CENTRE of POLICY STUDIES and the IMPACT PROJECT

Eleventh Floor, Menzies Building
Monash University, Wellington Road
CLAYTON Vic 3800 AUSTRALIA

Telephone: (03) 9905 2398, (03) 9905 5112 — from overseas: 61 3 9905 2398 or 61 3 9905 5112

Fax: (03) 9905 2426 — 61 3 9905 2426

e-mail: impact@buseco.monash.edu.au

Internet home page: http//www.monash.edu.au/policy/

Analysing a Hypothetical Pierce's Disease Outbreak in South Australia Using a Dynamic CGE Approach

by

GLYN WITTWER
Centre of Policy Studies
Monash University

SIMON MCKIRDY
The Cooperative Research Centre
for National Plant Biosecurity

RYAN WILSON
Plant Health Australia

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The Centre of Policy Studies (COPS) is a research centre at Monash University devoted to quantitative analysis of issues relevant to Australian economic policy.

Analysing a hypothetical Pierce's disease outbreak in South Australia using a dynamic CGE approach

Glyn Wittwer[1], Simon McKirdy[2] and Ryan Wilson[3]

Abstract

A dynamic computable general equilibrium model provides a tool for analysing the regional economic consequences of a hypothetical plant pest incursion. The model is very detailed at the industry and regional level. It includes a theory of regional labour market adjustment. In our example, a hypothetical Pierce's disease incursion, direct regional economic losses are magnified by consequent depressed investment in downstream wine processing sectors. Following elimination of the disease, it takes a number of years for the region to recover fully.

Key words: plant disease, CGE modeling

JEL classification: C68, Q11, Q68.

[1] Centre of Policy Studies
[2] The Cooperative Research Centre for National Plant Biosecurity
[3] Plant Health Australia

Contents

1. Introduction

The WTO Sanitary and Phytosanitary (SPS) Agreement does not allow a purely precautionary approach to quarantine restrictions except as a temporary measure (WTO, 1994). This implies that quarantine rules must accept a certain level of risk of pest transmission arising from international trade. It is helpful for policy makers to have at their disposal an economic model that estimates the economic impacts of a particular plant pest.[4] This can assist in evaluating expected welfare losses against the economic benefits of trade. It may also compare the economic consequences of a successful campaign with those of a failed campaign or inadequate response to an incursion.

The present study uses a dynamic computable general equilibrium (CGE) model to analyse the regional and national economic impact of a hypothetical plant pest incursion. This approach has been motivated by new cost sharing arrangements between the government and plant industries in Australia to deal with a broad range of potential emergency plant pest incursions (see www.planthealthaustralia.com.au). The dynamic model may quantify different policy responses to an incursion, ranging from a do-nothing approach to ongoing attempts at eradication and management.

1.1 A dynamic, general equilibrium, multi-regional approach

Previous studies have concentrated mainly on a partial equilibrium approach (see Mumford, 2002). There are a number of motivations for moving to a general equilibrium approach in examining the costs of pest incursions. Policy makers may prefer to measure social costs and benefits, rather than industry- or commodity-specific effects, given the involvement of public funding in pest prevention and management. Partial equilibrium (PE) approaches provide a method for such estimation, but leave out some of the economic effects that might be highly relevant to the analysis, including reallocation of capital and labour between sectors and real

[4] International Plant Protection Convention definition of a "pest" is used here, being "any species, strain or biotype of plant, animal or pathogenic agent injurious to plants or plant products" unless indicated otherwise.

wage impacts, and the impacts on related industries. In addition, PE approaches measure only the direct impacts of a scenario. Indirect impacts include, for example, the impact of changing industry costs on the general price level, changing industry incomes on investment and regional aggregate consumption, and the associated impacts on other sectors. Consequently, PE approaches tend to underestimate the overall impact by excluding indirect effects. On the other hand, particularly in the case of smaller crops of a regional rather than national interest, for which published statistics with an input-output level of detail are not available, the CGE approach may in the past have been perceived as either impractical or cumbersome. The database and theory of TERM (The Enormous Regional Model, Horridge et al., 2005), used in the present study, overcomes such concerns, by allowing CGE modeling at a regional and sectoral level not previously available. The cornerstone of TERM is a master database distinguishing 167 sectors and 58 regions. In applications, it is computationally convenient to aggregate the model to the focus of the study. This allows us to combine very detailed industry-level data with the full theory of a CGE model. The data are discussed in more detail in section 3.

While agriculture accounts for a relatively small share of GDP in Australia (around 3.5 per cent, Australian Bureau of Statistics 2005a), regions away from the major cities tend to be relatively dependent on primary activities. An incursion that disrupts agriculture in a particular region may have little effect nationally. However, at the regional level, it may have severe impacts on employment opportunities and household incomes. The regional labour market theory of the model, as described in section 3.1, allows real wages, employment and, in the long run, labour supply at the regional level to deviate from the baseline forecast. If labour supply in one region decreases in the long run due to deterioration in local labour market conditions (stemming from a negative impact such as a disease incursion), labour supply in other unaffected regions will increase correspondingly, as we assume in the long run that national labour supply and employment will return to baseline forecast levels. Events of economic significance at the regional level are important to policy makers, not only because politicians are elected by region. The four largest cities in Australia (i.e., Sydney, Melbourne, Brisbane and Perth), which account for around 55 per cent of the national population, are also growing at a faster percentage rate than the national population: events adverse to the prosperity of non-urban regions exacerbate this trend.

An alternative to a CGE modeling approach is to use input-output analysis based on Barossa Valley data. This approach is defensible in so far as the Barossa Valley is small compared with the Australian economy, so that losses and gains in the region have a relatively small national impact. However, it has limitations. Input-output models are linear, being able to solve for prices alone or quantities alone, without doing both simultaneously. This would omit price-induced substitution from our study, which is potentially important for the Barossa wine sectors, which source some grapes from outside the region. This approach would also potentially exaggerate national losses, as it would not account for diversions of labour and investment to other regions. Moreover, the input-output approach uses comparative statics: we believe a dynamic approach is most suitable for this study.

There are several advantages in choosing a dynamic model for this application. An incursion may persist for several years, during which time crop yields may fall, plantations may be removed and, due to additional spraying and precautionary measures, costs per hectare may rise. Regional impacts and national welfare effects therefore have a time path. Another advantage of the dynamic approach is that the magnitude of welfare losses will depend on whether an industry is expanding or shrinking: an incursion that reduces output in a shrinking sector will have smaller consequences than in the case of an expanding sector. Dynamics are also helpful in the treatment of compensation for lost output or destroyed plantations: lump sum payments may be treated as reduction in the stock of debt in a region (i.e., as a transfer from one region to another), so that no out-of-model calculation is required to convert it to an annualised flow.

Endogenous investment responses and their linkage to capital accumulation are a crucial part of dynamic modelling. Yet, we do not endogenise investment in the winegrape sectors in our application. This is because our scenario concerns hypothetical disease outbreaks that threaten the local winegrape sectors. The response to the outbreak involves a combination of actions by private grape growers and coordination of disease management and quarantine restrictions by a statutory authority, Plant Health Australia. We model vineyard removal as an exogenous reduction in capital stocks and vineyard land. During the recovery/replanting phase in the first scenario, we ascribe exogenous shocks to the investment levels of the grape sectors.

The dynamic theory of investment does apply to other sectors. Notably, investment levels in the downstream wine sectors will be affected. As the scarcity of winegrapes rises with the disease outbreak, the price of grapes purchased by wineries will rise, raising the costs of winery production and lowering rates of return on winery capital. Consequently, winery investment levels will fall relative to a baseline in which there is no disease outbreak. In turn, sectors whose sales are mainly in the local economy will be adversely affected by any regional downturn, with consequent falls in investment. Dynamics are also important in the labour market theory, elaborated in section 3.5.

The lag between plantings and commercial grape yields, which is typical of plantation crops, requires special treatment in the model. We use delayed productivity shocks, assuming that initial plantings lower the average productivity of vineyards as they are not yet bearing. That is, an x% increase in vineyard area by new plantings initially lowers productivity (relative to pre-outbreak productivity) by x% (excluding yield losses in vineyards that remain intact). Commercial yields in a region such as the Barossa would commence three years after planting, with full yields being realized after 5 years. However, some of the vineyards removed following the disease outbreak would have been aged and of relatively high quality. We cannot assume that within a decade or so, the quality of grapes in new vineyards will yet be equal to that of the vineyards prior to the disease outbreak. Therefore, when full yields are restored, we assumed that winegrape productivity in the Barossa Valley is still slightly less than pre-disease levels.

A previous study by Wittwer et al. (2005) considered a hypothetical outbreak of Karnal bunt in wheat in Western Australia in a dynamic, multiregional CGE model. The present study differs in several ways. First, the major source of losses arising from Pierce's disease will be real output rather than quarantine-imposed losses. Second, the level of regional disaggregation is more detailed in this level. Instead of the region of interest being modelled at the state level in a bottom-up form, with the sub-state or statistical division detail being presented in top-down form, as in Wittwer et al. (2005), the statistical division of interest is modelled in bottom-up form in the present application. That is, each statistical division of interest has its own input-output database, behavioural equations and trade matrices with other regions and the rest of the world. In particular, the regional labour market theory operates at the statistical division rather than state level. Third, we are dealing with a pest affecting a perennial (vine stocks) rather than annual plant (wheat). The implication is that destruction of the plant potentially will reduce incomes for a number of years to come. In this sense, vineyards or orchards are a form of capital, with initial investment over several years leading to eventual returns for many years to follow. The welfare implications of capital destruction, in this case, removal of vineyards, are more readily measured in a dynamic than comparative static framework, as it accounts for both stocks and flows. As with the earlier study, the dynamic approach allows us to update the model's database year-by-year. This is particularly relevant for the grape and wine sectors, which have exhibited extraordinary growth in Australia since the late 1990s (Anderson and Norman, 2003).

2. Background

2.1 Pierce's disease

Pierce's disease is a serious bacterial disease, caused by *Xylella fastidiosa*, that kills grapevines. The bacterium can reside in the water conductive system (xylem) of plants and eventually block water movement in the plant. Vines develop symptoms when the bacteria block the water conducting system and reduce the flow of water to affected leaves. Water stress begins in mid-summer and increases through autumn. Once infected, grapevines become nonproductive and may die within one to two years after infection (Varela *et al*. 2001). Pierce's disease is currently restricted to North America through to Central America and has also been reported from some parts of northwestern South America. The disease is restricted to regions with mild winters. The disease is less prevalent where winter temperatures are colder, such as at higher altitudes, farther inland from ocean influences, and at more northern latitudes (see http://nature.berkeley.edu/xylella/index.html).

X. fastidiosa has a very large host range and many plant species may host the pathogen without having any symptoms of disease (Luck *et al*. 2002). The bacterium is spread (vectored) from plant to plant by xylem feeding insects. The most important insect vector is the glassy winged sharpshooter (GWSS) (*Homalodisca coagulata*). The introduction of GWSS into southern California has dramatically changed the distribution and importance of Pierce's disease (Varela *et al*. 2001). There are several reasons why GWSS is a more important vector. It has faster movement and greater dispersal in vineyards. It feeds much lower on the cane than other sharpshooters resulting in infections that are more likely to survive the winter. This then enables vine-to-vine spread of Pierce's disease, which does not occur with other vectors. It feeds on dormant grapevines during the winter, and it will breed in large numbers in citrus orchards that are often adjacent to vineyards (see http://nature.berkeley.edu/xylella/index.html).

Australia is presently free from *X. fastidiosa* and *H. coagulata*. Both have been identified as serious threats to Australia's viticulture industry and research has indicated that most of Australia's viticultural regions are suitable for the establishment and spread of both the pathogen and its vector (Luck *et al*. 2002; Hoddle 2002; Hoddle 2004). The likelihood of entry of Pierce’s disease and GWSS in Australia has been assessed as “moderate” and the subsequent likelihood of establishment as “high” (Luck *et al*. 2001) though this likelihood has not been quantified. The likelihood of entry into Australia was assessed on the known occurrence of attempted illegal importation of grapevine budwood, the wide range of other hosts for the GWSS and the recent history of spread of the pathogen and vector. As such an active quarantine program is in place in Australia to minimise the risk of entry of either *X. fastidiosa* or *H. coagulata*. This includes quarantine treatments for imported table grapes to minimise the likelihood of introduction through this pathway.

2.2 The contribution of vineyards and wine to the local economy

The Barossa Valley accounts for approximately 0.2 per cent of national economic activity, so that even a regionally devastating economic event may transmit to a small impact at the national level. The valley is one of South Australia's oldest grape growing regions. The state's vineyards were never decimated by phylloxera, which is under official control and contained within a small region in Victoria, so that it retains some vineyards dating back to the 1840s, with heritage value partly reflected in the price of some of the wines produced from these grapes. At present, the region accounts for 4 per cent of the volume and 6 per cent of the value of wine grapes produced in Australia (Australian Wine and Brandy Corporation, 2006). The TERM database indicates that grape growing accounted for 7 per cent and wine production for 20 per cent of value-added activity in the region in 2005. At least half of the wine produced in the Barossa Valley is sourced from grapes grown outside the region, mainly from warm climate, inland regions several hundred kilometres away. Barossa grapes generally produce super-premium wine, with grapes sourced from elsewhere contributing more to lower quality commercial-premium of bulk wines. Virtually all Barossa Valley wine is exported either to other regions in Australia or to the rest of the world. The main implication of the sales structure is that total demand for Barossa Valley wine is relatively elastic.

The Barossa Valley remains different from most other wine regions in Australia. Following an extraordinary vineyard plantings boom in Australia in the second half of the 1990s, fuelled by rising red wine grape prices for seven consecutive vintages in the 1990s and accelerated depreciation provisions, Barossa red wine grape output increased by around 80 per cent between 1999 and 2004, while it more than trebled in some other regions. To some extent, growing wine export demand accommodated output growth: Australian wine exports grew from less than 30 megalitres in the late 1980s to 643 megalitres in 2004 with relatively little downward pressure on export prices. That is now changing, with prices falling particularly for given commercial-premium quality wine due to increasing competition from other wine-producing nations plus slower demand growth in importing nations. Reflecting both a smaller supply increase and a higher proportion of heritage vineyards in regional wine grape production than elsewhere, Barossa wine grape price falls in the vintages since the turn of the millennium have been smaller than national price falls (Australian Wine and Brandy Corporation, 2006). While grapes from relatively new vineyards have suffered similar price falls as elsewhere, heritage wine grapes have continued to attract high price premiums. Higher quality wines for which the Barossa is becoming increasingly famous have not faced the same growing international competition as commercial-premium quality wines.

3. The model

TERM is a dynamic, multi-regional CGE model of Australia (Horridge *et al*. 2005). The grape and wine sectors have been disaggregated in much more detail than available in input-output tables published by the Australian Bureau of Statistics. Price and quantity data on red and white wine grapes and export data by wine type prepared by the Australian Wine and Brandy Corporation (2005) have been combined with additional industry-specific data from the Australian Bureau of Statistics (2005b). In this application, red wine grapes, white wine grapes, multipurpose grapes, red wine, white wine and bulk wine are represented separately in the sectoral and regional detail of the model. Each sector includes labour, capital and, for the grape sectors, land. Each sector also uses intermediate inputs. On the sales side, each sector potentially sells to other industries, investors, households, exports and government. For example, red wine grape sales are sold entirely to the red and bulk wine industries. Red wine, in turn, is sold mostly to domestic households or exported. The aggregated database used for this specific study contains 25 sectors, including the grape and wine sectors listed above, and three regions, the Barossa Valley, the rest of South Australia and the rest of Australia. The database of the model used in this application therefore contains as much data as are available on the grape and wine sectors for the Barossa Valley. We do not lose any grape- and wine-specific detail in the Barossa region by aggregating the master database in sectors and regions not directly relevant to the study. Consequently, we are able to combine the detail of an industry-specific model with the economy-wide features of a CGE model.

3.1 The production structure of the model

The theory of TERM is much the same as that in national dynamic CGE models such as MONASH (Dixon and Rimmer 2002). Each industry in TERM selects inputs of labour, capital and materials to minimise the costs of producing its output. The levels of output are chosen to satisfy demands, which in turn reflect prices and incomes. Figure 1 shows the production structure of each sector in the model. Starting at the bottom left-hand corner of this figure, industry demands for intermediate inputs by region follow a constant elasticity of substitution (CES) form, used repeatedly in the model. For example, if the price of red wine grapes sold to red wine production in the Barossa Valley increases relative to other domestic red wine grape sources, there will be a decrease in the Barossa-sourced proportion of red wine grape purchases. Each domestic composite good is substitutable with the imported good. In the production technology, there are potentially *g* composite inputs used by each industry. Composites of each good also follow CES substitution possibilities with one another, though weakly so. Were the parameter unsuitably large, it would imply that red wine grapes were readily substitutable with other intermediate inputs in red wine production, which would not be realistic - or legal.

The bottom right-hand corner of Figure 1 shows substitution between different labour types. The labour input composite is substitutable at the next level with capital and land. The primary factor composite, other costs, and the intermediate input composite follow Leontief or fixed proportions technologies, with proportions determined by the output level as shown at the top of Figure 1.

Different types of technical changes are possible within TERM. Different variables describe primary-factor and intermediate-input-saving technical change in current production. In our simulations, these variables are held on their base case forecast paths except for grape production in the Barossa Valley, reflecting the assumptions of our scenarios.

3.2 Investment

Investment decisions in each industry are driven by rates of return. Capital stocks depend on past investments and depreciation. TERM allows for short-run divergences in the ratios of actual to required rates of return from their levels in the base case forecasts. Short-run changes in these ratios cause changes in the same direction in investment. Movements in investment are reflected with a lag in capital stocks. These adjustments in capital stocks gradually erode initial divergences in the rate of return ratios. In the present application, capital stocks in the the Barossa grape sectors (and in the Rest of South Australia grape sectors in the second scenario) are an exception: following the hypothetical Pierce's disease outbreak, grape industry capital decreases exogenously to reflect the removal of vineyards due to Pierce's disease. The Barossa wine sectors follow the usual investment theory of the model, so that rising costs due to rising grape scarcity are likely to depress winery investment in our scenarios.

3.3 Other final demands

Each region in the model contains a representative household. Aggregate consumption is determined via a consumption function linked to disposable income net of interest payments. Household demands for each commodity follow a linear expenditure system, otherwise known as the Stone-Geary or Klein-Rubin form. In addition to investors and households, the other final users in the model are foreign buyers and the government. Exports are assumed to be finitely elastic in the export demand equations, with typical export demand elasticities of around -4. This is based on a derivation of export demand elasticities from import substitution parameters as presented in Dixon and Rimmer (2002, pp. 222-225). Government spending is assumed to be exogenous, so that policy scenarios do not result in variations in real government spending on each commodity. An exception is in a variant of the second scenario, in which we model compensation payments to affected grape growers: increases in national income taxes are used to fund these payments. Unlike the single region national MONASH model, each industry and commodity in the model is represented at the regional level. TERM imposes a fixed exchange rate and free trade between regions, and common external tariffs. In this sense, TERM remains a national model, rather than international. The links to foreign markets are through the export demand equations and import supplies, which are assumed exogenous (that is, in perfectly elastic supply), on the basis that Australia's import share of global markets is too small to influence such prices.

3.4 The baseline forecast and policy modes

TERM can be run in two modes: baseline forecasting and policy. In baseline forecasting or control mode, it takes as inputs forecasts of macro and trade variables from organizations such as Access Economics (2005), together with trend forecasts of demographic, technology and consumer-preference variables. It then produces detailed baseline forecasts for industries and regions. Our study has been supplemented by industry-specific forecasts for the grape and wine sectors based on known vineyard plantings (Australian Bureau of Statistics, 2005b). In policy mode, it produces deviations from baseline forecast paths in response to shocks such as changes in government policies, technologies, world commodity prices and, in our study, pest incursions.

The macroeconomic variables in the model are aggregates of sectoral activities. Therefore, if we are to impose macroeconomic baseline forecasts on the model, such forecasts must impact directly at the sectoral level. For example, to impose a certain change in regional real GDP to match a given forecast, an endogenous all-industry technological change variable moves to accommodate the target. To fit an aggregate consumption target, a consumption function shifter is made endogenous, so that household demand for all commodities moves with the shifter according to the household demand theory of the model.

In running the model in policy deviation mode, important indicators include the deviation in macroeconomic variables from forecast. This implies that such variables need to be endogenous in our deviation run. To facilitate this, following the method detailed in Dixon and Rimmer (2002, chapter 2), when we run the policy simulation, variables such as the all-industry technological change and consumption function shifter variables are exogenous, and shocked by the same percentages as when they were endogenous and real GDP and aggregate consumption exogenous in forecast. Through this method, the macroeconomic variables become endogenous as required while we ascribe demand and supply shifts that are consistent with the underlying forecasts of the model. The forecast and policy simulations are run separately, year-by-year. The shocks are ascribed to the policy simulation for a given year, based on the policy simulation database for the previous year. We report deviations in the policy run from forecast.

3.5 Regional labour market dynamics

In section 3.1, we outlined how industry demands for labour are determined. Now, we turn to the dynamic theory of the labour market at the regional level. The regional labour market adjustment mechanism, in levels, is given by:

$$\left(\frac{W_t^r}{Wf_t^r}-1\right)=\left(\frac{W_{t-1}^r}{Wf_{t-1}^r}-1\right)+\alpha\left(\frac{EMP_t^r}{EMPf_t^r}-\frac{LS_t^r}{LSf_t^r}\right) \tag{1}$$

In policy mode, if the deviation shock weakens the labour market in region *r* and period *t* relative to forecast, real wages W_t^r in deviation will fall relative to forecast Wf_t^r. In addition, there will be an initial enlarged gap between labour market demand EMP_t^r and supply LS_t^r, relative to forecast levels $EMPf_t^r$ and LSf_t^r, based on the assumption that wages adjust slowly in the short term. In successive years, the gap between demand and supply will gradually return to forecast through a further decline in real wages. The speed of labour market adjustment is governed by α, a positive parameter.

The regional labour supply equation is:

$$\frac{LS_t^r}{LSf_t^r} = \frac{\left(W_t^r\right)^\gamma}{\sum_q \left(W_t^q\right)^\gamma S_t^q} \Bigg/ \frac{\left(Wf_t^r\right)^\gamma}{\sum_q \left(Wf_t^q\right)^\gamma Sf_t^q} \qquad (2)$$

The deviation from forecast in regional labour supply depends on the deviation in regional relative to national real wages. In (2), $\sum_q \left(W_t^q\right)^\gamma S_t^q$ is a measure of labour responsiveness to real wages summed across all regions, where γ is a positive parameter and S_t^q the share of region q in national employment. Within this theory, should the deviation from forecast in real wages in a region fall relative to that for national real wages, its labour supply will fall, while that in other regions will rise. Combining (1) and (2), adjustment in a weakened labour market in a given region will initially occur via a combination of additional unemployment and lower real wages, with sluggish wages adjustment. Unemployment will eventually return to forecast rates, with lower real wages. As real wages fall relative to control, the region’s labour supply will also fall. Labour market adjustment occurs as a combination of inter-regional labour migration and changes in regional real wage differentials within this theory.

4. The scenario

We assume that Pierce's disease affects 10 properties totalling 150 hectares. The outbreak response necessitates complete removal of all vines on these properties, plus placing these properties under quarantine until the disease is eliminated. The vineyards account for around 2 per cent of Barossa Valley's wine grapes. In addition, all vineyards within a 10 kilometre radius are subjected to additional spraying to restrict the vectors of the Pierce's disease. It is assumed that the most effective vector, the glassy winged sharpshooter, is also present in the affected region. This requires spraying virtually all vineyards in the Barossa Valley. Total additional spraying costs are estimated to be $5 million per annum, with a further $5 million (all reported dollar figures are in Australian dollars) of R&D and administrative costs. After five years, the pathogen is eradicated and affected properties are removed from quarantine.

The cost sharing arrangement splits the costs of disease management and compensation (known as Owner Reimbursement Costs) to affected growers between the Australian government (40%), the state governments (in this case that of South Australia, 40%) and industry (20%). The amount of compensation to growers has been devised to reflect profit losses, compensation for the depreciated value of the lost plantation (i.e., vineyards in our example) and lost income arising from land being placed in fallow during a quarantine period. The objective of compensation is that a grower is neither better nor worse off as a result of an incursion response. If compensation were too high, some growers would end up better off by earning as much as they would in the absence of an incursion, with reduced labour inputs. On the other hand, if compensation were too low, some growers would be financially disadvantaged by the incursion response, and may not be able to afford to remain in the industry.

In our scenario, we assume that growers who are required to remove their vineyards are paid a lump sum of $30,000 per hectare for the lost capital value. In addition, they are paid $8,000 per hectare for each year their vineyards are out of production. This is based on assumed average yield of 8 tonnes per hectare and an average grape price of $1,250 per tonne, less average costs of vineyard management and harvesting of $2,000 per hectare. The total costs of disease management and compensation in the first year, based on 150 hectares of removed vineyards, are $4.5 million in lost capital value, $1.2 million in annual income compensation and $10.0 million in additional spraying and management. The total costs in the first year of the management and compensation package are $15.7 million. The Australian and South Australian governments fund $6.3 million each in the first year, with $3.1 million coming from a levy on grapegrowers. Costs fall to $10.2 million in succeeding years after the initial lump-sum payment. Once the disease has been eradicated, we assume that payments to affected growers of $1.2 million continue for another five years to reflect expected income from the now destroyed crop.

To examine the modelled economic impacts of the incursion, we turn first the industry output results for the directly affected sectors (Table 1). The initial shrinkage in Barossa output of red and white wine grapes raises grape prices and consequent input costs for the wine sectors in the Barossa and other regions. Output of red wine shrinks by more than 0.2 percent in 2006 relative to the baseline forecast in both the Barossa and in the rest of South Australia, with shrinkages in the white wine sectors of the two regions by just under 0.2 percent. That wine outputs also fall in the rest of Australia in 2006 indicates that grape prices have risen in the composite region, with an increasing proportion of interstate grapes being sold to Barossa wineries for processing

Figure 2 shows the impact of the Pierce's disease incursion on wine grape producer prices in the Barossa and in the rest of South Australia. Producer prices rise during the period of the incursion, reflecting a greater scarcity of wine grapes within the Barossa Valley. Given that grapes from different regions are substitutable to some extent, bad news for Barossa grapes growers in this scenario (in which there is no threat of incursion and no additional management costs outside the Barossa) translates into good news for grape growers elsewhere, as Barossa wineries source grapes increasingly from outside the region. That grape outputs persists below forecast long after Pierce's disease has been eradicated from the Barossa Valley reflects slightly depressed investment in the wine sectors following raised grape prices for several years.

The contribution of various sectors to the change in income in the Barossa Valley relative to forecast is shown in Table 2. That is, the percentage change in each industry’s output is multiplied by its share of regional income. The table includes the factor income contribution to the deviation in real GRP from forecast for selected industries, with a separate row for technological and tax changes. In this study, technological change includes the additional spraying and administration costs, while the additional industry levy is an example of an industry tax. In 2006, direct impacts dominate the change in regional income: the grape sectors account for 0.64 percent out of a total income loss of 0.71 percent relative to forecast (i.e., red grapes -0.09%, white grapes -0.12%, technological (a negative contribution) plus tax changes (a small positive contribution) -0.43%).

By 2010, the year prior to the disease being eliminated, indirectly affected sectors make a larger contribution to the deviation from forecast. Investment in the grape and wine sectors in the Barossa Valley relative to forecast has fallen. In addition, a fall in aggregate consumption relative to forecast has reduced output of the relatively income-elastic housing sector. Each of these impacts leads to reduced output for the construction sector, whose sales consist almost entirely of investment activity. Housing’s contribution to the deviation in regional income from forecast is now -0.09%, while that of construction is -0.14%.

Aggregate consumption falls proportionally more than real GRP in the Barossa Valley, being 1.75 per cent below forecast in 2010 compared with a real GRP fall of less than one per cent. In part, this reflects the negative impact of reduced regional income on non-traded sector prices, including housing. Sectors relatively intensive in sales of goods traded out of the region are affected proportionally less. The Barossa Valley therefore has a real depreciation relative to forecast during the incursion, inducing an increase in net inter-regional and international exports as a share of real GRP, while regional domestic absorption decreases as a share of real GRP. Since government spending, one of the components of domestic absorption, is fixed by assumption, investment and consumption fall proportionally more than the overall fall in domestic absorption.

In 2015, although Pierce’s disease has been eradicated and investment in the region has been restored almost to baseline forecast levels (Figure 3), replanted vineyards are not yet fully bearing. Therefore, the grape sectors still make a substantial negative contribution to regional income relative to forecast (although most of the negative technical change contribution has been eliminated). The contribution of housing remains negative, recovering slowly in subsequent years – housing’s contribution to regional GDP is -0.09 per cent relative to forecast in 2010 and 2015, and still 0.03 per cent below forecast in 2025 (Table 2).

Figure 4 shows the impact of the incursion on the Barossa Valley's labour market, following the theory of labour market adjustment outlined in equations (1) and (2). The initial production loss wipes almost 0.3 per cent off the region's employment, equivalent to 80 jobs. Although additional spraying in the Barossa Valley creates some jobs, as does grubbing out vineyards (a one-off, relatively capital-intensive activity), these are more than offset by the negative employment effects. These include pruning and grape-picking that are no longer undertaken once vineyards have been removed. Placing land in quarantine and falling rates of return in Barossa vineyards discourage investment (a relatively labour-intensive activity) in vineyards, wineries and housing, so that employment continues to fall after the first year (2006) in which there is a response to the incursion. Real wages continue to fall until the pest has been eradicated, as labour supply remains above employment in this period. Following the eradication of Pierce's disease in 2011, after employment has bottomed out at 0.45 per cent or 120 jobs below forecast in the Barossa Valley, the region's employment thereafter rises above forecast very slightly due to catch-up investment. Real wages slowly return towards the baseline, but are not fully restored, reflecting our assumption that although yields recover within 5 years of replanting, grape quality in new vineyards does not match that of the vineyards they replaced. In addition, the incursion depresses investment in the Barossa Valley's wine sectors, so that wine processing capacity remains slightly below forecast at the end of the simulation period.

South Australia accounts for no more 6.5 per cent of national economic activity, but contains around half the nation's grape and wine production (including that of the Barossa Valley). In the rest of South Australia (i.e., excluding Barossa), there are gains for the wine grape sectors due to rising scarcity in the Barossa region, but these increase the production costs of wineries in the rest of the state. There are very small adverse employment consequences for the rest of the state, due to rising costs during the incursion and consequent slower-than-forecast investment in wine sectors during and after the incursion. After 2011, employment relative to forecast falls slightly, due to labour being drawn into the Barossa during the recovery phase, but bottoms out only 0.005 per cent or 35 jobs below forecast in 2017 (Figure 5).

4.1 Welfare impacts and sensitivity analysis

The discounted net present value of the national welfare loss, calculated as the deviation in national aggregation consumption from the baseline forecast, is $135 million. A similar calculation, confined to the deviation in the Barossa's real GRP from forecast (see Table 2 and Figure 5), reveals a discounted regional income loss of $120 million. Nationally, the discounted income loss is only $110 million. This implies higher than forecast income outside the Barossa, reflecting migration out of the region during the incursion. The difference between the discounted national consumption and income losses reflects in part additional investment required to replant vineyards. It also reflects a very weak terms-of-trade deterioration arising from the incursion that reduces consumption's share of national income slightly.

The welfare result depends to some extent on assumed rate of adjustment in the labour market. This depends on two parameters, α in equation (1), governing regional real wage adjustment, and γ in equation (2), governing inter-regional migration. The default setting for α is 0.5 which implies that half of the gap between regional labour demand and supply will be eliminated in the following year via real wages adjustment. Raising this parameter to 0.9 implies that most real wages adjustment will occur within a single year, thereby lessening job losses when the labour market weakens. Raising γ from the default setting of 0.2 to 0.5 implies more rapid inter-regional migration in response to regional labour market changes. The scenario was run again three times, with α set to 0.9, γ set to 0.5 and with both parameters at the higher settings. In each case, the net present value of the welfare loss diminished slightly, to around $120 million (relative to $135 million with the default parameters), indicating that employment losses play only a small part in the overall welfare impact of the incursion.

5. Conclusion

This paper has analysed the economic impacts of a hypothetical incursion of Pierce's disease in the Barossa Valley region of South Australia. We assume Pierce's disease is controlled within 5 years with limited damage at the regional level. Our scenario assumed that industry and public funding were used in a successful campaign to eradicate the pathogen. The success of such a campaign would depend on early detection and thus an industry culture of early reporting, followed by an active field-based eradication campaign. Even in this relatively moderate incursion response, the welfare loss was $135 million in discounted net present value terms.

Perhaps the main issue in allocating resources to preventive measures is that these need not be incursion-specific. To the extent that resources directed at disease prevention can apply to a number of diseases across a range of crops, an appropriate level of preventive resources would reflect expected welfare losses, that is, the probability of each incursion multiplied by estimated welfare losses summed across all possible incursions. While the expected welfare loss may be sufficient to justify some preventive or contingency measures specifically for Pierce's disease, the summed expected welfare losses across many possible significant exotic threats are more substantial: Plant Health Australia usually deals with a number of minor incursions each year and a major incursion every year or two in the crops covered by its partner organisations. This warrants generic risk mitigation and contingency measures to minimise the likelihood of entry and maximise the potential for successful eradication campaigns in the future.

The multi-regional framework of our dynamic model, with its theory of imperfect, regional labour market adjustment would be useful in applications, for example, to regions within the European Union. There may concerns among farmers in Western Europe that pest and disease incursions could affect specific agricultural regions, such as the historic wine producing regions in parts of Europe. Moreover, interest in policy debate is increasingly on regional rather than national implications. Development of a database of Europe for relevant policy analysis within TERM is feasible, following a methodology outlined in Horridge et al. (2005).

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Table 1: Outputs of grape and wine sectors (% deviation from baseline forecast)

Barossa	**2006**	**2010**	**2015**	**2020**	**2025**
Red grapes	-3.69	-3.58	-2.41	-1.53	-0.94
White grapes	-2.13	-2.09	-2.09	-1.16	-0.59
Red Wine	-0.28	-0.26	-0.41	-0.42	-0.38
White Wine	-0.17	-0.17	-0.37	-0.41	-0.34
Construction	-0.01	-0.97	-0.17	0.06	-0.04
Trade	-0.12	-0.2	0.04	0.03	-0.02

Rest of Sth Aust	**2006**	**2010**	**2015**	**2020**	**2025**
Red grapes	0.16	0.07	-0.18	-0.23	-0.26
White grapes	-0.03	-0.12	-0.21	-0.25	-0.27
Red Wine	-0.24	-0.36	-0.47	-0.38	-0.3
White Wine	-0.16	-0.29	-0.35	-0.29	-0.24

Rest of Aust	**2006**	**2010**	**2015**	**2020**	**2025**
Red grapes	0.1	0.02	-0.19	-0.23	-0.24
White grapes	-0.04	-0.14	-0.22	-0.23	-0.23
Red Wine	-0.19	-0.33	-0.45	-0.37	-0.31
White Wine	-0.16	-0.28	-0.36	-0.29	-0.26

Table 2: Contribution of selected sectors to Barossa Valley's real GRP (% deviation from baseline forecast)

	2006	**2010**	**2015**	**2020**	**2025**
Red grapes	-0.09	-0.12	-0.10	-0.08	-0.08
White grapes	-0.12	-0.15	-0.17	-0.14	-0.12
Agricultural services	0.01	0.02	0.01	0.00	0.00
Red Wine	-0.02	-0.02	-0.03	-0.03	-0.03
White Wine	-0.01	-0.01	-0.02	-0.03	-0.02
Construction	-0.01	-0.14	-0.03	0.02	-0.01
Trade	-0.02	-0.01	0.02	0.02	0.02
Housing	-0.01	-0.09	-0.09	-0.05	-0.03
Other sectors	-0.03	0.07	0.16	0.14	0.13
Total	-0.28	-0.45	-0.25	-0.14	-0.14
Tech. change + indirect taxes	-0.43	-0.45	0.08	0.08	0.06
Real GRP	-0.71	-0.90	-0.17	-0.07	-0.08

Figure 1: Structure of production in TERM

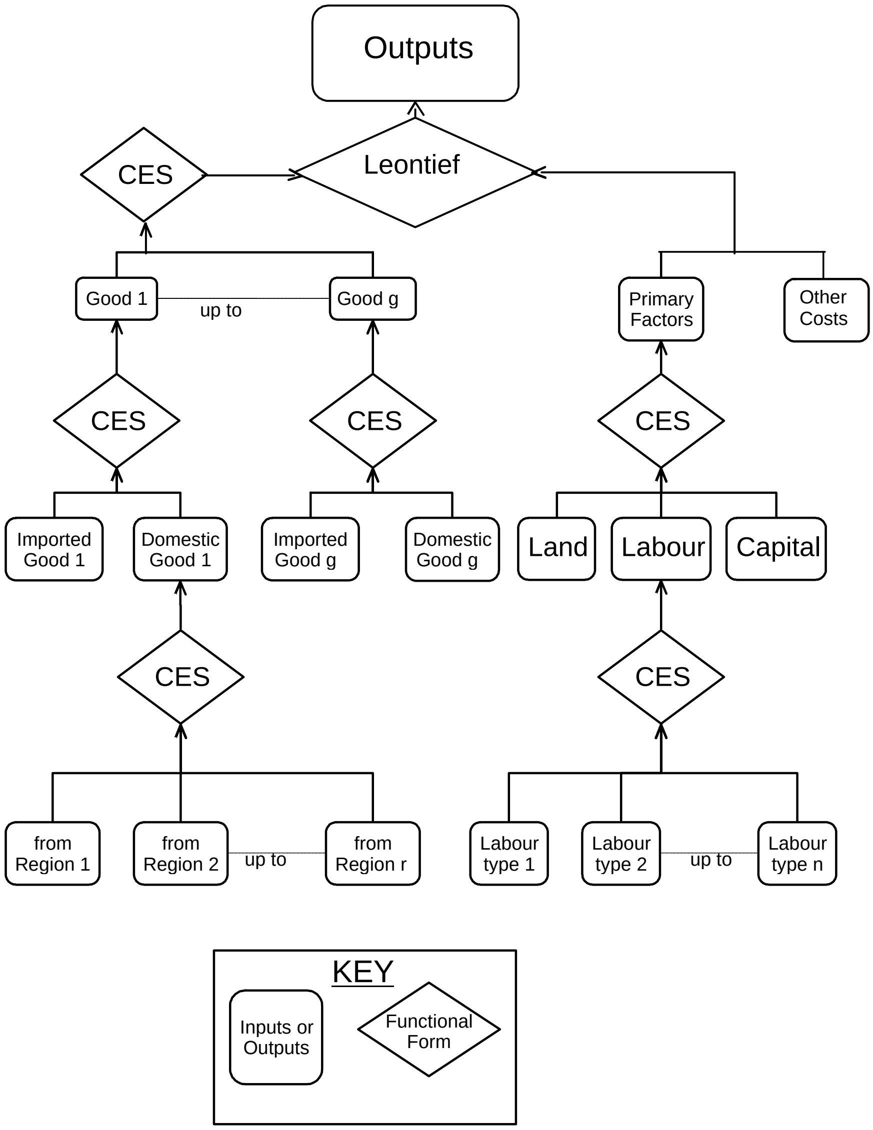


Figure 2: Impact of the incursion on wine grape prices in the Barossa Valley and the rest of South Australia (% deviation from baseline forecast)

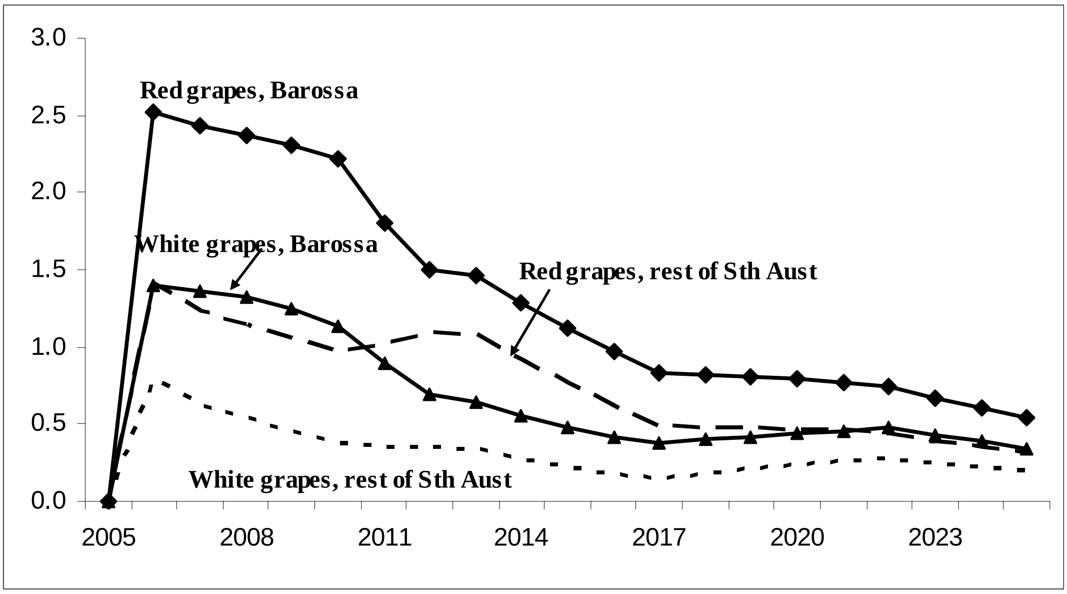


Figure 3: Impact of the incursion on Barossa Valley's aggregate consumption and investment (% deviation from baseline forecast)

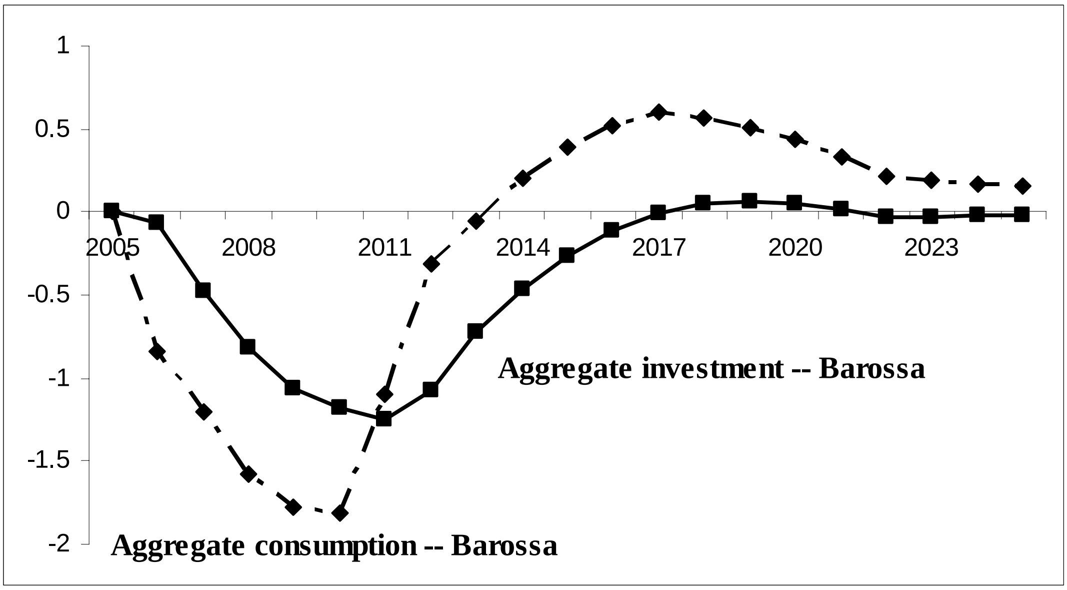


Figure 4: Impact of the incursion on the Barossa Valley's labour supply, employment and real wages (% deviation from baseline forecast)

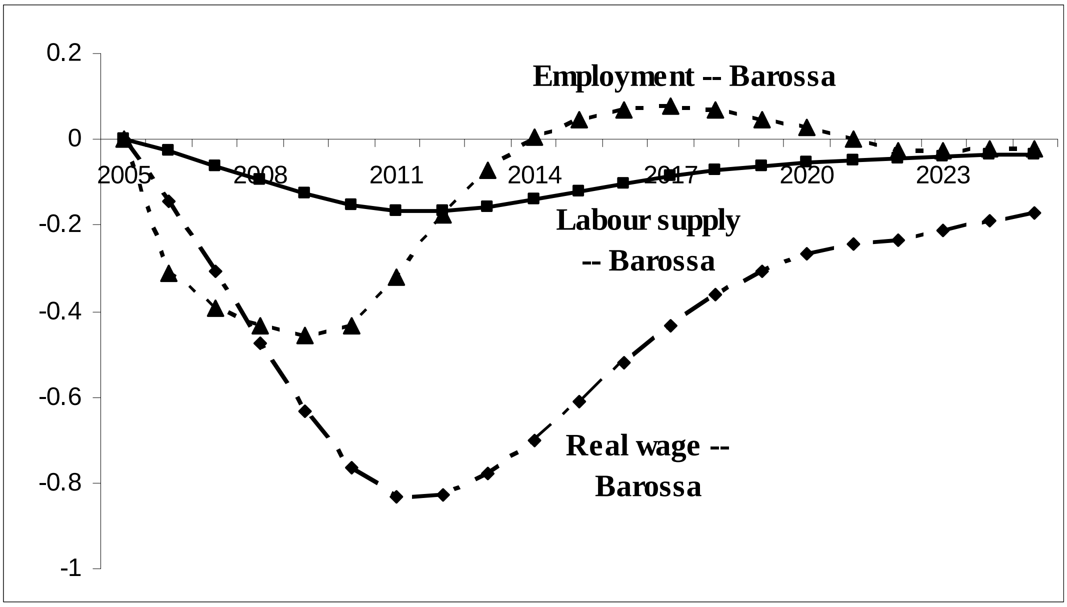
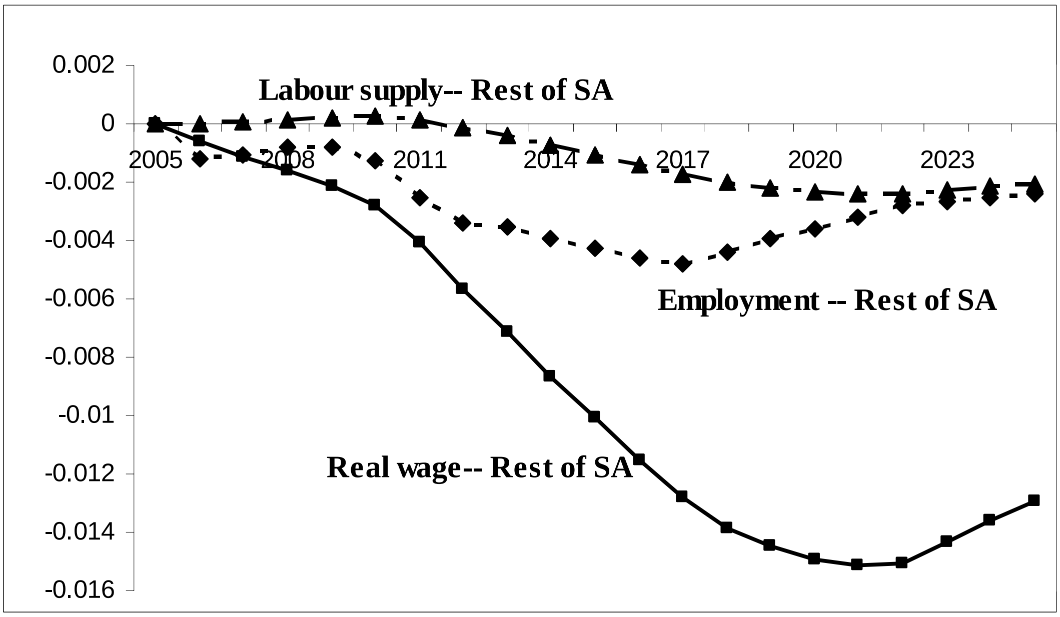


Figure 5: Impact of the incursion on the Rest of South Australia's labour supply, employment and real wages (% deviation from baseline forecast)



Appendix: a no-recovery scenario

Available evidence from California indicates that Pierce’s disease could be so far advanced on detection that no recovery of vineyards in the affected region is possible. In this alternative scenario, the vector for the of Pierce's disease is not brought under control. This scenario depicts a policy response in which the focus is entirely on structural assistance into other economic activities, without any effort being devoted to disease eradication. The decision not to attempt to eradicate the disease may be due to a judgment by industry and statutory bodies that the outbreak is too widespread when detected to be manageable. The initial outbreak in this scenario results in one tenth of the region's vineyards being removed in 2006. Thereafter, in this scenario, vineyards in the Barossa Valley are successively removed over time as Pierce's disease spreads through the region. At the end of the simulation period in the year 2025, four fifths of the Barossa Valley's vineyards have been destroyed by Pierce's disease. At the same time, the disease had spread to other vineyard districts in South Australia (the outbreak becoming apparent a year later than in the Barossa), particularly to the south of the Barossa, given the expectation that the vector would travel relatively long distances with hot northerly spring and summer winds. In this hypothetical case, the incursion is too widespread for the cost sharing arrangements to apply. All that growers can expect is some government funding to assist in movement into other industries.

The outcomes for wine grape prices and outputs differ markedly between the Barossa, the rest of South Australia and the rest of Australia. In the Barossa, in which four-fifths of output is wiped out by 2025, output prices have not quite doubled by then, indicating substantial losses in regional grape revenue (Figure A1). In the rest of South Australia, which is a net exporter of grapes to the Barossa prior to the incursion, grape revenue increases relative to forecast even though some vineyards are destroyed by Pierce's disease. For example, by 2025, red wine grape prices have increased by 25 per cent, coupled with an output decline of 8 per cent, indicating revenue increases relative to forecast (Figure A2). It follows that growers outside South Australia benefit from higher prices, induced by a degree of substitutability with South Australian grapes, without suffering the output reducing impacts of the disease. Indeed, higher rates of return to vineyard investment interstate, induced by growing scarcity in South

Australia, contribute to a rise in grape output in the rest of Australia relative to forecast (Figure A3).

Figure A4 reveals the impact of this pessimistic scenario on the Barossa Valley's labour market. Due to ongoing vineyard removals, real wages are still falling further relative to forecast in 2025 in the ever-weakening labour market. Real wages have fallen relative to forecast by 15 per cent in 2025. At the same time, employment has fallen by around 5 per cent or 1,500 jobs. In addition, there has been a net migration to other regions, reflected in falling labour supply, of 3 per cent or 900 workers (45 workers per year), and an increase in jobless in the Barossa Valley relative to control of 600 by 2025. In the larger economy of the rest of South Australia, labour supply has fallen relative to forecast by 0.04 per cent in 2025, amounting to outward net migration of 280 workers. Unemployment has worsened, as the number employed in the region has fallen by 700 relative to forecast. The fall in wages in South Australia is just over 0.3 per cent relative to forecast by 2025.

The macroeconomic impacts on the expenditure and income sides respectively for the Barossa Valley are shown in figures A6 and A7. Aggregate investment and consumption in the region both fall continuously relative to forecast, by 15 per cent and 25 per cent respectively in 2025 (Figure A6). The decline in aggregate investment tracks real GRP, which is 14 per cent below control in 2025 (Figure A7). As in the first scenario, the percentage decline in aggregate consumption is larger than real GRP, reflecting both the impact of a real devaluation on regional domestic absorption and the assumption that aggregate government spending (excluding adjustment assistance to growers) in the region has not changed relative to forecast. As an indicator the region’s real devaluation, the sector with the largest price decline is housing: prices in this non-traded sector have fallen 30 per cent relative to forecast by 2025, compared with a decline in the region’s CPI (which includes traded goods) of 6.5 per cent.

In the rest of South Australia, in which grapes make a relatively small contribution to the economy, the economy slowly declines relative to forecast. Initially, in 2006 before the disease has affected vineyard outputs outside the Barossa Valley, aggregate consumption in the rest of the state rises relative to forecast (Figure A8). This is because the rise in grape prices, without any offsetting output loss in the region, improves the region's terms-of-trade temporarily, so that aggregate consumption as a share of GRP rises. In subsequent years, despite wine grape revenues in the region increasing, production costs for wineries rise, worsening as vineyard removals continue, leading to declines in winery investment. In both the Barossa Valley and the rest of South Australia, aggregate capital stocks decrease proportionally more than labour (Figures 13 and 15). This is because we assume regional wages can adjust downwards in response to a regional economic downturn, whereas rates of return on capital are determined in international markets, and therefore not likely to persist below forecast rates of return in the long run. With real wages falling relative to capital rentals, the labour to capital ratio in industries in these regions must increase.

We assume in this scenario that after a two year period of quarantine, former vineyards are moved into other farming activities. Some land switched to other horticultural production may earn returns per hectare similar to those earned by vineyards prior to the outbreak. Through lack of access to irrigation water and insufficient rainfall for other horticulture, other land grubbed of vineyards is suitable only for broadacre activity. Overall, the returns from alternative land uses per hectare are lower than for vineyards. Moreover, grubbed vineyards represent lost capital that has a marked effect on income earning capacity. The value of lost vineyards combined with lost employment make substantial contributions to overall welfare losses. In this scenario, the discounted net present value of welfare losses is $4.2 billion by 2025, and still growing as a consequence of ongoing vineyard removals and ongoing disruption to the labour market.

Figure A1: Impact of the incursion on the Barossa Valley's wine grape outputs and producer prices: no recovery scenario (% deviation from forecast)

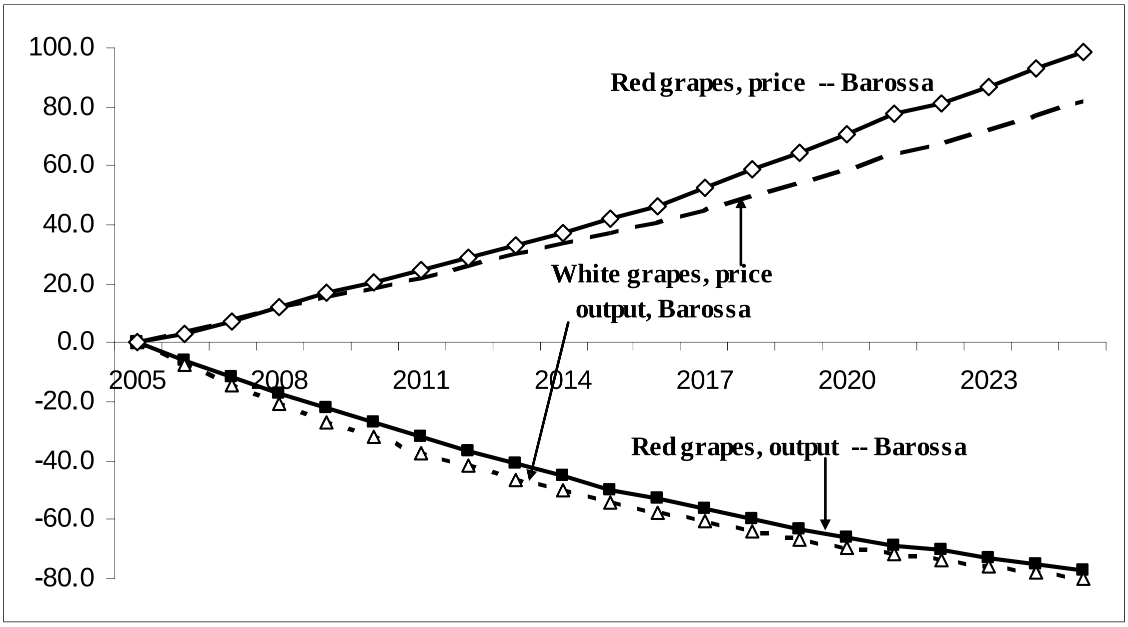


Figure A2: Impact of the incursion on Rest of South Australia's wine grape outputs and producer prices: no recovery scenario (% deviation from forecast)

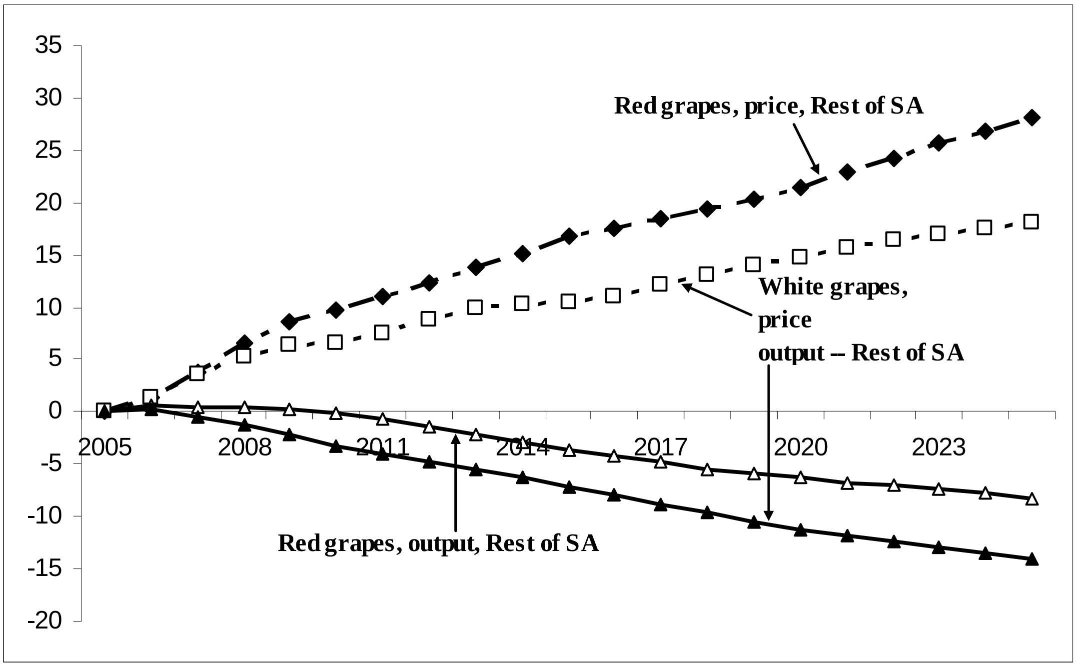


Figure A3: Impact of the incursion on Rest of Australia's wine grape outputs and producer prices: no recovery scenario (% deviation from forecast)

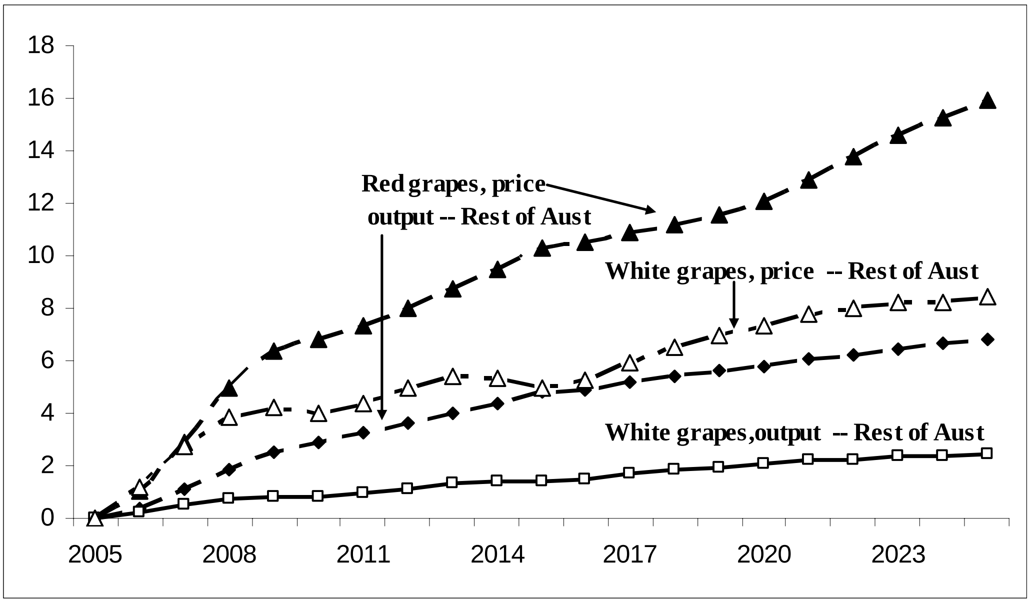


Figure A4: Impact of the incursion on Barossa Valley's labour supply, employment and real wages: no recovery scenario (% deviation from forecast)

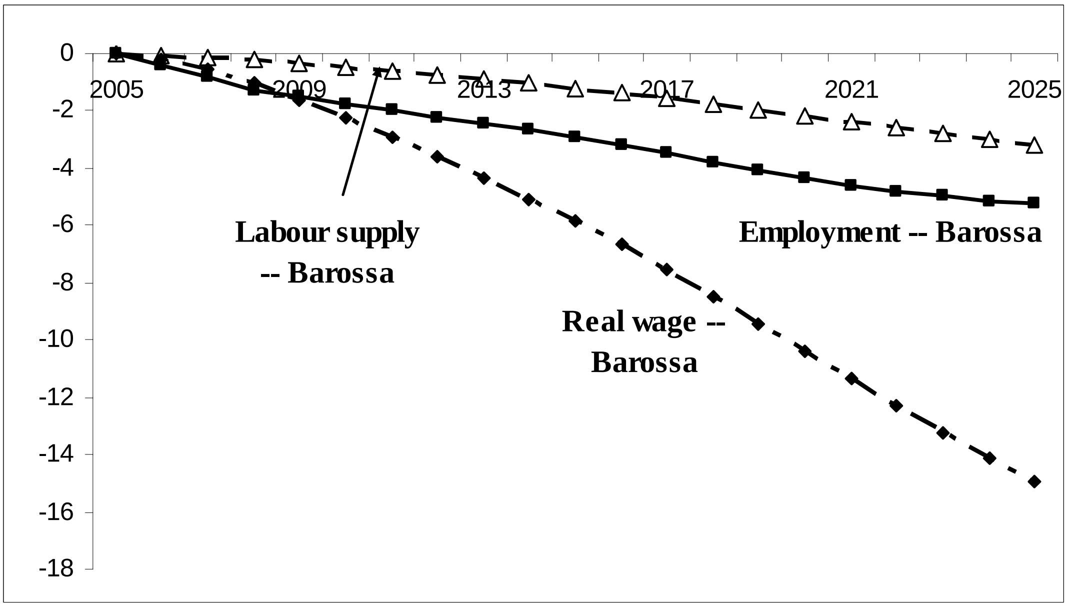


Figure A5: Impact of the incursion on Rest of South Australia's labour supply, employment and real wages: no recovery scenario (% deviation from forecast)

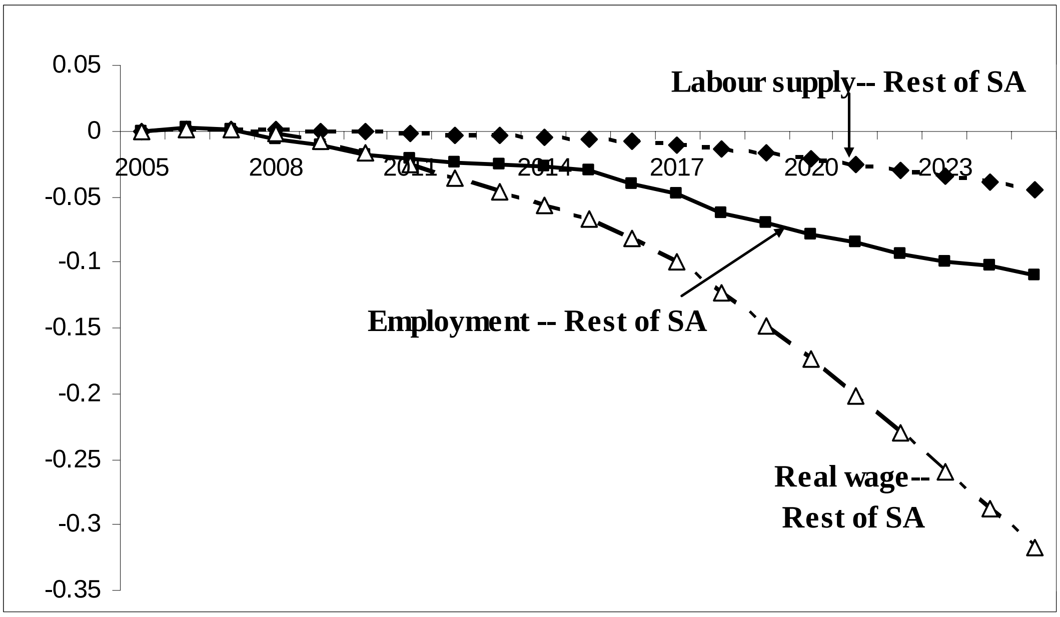


Figure A6: Impact of the incursion on Barossa Valley's aggregate consumption and investment: no recovery scenario (% deviation from forecast)

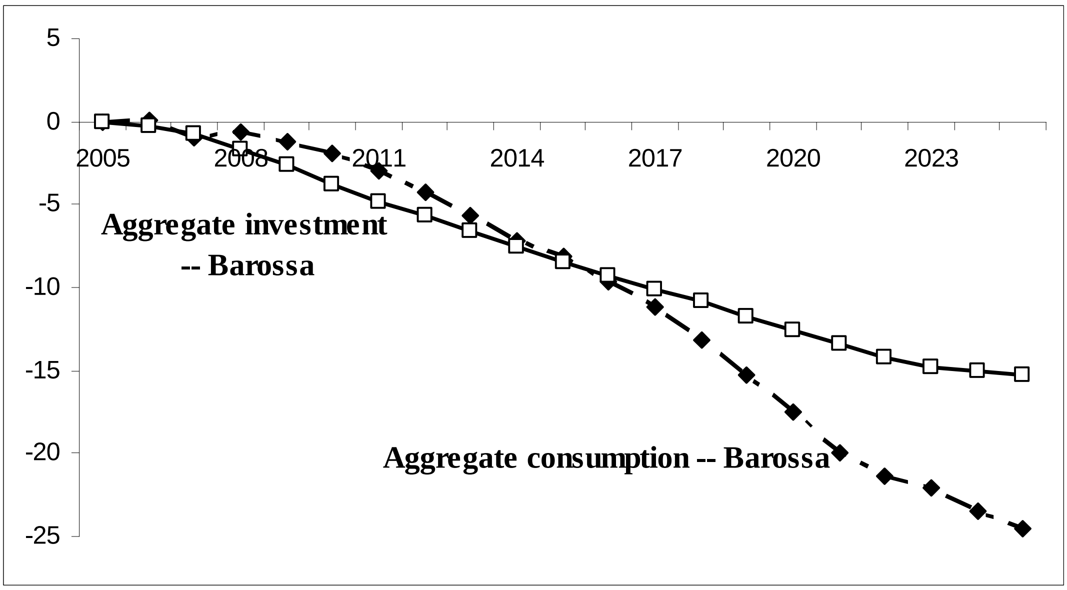


Figure A7: Impact of the incursion on Barossa Valley's aggregate capital, labour and real GRP: no recovery scenario s (% deviation from forecast)

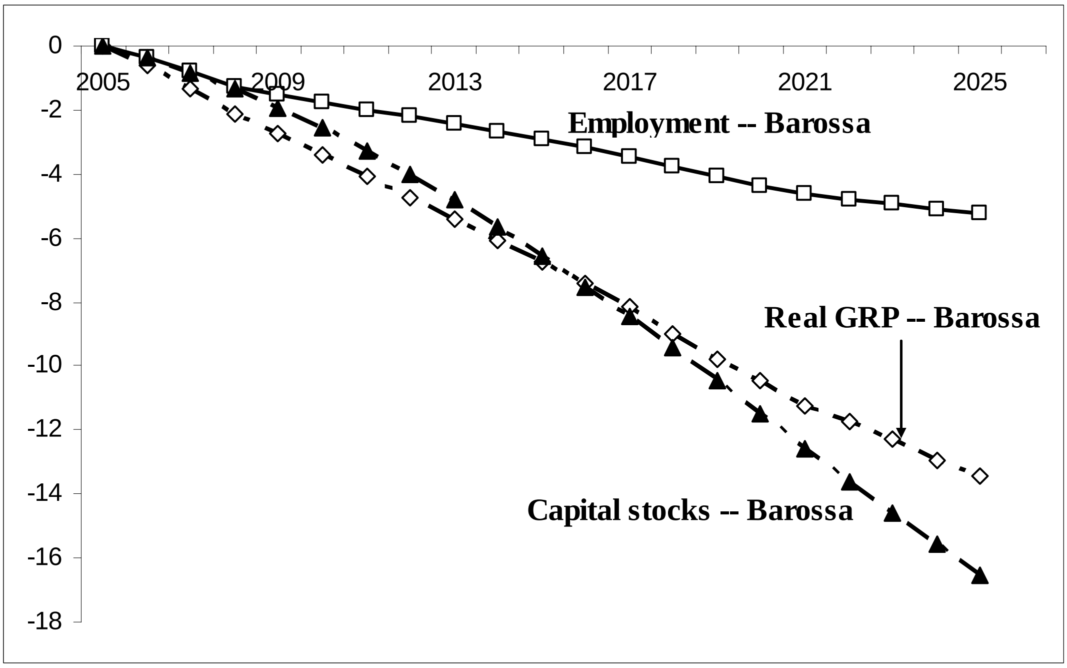


Figure A8: Impact of the incursion on Rest of South Australia's aggregate consumption and investment: no recovery scenario (% deviation from forecast)

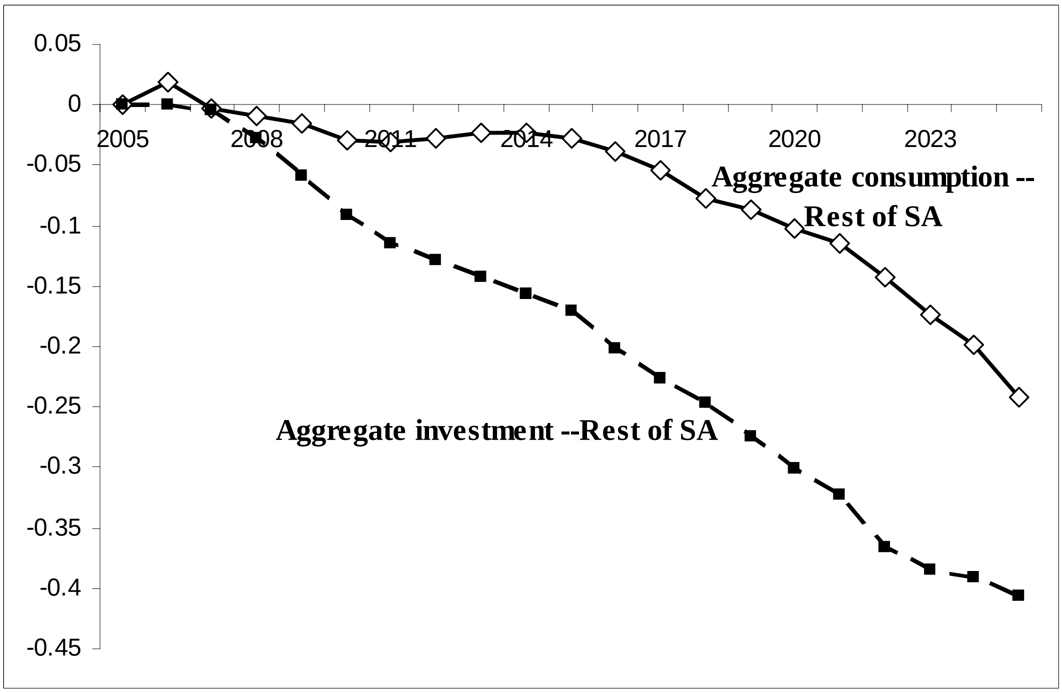


Figure A9: Impact of the incursion on Rest of South Australia's aggregate capital, labour and real GRP: no recovery scenario (% deviation from forecast)