***.

The time dimension is also important when thinking about likely responses to the shortages by various private agents. These will depend on the perceptions of agents as to whether the shortages are temporary or not: a shortage that is expected to last a few days and not to be repeated will evoke a different response to one that is expected to be sustained for some length of time.

1.4 Administered prices, rationing and electricity in South Africa

The differences between market- (price-) based and rationing responses to the shortages are at the heart of our analysis below. It is therefore useful to set out some broad issues that affect the modelling strategy we have adopted.

South African electricity price changes are based on negotiations between ESKOM and NERSA. This does not result in prices that respond to market conditions. It appears that while the regulator can consider cost-side issues, it cannot consider those on the demand-side; price increases can be permitted because costs have risen, but not because there is a need to reduce demand.

Problems inherent in this procedure have been masked up to now by the fact that there has been excess supply of electricity. Effectively, ESKOM has been able to meet the demands of all users at the existing price without running into a supply constraint. Increased demands from existing or new users could be accommodated within existing capacity constraints. Effectively, changes in

[6] This classification is adapted from Rose and Gauri-Shankar (2004)

demand have been met at a (low) fixed price by varying profits. Indeed, until recently Eskom has attempted to encourage users to increase consumption (and users of competing energy to switch to electricity). This is entirely what one would expect from an industry which has excess production capacity and is effectively unable to vary its price.

Problems are surfacing now because the surplus capacity has disappeared. If the price is not permitted to rise in the face of this, there has to be some other method of deciding which users will have to reduce their consumption and which will not. As indicated above, this could be through direct and/or indirect rationing. Indirect methods may be haphazard in their effects on different users, unless there is a very clear geographical pattern of use. Businesses may benefit by being on the same grid as users who are exempted from load shedding; but which businesses these are has been determined by a largely random (in terms of electricity use) historical process.

Unless direct rationing reduces use by at least the total excess demand, other mechanisms have to be brought into play. This is difficult to ensure, even where demand is not growing (assuming that the rationers would prefer not to cut excessively). It is even more difficult in a dynamic setting. If demand rises over time while capacity does not, one necessarily needs to keep tightening the rationing. Given the difficulty of changing direct rations frequently, it probably becomes increasingly necessary to resort to indirect rationing: unplanned load shedding is likely to become more frequent over time.

The quantity of electricity consumed by rationed users under rationing will be less than under the price increase. This is a result that applies under all rationing schemes. Under the price increase, the required aggregate cut is distributed across a wider spectrum of users than under rationing. To meet the same aggregate cut, under rationing, those rationed necessarily have to reduce consumption by more. Those in favour of rationing are actually motivated by this. They feel that some users should have bigger and others smaller cuts than they would under the market solution, whether on grounds of fairness, ability to absorb cuts, economic impact or what have you.

1.5 Analysis of the economy-wide impacts of the shortages

As indicated above, although the figures in Table 2, Table 3 and Table 4 are useful for assessing electricity use by sectors taken on their own, they do not give any idea of indirect usage of electricity. Industries use electricity not only directly but also indirectly through the inputs they purchase from other sectors. To examine these we need to consider inter-industry linkages. Nor do the tables show us the influence of economy-wide constraints and feed-backs. These might change the conclusions we draw from a sector-focussed study. For example, when we examine a sector in isolation it is obvious that a cut in electricity supplies can only be harmful or, at best, have no impact: it cannot be beneficial. If we reduce the availability of a necessary input, we reduce the sector's capacity to produce and, to the extent that it cannot make costless ameliorating adjustments, will reduce its output. However, when the cuts affect a number of sectors simultaneously, other factors are brought into play. As sectors cut back their output they reduce their demand for inputs. Depending on the time horizon over which the effects are measured, this can reduce prices and costs for other firms that use them. This provides a positive impetus that counteracts the negative effects of the cuts. Whether the net effect is negative or not will depend on the importance of electricity as an input and the size of any price reducing impacts.

Other economy-wide effects may also be important. The exchange rate may depreciate, stimulating export oriented sectors. Labour costs may be affected as labour is shed from contracting sectors.

To examine these we need to locate any particular sector within the whole economy. Various techniques for economy-wide analysis allow us to do this and help us to think through some of the issues. We make use primarily of a computer based model – technically a computable general equilibrium (CGE) model – that captures economy-wide interlinkages between production, income-distribution and consumption, and which incorporates some behavioural responses to the shocks. We supplement this with an input-output model, which assumes fixed proportions, to examine cost-push implications of electricity price increases.

We need to be clear at the outset that the approaches we use do not give us forecasts, but allow us to isolate the effects of the shortages. They do **not** give us a picture of the South African economy in (say) 5 years time. Rather they provide us with a laboratory that allows us to think about the impacts of the shortage *if nothing else changes*. We capture changes that occur as a consequence of the shortages, but not those that might occur if, for example, world commodity prices collapse in addition to the shortages.

The CGE model we use has been used to analyse a number of issues in South Africa (see Thurlow and van Seventer, 2002, for a full specification and discussion of the model). It is essentially a market oriented model that assumes that prices are allowed to adjust in response to changes in supply and demand. Imposing rationing in such a model requires further model development, which is still being undertaken. Nonetheless, some preliminary lessons can be drawn from the unrefined model.

Our modelling strategy is as follows. We assume that there is a 10% fall in electricity output consequent upon a reduction in the capacity of the sector. We examine the consequences for the rest of the economy in a static, one-period model. It might be more appropriate to use a dynamic model, which tracks the path of the economy over time, with and without the constraint on electricity supply. However, to do so would require better information than we have about how investment and technology in different sectors responds to the shortages. This is important to examine, but will take more time than was available for this report. We believe that the static approach we use is a simple way of capturing the situation in South Africa, which has arisen because demand growth has outstripped capacity. It gives us useful insights while avoiding further complicating assumptions that a more dynamic analysis would require.

Within this framework, we analyse two broad scenarios. The first, a market scenario, allows the price of electricity to adjust to match demand with available supply. The second, a rationing scenario, forces selected sectors to reduce their electricity consumption. We actually run a set of these rationing scenarios, varying the selected sectors. In all of them, we allow the price of electricity to change so as to allocate electricity amongst the remaining non-rationed sectors.

Allowing prices to rise in this way may seem to miss an essential aspect of electricity in South Africa, namely that its price is an administered rather than a market one that responds to demand changes. However, as discussed in the previous section, unless rationing reduces demand sufficiently to erase all excess demand, we need a rule for allocating the remaining excess demand. We do not know what rules are used for deciding on load shedding, or how such indirect rationing maps into different economic sectors. We have therefore not tried to simulate such rationing. Rather, we examine the extent to which rationing targeted sectors reduces the price increase that would otherwise be required. This captures part of the motivation behind rationing: by imposing a certain burden on some users, we can reduce the burden placed on others.[7]

There are a number of modelling concerns that have to be addressed:

- ***Prices in the model are relative prices.*** When we talk below of a change in the price of electricity, we mean that its price must change relative to all other prices. We keep the CPI constant. This is important when interpreting the results, and we will re-emphasise it later. It means that the modelling *per se* cannot tell us about the inflationary impact of prices changes. To measure this, we insert the predicted electricity price increases into a separate model based on the same Supply-Use tables.

[7] Those who are unhappy with the model permitting price changes might prefer to interpret them as indicating the pressure of unsatisfied demand remaining after rationing has been implemented. A higher price rise suggests a greater demand by non-rationed users and a greater problem for the rationing scheme.

- ***Additional profits from electricity price increases are retained in the electricity sector.*** It is reasonable to assume that the price increase will generate extra revenue for electricity producers (implicitly assuming the elasticity of demand for electricity is less than one). What happens to this revenue? This is not only a modelling issue, but also has to be addressed in the real world. In practice, Eskom's profits are either distributed as dividends to government or retained and (presumably) invested. Surpluses generated by municipalities, if any, presumably go into local government financing.[8] For the modelling, we have assumed that any additional profits are retained in the sector. They raise aggregate savings directly and thus indirectly permit aggregate investment to rise. However, since we use a static model, we do not consider the sectoral distribution of investment.

- ***The nominal exchange rate is kept fixed.*** The shortages might be expected to affect exports and imports. We examine the impact on the current account balance, although we will also consider what the consequences of permitting the exchange rate to vary to maintain a fixed current account balance.

- ***The government budget balance is allowed to vary.*** Electricity shortages might be expected to have direct and indirect effects on government revenue and spending. We choose not to neutralise this effect (for example, by assuming that tax rates are adjusted).

- ***Equality between aggregate savings and investment is maintained through a 'balanced closure'.*** We assume that investment is a constant proportion of domestic absorption and that savings rates adjust to maintain the equality between savings and investment that is required for macroeconomic consistency.

- ***There is unemployment and no skills shortage***. We have assumed that there is unemployment in the model, and that there is no shortage of skilled labour. This allows us to focus on what happens to the demand for labour and the potential for creating or losing jobs.

In each of the experiments that make up the set of rationed scenarios, we target different sectors for rationing. While we have selected sectors partly on the basis of those that have already been targeted for rationing (gold and other mining, smelters, commercial businesses, households), our main interest is to understand how the impact of rationing is affected by the characteristics of the targeted sectors so as to draw out some broad lessons.

We have to make a decision on the extent of the rationing we should model in each sub-scenario. The initial discussions about rationing did specify targets for the cuts in the targeted sectors. For example, one suggested set of cuts (not implemented) was that industrial users would be cut by 10%, commercial by 15%, hotels, resorts and shopping malls by 20%, large office buildings, government, municipal & electricity offices by 15%, agriculture by 5%, residential by 10%, large users by 10% and that coal mining, electricity and water would not be rationed at all. These targets were probably set on the assumption that direct rationing would be required to reduce consumption by the full expected shortfall of 10%. However, as it turned out, responses of users to the threat of rationing meant that such drastic direct rationing was not required. Furthermore, the targets were also probably set on the assumption that they did not exceed what we have termed Phase I cuts for most users; they could be made without affecting output drastically. This being the case, it does not make sense to implement them in a model that analyses Phase II cuts.

Thus, although there may be apparent merit in replicating actual or proposed rationing schemes, it does not make sense to model these early proposals.[9] More importantly, there is not a lot to be learned from implementing such cuts. More can be learned by simulating rations targeted at

[8] It is possible that higher revenues do not translate into higher profits/surpluses, but are appropriated as higher salaries and wages in the sector.

[9] While some sectors are being rationed at present, we do not have detailed information on what the rationing strategy is.

different sectors or groups of sectors, comparing the impacts and trying to understand why there might be differences. To do this we need to eliminate certain obvious reasons for the differences. For example, the same percentage reduction in sectors that consume very different quantities of electricity will obviously have very different impacts. We need to set the rations so that we compare like with like. To do this we have assumed that the aim of rationing is to reduce the initial excess demand for electricity by a given amount, regardless of which sectors are rationed. When there are a group of sectors targeted, we assume that they are all cut by the same per cent. For comparative purposes, we also apply uniform 10% cuts in electricity use by rationed sectors.

The target we select for the rationing exercises is to reduce the excess demand for electricity by 10%. This is a relatively small target, but is predicated on the relatively small electricity consumption of most sectors. Since most sectors consume considerably less than 10% of total electricity, trying to recover the all of the shortage from a small sub-set of them would entail closing them down.

Table 5 summarises some of the impacts of five different schemes: a market solution plus two rationing schemes, targeted at different groups of sectors. For each of these we show uniform cuts in the targeted sectors both by 10% (columns 2A and 3A) and by a percentage that reduces overall excess demand by 10% (2B and 3B). Thus, because the 'mining and smelter' sectors are such large users relative to the 'commercial', we would need to cut their use by only 4.3% to achieve the same overall reduction in demand as against a 15.7% across the-board-cut in the 'commercial' sectors.

1.5.1 The Electricity Price

The price of electricity would have to rise by 71.3% if it was relied on to bring demand into line with the reduced supply (the 'market solution').[10] As expected, this increase is mitigated when various rationing schemes are introduced, with the required increases varying between 13.9% and 65.0%. There is thus scope for rationing to mitigate price increases.

Why is there such a difference in the price impact of different rationing schemes? The differences in the interindustry linkages of the sectors are at the heart of the explanation. The targeted commercial sectors have more significant linkages to other industries than do the mining and smelting sectors. This means that the reduction in commercial output consequent upon the rationing has a larger (negative) knock-on effect than does the reduction in mining and smelting. For example, the output multiplier derived from the SUT is 3.0 for Other Mining, whereas it is 4.2 for Business Services. The decline in business services thus has a bigger initial impact on outputs of other sectors. This not only feeds into bigger reductions in demand for electricity by other sectors, but also (through its greater impact on employment and household income), a greater decline in demand for electricity by households. Although we have cut the demand for electricity by the same amount in both rationing schemes 2B and 3B, the secondary consequences of 3B are such as to induce a bigger further reduction in demand, thereby requiring a smaller price increase to restore balance between supply and use.

By this token, other things equal, we would prefer to target 'commercial' sectors for rationing. More generally, targeting sectors with greater linkages to the rest of the economy will provide more effective rationing, insofar as our aim is to mitigate price increases. Unfortunately, there is a cost to this: the output and employment impacts are commensurately worse.

1.5.2 Macroeconomic outcomes

With full price adjustment, GDP falls by 0.9% in real terms. The rationing schemes worsen this impact. However, rationing commerce has a much bigger negative impact than rationing mining and smelting: when we compare the two equivalent schemes (2B and 3B) we see that the negative

[10] Recall that this is a *relative* price, meaning that the electricity price would have to rise by another 71.3% over and above any underlying rate of inflation. If the rate of inflation is 10% the price of electricity would have to rise by 88%.

impact on GDP of rationing commerce is almost 10 times that or rationing mining and smelting. Similarly, the impact on employment is much greater.

The reason for this is the same as the reason why the electricity price does not rise as much. The stronger linkages of the commercial sectors to the rest of the economy induce a stronger (negative) output effect. This simultaneously means that there is less need for price increase to cope with excess demand **and** that GDP and employment fall more.

There are several reasons why all the rationing schemes lead to a larger output and employment decline than price adjustment. When a lower electricity input reduces the output of a using sector, it can raise its price. This will offset somewhat the contractionary effect of the electricity shortage, providing an inducement to produce more. With price adjustment, sectors are able to balance these two effects and decide how far it is profitable to reduce output (if at all). We thus get a smoother adjustment across the economy, with a number of sectors making small cuts in electricity usage. In principle sectors where cuts have least impact on profits make the most adjustment. Rationing imposes large cuts on a few sectors and does not allow them to respond (in the short run) to off-set the effects.

The sectoral output changes shown in Table 6 illustrate the problem.[11] In the un-rationed scenarios where firms adjust to a price increase, the output of non-ferrous metals falls by 3.3%, gold mining by 1.8% and other mining does not change. They are able to absorb the electricity price increase with relatively little adjustment to their output. In the rationed scenario however, we impose a 10% cut on their output. Although this releases more electricity, ameliorating the rise in the market clearing price of electricity, it is a much bigger cut than would otherwise have occurred.

We have assumed that the exchange rate adjusts to keep the current account of the balance of payments stable. Although the impact on the exchange rate is small (well within the margin of error), it is instructive to look at it. With un-rationed adjustment, a slight appreciation occurs. This surprising result is a consequence of the shrinking GDP causing a fall in import demand that outweighs the decline in exports. However, with rationing, the exchange rate depreciates. We are rationing export sectors, forcing their output (and exports) to fall more than they would have without rationing.

The larger decline in GDP with rationing also occurs because of the loss of markets for some sectors. The enforced decline in the rationed sectors spills over into reduced demand for outputs from sectors supplying them with intermediate inputs.

We have assumed that all labour is relatively abundant, so that changes in demand for it are met by changes in supply, with no increase in wages. In both the unrationed and the rationed scenarios, employment falls. As should be expected it falls less in the market solution than in any of the rationed solutions.

Household income also falls. However, unlike the impact on other variables (where rationing has a bigger impact than the market solution), household income falls by a smaller percentage in some of the rationing solutions than in the market solution. The higher rise in the price of electricity in the market solution simultaneously raises Eskom's profits and squeezes other sectors' profits more than under rationing. Recall that we assume that Eskom retains its capital income. Household income depends on capital income in other sectors, and since these are squeezed less under rationing than the market solution, it is possible that more capital income is distributed to households. There will not necessarily be the same outcome across all rationing scenarios, since other factors affect capital income. In particular, profits in the rationed sectors are affected, and this may off-set the foregoing effect.

This is a complex story, and is clearly driven by the assumptions of the model. It does suggest, however, that the management of Eskom's profits when electricity prices are raised will have an important impact on overall outcomes.

[11] Only summary statistics are presented to preserve space.

1.5.3 Sectoral Changes

One of the concerns informing the management of the shortages has to be the impact on different sectors. The database underlying our analysis covers 110 sectors and thus provides a mass of data. At the risk of over-burdening the reader, we present detailed impacts on sectoral outputs under the different scenarios in Table 6.

There are a number of 'patterns' that are apparent in the table.

- The effects of the shortages are negative on all sectors;
- The effects are bigger the stronger the rationing.
- As measured by the unweighted average impact, the market solution has a smaller impact than any of the rationed solutions. However, the median impact for 2B is much the same as for the market solution;
- The two schemes rationing mining and smelters seem to have a much more varied impact on sectors than the market solution, which is more varied than the two commercial rationing schemes (as indicated by the coefficients of variation). This is probably for the same reason that the commercial rationing has a bigger impact on output: the inter-industry linkages are stronger and thus generate bigger, but more uniform impact.
- The impacts of the different schemes on the different sectors vary considerably. While the correlation between the ranking of the impacts is reasonably strong within each broad scheme, it is low across schemes. Thus the correlation coefficient between rankings under the two equivalent schemes (2B and 3B) is 0.47. Coal mining is the worst affected sector under the market solution, simply because it is a major input into electricity. Under rationing of mining, we see that the Jewellery sector is worst hit, while it is Office Equipment under the commercial rationing scheme. Indeed, output in these sectors falls even more than the fall in the output of the rationed sectors.

1.5.4 Other considerations

The results we have presented above are based on a particular set of assumptions embodied in the model. It is useful to consider how these affect the results. Two sets of considerations are of particular relevance: the elasticities used and the assumptions about exchange rates. Here we consider briefly how different assumptions would affect the results.

We have discussed earlier how the impacts of shortages depend on the time period over which they are measured (see section 1.3). One way to capture the effects of time is through the elasticities which govern how producers respond to changes in prices. For the above results we have assumed that the elasticities are low, in an attempt to measure short-run impacts. With a higher set of elasticities we find that the price effects are somewhat ameliorated, while the output effects are worsened. Thus in the market solution, raising elasticities of substitution from 0.3 to 1.2 across the board reduces the required electricity price rise from 71.3% to 56.8%, but increases the drop in GDP from -0.9% to -1.8%. Similar patterns are found in the rationing schemes.

We have also assumed in our results above that the exchange rate is kept fixed, with the current account balance adjusting. If instead the exchange rate is flexible and adjusts to maintain a constant current account balance, we find a similar effect to raising elasticities: the price effect is ameliorated and the output effects are worsened. GDP would fall by several percentage points more.

1.6 Conclusion

This paper has looked at some of the economy-wide considerations that should be taken into account when considering policy responses to the electricity shortages in South Africa. Market (price) driven solutions are found to be less harmful than rationing. This is hardly a surprising conclusion, especially from a model that is primarily concerned with real resource allocation effects.

However, the paper also points to a number of weaknesses in our understanding and gaps in the data concerning electricity use in South Africa. These shortcomings are relevant not only for the analysis of this problem but also for the longer run issue of changing energy use related to the environment and to climate change. It would probably be sensible for more work to be done on filling these gaps. In particular, more work needs to be done on modelling electricity use in production at the micro level.

1.7 References

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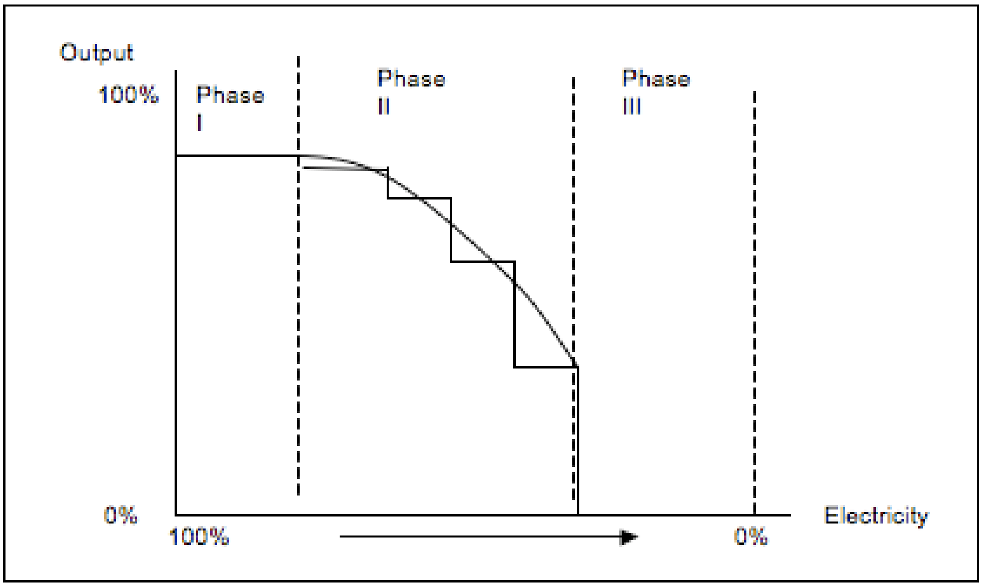

Figure 1: A schematic illustration of the impact of electricity cuts on a sector

Table 1: Data on SA Electricity Production and Use

	Peak demand	Installed Capacity	Operational Capacity	Reserve Margin	Volume of electricity available for distribution	Ratio of Demand to Consumption	Consumption/ installed capacity
	GW	GW	GW	%	GwH	MW per GwH	GwH per MW
	[1]	[2]	[3]	[4]	[5]	[6]	[7]
1991	22,5	33,0	29,5	32%	153,776	0.146	4.66
1992	22,6	34,9	30,1	35%	154,083	0.147	4.41
1993	23,1	35,9	31,1	36%	159,505	0.145	4.44
1994	24,4	36,8	32,0	34%	165,985	0.147	4.51
1995	25,0	36,7	32,0	32%	171,401	0.146	4.67
1996	28,0	37,5	32,8	25%	180,370	0.155	4.81
1997	28,1	38,0	33,2	26%	187,507	0.150	4.93
1998	27,9	38,8	34,6	28%	187,516	0.149	4.83
1999	28,0	39,3	35,4	29%	190,120	0.147	4.84
2000	29,1	40,0	36,2	27%	195,660	0.149	4.89
2001	30,5	40,5	37,1	25%	196,063	0.156	4.84
2002	31,9	40,5	37,1	21%	206,020	0.155	5.09
2003	32,0	40,5	37,1	21%	213,461	0.150	5.27
2004	34,1	40,5	37,1	16%	221,938	0.154	5.48
2005	33,2	40,5	37,1	18%	223,257	0.149	5.51
2006	35,2	40,5	37,5	13%	231,323	0.152	5.71
2007	37,1	41,2	38,8	10%	241,414	0.154	5.86
2008	38,6	42,0	40,2	8%	-	-	-

Sources: Cols [1] to [3]: DME (2008); col [5] StatsSA (1996) and StatsSA (2007);
Notes: [4] = ([2] – [1])/[2] ; [6] = [1]/[5] x 1000 ; [7] = [5]/[2] x 1000

Table 2: Electricity Usage and Cost Structure for Sectors and Selected Industries

Rank	Sector	Share of Electricity in sector input costs	Share in National Electricity Consumption	Share in National Gross Output	Share in National Value Added
		%	%	%	%
1	Non-ferrous metals	16.1	13.2	1.1	0.8
2	Gold	12.3	9.4	1.8	2.6
3	General hardware	10.9	0.9	0.1	0.1
4	Knitting mills	8.4	0.8	0.1	0.1
5	Water	7.6	2.8	0.5	0.5
6	Other textiles	7.3	0.3	0.1	0.0
7	Tyres	7.0	1.4	0.3	0.2
8	Accommodation	6.5	4.8	1.1	1.0
9	Fish	5.4	0.3	0.1	0.1
10	Pharmaceuticals	5.1	3.3	0.8	0.4
11	Soap	5.1	3.3	0.8	0.4
…	…	…	…	…	…
83	Motor vehicle parts	0.3	0.2	1.0	0.8
84	Plastic	0.3	0.2	0.9	0.7
85	Buildings	0.2	0.4	2.6	1.2
86	Business activities	0.2	0.4	3.8	3.8
87	Other food	0.1	0.0	0.4	0.3
88	Other paper	0.1	0.0	0.3	0.1
89	Pesticides	0.1	0.0	0.2	0.1
90	Wire & cable	0.0	0.0	0.3	0.1
91	Special machinery	0.0	0.0	0.3	0.3
92	Motor vehicles	0.0	0.0	3.5	1.0
93	Recorded media	0.0	0.0	0.0	0.0

Source: calculated from StatsSA 2005

Table 3: Top Fifteen Sectors ranked by Shares in Electricity Purchases

		Share of Use		Share of Gross Output		Share of Value Added	
		%	Cum.	%	Cum.	%	Cum.
1	Non-ferrous metals	13.2	13.2	1.1	1.1	0.8	0.8
2	Gold	9.4	22.5	1.8	2.9	2.6	3.5
3	Transport services	7.8	30.3	5.9	8.8	5.8	9.3
4	Trade	6.6	36.9	10.3	19.1	13.0	22.3
5	Other mining	5.7	42.7	3.6	22.7	4.7	27.0
6	Petroleum	5.0	47.6	2.5	25.2	1.5	28.5
7	Accommodation	4.8	52.4	1.1	26.3	1.0	29.5
8	Communications	4.6	57.0	4.0	30.3	4.0	33.5
9	Soap	3.3	60.3	0.8	31.1	0.4	33.9
10	Pharmaceuticals	3.3	63.7	0.8	31.9	0.4	34.3
12	Real estate	3.2	66.8	4.3	36.2	6.1	40.4
13	Iron & steel	3.0	69.8	2.9	39.1	1.3	41.7
14	Water	2.8	72.6	0.5	39.6	0.5	42.2
15	Activities/ services	2.4	74.9	2.5	42.1	3.7	45.9

Table 4: Sectoral Electricity Dependence and Use

		SHARE OF ELECTRICITY CONSUMPTION				
		1	2	3	4	5
SHARE OF ELECTRICITY IN INPUT COSTS	1	Recorded media (0.00, 0.00) Motor vehicles (0.01, 0.02) Special machinery (0.02, 0.00) Wire & cable (0.04, 0.01) Pesticides (0.12, 0.02) Other paper (0.13, 0.04) Other food (0.14, 0.04) Agricultural machinery (0.33, 0.02) Engines (0.34, 0.02) Radio & television (0.44, 0.08)	Plastic (0.30, 0.20) Structural metal (0.32, 0.16) Mining machinery (0.34, 0.10) Containers of paper (0.37, 0.17) Electrical equipment (0.44, 0.11)	Business activities (0.16, 0.39) Buildings (0.16, 0.36) Motor vehicle parts (0.31, 0.22)	Other construction (0.38, 0.43)	
	2	Footwear (0.46, 0.05) Household appliances (0.58, 0.08) Electricity apparatus (0.70, 0.07) Lighting equipment (0.90, 0.05)	Jewellery (0.75, 0.10) Sugar (0.81, 0.15) Leather (0.86, 0.12)	Publishing (0.55, 0.24) Textiles (0.62, 0.21) Wearing apparel (0.64, 0.31) Fertilizers (0.67, 0.30) Other Transport (0.86, 0.25)	Other manufacturing (0.55, 0.50) Wood (0.79, 0.41) Beverages & tobacco (0.92, 0.93) Fabricated metal (0.97, 0.64)	General government (0.53, 1.91) Insurance (0.63, 1.90)
	3	Non-structural ceramics (1.08, 0.02)	Electric motors (1.03, 0.13) Optical instruments (1.19, 0.13) Other rubber (1.32, 0.10) Textile articles (1.33, 0.16) Glass (1.48, 0.19)	Animal feeds (1.05, 0.29) Paints (1.08, 0.41) Furniture (1.3, 0.26) General machinery (1.34, 0.31) Other non-metallic (1.42, 0.36)	Health & social work (0.97, 1.52) Basic chemicals (1.03, 0.57) Primary plastics (1.04, 0.80) Paper (1.16, 0.63) Dairy (1.40, 0.49)	Agriculture (1.17, 2.15) Iron & steel (1.19, 2.96) Trade (1.26, 6.59)
	4	Carpets (1.57, 0.06) Food machinery (1.91, 0.06) Handbags (2.34, 0.05)	Pumps (1.63, 0.12) Confectionery (1.73, 0.19) Accumulators (2.18, 0.17)	Fruit (1.51, 0.32) Oils (1.67, 0.39) Structural ceramics (2.62, 0.33)	Grain mills (2.02, 1.09) Bakeries (2.20, 0.48)	Meat (1.82, 2.19) Communications (1.83, 4.56) Real estate (1.88, 3.15) Transport services (2.13, 7.80) Activities/ services (2.30, 2.36) Petroleum (2.41, 4.96) Coal (2.52, 2.16)
	5	Office machinery (2.67, 0.03)	Gears (3.41, 0.15) Machine tools (3.47, 0.12)	Lifting equipment (2.77, 0.37) Fish (5.42, 0.31) Other textiles (7.31, 0.34)	Other chemicals (3.49, 1.43) Treated metals (3.76, 0.47) Cement (4.20, 0.46) Tyres (6.96, 1.42) Knitting mills (8.43, 0.77) General hardware (10.93, 0.89)	Other mining (3.31, 5.73) Soap (5.07, 3.34) Pharmaceuticals (5.11, 3.34) Accommodation (6.49, 4.82) Water (7.57, 2.79) Gold (12.28, 9.35) Non-ferrous metals (16.10, 13.19)

Note: Rows represent quintiles for share of electricity in costs. The upper boundaries for the quintiles are: 1 = 0.45%, 2 = 0.97%, 3 = 1.49%, 4 = 2.65%, 5 =16.10%.
Columns represent quintiles for share in use. Upper boundaries are: 1 = 0.90%, 2 = 0.21%, 3 = 0.41%, 4 = 1.75%, 5 = 13.19%. Numbers in brackets are percentages for (Share of costs, share in use). The electricity sector is excluded.
Source: estimated from StatsSA (2004)

Table 5: Summary of selected impacts of alternative allocative schemes

		Market Solution	Rationing Solutions			
			Mining and smelters		Commercial	
		1	2A	2B	3A	3B
	Cut		10.0%	4.3%	10.0%	15.7%
1	Electricity price increase	71.3%	53.8%	65.0%	37.0%	13.9%
2	Impact on GDP	-0.9%	-1.6%	-1.1%	-5.9%	-10.1%
3	Employment	-1.4%	-1.9%	-1.5%	-7.9%	-13.9%
4	Household income	-1.2%	-0.5%	-0.9%	-6.8%	-11.5%
5	Impact on CPI	2.5%	1.86%	2.25%	1.28%	0.48%

Note: 'Mining and smelters' = Gold mining, other mining and non ferrous metals; 'commercial' = financial services, real estate, business services and other services excluding health.

Table 6: Changes in Sectoral Output (%)

MARKET SOLUTION		RATIONING SCHEMES							
		Mining and Smelters				Commercial			
[1]		[2A]		[2B]		[3A]		[3B]	
SHORTAGE SECTOR									
Electricity	-10.00	Electricity	-10.00	Electricity	-10.00	Electricity	-10.00	Electricity	-10.00
RATIONED SECTORS									
		Gold	-10.00	Gold	-4.33	Insurance	-10.00	Insurance	-15.70
		Other Mining	-10.00	Other Mining	-4.33	Real Estate	-10.00	Real Estate	-15.70
		Non-Ferrous Metals	-10.00	Non-Ferrous Metals	-4.33	Business Activities	-10.00	Business Activities	-15.70
						Activities/ Services	-10.00	Activities/ Services	-15.70
NON-RATONED SECTORS									
Summary Characteristics									
Mean	-0.74		-1.11		-0.83		-4.52		-8.19
Coeff.of Variation	62.7		118.8		77.8		50.1		48.2
First quartile	-0.93		-0.26		-0.38		-2.61		-5.12
Median	-0.68		-0.82		-0.67		-4.70		-8.39
Third quartile	-0.40		-1.51		-1.14		-5.97		-10.73