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Southern Africa – Towards Inclusive Economic Development

SA-TIED Technical Note 1

Modelling the effects of COVID-19 on the South African economy

A technical guide to the scenario builder

Rob Davies and Dirk van Seventer

May 2020

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

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Rob Davies[1] and Dirk van Seventer[2]

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Abstract: There is a demand for quick studies evaluating the economic impact of the lockdowns used by many governments to deal with the COVID-19 pandemic. Multiplier analysis is an appropriate method for examining the impacts of the lockdowns, particularly in the short run when both prices and technology are relatively fixed. This technical report provides a guide to an economywide model that applies the approach to South Africa by using a social accounting matrix. The report provides a brief explanation of the theory behind the approach. It then gives a detailed guide to the framework as implemented in Microsoft Excel. Although it was developed for a specific application in South Africa, it may be useful in other circumstances.

Key words: COVID-19, economywide model, multiplier, social accounting matrix

Acknowledgements: The work reported here was undertaken as part of a broader project under the auspices of the International Food Policy Research Institute, UNU-WIDER's 'Southern Africa—Towards Inclusive Economic Development' project, the South African National Treasury, and the South African Reserve Bank. The project team was Channing Arndt, Sherwin Gabriel, Laurence Harris, Konstantin Makrelov, Boipuso Modise, Sherman Robinson, and Witness Simbanegavi. The authors would like to thank all of them, particularly Sherman Robinson and Sherwin Gabriel, for their discussion and input.

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This study has been prepared within the UNU-WIDER project 'Southern Africa. – Towards Inclusive Economic Development' (SA-TIED).

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Typescript prepared by Merl Storr.

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The Institute is funded through income from an endowment fund with additional contributions to its work programme from Finland, Sweden, and the United Kingdom as well as earmarked contributions for specific projects from a variety of donors.

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1 Introduction

There is a demand for quick studies evaluating the economic impact of the lockdowns used by many governments to deal with the COVID-19 pandemic. This technical report provides a guide to a framework developed for examining these impacts. Although the framework was developed for a specific analysis, it may be useful more generally.

The framework was implemented using Microsoft Excel. This note is primarily a manual explaining how to use it. But in order to do so, the user needs to understand a little about the theoretical approach taken. A brief explanation of this is given in section 2, followed by a detailed guide to the framework in sections 3 to 7. Section 8 concludes.

2 Background to the approach

Governments have used various forms of lockdown to try to end the spread of COVID-19. It is recognized that this way of dealing with the medical crisis comes at an economic cost. It has been characterized as a deliberately induced recession. The unacceptable loss of human lives that would result from an uncontrolled pandemic makes governments willing to accept these costs. As the length of lockdowns is extended—which is happening in most countries—these costs rise, and economic recovery becomes more difficult.

Lockdowns have direct impacts on supply, primarily because people are not allowed to go to work. There are also demand effects: even without the lockdown, restaurant services and tourism would decline as people self-isolated. But the impacts are not limited to these direct effects. The fall in the level of production in some sectors has negative impacts on others through both backward and forward linkages. Considering these indirect effects is an important part of assessing the overall impact.

Multisector multiplier analysis is one method that can be used to undertake this assessment. It is a well-established technique that has been part of the economist's toolkit since the 1950s. The approach was developed to capture the complexity of an interconnected economic system, focusing on interindustry linkages (supply chains) as measured by input-output tables (IOT). An extension of that work is based on a social accounting matrix (SAM) that expands the IOT to include (or 'endogenize') more linked economic actors than just industries.

A SAM is an accounting framework: a matrix (spreadsheet) showing the receipt/expenditure accounts of industries, commodity markets, factors of production, enterprises, households, savings/investment, government, and the rest of the world (exports and imports). The SAM integrates input-output (IO) accounts with the national income and product accounts (or in United Nations terminology, the system of national accounts). The SAM shows the flows of goods and services around the economy, and the corresponding income and expenditures of all economic actors. We use a SAM for South Africa in 2015, constructed on the basis of data from Statistics South Africa (van Seventer et al. 2019).

SAMs show the full circular flow of income in the economy, including the generation of income (value added) in production value chains. They also show how that income is distributed to households and government (through taxes), providing households with income to buy the goods and services produced in the economy. A SAM offers a highly disaggregated picture of the economy. In the SAM for this study, there are 62 production sectors (industries), employing four different types of labour distinguished by education level, and capital to produce 102 different commodities. The income generated in the production sectors is distributed to 14 different household types (differentiated by income level). The income they receive is used for private consumption expenditure (disaggregated by commodity), savings, transfers, and taxes. The government receives taxes and makes expenditures, including transfers to households. There are also indirect taxes on production and commodities. Finally, the economy is open, with imports of goods and services adding to domestic supplies, and exports and other net international transfers adding to demand and incomes.

There are other methods for dealing with economywide impacts of shocks to the economy, and some justification must be given for using this approach rather than another. Each method has its own merits and limitations. As with all models, the question is not which model is right, but which will be useful in the circumstances to be analysed. Broadly speaking, macroeconomic models are useful for estimating impacts on high-level aggregates in the economy, but they say little about impacts at the level of detail embodied in a SAM. Microeconomic or sector-focused methods are important for understanding the impact on individual sectors, but generally ignore knock-on and feedback effects arising from interactions with other sectors. Some form of economywide framework is required to do this.

Within the broad class of multisectoral economywide models are linear multiplier models of the kind used here, and a variety of computable general equilibrium (CGE) models. These are sometimes referred to as first- and second-generation economywide models, implying that CGE models have superseded linear multiplier models. However, the latter retain their usefulness for some applications, and we think this is one of them.

In standard multiplier analysis, there are two key assumptions:

- Industries demand inputs in fixed proportions to output: technology is linear.
- Prices are fixed: adjustments to shocks work through changes in quantities, not prices.

These assumptions, while strong, are reasonable for analysing the impact of the pandemic. The shocks we are observing are working through the economy in weeks or months, not years. In such a short period, it is unlikely that production technologies will be changed significantly by the pandemic. Nor will the pandemic cause significant changes in relative prices or wages of employed labour in the short run. While there appear to be some profiteering price increases, they have acted as short-term rent-seeking and rationing devices, not as signals or incentives to stimulate production. In CGE models, adjustment works through changes in prices and wages operating smoothly in commodity and factor markets. While CGE models are very useful for considering shocks that work through market mechanisms, that is not what is happening in the COVID-19 crisis in the short run. Perhaps as economies recover, CGE models will be a useful tool to consider how they will operate in the changed, post-crisis economic environment.

2.1 Setting up a multiplier model

Users of this framework should have some understanding of the theory underlying the construction and use of multipliers in linear economywide models. This section provides a cursory account of the theory, and can safely be skipped by users who are already familiar with it.

A SAM multiplier model is an extended version of a basic IO model. A generic IO model can be written in the following way:

$$\mathbf{x} = \mathbf{Z} + \mathbf{f} \tag{1}$$

$$\mathbf{x} = \mathbf{A} \cdot \mathbf{x} + \mathbf{f} \tag{2}$$

$$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1} \cdot \mathbf{f} \tag{3}$$

$$\mathbf{\Delta x} = (\mathbf{I} - \mathbf{A})^{-\mathbf{1}} \cdot \mathbf{\Delta f} \tag{4}$$

where

- $\mathbf{x}$ is a column vector of industry outputs in an economy ($\mathbf{\Delta x}$ denotes a change in outputs);
- $\mathbf{Z}$ is a matrix of intermediate sales/demands in an economy;
- $\mathbf{A}$ is a matrix of intermediate demands per unit of industry output for an economy;
- $\mathbf{f}$ is a column vector of final demand for goods and services supplied by industries in an economy ($\mathbf{\Delta f}$ denotes a change in final demands).

A vector of changes in final demand, $\mathbf{\Delta f}$, can be created to represent an exogenous change or policy intervention. In our case, $\mathbf{\Delta f}$ is broadly tuned to be a change in each of the gross domestic product (GDP) final components (C+I+G+E, where C is private consumption expenditure, G is government current consumption expenditure, I is gross capital formation, and E is exports) such that a target change in the supply of output $\mathbf{\Delta x}$ is matched to what is anticipated to be the case.

The $(\boldsymbol{I} - \boldsymbol{A})^{-1}$ matrix is often referred to as the Leontief matrix, and it gives the multipliers. Each of its columns shows the direct and indirect effects of a one-unit rise in final demand for the account represented by the column on the outputs of each of the accounts in the rows. The column total gives the impact on gross output in the economy as a whole.

The above system estimates the direct and indirect effects of changes in exogenous final demand on sectoral gross outputs. Using further linear relationships, we can calculate results for value added, household income, imports, tax revenues, and employment, among others. Impacts on value added (GDP at factor costs) are based on ratios of industry-level value added to gross output. These ratios are assumed to hold at the margin and can be multiplied with the estimated output impacts. The same applies to imports and tax revenues. This amounts to assuming that the elasticity of each variable with respect to gross output is equal to one.

This is typically assumed with respect to employment as well. However, this may be considered a more heroic assumption than the linearity of the base model itself (Bulmer–Thomas, 1982, p. 61)(Bulmer-Thomas 1982: 61). Firms may hold onto labour in downturns in order to avoid costly search and training when the economy turns around. That is even more likely to be the case in the current crisis, when the turnaround is expected relatively soon. We can therefore assume that the sectoral elasticities of employment with respect to gross output are less than one. We use estimates of employment output elasticities made for South Africa by Moolman (2003), (Moolman, 2003)mapping them to the industries and labour categories (by education). A similar modification could be made for tax revenues, but we do not have any estimates on which to base it.

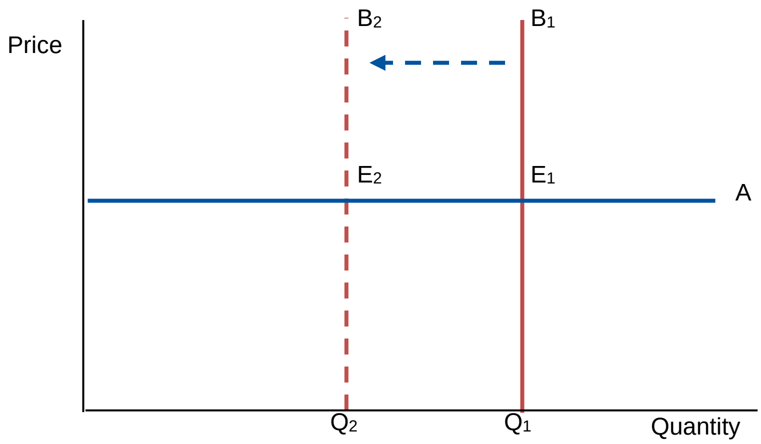
The SAM multiplier model operates in the same way as the IO model, but with a different set of endogenous accounts. A key difference is that the SAM distinguishes between sectors and the commodities they produce. In the version implemented here, factor incomes are also endogenous. Some SAM multiplier models also include households in the endogenous accounts, which increases the size of the multipliers. We do not endogenize them in the current framework. However, the impact of changing factor earnings on households' incomes can be calculated *ex post*, using the income distribution details in the SAM. Thus, while impacts on household income can be estimated, there is no feedback from that change in income, via changed household expenditure, to the production circuit of the economy. While it might be useful to capture such feedback, it will be seen later that the initial impact on the economy is modelled primarily by changing household expenditures, which therefore must be kept exogenous, under the modeller's control. This implies that the impact of household expenditure is not accounted for by the model.

2.2 Supply shocks in the multiplier framework

Standard multiplier models are demand-led, assuming fixed prices with perfectly elastic supplies. But the COVID-19 crisis is, in the first place, a supply shock. Strictly, to model such a shock, supply should be exogenous, under the control of the modeller, not the model. There are supply-constrained multiplier models, in which the capacity for a sector or sectors to respond to an increase in demand can be restricted. These models can also be used to downsize the output of a particular industry. But they are rather hard to implement for the current exercise of an economic downturn, since it is difficult to calibrate the size of the initial shock and what happens in terms of associated demand-switching.

However, we can simulate the supply shock by a negative demand shock. This may initially seem counter-intuitive, so we provide the rationale here. The model assumes fixed prices with quantities adjusting. Showing this in Figure 1, we make A the supply curve. Final demand is exogenous and can be represented by B_1. An exogenous fall in demand to B_2 causes the quantity demanded to fall. This is fed into the multiplier model as the exogenous shock. The model then uses equation [4] to estimate the direct and indirect changes in gross outputs of sectors (supply) that would be needed to be consistent with this fall in final demand.

Figure 1: Demand and supply shocks



Source: authors' illustration.

Were we to think in supply terms, we would want to say that A is the fixed price *demand* curve, and the Bs are the fixed *supply* quantities before and after the shock. The change in the quantity would be the same. We can simulate the supply shock in the demand-driven model by reducing final demand to drive down gross output to the expected level. In practice, we are imposing an exogenous shock on the model—a change in Q—and it is immaterial in technical terms whether that is driven by the demand curve or the supply curve shifting leftwards.

Although we specify **f** as a vector, final demand normally comprises C, G, I, and E. The multipliers are the same for each of them, and the only difference in shocking them is the size of the shock we impose. A one-unit drop in C for a good has the same impact as a one-unit drop in E of the same good. We may want to distinguish between them in the demand-led model, because of the questions we ask: for example, how does the effect of a 10 per cent fall in household expenditure on agricultural commodities differ from the effect of a 10 per cent fall in exports of agricultural commodities?

When we are using the demand-led model to simulate a supply shock, we are no longer particularly interested in the question of which demand components drive the change. Rather we reduce overall final demand categories so that the $\mathbf{\Delta x}$ meets our target. To achieve this, we simply need a single vector of exogenous drivers of the change. We call it 'final demand' because that is the driver in the demand-driven model, but the shock need not be linked to any particular single component of final demand. If C and E each comprise 50 per cent of final demand, and we determine that a 50 per cent fall in final demand will be sufficient to drive the output down by the amount determined by the target, it does not matter if we eliminate C entirely or E entirely, or if we shock them in any combination that sums to 50 per cent.

However, we are also interested in what happens to GDP and its component aggregates. We have imposed shocks on each commodity to build our view of the supply shocks from the bottom up. By considering the aggregates of each component, we impose an additional constraint on our best estimates. The disaggregated changes in, say, export demand for each commodity provide a view not only of the *structure* of the changes in exports but also of the change in the level of each export commodity. Indeed, it is likely that we have a better view of the latter, and the structural changes emerge implicitly. This view, in the current exercise, is formed partly by our understanding of changes in export demand for commodities (paying attention to the impact of the pandemic on the various destination countries), and partly by our understanding of the likely impacts on capacity to supply exports because of reduced production capacity caused by the lockdown.

An alternative view might be formed from a top-down analysis of exports in aggregate, as emerges from a macroeconomic model. We can scale our disaggregated changes to reproduce this aggregate level. When we do this, we may find that the impact on industry capacity is different from what was determined at the disaggregated level. This inconsistency can lead to a fruitful discussion between macroeconomists and the economywide modellers, industry experts, and policy makers.

2.3 Specific application: lockdown, demand/supply, investment, and exports

The multiplier model is an empirical model and requires specific numerical data to represent the shocks. Constructing these shocks is difficult. It requires expert judgement of what the direct effects of the lockdown and pandemic-driven falls in demand will be. While there may be a relative consensus among experts on which sectors will be affected, it is not easy to attach quantitative measures to these effects. The process of constructing these shocks will typically require some back-and-forth between the experts and the modellers. Such a discussion is in itself an important part of coming to a sensible assessment of the impacts. As we have suggested before, the modelling provides a useful framework for systematic discussions.

Although shocks are fed into the model in the form of changes in demand for goods and services, many expert judgements will be about how particular industries are affected. These must be translated into the implied changes in associated commodity supplies/demands in order to impose them on the model. The framework translates any changes in demand for commodities directly into changes in the output of the sectors producing the commodities. These are presented in the results as first-round impacts, and can help us to assess whether the shocks are consistent with expert judgements.

The model was initially developed to address a particular set of assumptions regarding lockdown and recovery in the South African economy.

For household demand shocks, we specify exogenous changes in consumption demand. To capture the impact on supply of a lockdown of industries, we cut all final demand for the commodities produced by the industries, which effectively cuts production in those industries.

From both the demand and supply sides, the lockdown results in a decline in demand/supply in many industries. The effect is widespread across industries, but especially large in services sectors (e.g., restaurants, entertainment, tourism, travel, hotels, etc.). The lockdown alone causes major impacts on employment, production, and demand.

In addition, these impacts spill over into the macro economy. Industries are facing an uncertain future and are hesitant to engage in investment projects, resulting in a decline in aggregate investment. The pandemic is global, leading to a major decline in world trade. Thus, we also consider the impact of the crisis on macro aggregates: investment and exports. If household demand for particular goods and services is zero or very low, it is necessary to resort to additional cuts in E or I as a proxy for the lockdown

Beyond lockdown, recovery scenarios can be set up in which the downward assumptions are gradually reduced.

2.4 Interpreting the results

After the shocks are imposed, the model generates the endogenous changes in sector outputs, commodity supplies, value added, etc. that are consistent with the shocks. These are converted to percentages off the pre-shock level of the relevant variable. These percentages are independent of the period under consideration. For a typical short-run pandemic impact analysis, results are reported on a quarterly or annual basis. All that differs when we compare annual with quarterly impacts is the base to which the percentages are applied—the annual value or the quarterly value. This is important when it comes to averaging quarterly changes to get an annual average. We do not need to annualize the quarterly change.

Quarterly macroeconomic models may generate a result for GDP growth in the quarter—say, one per cent. This represents the growth in GDP during the quarter. When this result is reported, however, it will often be scaled up to reflect what the annual growth rate would be if this quarter-to-quarter growth were sustained over the whole year. This is sometimes referred to as the annualized quarterly growth rate.

In this model, we do not need to do that. The results we generate are the percentage changes in GDP as a result of the shock. Say we generate a fall in GDP of five per cent. If quarterly GDP were ZAR100 billion, we would say the shock would bring it down to ZAR95 billion. If annual GDP were ZAR500 billion, we would say the shock would bring it down to ZAR475 billion.

This result and interpretation arise because it is a linear model. The proportional results are the same whether we investigate a one-unit change in final demand or a thousand-unit change. It is the linearity that allows us to estimate multipliers—which are normally expressed as the consequences of a unit change in demand—and to scale them up to examine the impact of much larger changes.

2.5 Limitations

As with all methods for making sense of the world, the multiplier approach has limitations that should be borne in mind when the results of the scenarios are used to inform policy. Given the unprecedented nature of the shocks and their large magnitude, all approaches will have to contend with high levels of uncertainty. All models, including the epidemiological models, are suffering from the lack of up-to-date data and parameter values. This is inevitable in the current context, and it is something we have to live with and hope to improve as time passes. In addition to such empirical difficulties, the underlying structure of the models themselves may be questioned. Several aspects of the current model will be questioned on these grounds. Such questions include:

- Are the production structures derived from annual data relevant to shorter periods?
- How can a linear model be relevant for such big shocks?

In the current context, a potential limitation of multiplier analysis relates to the speed of realization of indirect effects. For example, cessation of production of a key intermediate good, such as ball bearings, will have implications for manufacturers as soon as their stocks of ball bearings run out. A second example relates to business services. A manufacturer may regularly purchase business services such as accounting; however, the absence of accounting services is unlikely to halt production in the near term. The multiplier framework deployed allows comparative static analysis in which the economy after the shock is compared with the economy before. The length of time between 'before' and 'after' is not specified but is implicitly long enough for the shocks to work through. All adjustments occur in the time period of the model.

It might therefore be argued that the method overstates the impact that will occur in a short period because not all adjustments will have had time to work themselves out.

One response is that the model provides bounds—in this case, a lower bound—to the likely impact in a given period. Nevertheless, it is likely that any such overstatement of indirect impacts will be relatively small, for two reasons. First, the lockdown shocks are weighted towards final demand with services sectors, and their demand for intermediates are particularly strongly and quickly affected. For example, closed restaurants will reliably use less electricity, food, and other inputs from the day they close. Second, looking downstream, many critical and non-essential items (e.g., ball bearings) are in short supply in the current circumstances, but the critical shortages will predominate. In other words, when a firm is not producing because it is locked down or because it lacks access to critical intermediates such as ball bearings, it matters little if that firm can operate without accounting services for a period. It is the binding constraints that matter.

Turning to the second query listed above, assuming linearity provides a reasonable approximation to the result from a non-linear process when the shock is small. We move along the tangent to the curve, rather than the curve itself. As the shock gets larger, the extent of divergence depends on the non-linearity of the process. We have argued above that the lockdown impact is likely to be fairly linear in the short run. In the actual modelling, described below, we allow for some non-linearity with respect to the employment impacts. Furthermore, it is not clear which way any non-linearity might go. Thus, we expect short-term declines in employment to be less than proportional to changes in GDP, while the decline in income tax revenue is likely to be more than proportional.

Limitations such as these should be borne in mind when one uses the results generated by the model. It bears re-emphasizing that these results are not forecasts. The purpose of the model is to provide a structured framework within which likely impacts of the pandemic can be assessed. Model results are only one input into this assessment.

3 A guide to the framework

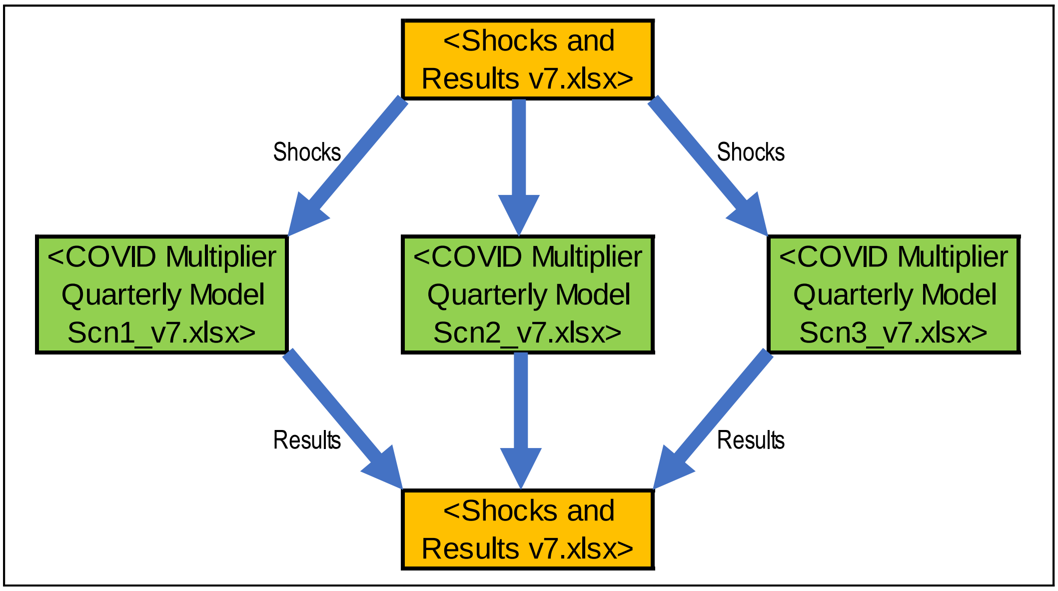
In order to operationalize the above ideas, a suite of Excel workbooks has been developed that uses multiplier analysis to analyse scenarios. The rest of this paper explains how the suite works.

The suite allows us at this stage to construct three scenarios, and it consists of four workbooks:

- <COVID Multiplier Quarterly Model Shocks and Results_v7.xlsx>;
- <COVID Multiplier Quarterly Model Scn1_v7.xlsx>;
- <COVID Multiplier Quarterly Model Scn2_v7.xlsx>;
- <COVID Multiplier Quarterly Model Scn3_v7.xlsx>.

A flow diagram of the elements of the modelling suite is shown in Figure 2. The version numbers may have changed.

Figure 2: Flow diagram of the modelling suite elements



Source: authors' illustration.

The basic shocks for each scenario are initially set up in the first workbook (<COVID Multiplier Quarterly Model Shocks and Results_v7.xlsx>). This workbook also consolidates the results from each scenario so that they can be compared easily. The last three workbooks are identical in structure and allow the user to prepare and run three different scenarios.

All of the scenario modelling workbooks (e.g., <COVID Multiplier Quarterly Model Scn1_v7.xlsx>) are linked to the central <COVID Multiplier Quarterly Model Shocks and Results_v7.xlsx> workbook (but not to each other). We suggest that <COVID Multiplier Quarterly Model Shocks and Results_v7.xlsx> should be opened first, and then the scenario modelling workbooks, to ensure that links are not broken. Accept 'update links' if this message appears when a workbook in the suite is opened. If links are broken, use >data>edit links to restore them by clicking the 'change source' button and directing the path to the relevant folder.

The structure of the suite is that the basic shocks are set up for each quarter of each scenario in the <COVID Multiplier Quarterly Model Shocks and Results_v7.xlsx> workbook. Although the user can enter the shocks directly into the scenario workbooks, we have found it useful to be able to see the series of shocks together in one place.

The framework was developed for an application that required a focus on quarters throughout a year. However, the 'quarters' are not linked to each other and can be viewed as time periods of different lengths, as will be explained below. For convenience, in what follows we refer to the periods as quarters.

Each quarter in each of the scenario workbooks is modelled in three worksheets:

1. (Q1–Q4)BaseShocks reads in the shock data from <COVID Multiplier Quarterly Model Shocks and Results_v7.xlsx>.
2. (Q1–Q4)Shocks checks and prepares the shocks for model inputs.
3. (Q1–Q4)Impacts models the impacts and provides several useful results at headline and SAM levels of disaggregation.

In addition, each scenario workbook has a summary results sheet that brings together the results of all the quarters at a more aggregated level, and an AveQ1–4 Impacts sheet that consolidates some detailed SAM-level results by averaging across the periods.

Within this broad structure, there are several options for controlling the basic shocks that are read in. There are also options for modifying aspects of the basic shocks after they have been read in. This adds to the nuances of the shocks, but also makes it more complex to operate.

We will now go through each of these steps and discuss the options.

4 Shocks and Results workbook: set-up

The <COVID Multiplier Quarterly Model Shocks and Results_v7.xlsx> workbook consists of a number of worksheets, listed in Table 1.

Table 1: List of worksheets in the <COVID Multiplier Quarterly Model Shocks and Results_v7.xlsx> workbook

Sheets	Description
Notes	
Scenarios	Macro Scenarios for each Period
Shocks	Detailed Base Scenarios
Scn1	Combining Detailed Base and Macro Scenario 1
Scn2	Combining Detailed Base and Macro Scenario 2
Scn3	Combining Detailed Base and Macro Scenario 3
Annual Results	Full Period Headline Results for all Scenarios
Quarterly Results	Detailed Period Headline Results for all Scenarios

Source: authors' compilation.

Macro scenarios are designed (specifically for the analysis at hand) in the scenarios worksheet. Commodity-level detailed scenarios are available in the shocks worksheet. Detailed and macro-level scenarios are combined in Scn1, Scn2, and Scn3 and feed into the workbooks for the relevant scenarios (e.g., <COVID Multiplier Quarterly Model Scn1_v7.xlsx>). The action then continues in those workbooks before returning to the annual results and quarterly results sheets in the

<COVID Multiplier Quarterly Model Shocks and Results_v7.xlsx> workbook. The details of each worksheet are now discussed in turn.

4.1 Scenarios worksheet

In this worksheet, macro scenarios are presented, one for each period (Table 2). Note that this worksheet is set up for a specific application and serves here as an example. Other applications may require a different approach.

Table 2: Macro scenarios for each period

			Scenario 1: Quick	Scenario 2: Slow	Scenario 3: Long
1a		Path of the Pandemic	South Africa manages to control the growth in new infections by the end of Q2.	The epidemic is not controlled within the 21 days and the lockdown period is extended to 8 weeks. The health system can provide enough ICU beds.	South Africa experiences Italian type of scenario across its major cities, exacerbated by winter and the inability to sustain a lockdown beyond 8 weeks. The health system is not able to provide enough ICU beds.
1b		Lockdown	The complete lockdown is limited to 21 days but social distancing and partial lockdowns continue to affect economic activity well beyond the 21 days. This is in line with results from current epidemiological models.	The complete lockdown is extended to 8 weeks.	Complete lockdown for 8 weeks but attempts to extend it beyond that are partially successful
2	Q2		The economy operates at about 80 per cent of its pre-crisis levels on average.	The economy operates at 65 per cent of its pre-crisis levels on average.	The economy operates at 55 per cent of its pre-crisis levels on average.
2a-d			The impacts on household consumption, tourism, investment and exports are generated by the model		
			All percentages below refer to the pre-crisis level		
3		Narrative	Economic recovery accelerates in Q3 supported by stronger global growth, improved confidence and low borrowing costs.	Economic recovery accelerates in Q3, but the global recovery is weaker and South Africa's fiscal situation generates larger crowding out effects than in Scenario 1	Economic recovery accelerates in Q3 but it is weaker than in Scenario 2. The fiscal situation deteriorates further.
3a	Q3	Household consumption	90 per cent	70 per cent	60 per cent
3b		Tourism	50 per cent	50 per cent	the same as in Q2
3c		Investment	90 per cent	70 per cent	60 per cent.
3d		Exports	90 per cent	80 per cent	80 per cent
4		Narrative	Household consumption, investment and exports recover to their pre-crisis levels, while tourism demand remains down	Household consumption, investment and exports reach the Scenario 1:Q3 levels, while tourism demand does not recover as much	Household consumption, investment and exports reach Scenario 2:Q3 levels, while tourism demand is below Scenario 2:Q4 levels.
4a	Q4	Household consumption	100 per cent	90 per cent	60 per cent
4b		Tourism	80 per cent	70 per cent	the same as in Q2
4c		Investment	100 per cent	90 per cent	60 per cent
4d		Exports	100 per cent	90 per cent	80 per cent

Source: Arndt et al. (2020: 18).

The rationale for these macro scenarios is explained in the report 'Impact of Covid-19 on the South African Economy' (Arndt et al. 2020). This worksheet assumes that the periods are quarters (three months). This can be changed by the user. The user can also change the assumptions for each quarter. These assumptions will feed into the Scn1, Scn2, and Scn3 worksheets of the <COVID Multiplier Quarterly Model Shocks and Results_v7.xlsx> workbook.

4.2 Shocks worksheet

Detailed base shocks, applicable to each scenario, are presented in the shocks worksheet. These shocks are administered at the commodity level. The shocks' rationale is explained in Arndt et al. (2020). There are 104 commodities identified in the underlying SAM. Figure 3 shows the first two and last two commodities.

Figure 3: Partial view of detailed shocks applicable to all scenarios

	Sim1: Supply Shock				
	Percent change				
		C	I	G	E
1	cagri	-5.0			
2	clani	-5.0			
103	cheal	15.0			
104	cosrv	-70.0			

Sim 2: Supply shock with tourism demand down				
Percent change				
	C	I	G	E
cagri	-5.0			
clani	-5.0			
cheal	15.0			
cosrv	-70.0			

CHANGE DUE TO ADDING TOURISM				
Percent change				
	C	I	G	E
cagri	0.0	0.0	##	0.0
clani	0.0	0.0	##	0.0
cheal	0.0	0.0	##	0.0
cosrv	0.0	0.0	##	0.0

Sim 3: Sim2 + Export Shock				
Percent change				
	C	I	G	E
cagri	-5.0			-40.0
clani	-5.0			-40.0
cheal	15.0			-40.0
cosrv	-70.0			-70.0

CHANGE DUE TO ADDING EXPORTS				
Percent change				
	C	I	G	E
cagri	0.0	0.0	##	-40.0
clani	0.0	0.0	##	-40.0
cheal	0.0	0.0	##	-40.0
cosrv	0.0	0.0	##	-70.0

Sim 4: Sim 3 + Inv Shock (Rob &Dirk's original shocks)				
Percent change				
	C	I	G	E
cagri	-5.0	-65.0		-40.0
clani	-5.0	-65.0		-40.0
cheal	15.0	-65.0		-40.0
cosrv	-70.0	-70.0		-70.0

CHANGE DUE TO ADDING INVESTMENT				
Percent change				
	C	I	G	E
cagri	0.0	-65.0	0.0	0.0
clani	0.0	-65.0	0.0	0.0
cheal	0.0	-65.0	0.0	0.0
cosrv	0.0	-70.0	0.0	0.0

Source: authors' illustration.

The base shock consists of a sequence of four components: Sim1, Sim2, Sim3, and Sim4, starting in Sim1 with the supply shock. In Sim2, the tourism demand shock is added, while Sim3 adds the export shock, and finally in Sim4 the investment shock is added. Users can change these assumptions here but should note that in the scenario workbooks they may be subjected to adjustment factors and automatic stabilizers, in order to preserve consistency with macro aggregates. These stabilizers ensure that the final assumption that will drive the model and its negative impact is not larger than the base value identified in the underlying data.

4.3 Scn1, Scn2, and Scn3 worksheets

The scenario worksheets in this workbook collate the scenarios for transmission to the main scenario workbooks (e.g., <COVID Multiplier Quarterly Model Scn1_v7.xlsx>). No inputs are required from the user in these worksheets. However, this is where new shocks can be entered if the user wants to overwrite the default shocks currently in the framework.

Each sheet assembles shocks for the four quarters. Thus, the user can take a view on the quarter-on-quarter progression of the shocks throughout the year.

4.4 Annual results worksheet

Since the annual results worksheet deals with the results of the modelling discussed in the next section, this worksheet is discussed in section 6.1

4.5 Quarterly results worksheet

Since the quarterly results worksheet deals with the results of the modelling discussed in the next section, this worksheet is discussed in section 6.2.

5 Scenario workbooks

After the scenarios are collated in the <COVID Multiplier Quarterly Model Shocks and Results_v7.xlsx> workbook (see section 4), they are checked and fine-tuned before being modelled in separate workbooks, one for each scenario. In this section we discuss these scenario workbooks. They are:

- <COVID Multiplier Quarterly Model Scn1_v7.xlsx>;
- <COVID Multiplier Quarterly Model Scn2_v7.xlsx>;
- <COVID Multiplier Quarterly Model Scn3_v7.xlsx>.

These scenario workbooks are set up in the same format. These workbooks all contain the same worksheets. They are reported in Table 3.

Table 3: List of worksheets in the scenario workbooks

Sheets	Description
Readme	
Notes	
Summary Results	Headline Summary Results
AveQ1-4Impacts	Detailed Period Average Summary Results
Q1BaseShocks	Quarter 1 Development of Basic Shocks
Q1Shock	Quarter 1: Preparation of Shock for Model Inputs
Q1Impacts	Quarter 1: Scenario Modelling
Q2BaseShocks	Quarter 2 Development of Basic Shocks
Q2Shock	Quarter 2: Preparation of Shock for Model Inputs
Q2Impacts	Quarter 2: Scenario Modelling
Q3BaseShocks	Quarter 3 Development of Basic Shocks
Q3Shock	Quarter 3: Preparation of Shock for Model Inputs
Q3Impacts	Quarter 3: Scenario Modelling
Q4BaseShocks	Quarter 4 Development of Basic Shocks
Q4Shock	Quarter 4: Preparation of Shock for Model Inputs
Q4Impacts	Quarter 4: Scenario Modelling
Employment	Employment Data (hidden)
Empl Elast	Employment Elasticities (hidden)
SAM and Preps	SAM Data (hidden)

Source: authors' compilation.

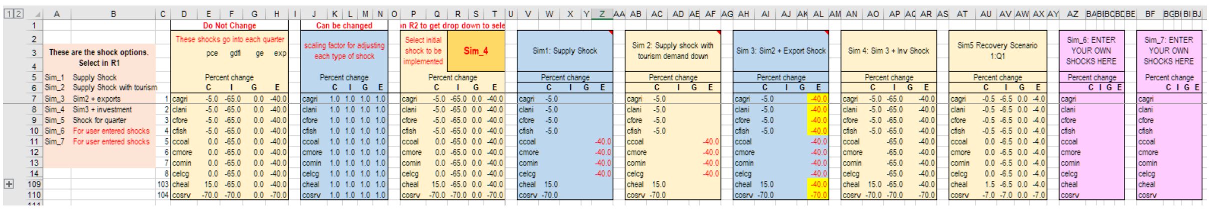
5.1 Base shocks worksheets

In each scenario workbook, several predetermined shocks for each quarter are available in the worksheets Q1BaseShocks, Q2BaseShocks, Q3BaseShocks, and Q4BaseShocks. The user is able to select which of these shocks to use as the base for an analysis. In addition, there is space for user-designed shocks.

The base shock for Q1 is reported in Figure 4. As in Figure 3, shocks are prepared at the commodity level. Figure 4 shows only the first eight and last two commodities.

Columns A and B list the shock options that can be selected by the user. Currently there are four scenarios hard-coded into each scenario workbook. Sim_1 shows the initial supply shock; Sim_2 adds in the immediate demand shock directly related to the pandemic. Most of these demand shocks are related to tourism. Sim_3 adds in anticipated losses in export demand, and Sim_4 includes shocks to investment demand. Sim_4 coincides with the FULL simulation described in Arndt et al. (2020). (Although Sim_1 to Sim_4 are also shown in the shocks worksheet of the central <COVID Multiplier Quarterly Model Shocks and Results_v7.xlsx> workbook shown in Figure 3, they are not linked to that workbook.)

Figure 4: Partial view of a detailed base shocks worksheet in a scenario workbook



Source: authors' illustration.

Sim_5 is a hypothetical recovery scenario that can be selected if desired. This is linked to the central <COVID Multiplier Quarterly Model Shocks and Results_v7.xlsx> workbook. Finally, there are two empty simulations, Sim_6 and Sim_7, in which users can create their own simulation shocks.

The user can select which of these simulations to base a scenario on from a drop-down menu in cell R1. In Figure 3, Sim_4 is selected (see columns AN to AR).

Once a base simulation is selected, its shocks are fed through columns K to N into columns E to H, which are the shocks fed into the shocks sheets. This rather roundabout way of constructing the shocks is to allow some constraints and checks on the shocks. We will see later that the user can scale the shocks up or down. The set-up in columns K to N ensures that only negative shocks are scaled. It is assumed that positive shocks, such as to the health and pharmaceutical sectors, are driven by the medical crisis and are independent of the economic effects of the lockdown. Columns E to H make sure that the scaling does not result in shocks that are greater than the relevant base values. In that way the impact on any commodity is not larger than its initial demand/supply. We will see in section 5.4 that the user can also impose lower bounds on the individual shocks.

It is possible for the user to fine-tune the bottom-up shocks by overwriting cells in columns K to N. For example, if the user feels that the shock to the export demand for coal in cell H11 should be -60 per cent rather than -40 per cent, cell N11 can be changed from 1.0 to 1.5. However, this will replace the current formula in N11, and we recommend that users rather alter shocks in the appropriate part of the Shocks and Results workbook.

When designing shocks, the user should bear in mind that some elements of final demand are zero. For example, households do not buy metal ores. Although a shock might seem to be applied to this, since a percentage change is applied to it, it will not have an effect. We will see this in the next section.

5.2 Shocks worksheets (Q1Shock, Q2Shock, Q3Shock, and Q4Shock)

In these sheets, shocks are prepared for model inputs, and consistency checks are carried out. No input from the user is required. However, the user can inspect columns D to G to see which final demand elements are zero and where warning signs occur, as discussed in the next section.

5.3 Impacts worksheets (Q1Impacts, Q2Impacts, Q3Impacts, and Q4Impacts)

In these sheets, the shocks are submitted to the model, and results are generated. No input from the user is required.

Detailed results can be examined in these sheets. Key variables are:

- the exogenous shock (column P);
- the endogenous change in gross output/supply/factor income in ZAR millions (Q) and as percentage changes from their base values (U);
- the first-round impact (X), which shows how the shock to commodities initially (i.e. in the first round) translates into sector output changes;
- the indirect impact (Y), which is the difference between the endogenous change (Q) and the first-round impact (only for sectors); measuring these is the essence of the economywide multiplier approach.

For convenience, rank and sort functions are used to present detailed results in absolute values for several variables, such as first-round, indirect, and total multiplier impacts on gross output (columns AD to AI), and total multiplier impacts on GDP (at factor costs) and on total employment (columns AW to AZ), as well as percentage change impacts for the latter two (columns BQ to BX).

Column O, which is headed 'constraint selector=1', provides an option to constrain output of a sector or sectors. This is used in a different approach to modelling the impacts and should not be used in the current exercise.

5.4 Summary results worksheet

Each scenario workbook has one summary results worksheet, which consolidates results from the quarterly impacts worksheets. Several macro adjustments can also be made in this worksheet. In summary, these are:

- scaling up or down the demand components of the bottom-up shocks;
- changing the weighting of each quarter in the annual averages;
- imposing lower bounds on the bottom-up elements of each shock.

Each is discussed in turn below.

5.4.1 Scaling demand components

While the shocks imposed on each of the demand components have been constructed from the bottom up at the micro level, based on expert judgements of how sectors might be affected, there may also be information about how they are expected to perform as macro aggregates. Macroeconomic experts might expect a certain level of investment in a given quarter. Trade experts might have a view on how impacts on trading partners affect the level of exports. Indeed, there are estimates from macroeconomic models of likely declines in GDP. These can be treated as providing targets which the modellers want to impose on the scenarios. Alternatively, the model can be used to explore the micro-level disaggregated implications of such high-level expectations.

Each demand component in the national accounts can be controlled by a single adjustment factor in D2 to G5 (see Figure 5). This can be used to scale the components to meet a target change. This will scale the model's bottom-up shocks up or down in the appropriate shock sheet. The structure of the shocks will not change, but they can be made consistent with the macroeconomists' estimates. Should the modeller wish to target a particular change in GDP, all components can be scaled accordingly.

Figure 5: Partial view of summary results worksheet of the COVID Multiplier Quarterly Model Scn1_v7 workbook

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1				Q1:Sim_4	Q2:Sim_4	Q3:Sim_5	Q4:Sim_5	Warning Δfd > 100% ==>1				LB	PCE	GE	GDFI	Exp
2		Select proportion of full impact shock for each component in the	Consumption	0.0	0.5	1.0	1.0	0	0	0	0	Q1	-100	-100	-100	-100
3		quarter -->	Government	0.0	0.5	1.0	1.0					Q2	-100	-100	-100	-100
4			Investment	0.0	0.5	1.0	1.0	Quarter weights				Q3	-100	-100	-100	-100
5			Exports	0.0	0.5	1.0	1.0	0.25	0.25	0.25	0.25	Q4	-100	-100	-100	-100
6			Base Values	Quarterly change (Rm)				Annual % change				Ann-	Annualised Q on Q			
7		High Level Post-Impacts on Exogenous Model Variables	Rm	Q1Impacts	Q2Impacts	Q3Impacts	Q4Impacts	Q1	Q2	Q3	Q4	ual	Q1	Q2	Q3	Q4
8		Gross (activity) output @ basic prices	7,924,003	0	-1,465,132	-345,406	-24,008	0.0	-18.5	-4.4	-0.3	-5.8	0.0	-18.5	14.1	4.1
9	GDP	PCE	2,417,271	0	-367,639	-108,616	-16,113	0.0	-15.2	-4.5	-0.7	-5.1	0.0	-15.2	10.7	3.8
10	Expend	GE	828,934	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11		GDFI	828,245	0	-314,678	-62,936	0	0.0	-38.0	-7.6	0.0	-11.4	0.0	-38.0	30.4	7.6
12		DSTK	29,155	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13		Exports	1,221,748	0	-330,755	-66,151	0	0.0	-27.1	-5.4	0.0	-8.1	0.0	-27.1	21.7	5.4
14		Imports	1,273,933	0	-315,873	-73,526	-4,807	0.0	-24.8	-5.8	-0.4	-7.7	0.0	-24.8	19.0	5.4
15		GDP @ market prices	4,051,420	0	-697,198	-164,176	-11,306	0.0	-17.2	-4.1	-0.3	-5.4	0.0	-17.2	13.2	3.8

Source: authors' calculations and illustration.

5.4.2 Changing the quarter weights

Cells H5 to K5 contain weighting factors used when the results for all quarters are combined into an annual rate. At present the weights are all set at 0.25, because there is little seasonality displayed in South Africa's historical quarterly data. But the user could choose weights to represent the length of time over which the particular shock operates.

5.4.3 Placing lower bounds on disaggregated shocks

When the bottom-up shocks are scaled as described in 5.4.1, it is possible that an individual element in the relevant base shock sheet will go below -100 per cent. For example, we might set the consumption demand for catering services at -90 per cent, but then scale the overall shock by 1.4. This would increase the negative demand shock to 126 per cent. While it is possible to make up explanations for this, it seems better to restrict shocks to individual elements so that they cannot fall below -100 per cent. Although -100 per cent is logical, the choice of lower bounds is flexible. They can be selected in M2 to P5. The user can thus choose that no export demand, for example, will fall by more than 50 per cent. If the user would like demands to fall by more than 100 per cent, the lower bound can be set to some arbitrarily large (negative) number. Should any shock fall below -100 per cent, a warning will appear for the appropriate quarter in H2 to K2, and the user can inspect the relevant shock sheet. The commodity for which the shock is below -100 per cent will be indicated by a unit value (one) in column T.

5.4.4 Further interpretation of the summary sheet

We can see the implementation of the above options in the example in Figure 5, which offers a partial view of the summary results worksheet. It can be seen that Sim_4 was selected as the shock for the second quarter (column E), but only 50 per cent of it was implemented for each final demand component of the shock. This adjustment is a proxy for a three-week lockdown. Although the lockdown is officially for three weeks, it is expected that the economy is disrupted for half the quarter. The full force of the Sim_5 shock is administered in the third and fourth quarters (columns F to G). However, these shocks are not as negative, since they are part of the recovery, as can be seen in the range J15 to K15. Together, this results in an average 5.4 per cent decline of GDP at market prices over the 2020 calendar year (cell L16).

In scenarios 2 and 3, the second quarter is hit harder by the imposition of higher adjustment factors. This is not shown in Figure 5, but it could be that this leads to inconsistencies where for any particular final demand component, the shock is higher than the base value. While there is an automatic corrector in place, the range H2 to K2 will show the number of commodity lines where this may still occur for any of the quarters. Further manual adjustment is required by checking the entries in column T of sheet Q2Shock (in this case) for unit values. Correction can be made by adjusting the lower bound of the impact on each final demand component and each quarter in the range M2 to P5.

5.5 AveQ1–Q4Impacts worksheet

In this sheet, results are consolidated as weighted quarterly averages for the full period at the detailed activity level. The weights are taken from the range H5 to K5 in the summary results sheet. No inputs from the user are required here.

The layout of these sheets is the same as that of the impacts sheets described above. The user can use them to explore the results at a more disaggregated level than is presented in the summary results sheets.

Rank and sort functions are used to present results in absolute values for several variables, such as first-round, indirect, and total multiplier impacts on gross output (columns AD to AI), and total multiplier impacts on GDP (at factor costs) and on total employment (columns AW to AZ), as well as percentage change impacts for the latter two (columns BQ to BX).

6 Shocks and Results workbook: consolidation and comparison

As mentioned earlier, the <COVID Multiplier Quarterly Model Shocks and Results_v7.xlsx> workbook not only sets up the initial scenarios, but also presents combined results so that all scenarios can be viewed together. This takes place in two worksheets, each of which is discussed in turn below.

6.1 Annual results worksheet

Annual results are full-period results calculated as weighted averages of the percentage changes in each subperiod. The weights should be the proportion of a year that each subperiod is taken to represent. The other interpretation is that the weights may represent period lengths different from quarters (see section 7). In Arndt et al. (2020), each subperiod is considered to be a quarter, and they carry equal weight. These results are sourced from the individual scenario workbooks discussed in the previous section. Selected graphs have been created, some of which are linked to a spinner button in the top left-hand corner of the worksheet that allows the quick generation of graphs. Other graphs are generated in a static way. The user can add further graphs if desired.

6.2 Quarterly results worksheet

Quarterly results are subperiod results calculated in two ways:

- as a percentage change off the pre-crisis levels;
- as a quarter-on-quarter percentage change.

The sources of these results are the individual scenario workbooks discussed in the previous section. Selected graphs have been created. These graphs are linked to a spinner button in the top left-hand corner of the worksheet that allows the quick generation of graphs. The user can add further graphs if desired.

7 Using periods other than quarters

The foregoing description has proceeded on the basis that the periods of the shocks are quarters, and the Excel workbooks have been set up using this terminology. However, the set-up is strictly speaking four separate models, each independent of the other. It has been suggested that where the shocks are deemed to last for less than a quarter, the adjustment factor in the summary sheets can be scaled down accordingly.

A different approach would be to adjust the weights for each period (set in the summary sheets) to reflect their relative lengths. For example, if it is felt that the lockdown impact effects last for eight weeks, followed by a 15-week first recovery phase, a 20-week second recovery phase, and then a full recovery, one could apply the full shock to each period but weight them differently: periods 8/52, 15/52, and 20/52. The residual nine weeks would have no shock and carry a weight of 9/52. In principle, this would give the same results as scaling down the shock appropriately for each period and giving them equal weights. In practice, there are differences because of the exclusion of commodities with positive impacts from the scaling.

Adopting this approach would also require some post-solution calculations to convert results to quarters, so that discussions with macroeconomists and policy makers could proceed with the periods to which they are accustomed.

8 Conclusions

This note has discussed some of the thinking behind using a multiplier model to examine the economic impacts of COVID-19, and has provided a guide to a suite of Excel workbooks in which the approach has been implemented. The workbooks were set up for a specific application to a specific country. Other applications may be designed in a different way, which may require a redesign of selected elements of the approach described here. Nevertheless, users might find the set-up useful in deciding how to design their own application.

We re-emphasize that all such modelling exercises are designed to assist in making a sensible assessment. In our experience, it is the process of adapting and implementing the model that provides the most insight into what the impact might be. We encourage any users to use this framework in that way.

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Addendum: the standalone version

The foregoing sections have presented the suite of workbooks used in the modelling in Arndt et al. (2020). They have been presented in detail so that those who are interested can see what underlay the results in that paper.

However, the suite was developed for a particular purpose under the initial urgency surrounding the start of the pandemic and may be difficult for those who wish to use a similar framework to develop their own scenarios. A simplified standalone scenario workbook has therefore been developed and is included in the pack <COVID Impact Multiplier Model SA.xlsx>. Users will find it easier to set-up and run their own scenarios in this version, which does not have a number of unnecessary bells and whistles. The flexibility to run a supplied constrained multiplier model has been abandoned. The rather complicated way of setting up scenarios in one workbook before linking them to the scenario workbooks, which suited the requirements of Arndt et al. (2020), has also been dropped. All the modelling and results are contained in a single workbook. Although the structure of this workbook is similar than those from the suite, further development has taken place based on more recent in-house modelling work, and the results will not be entirely consistent.

Using this workbook as a starting point is strongly recommended. The user can modify the built-in simulations or design their own simulations in the Sim_6 and Sim_7 areas of the Q1BaseShocks-Q4BaseShocks worksheets and select the desired scenario in the drop-down menu in cell R1.

The discussion of the Scenario workbooks above will also provide guidance to users of the standalone version. However, it should be noted that while the Impacts sheets contain the same columns as in the Scenario workbooks in the suite, their order has been changed to make access to results easier.

If users want to set up and run multiple scenarios, this workbook can be copied and new scenarios with new sims can be designed and examined. Users can develop their own set-up to combine results in a separate workbook.