The Australian Journal of
Agricultural and
Resource Economics

AARES
AUSTRALASIAN AGRICULTURAL & RESOURCE ECONOMICS SOCIETY

Australian Journal of Agricultural and Resource Economics, 65, pp. 776–801

The impacts of COVID-19 containment on the Australian economy and its agricultural and mining industries*

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We simulate the economic impacts of the COVID-19 pandemic on the Australian economy using VURM, a detailed computable general equilibrium model for Australia. We identify five sources of economic perturbations: changes to productivity due to changing work practices, changes in household demand imposed by voluntary and mandated social distancing behaviour, changes in international trade due to a weakened world economy and severe curtailment of international travel, reduced population growth due to lower net migration and large debt-financed fiscal stimulus. Variants of these shocks and associated recovery paths are simulated in VURM, with three scenarios describing potential recovery arcs. The macroeconomic and industry impacts are reported for each scenario. Ultimately, our focus is on the impact on output and employment in the agriculture and mining sectors, and on their likely recovery prospects. At the peak of economic impacts, output in these sectors declines by about 6 per cent relative to a no-COVID baseline. Compared to the economy-wide average, the decline in agriculture and mining output is small. This can be explained by relatively minor impacts on work practices, relatively low negative impacts on demand for intensive agriculture (helped by fiscal supports for households) and relatively low disruption to export demand.

Key words: computable general equilibrium model, COVID-19, energy, pandemic, recession.

1. Introduction

To slow the spread of COVID-19 and reduce its negative public health consequences, governments around the world instituted a range of policies to reduce physical contact between people. State governments in Australia declared states of emergency in March 2020 and introduced restrictions including bans on gatherings of more than 500 people and 14 days of isolation for travellers arriving from abroad. The restrictions were progressively tightened and broadened to include the closure of schools, workplaces and recreation venues as well as bans on people leaving their homes for any but a short list of prescribed purposes.

*The authors are grateful to Dr Louise Roos and Professor Glyn Wittwer for valuable comments on this paper.

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While the restrictions were considered necessary from a public health perspective, they had strong negative economic consequences. The restrictions prevented many businesses from operating and forced many workers not to work or to work from home. To counteract these effects, the Federal, State and Territory governments instituted a set of stimulus measures to support businesses and maintain household finances.

Since those initial months, there has been an irregular cycle of shutdowns and openings in different regions in response to new outbreaks of infection. In this paper, we use the Victoria University Regional Model (VURM, Adams et al., 2015), a Computable General Equilibrium (CGE) model of Australia to understand the economic effects of the cycle of COVID-19 containment at the time of writing (early 2021) through to the middle of 2023. The detailed CGE framework enables analysis of the effects of the pandemic on all sectors of the economy, including agriculture and mining, which are reported in this paper.

Our analysis is based on the modelling of four scenarios (each starting in the first quarter of 2020):

1. A hypothetical No-COVID *Basecase* in which COVID-19 does not exist;
2. *Most Likely (ML),* reflecting history through to the first quarter of 2021 and then our current most probable estimates of a fairly smooth recovery arc after 2021;
3. *Pessimistic (P),* reflecting history through to the first quarter of 2021, and then assumptions in which the world economy recovers with a lag of around one year relative to the *Most Likely* case; and
4. *Worst Case (WC),* reflecting history through to the first quarter of 2021, and then a situation in which current vaccination efforts in Australia and overseas prove much less effective for outbreak control than is assumed in the other two scenarios leading to little or no recovery before 2023.[1]

Note that at the time of running the simulations, data through to the December quarter 2020 (2020Q4) were available for a range of key economic variables from the Australian Bureau of Statistics (ABS). These cover national accounts, balance of payments and labour force statistics. Hence, the three COVID scenarios differ only from the beginning of 2021.

The rest of this paper is organised as follows. Section 2 contains a short literature review of recent CGE-related modelling of COVID containment. VURM and aspects of simulation design are described in more detail in

[1] Underlying our thinking behind the *Most Likely* scenario is the assumption of strong outbreak control in Australia and elsewhere which allows the world to prevent new and major outbreaks, with most domestic restrictions phased out by the end of 2021. The *Pessimistic* scenario assumes that strong testing and tracing contain COVID-19, but globally some areas are impacted by a profound second wave of infection, hindering global recovery. In the *Worst Case*, current vaccines ultimately prove largely ineffectual and COVID-19 becomes a lingering disease in the global economy. Australia experiences a slower recovery relative to the first two scenarios, and the rest of the world remains depressed through to the end of 2023.

Section 3, followed by a discussion of general economic results in Section 4. Industry results with specific reference to agriculture and mining are summarised in Section 5. Section 6 contains concluding remarks.

2. Recent CGE modelling of COVID containment

There has naturally been an interest in the economic effects of COVID-19 and the policy response from policymakers, researchers and the public. Research into the economic effects of the pandemic has included a number of CGE-based studies summarised below.

CGE-based research on the economic effects of COVID containment has been conducted using a range of approaches, with new and existing models applied to countries on all parts of the development spectrum. Some work has also focused on the consequences for specific sectors.

Early in the Pandemic, Porsse et al. (2020) projected its effects on the Brazilian economy using a national CGE model. They studied two sources of economic damage: increased rates of illness and death and shutting down ‘nonessential’ economic activities. They simulated each type of damage in separate simulations with the damage applied over periods of 3 and 6 months. The simulations were conducted using a Brazilian version of The Enormous Regional Model (TERM). They found substantial effects on the national economy, with Brazil’s GDP growth being reduced by up to 10 per cent. Illness and death were found to have larger negative effects on GDP than the shutdowns. The effects were projected to be negative in almost every state in every scenario, with cities and regional areas affected to similar degrees.

Also early in the Pandemic, Keogh-Brown et al. (2020) conducted a CGE study on its effects in the United Kingdom. They modelled the economic effects of COVID containment using a CGE model for the economy and with inputs from an epidemiological model for the spread of the disease. They found that the proposed government restrictions would reduce deaths by more than 95 per cent and thus greatly soften the economic consequences.

In a paper finalised in July 2020, Malliet et al. (2020) studied the effects of the COVID-related government measures on the economy and environmental outcomes in France, using a CGE model. They found that the measures have led to substantial decreases in GDP and in CO_2 emissions, though they predict that these changes will only be temporary. They also claimed that aggressive carbon pricing will spur recovery from the crisis while also keeping CO_2 emissions lower than the baseline in the longer term. The model they applied is the French version of the open-source CGE model *ThreeME*, which was designed to study the short-, medium- and long-term consequences of energy and environmental policies.

Djiofack et al. (2020) conducted an early study of the effects of the Pandemic on countries in Sub-Saharan Africa. They predicted decreases in GDP and employment along with increased demands on the public sector due in particular to increased spending on healthcare, worsening the fiscal situations of the national governments. They also found that the poor would be disproportionately affected.

Given the short history of the Pandemic and its rapid development, more recent work has a substantial advantage in the amount of data and experience it can draw on. Dixon and Rimmer (2021) have been analysing the effects of the Pandemic on the US economy with quarterly updates since April 2020. They conduct their analysis using a quarterly version of the USAGE model that has long been used at the Centre of Policy Studies to analyse the US economy. Their most recent findings present a cautiously optimistic picture, with a stronger recovery than initially expected and a return to the previous growth path within the next couple of years.

Other researchers have studied the effects of the Pandemic and associated policies in developing countries using CGE models. Kinda et al. (2021) conducted a study of the effects of the Pandemic on the economy of Burkina Faso. The CGE model they used was based on the established PEP 1-t model, a dynamic single-country model that they adapted to apply to Burkina Faso. They found that the Pandemic will lead to increased unemployment, higher consumer prices in certain sectors and roughly stagnant GDP growth, which contrasts with the 5.7 per cent GDP growth experienced by Burkina Faso in 2019.

Madaï Boukar et al. (2021) studied the effects of the Pandemic on the economy of Cameroon, using a modified version of an established CGE model. An advantage of their approach, for the particular context of this type of developing country, is that their model explicitly treats the informal sector. They found that the negative consequences for the economy of Cameroon would largely be in export-oriented industries and would be larger in the formal than the informal sector.

McKibbin and Fernando (2020 and 2021) conducted an analysis of the macroeconomic effects of the Pandemic for several countries using a DSGE/CGE model. The model they applied is G-Cubed, a multi-country model based on trade data and input–output data from GTAP. They considered seven scenarios of the spread of the disease. Their main findings were that the global economy could be greatly affected even by a limited outbreak, that the economic costs could be greatly reduced by spending on public health, and that it would be most effective to direct spending to places with poor public health systems and high population density.

Though most of the CGE studies of the effects of the Pandemic have focused on the aggregate effects at the country or regional level, Cui et al. (2021) studied the effects on the transport sector in particular. Their study was of China, and they carried out their analysis using the CHINAGEM model. They argued that transport is particularly exposed, due to restrictions on travel and issues with trade. Their findings were that both the freight and passenger transport sectors would be negatively affected, with vastly larger effects on the passenger transport sector.

Robinson et al. (2021) studied the effects of the Pandemic on four countries: the United States, the UK, Mexico and South Africa. They used a social accounting matrix (SAM) approach, which can be regarded as a specific application of a CGE model with certain restrictive assumptions, though they also discussed the use of CGE modelling as the term is typically used. Nonetheless, they preferred the former for their analysis as they argued that it better suits the nature of the crisis. They quantified a set of Keynesian multipliers used in SAM models and applied their model to assess the effects of government income support measures.

The current work adds to this body of economic modelling in three ways. Firstly, the modelling represents Australia's unique experience of the pandemic. Australia has had relatively low case numbers, so impacts on the economy derive not from direct health effects, but from the implementation of tight social distancing restrictions, and the strong fiscal supports that were put in place in tandem with these. Secondly, like many of the single-country studies above, the modelling reflects the structure of a particular economy, in this case, Australia's. In particular, with its high dependence on international migration, Australian population growth stalled when international travel restrictions were imposed. Thirdly, the study incorporates a number of novel features not normally found in a detailed CGE system, including quarterly modelling and a framework allowing for capital idling.

3. Modelling

In this section, we provide a brief description of VURM (Section 3.1), including details on features added to make it more appropriate to studying the COVID-19 pandemic. Shocks are discussed in Section 3.2. The economic environment assumed for the scenarios is explained in Section 3.3.

3.1 VURM

VURM is an 83-industry computable general equilibrium model of Australian states and territories (see Adams et al., 2015). To parameterise VURM, CoPS relies on data from a variety of sources, including ABS Census data, Agricultural Census data, state accounts data and international trade data. The core VURM model database underwent a significant update during the first half of 2020 to incorporate the ABS 2016/17 Input-Output data release, together with updated Government Financial Statistics data from ABS cat. No. 5512.0.

Each region in VURM has a single representative household and a single state/local government agent. The federal government operates in each region. The foreign sector is described by export demand curves for the products of each region and by supply curves for international imports to each region. Supply and demand schedules for each regionally produced commodity are the outcomes of optimising behaviour. Regional industries are assumed to use intermediate inputs, labour, capital and land in a cost-minimising way, while operating in competitive markets. Region-specific representative households purchase utility-maximising bundles of goods, subject to given prices and disposable income. Regions are linked via interregional trade, interregional migration and capital movements, and governments operate within a fiscal federal framework.

Investment in each regional industry is positively related to expected rates of return on capital in each regional industry. VURM recognises two investor classes: local investors (i.e. domestic households and government) and foreign investors. Capital creators assemble, in a cost-minimising manner, units of industry-specific physical capital for each regional industry.

VURM normally provides results for economic variables on a year-on-year basis. The results for a particular year are used to update the database for the commencement of the next year. More specifically, the model contains a series of equations that connect capital stocks to past-year capital stocks and net investment. Similarly, debt is linked to past and present borrowing/saving, and the regional population is related to natural growth and international and interstate migration. The model is solved with the GEMPACK software package (Horridge et al., 2018).

In solving VURM, we typically undertake two parallel model runs: a basecase simulation and a scenario simulation. The basecase simulation is a business-as-usual forecast for the period of interest. The scenario simulation is identical to the basecase simulation in all respects, other than the addition of shocks describing the scenario under investigation. We report results as cumulative deviations (either percentage or absolute) away from basecase in the levels of variables in each period of the scenario simulation.

3.1.1 Features added to VURM to enhance modelling COVID containment

COVID containment measures initially produce a large, sudden drop in demand. Enhancements to the usual CGE framework were added to VURM to suitably capture the impact of sharp changes in activity.

Quarterly modelling. The model time interval was shortened to quarters rather than the usual financial years. This allows the depth and timing of the downturn and recovery to be captured. For example, a one-off downturn in industry activity of 80 per cent in one quarter followed by a rapid recovery would appear in an annual model as a year-long downturn of 20 per cent.

The adoption of quarterly modelling is conceptually simple but required modifications to the VURM stock-and-flow relationships (e.g. the accumulation of capital or debt), and to lagged adjustment mechanisms. Quarterly modelling also adds significantly to model solution times.

Capital idling. In the usual CGE framework, output is a function of capital, labour and productivity. The endowment of capital is usually assumed to be fixed. A large fall in demand therefore results in a fall in output, facilitated by a fall in employment and a fall in output prices. This leads to real currency depreciation and a strong move to trade surplus. Full utilisation of capital is the cause of this result. Under recession conditions, we replace the assumption of full capital utilisation with a theory that reflects capital idling. For the modelling reported in this paper, a special version of capital idling theory is adopted, with endogenous utilisation of capital adjusting to prevent the real rental return on capital from falling more than 20 per cent in a single period.

With stickiness in both the wage and the capital rental price, industry supply curves are more elastic than they are in standard CGE models. Large falls in demand lead to large falls in output and moderate falls in prices, an appropriate response for a short-term negative demand shock.

Treatment of tourism and international education exports. International exports of tourism and education are treated as bundles in the VURM export theory. International visitors are assumed to consume a bundle of commodities in fixed proportions, and exports of this bundle are linked to the price of this bundle rather than prices of the individual services within the bundle.

For example, exports of accommodation services to tourists do not respond only to the foreign currency price of accommodation services. Rather, they respond to the price of the tourism 'bundle', of which accommodation services are a component. Similarly, exports of residential dwelling services to international students respond to the price of the international education bundle, which comprises exports of international education (university fees), travel-related services and living expenses.

3.2 Model shocks

Our COVID scenarios are generated as deviations away from the hypothetical No-COVID Basecase. The No-COVID Basecase contains business-as-usual assumptions for productivity and other key economic drivers, and makes no allowance for COVID-19 and containment policies.

The COVID scenarios (Most likely, Pessimistic and Worst Case) deviate from No-COVID in response to five sets of shocks[2]:

- Productivity shocks,
- Physical distancing (demand) shocks,
- Shocks to the world economy,
- Fiscal shocks, and
- Shocks to population derived from reduced net overseas and interstate migration.

[2] In addition, for quarters through to 2021Q1, some observed data for industry production and exports were imposed in the modelling.

Each set of shocks has a magnitude and path to recovery that is based on a combination of evidence, legislation and judgement based on the scenario's recovery path. Model results derived from these shocks are our estimates of the economic impacts of COVID and associated containment should these shocks play out as we have assumed.

The five sets of shocks are described below. Table 3 and associated notes in Section 3.3 provide more detail on the model variables that are shocked, and what variables made endogenous to allow the exogenously imposed changes.

3.2.1 Part 1: Productivity shocks relating to physical distancing

The physical distancing strategy for containment of COVID-19 requires people to work from home where possible. This imposes a productivity loss, exacerbated by school closures and the unavailability of informal childcare arrangements. For workplaces that operate with staff on-site, productivity is also negatively impacted, due to additional cleaning and hygiene requirements and physical distancing requirements such as limits on the number of passengers in lifts, and the need for a mandated minimum square metres of space per person.

In the context of these restrictions, data for the impact on productivity of working from home are unavailable, as are data on the impact of additional hygiene requirements in the workplace. We assume at the start of the pandemic initial productivity losses of between 1 per cent and 3 per cent, equivalent to losing 5–15 minutes of productive time per 8-hour workday.

For each industry, the productivity loss is put in place for 2020Q2 and unwound in 2021Q2, by which time we assume that strict hygiene measures are relaxed, and to the extent to which they remain, businesses have adapted. The extent of productivity losses and recovery is the same across all three scenarios.

Implementing these shocks in VURM is straightforward. As indicated in row 8 of Table 3, productivity is a naturally exogenous variable.

3.2.2 Part 2: Domestic containment measures

Domestic containment shocks relate to limits on social gatherings and nonessential travel. To represent domestic containment, negative shocks are applied to domestic final demand in selected industries.

Shocks to demand were devised using data on industry production (19 ANZSIC classes) provided in the ABS's quarterly national accounts publication. Changes in production were split across elements of demand (final and intermediate) in line with sales shares in the existing VURM database. Shocks were applied for the two quarters 2020Q2 and 2020Q3 and unwound in line with the characteristics of each scenario (see Appendix S1).

3.2.3 Part 3: International shocks

Trade in goods and services. The slowing of the economies of all of Australia's major trading partners and the heavy restrictions on international travel have an impact on demand for exports. From world economic growth of 2.9 per cent in 2019, preliminary data point to a decline of 3.3 per cent in 2020, a negative turnaround of over 6 per cent.

Shocks to exports of non-service commodities in 2020 are derived from an average of the actual impacts on growth by country, weighted according to Australia's export profile of agriculture, mining and manufactured goods to each country. The export demand shift for mining is somewhat less negative than the shifts for Agriculture or Manufacturing because China, with a relatively high weight on mining, has a lower-than-average decline in GDP growth. The average impact on the growth of our trading partners, weighted for each set of commodities, is given in Table 1 below (Row 1). We apply an adjustment to reflect our trading partners becoming more inward looking. The adjustment is larger for Agriculture and Manufacturing, as exports of Australian food products and pharmaceuticals are relatively expensive items and will be impacted by falls in discretionary spending in China and other trading countries. This is given in Table 1 (Row 2). The impact on 2020 growth is distributed across the four quarters of 2020 as shown in Row 3, with the majority of the impact occurring in 2020Q2 and 2020Q3.

After 2020, export recovery is governed by the nature of the scenarios to be modelled.

Travel-related exports. Shocks to travel-related exports are much more significant. These shocks have an impact on accommodation, restaurants, air transport and other sectors. The shocks begin in 2020Q1, ahead of significant numbers of COVID-19 cases in Australia and domestic physical distancing measures.

Tourism shocks are shown in Figure 1 for each scenario. The shocks are expressed as percentage deviations relative to No-COVID levels.

In each scenario, tourism exports are assumed to fall to a level 90 per cent below No-COVID values during 2020. In the Most Likely case, tourism exports gradually recover by 2024Q4. In the long-term, tourism is assumed to remain 8 per cent below No-COVID levels, equivalent to the loss of 12 to

Table 1 Export demand shocks applied in 2020 (percentage deviations relative to No-COVID levels)

	Agriculture	Mining	Manufacturing
(1) Average impact on growth of trading partners, 2020	−4.8	−4.3	−6.6
(2) Assumed impact on exports, 2020	−8.1	−7.3	−11.8
(3) Distribution of impact over 2020			
2020Q1	−2.1	−2.0	−3.1
2020Q2	−8.0	−9.0	−18.3
2020Q3	−7.1	−7.8	−10.7
2020Q4	−4.9	−5.7	−7.9

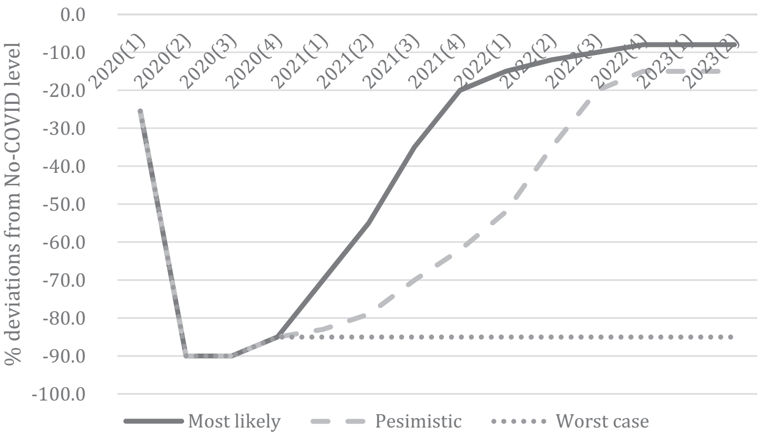

Figure 1 Assumed paths for tourism exports (percentage deviations from No-COVID levels).

18 months of growth. In the pessimistic scenario, the recovery stalls for four quarters, while in the Worst Case there is no recovery in the simulation period.

Shocks to higher education exports in the Most Likely scenario in 2020 and 2021 are consistent with Hurley and Van Dyke's (2020) 'optimistic' scenario, in which there is an intake of students in 2021. As shown in Figure 2, higher education exports in the Most Likely scenario are assumed to return to 92 per cent of their No-COVID levels over 2 years. In the Pessimistic scenario, the recovery stalls one year, while in the Worst Case there is no recovery.

3.2.4 Part 4: Fiscal response

Overview of commonwealth response. In response to the COVID-19 pandemic, the Federal government initially announced three support packages to

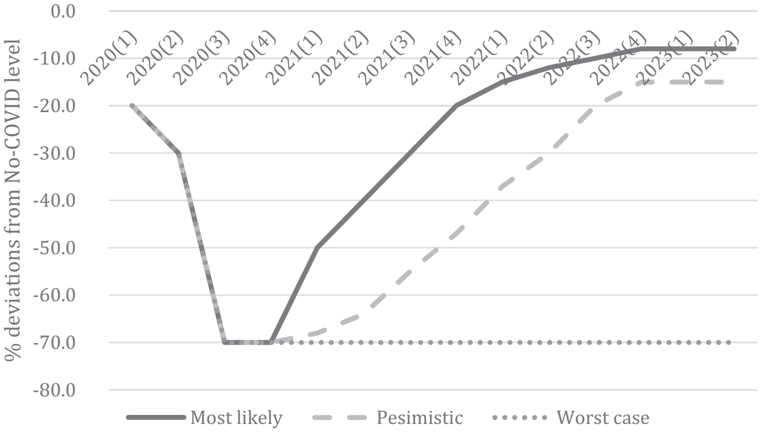

Figure 2 Assumed paths for education exports (percentage deviations from No-COVID levels).

the value of $150 billion' while the Reserve Bank of Australia announced a $90 billion funding facility to assist banks with their lending to business. The first Federal support package of $17.6 billion was announced on the 12th of March 2020 and provided support for business investment and cash flow, with additional targeted support for the most severely affected sectors, regions and communities, and direct payments to lower income households. The second rescue package, worth $66.1 billion, included further support to households and assistance to business to keep workers employed. The third support package, known as *JobKeeper*, provides a payment to approximately 3.5 million workers to the value of $70 billion (Commonwealth Treasury, 2020).

JobKeeper in VURM. *JobKeeper* is the largest single government support package at any level of government. Initially, it was worth $70 billion and was to be paid over the 2nd and 3rd quarters of 2020. Subsequently, the Government extended the scheme (at a reduced rate) until the end of the 1st quarter of 2021. The latter tranche of funding targeted those businesses and not-for-profits who continued to be significantly impacted by COVID-19 after much of Australia had started to open up.

There are two mechanisms in VURM that are used to represent *JobKeeper*: wage subsidies and transfer payments. Wage subsidies reduce the employer cost of labour, while transfer payments (from government to households) are not linked to any other transaction and do not change incentives. To some extent, *JobKeeper* is a wage subsidy, and to some extent it acts like a transfer payment from the government to workers (although administratively it passes through the employer). As a wage subsidy, *JobKeeper* is limited to eligible employees of eligible employers.

The final representation of *JobKeeper* in VURM is given in Table 2.

From 2021Q2 onwards, we assume that federal and state support for industries, workers and households continue as modelled through to 2021Q1 at rates sufficient to maintain real household income at No-COVID levels. Support rates in the Pessimistic scenario will be proportionately higher than in the Most Likely case and proportionately lower than in the Worst Case.

Table 2 JobKeeper in VURM (Budgeted spending, $ billion)

	2020Q2	2020Q3	2020Q4	2021Q1
Direct payments to households – payments to employers	15.0	25.0	16.0	12.0
Direct payments to households – payments to employees	4.6	2.3	1.0	1.3
Labour subsidy	15.4	7.7	4.0	5.0
Total	35.0	35.0	21.0	18.3

3.2.5 Part 5: Net overseas migration

COVID-19 containment in Australia and the rest of the world has dramatically reduced the international movement of people. For Australia, net overseas migration is expected to fall in 2020, before slowly and only partly recovering. Net overseas migration accounts for 56 per cent of population growth. Population growth rates are adjusted accordingly over the forecast period (see Figure 3).

3.3 Economic environment

Main macro level assumptions adopted in each scenario are summarised in Table 3 and associated notes that follow.

4. Macroeconomic effects of COVID containment through to 2023Q2

The effects of COVID containment are calculated by comparing COVID scenarios with the No-COVID Basecase and reporting deviations away from the basecase. The scenarios are run out to the end of 2029, but for expositional convenience, we show results only for the quarters through to 2023Q2. We report national results only, although the model also produces results for states and territories. Shocks specific to each of the three alternative scenarios are summarised in the Appendix S1.

4.1 Employment

Figure 4 shows changes away from No-COVID levels for Australian employment, expressed in thousands of jobs. Initial containment reduces employment by around 600 thousand persons relative to No-COVID levels.

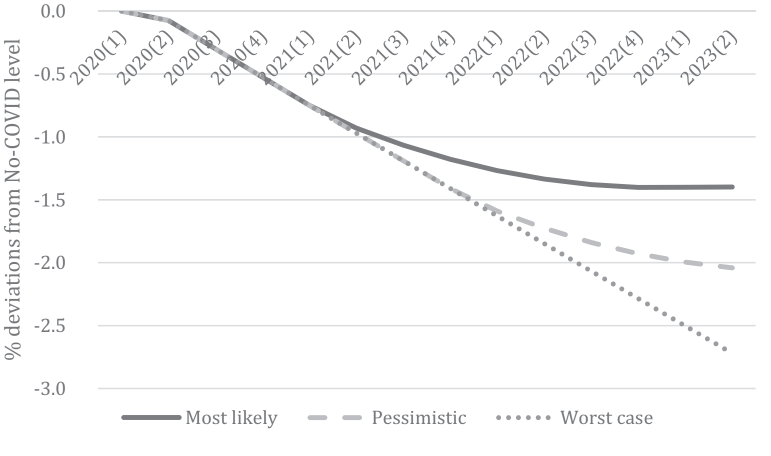

Figure 3 Australian population (percentage deviations from No-COVID levels).

Table 3 Summary of closure and shocks

		2020				2021		2022	2023
		Q1	Q2	Q3	Q4	Q1	Q2-4	Q1-4	Q1-4
1	Household consumption	N	X	X	X	X	X	N	N
1a	Saving rate	X	N	N	N	N	N	X	X
2	Gov't consumption	N	X	X	X	X	X	N	N
3	Exports	N	X	X	X	X	X	X	X
4	Imports	N	N	N	N	N	N	N	N
5	Investment	N	N	N	N	N	N	N	N
6	Employment	N	N	N	N	N	N	N	N
7	Capital utilisation	N	N	N	N	N	N	N	N
8	Productivity	X	X	X	X	X	X	X	X
9	Transfer payments	X	X	X	X	X	X	X	X
10	Wage subsidy	X	X	X	X	X	X	X	X
11	GDP and GSP	N	N	N	N	N	N	N	N
12	Population	X	X	X	X	X	X	X	X

X = exogenous, N = endogenous.
1. *Household expenditure* is normally determined in VURM as a function of household income and an exogenous saving rate. Here, we endogenise the savings rate (1a) to accommodate the negative shocks in 2020Q2 and 2020Q3 and recovery thereafter. Taste changes are also endogenised to capture the change to the commodity composition of household expenditure under physical distancing requirements. In all three scenarios, from 2022Q3 the saving rate is exogenous.
2. *Government expenditure* is normally determined as a function of population size. Like household expenditure, it is exogenised from 2020Q2 to 2021Q4 to incorporate productivity and physical distancing shocks. In all three scenarios, from 2022Q1 government expenditure is determined as a function of population size.
3. *Exports* Exports of key goods and services (e.g. tourism) are exogenous in all three scenarios.
4. *Imports* are endogenous and treated as imperfect substitutes for domestically produced goods and services with the same name.
5. *Investment* by industry is endogenous and responds to changes in capital utilisation and rates of return.
6. *Employment* is endogenous and responds to changes in the marginal product of labour and the real wage. Over time, the real wage adjusts slowly to return the national unemployment rate to its basecase level.
7. *Capital utilisation* is endogenous and responds to changes in the marginal product of capital and the real rental rate. If capital rentals fall relative to the CPI, owners of capital are assumed to reduce capital utilisation. In the basecase, capital utilisation averages around 95 per cent, so there is limited scope to increase capital utilisation but ample scope to reduce utilisation in an unanticipated downturn.
8. *Productivity* is exogenous in the policy simulation. It would normally take on the same growth rate as in the basecase. To model COVID-19 and its containment, an additional exogenous shock is applied to productivity from 2020Q2 to 2021Q1, after which it resumes its original path (see Section 2.2.1).
9. *Transfer payments and* 10. *Wage subsidies* are exogenous and reflect *JobKeeper* and other packages (Section 3.2.4).
11. *GDP* is endogenous and reflects the shocks applied to the major components of expenditure: household, government and exports.
12. *Population* is assumed to grow more slowly throughout the simulation in all three scenarios due to lower net overseas migration.

This increases the unemployment rate from 5.2 per cent in 2020Q1 to 7.8 per cent in 2020Q2.

Employment recovers somewhat in 2020Q3 in line with the easing of initial containment measures. After 2020Q4, employment recovers gradually as containment measures are eased. In the Most Likely scenario, employment does not make a full recovery, as the population gradually falls away from its No-COVID level due to reduced net overseas migration (see Figure 3). In the

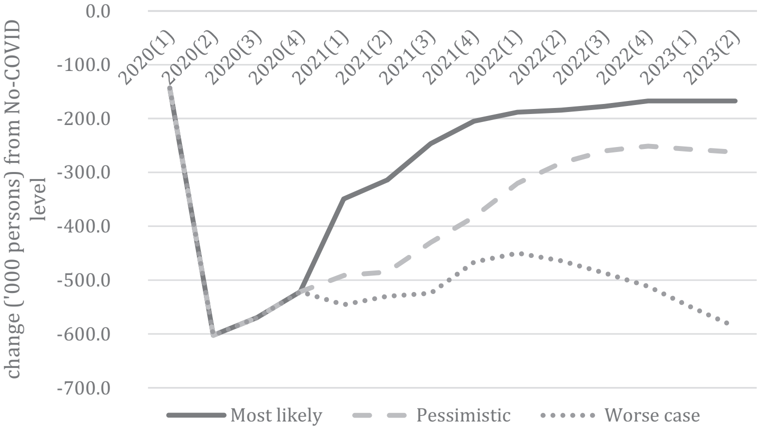

Figure 4 Australian employment – persons (changes ('000 persons) from No-COVID levels).

Pessimistic scenario, employment recovery lags roughly one year, while in the Worst Case scenario employment never recovers back to No-COVID levels. Indeed, in the Worst Case, at the end of the period employment is still around 600 thousand below its No-COVID level.

The gradual return to No-COVID employment levels in the Most Likely and Pessimistic scenarios is facilitated by two factors. First, the recovery in conditions as work from home restrictions, school closures and other physical distancing measures are lifted will naturally reverse the productivity and demand-driven losses assumed in 2020Q2. Second, wage growth will be dampened as employees and job seekers suffer a loss of bargaining power in an environment of high unemployment. The same factors operate in the Worst Case, but are increasingly offset over time by the declining population (labour force).

4.2 Real GDP

Figure 5 shows percentage deviations in Real GDP away from No-COVID levels. In 2020Q2, GDP falls significantly to be 10.5 per cent below its No-COVID level. The fall reduces to 7.8 per cent by the fourth quarter.

In the Most Likely scenario, recovery begins thereafter as conditions return to normal. The result for GDP is closely linked to the demand shocks due to physical distancing and the slowing of international trade. In the Pessimistic scenario, recovery is lagged around one year. In the Worst Case, there is a mild short-term recovery that then stalls; in 2023Q2, real GDP is projected to be 5.1 per cent lower than its No-COVID level.

In per capita terms, real GDP returns to No-COVID levels after 2022Q4 in the Most Likely and Pessimistic scenarios, but remains well below No-COVID values in the Worst Case.

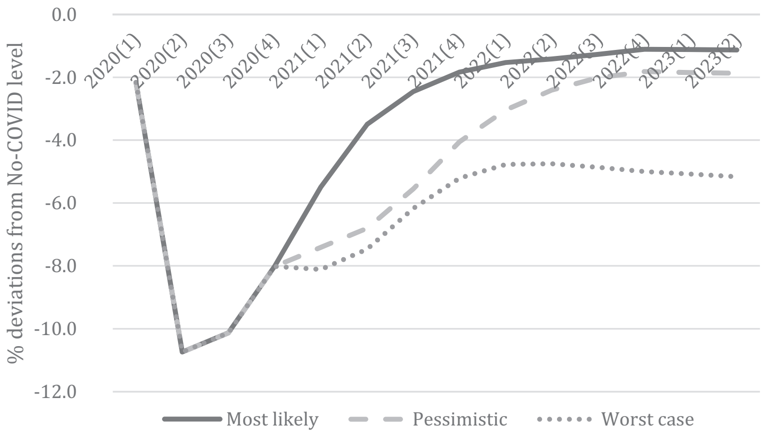

Figure 5 Real GDP (percentage deviations from No-COVID levels).

4.3 Real household consumption

JobKeeper, *JobSeeker* and other stimulus packages have a significant impact on household income into 2021. Nationally, the combined impact of these packages will be a transfer of around $195 billion from government to households between 2020Q2 and 2021Q1, an increase of 16 per cent over normal levels of household income for this period. At the same time, real household factor income – the income derived from employment and business profits – falls below its No-COVID level commensurate with the deviation in GDP.

On the expenditure side, in 2020 real household consumption falls 13.6 per cent below No-COVID levels. Around 40 per cent of household expenditure is allocated to activities that are affected by domestic containment measures. Expenditure on these activities is assumed to drop by an average of 30 per cent, accounting for almost all of the fall (12 per cent) in household expenditure.

Overall, as shown in Figure 6, consumption falls by more than income in 2020, meaning that savings are accumulated between 2020Q2 and 2021Q1. From 2021Q2 onwards, there is a period of dis-saving, as household consumption recovers. In the Most Likely scenario, the recovery is relatively quick. In the Pessimistic and Worst Case scenarios, with continuing Federal and state support (Section 3.2.4), recovery is lagged around one year.

4.4 Real investment

Real investment expenditure falls as a result of low capital utilisation. During the domestic containment period, with significant amounts of capital unutilised, the incentives for investment in new capital are low. Investment recovers in line with the assumed recovery in household expenditure after

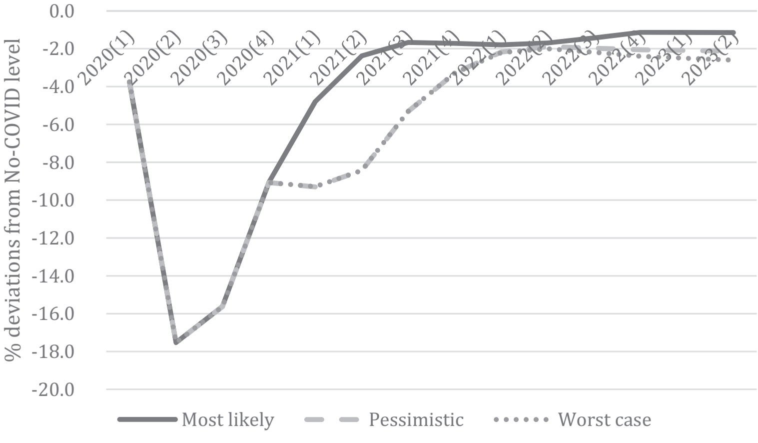

Figure 6 Real household consumption (percentage deviations from No-COVID levels).

physical distancing. However, the incomplete recovery in export expenditure (see Section 4.4.6) and lower population (3.2.5) suppresses investment and it remains below No-COVID levels throughout the simulation period.

The extent to which investment expenditure remains below basecase levels across the three scenarios reflects, in the main, the respective recovery paths. As shown in Figure 7, recovery occurs quickly in the Most Likely scenario and with a one-year lag in the Pessimistic scenario. In the Worst Case, there is no recovery, with real investment remaining around 6 per cent below No-COVID levels.

4.5 Real government consumption

Real government consumption falls in line with the assumed impact of physical distancing. While expenditure on public administration and defence

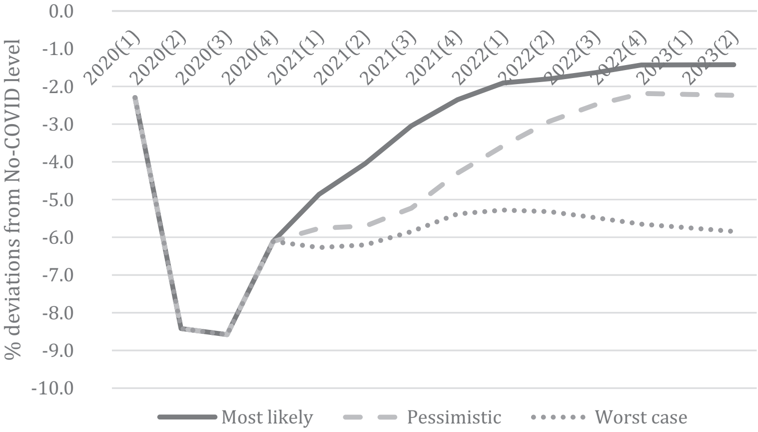

Figure 7 Real investment (percentage deviations from No-COVID levels).

is unchanged (comprising around 40 per cent of total government expenditure), expenditure on other services will fall, including health care, tertiary education, school education and arts and recreation. Expenditure on these services will recover quickly after physical distancing is no longer required.

As shown in Figure 8, that recovery will be quickest in the Most Likely scenario, followed by the Pessimistic scenario. In the Worst Case, recovery is relatively weak.

4.6 Real exports

Through to the end of 2020, foreign exports are assumed to fall in line with travel bans and a fall in world economic growth.

In the Most Likely scenario, the world economy recovers relatively quickly (see Section 3.2.3). World recovery in the Pessimistic scenario is lagged one year, while there is no recovery in the Worst Case. The export deviations shown in Figure 9 reflect these assumptions.

4.7 Real imports

Through to the end of 2020, foreign imports are assumed to fall in line with suppressed demand. Another contributing factor is devaluation of the real exchange rate which occurs as the demand for exports contract.

In the Most Likely scenario, imports return to No-COVID levels as the domestic economy recovers. In the other two cases, imports move back towards their No-COVID level, but persistent real devaluation (particularly in the Worst Case) prevents full recovery. Indeed, in the Worst Case, even in the final quarters imports remain around 8 per cent below No-COVID levels Figure 10.

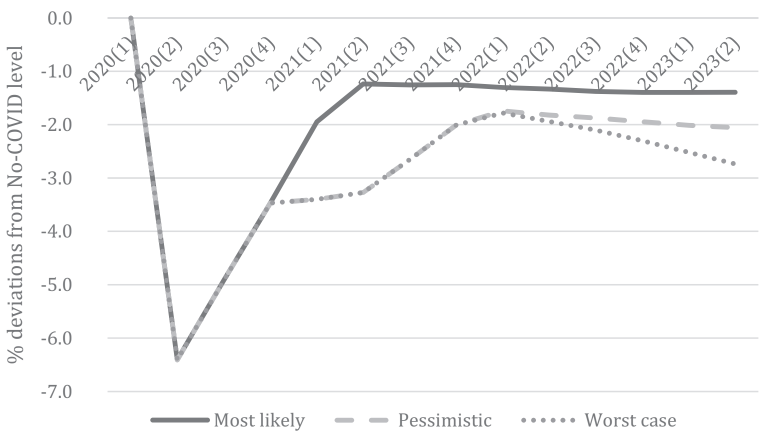

Figure 8 Real government consumption (percentage deviations from No-COVID levels).

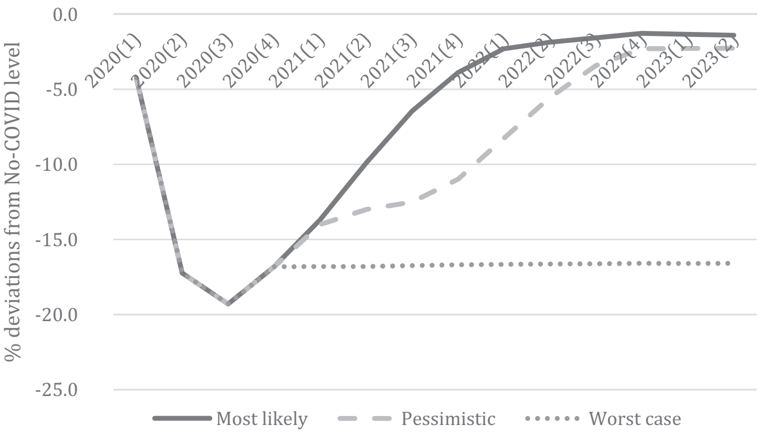

Figure 9 Real exports (percentage deviations from No-COVID levels).

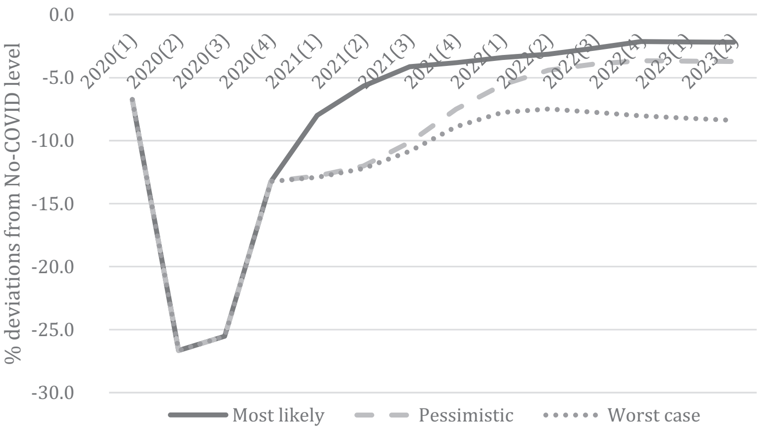

Figure 10 Real imports (percentage deviations from No-COVID levels).

5. Industry effects of COVID containment

This section has two parts. In the first, we discuss the initial effects of COVID containment in the peak quarter 2020Q4 across all industries. In the second part, we look more closely at the agricultural and mining industries and how their medium-term prospects might change out to 2023Q2.

5.1 Initial effects in 2020Q2

Industry results can be understood in terms of the shocks implemented and the macroeconomic environment assumed. Figure 11 shows deviations in output for industries aggregated to the ANZSIC division level in 2020Q2 – at the peak of initial Australia-wide containment efforts.

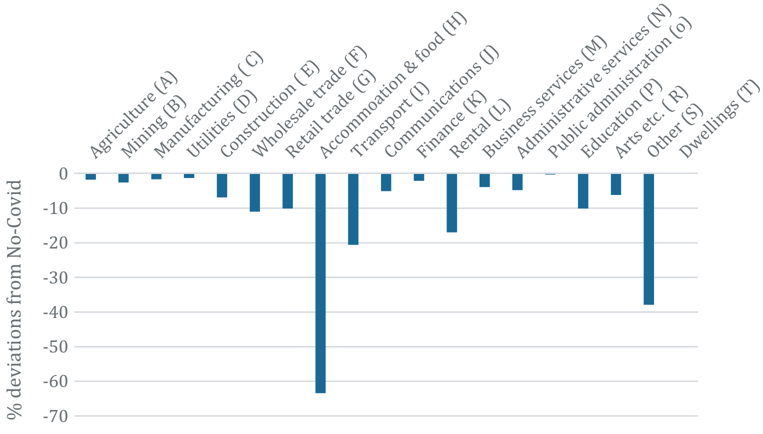

Figure 11 Industry output, 2020Q2 – Peak of Physical Distancing (percentage deviations from No-COVID Levels for ANZSIC major categories).
[Colour figure can be viewed at wileyonlinelibrary.com]

Divisions R (Arts and Recreation), H (Accommodation and Food services) and S (Other Services) are the most negatively impacted in 2020Q2. These industries are affected by both domestic physical distancing measures and international travel bans.

Division I (Transport) is also negatively affected by travel bans, which affect air transport and road and rail passenger transport. This division also includes postal, delivery and warehousing services, which are assumed not to be directly affected by travel bans or physical distancing.

Division L (Rental) is negatively affected directly by physical distancing and indirectly through its links to the construction sector and dwelling investment. This division includes real estate services, which is negatively affected by physical distancing, and passenger car hire, which is negatively affected by the travel bans. It also includes rental and leasing of heavy machinery and other equipment, for which the construction sector is an important customer.

Construction is not assumed to be directly impacted by physical distancing or a downturn in exports, yet activity in the construction sector falls by 7.3 per cent. This is a consequence of the overall decline in investment (Figure 7).

The decline in Division C (manufacturing) output is relatively small. Manufacturing has some indirect links with the negative impacts of physical distancing via supplying food and drinks to restaurants and bars; however, this accounts for a small share of manufacturing output. An increase in retail sales of food and drink to households offsets the negative impact of links to restaurants. Moreover, there is scope for manufacturing activity to expand to offset the decline in imports as domestic manufactured goods become more competitive with imports under a weaker exchange rate.

The small decline in Division O is due to a fall in sales to the non-government sector, including sales to households and industries including

Professional, Scientific and Technical Services, Construction, Transport and Communication.

5.2 Recovery paths for agricultural and mining industries

In this section, we focus on each of the two broad components of ANZSIC divisions A (Agriculture) and B (Mining). Our analysis covers the current situation and possible future recovery to 2023Q2 under the three COVID scenarios. Deviations in production are shown in individual charts. Table 4 summarises changes in employment for each of the four industries.

5.2.1 Broadacre agriculture

The broadacre agricultural industry produces a diverse range of livestock (live cattle and sheep), livestock products (principally wool) and grains such as wheat and barley generally on large land holdings. Much of its product is produced for export either directly (e.g. wool and wheat) or indirectly through downstream manufacturing industries such as meat products.

Figure 12 shows projected percentage deviations from No-COVID values for broadacre production. For the quarters through to 2021Q1, our modelling is constrained, in part, by observed data. Thereafter, the deviations are entirely model-generated using the shocks and assumptions described in Sections 3.2 and 3.3.

Table 4 Employment in selected Agricultural and Mining Industries (differences ('000 jobs) from No-COVID levels)

	2020Q2	2021Q2	2022Q2	2023Q2
Broadacre agriculture				
Most likely	−4.1	−1.9	−0.4	−0.3
Pessimistic	−4.1	−2.6	−0.9	−0.4
Worst case	−4.1	−3.2	−2.5	−2.6
Intensive agriculture				
Most likely	−0.7	−1.9	−0.7	−0.6
Pessimistic	−0.7	−2.0	−1.3	−0.9
Worst case	−0.7	−2.5	−3.0	−3.2
Energy mining				
Most likely	−1.4	−1.1	−0.1	−0.1
Pessimistic	−1.4	−2.7	−0.2	−0.2
Worst case	−1.4	−3.0	−2.9	−3.0
Metal mining				
Most likely	−2.5	−2.0	0.0	0.0
Pessimistic	−2.5	−1.8	−0.6	0.0
Worst case	−2.5	−2.8	−2.7	−2.8
Total				
Most likely	−8.7	−6.9	−1.2	−1.0
Pessimistic	−8.7	−9.1	−3.0	−1.5
Worst case	−8.7	−11.5	−11.1	−11.6

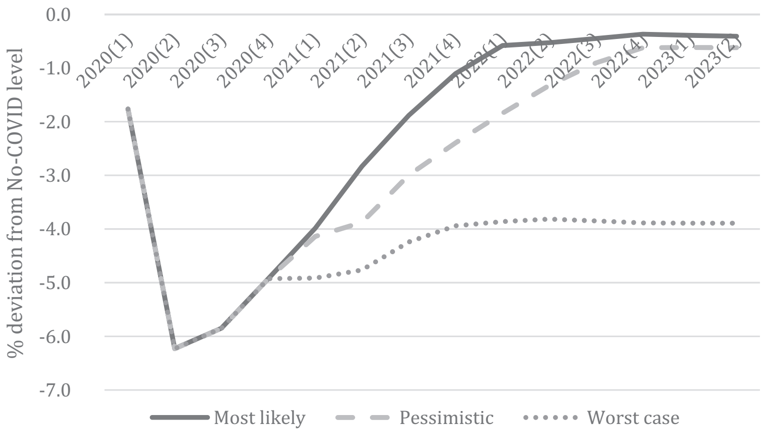

Figure 12 Broadacre agricultural production (percentage deviations from No-COVID levels).

During the observed period (to 2021Q1), broadacre production falls relative to No-COVID levels, reflecting the downturn generally in world demand for Australian products (Section 3.2.3). Domestic demand for broadacre products is fairly steady thanks, in part, to government support packages that maintain household demand for food products.

Over time, as exports recover, so does broadacre agricultural production. In the Most Likely case, production rises back to No-COVID levels by 2020Q1, while in the Pessimistic scenario production levels are largely restored one year later. In the Worst Case, however, production remains depressed relative to No-COVID levels, with a projected decline of around 4 per cent in 2023Q2.

In terms of jobs (Table 4), initially the sector loses just over 4,000 jobs, but employment progressively returns to No-COVID levels in the Most Likely and Pessimistic scenarios. In the Worst Case, though, there is only a modest jobs recovery, with employment still down by around 2,000 jobs at the end of the period.

5.2.2 Intensive agriculture

This industry covers other forms of agriculture not included in the Broadacre industry. Key products include fresh milk, fruit and vegetables. Compared to Broadacre products, intensive agricultural output is sold mainly to the domestic market, with only around 20 per cent of production destined directly or indirectly for exports.

Figure 13 shows projected deviations from No-COVID levels in intensive agricultural production. Through to 2021Q3, the deviations show a different pattern to those for Broadacre agriculture. Due to government support packages, consumption of fresh food changes little relative to basecase levels through 2020. But when that strong level of support finishes, domestic demand falls away. By 2021Q1, production of intensive agriculture is down 4

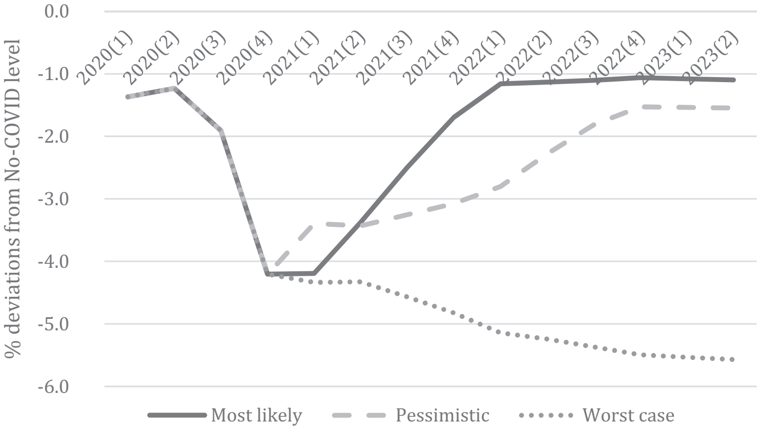

Figure 13 Intensive agricultural production (percentage deviations from No-COVID levels).

per cent relative to its No-COVID level, and employment losses amount to around 2000 jobs (Table 4).

Thereafter, production and employment return to their basecase levels in the Most Likely scenario and with a lag in the Pessimistic scenario. In the Worst Case, though, there is no recovery. In 2023Q2, production is down around 4.5 per cent and over 3,000 jobs are lost.

5.2.3 Energy-based mining

This sector produces metallurgical and thermal coal, gas for domestic use, LNG for export and crude oil for sales to overseas refiners. The sector is strongly export focussed, with around 80 per cent of its output exported. Accordingly, it is no surprise to see the significant fall off in production in line with general decline in exports (see Section 3.2.3), with a relatively quick turnaround back to No-COVID levels from 2021Q1 onwards. At its trough, production is down 5.1 per cent and around 1,500 jobs are lost.

Production of primary energy for the domestic market deviates by less than the deviation in energy exports, especially through to 2021Q3, suggesting that sales to domestic customers insulate the energy industries to some extent from the significant shifts in international demand. Indeed, domestic demand for energy remains within a tight band of 0 to −1.2 per cent of No-COVID levels through to the end of the projection period.

Recovery is quick in the Most Likely case and lagged in the Pessimistic case. In the Worst Case, there is no recovery with the initial production and job losses persisting through to the end of the projection period.

It is of interest to note that even though production is down, the sector does better than the economy in general as summarised by the changes in real GDP (Figure 14 with Figure 5).

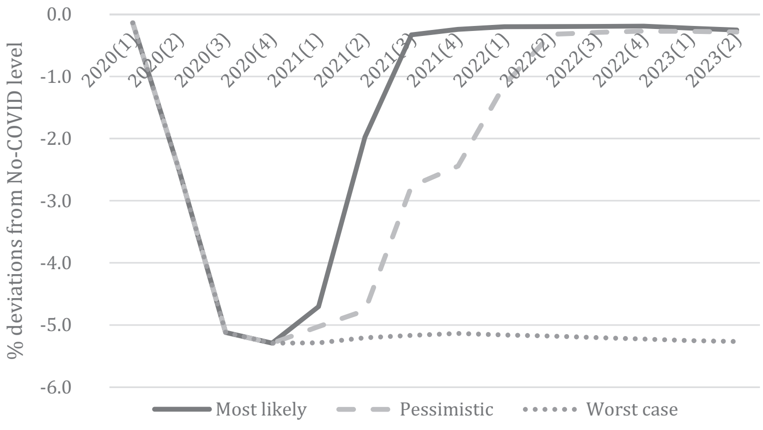

Figure 14 Energy-based mining production (percentage deviations from No-COVID levels).

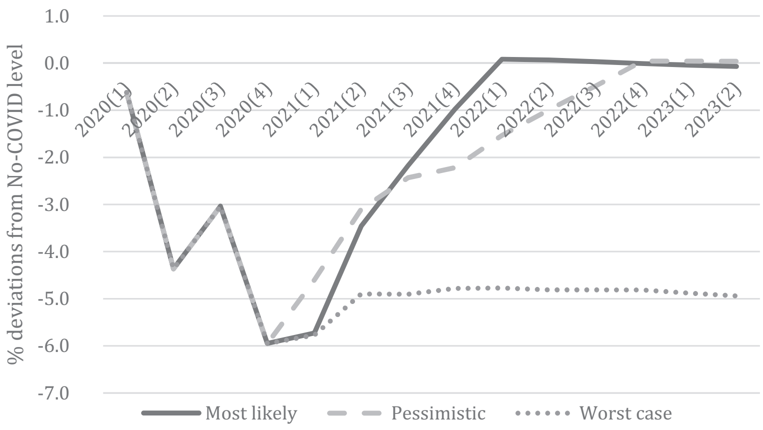

Figure 15 Metal-based mining production (percentage deviations from No-COVID levels).

5.2.4 Metal-based mining

This sector produces ferrous and non-ferrous ores for smelting and refining by downstream industries in Australia and overseas. Relative to energy-related mining, metal-based mining (iron ore aside) is more domestically focussed. Hence, during the first quarters of 2020, production falls at most by around 4.0 per cent relative to the No-COVID scenario. Job losses in 2020Q3 amount to around 2,700 (Figure 15).

Following a short-lived rebound in 2020Q4, output declines further in the first half of 2021 to around 6 per cent below basecase values. This reflects our assumptions for iron ore exports. For the first two quarters of 2021, we have assumed contractions in Chinese iron ore demand as it deals with an over-supply of steel. The over-supply is both cyclical and COVID-induced. The latter relates to COVID-induced reductions in Chinese investment in the last half of 2020.

Recovery in metal-based mining production relative to basecase starts in the middle of 2021, with output back to No-COVID values by the start of 2022 in the Most Likely case. Although not taken into account by the modelling, the iron ore price surged to over $US200/ton in May 2021, suggesting that a recovery in iron ore exports started to take place just ahead of the modelled recovery. In the Pessimistic scenario, output returns to base at the end of 2022. In the Worst Case, there is not recovery: output remains around 5 per cent lower than no-COVID with job losses of around 3,000 persisting through to the end of the projection period.

6. Conclusions

In this paper, we use the VURM model to better understand the impact of COVID-19 and containment measures on the general economy and agricultural and mining industries. The simulations attempt to create an accurate representation of the period through to 2021Q1, which we loosely term the observed period, for which data were available, and then to describe the recovery of the economy for three different scenarios: Most Likely, Pessimistic and Worst Case.

The modelling was based around five channels of effects:

- Impacts on productivity;
- Changes to consumption patterns relating to physical distancing;
- Impacts on demand for exports;
- Fiscal stimulus measures; and
- A reduction in international migration.

Incorporating these into the model required several enhancements to VURM, including changing the basic period of time from annual to quarterly, introducing variable usage rates for capital and enriching the model's existing treatment of international visitor and student exports.

The simulations for each of the three different recovery paths show that Australian economic activity is unlikely to fully return to No-COVID levels. In the near term, real GDP will be significantly below No-COVID levels, along with employment, capital utilisation and all components of domestic absorption (household consumption, public consumption and investment). Commonwealth and state support packages provide a significant boost to household incomes through the worst affected period of 2020 and early 2021. Thereafter, household income will slowly return to normal growth rates, other than in the Worst Case.

In terms of recovery paths for agricultural and mining industries, put simply in the Worst Case there is no recovery within the simulation period from the troughs experienced in 2020. However, in the Most Likely scenario, almost full recovery is projected by the end of the simulation period, 2023Q2. At that point, job losses in the four industries of focus amount to around

1,000 relative to No-COVID levels. This compares to losses in 2020Q2 of around 8,700 (again relative to No-COVID).

The modelling shows the usefulness of CGE modelling for evaluating the economic impacts of complex shocks on the Australian economy through real time. That usefulness lies in part with the amount of detail that the model can absorb (see Section 3.2 and the Appendix S1) and give back in terms of estimated impacts (Sections 4 and 5). The use of scenarios provides a range of expected results. The simulations were run in the first half of 2021, when the Most Likely scenario was genuinely considered to be most likely. At the time of writing (September 2021), the Pessimistic and Worst Case scenarios are beginning to look more likely as parts of the country struggle to contain the Delta strain.

Finally, we note that the projected impacts on agricultural and mining industries have important policy implications. For state and federal government departments concerned with regional development, knowing that COVID-19 containment will *Most Likely* have no significant effect on agricultural and mining industries will allow them to focus their minds on more pressing issues. Of course, knowing too that in the *Worst Case* those effects might be significant, should send a clear message regarding monitoring and being prepared to provide further assistance. For private and public sector organisations concerned with investment portfolios, having information on future performance across industries will aid equity portfolio allocation and assessment of investment risk.

Data availability statement

The authors elect to not share data.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Appendix S1. Summary of the shocks for the three COVID-19 Scenarios.