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Using a Highly Disaggregated Multi-Regional Single-Country Model to Analyse the Impacts of the 2002-03 Drought on 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.

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Abstract

TERM (The Enormous Regional Model) is a "bottom-up" CGE model of Australia which treats each region as a separate economy. TERM was created specifically to deal with highly disaggregated regional data while providing a quick solution to simulations. This makes it a useful tool for examining the regional impacts of shocks that may be region-specific. We include some details of how we prepared the TERM database, using a national input-output table, together with regional data showing output (for agriculture) and employment (in other sectors) for each of 144 sectors and 57 regions [the Australian statistical divisions]. Using a 38-sector, 45-region aggregation of the model, we simulate the short-run effects of the Australian drought of 2002-03, which was the most widespread for 20 years. The effects on some statistical divisions are extreme, with income losses of up to 20 per cent. Despite the relatively small share of agriculture in Australian GDP, the drought reduces GDP by 1.6 per cent, and contributes to a decline in unemployment and to a worsening of the balance of trade.

JEL Classification: D58, R13, N57, O13.

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1. Progress in Australian regional economic modelling

The ORANI model (Dixon et al., 1982), which distinguished over 100 sectors, introduced large-scale computable general equilibrium modelling in 1977. Since then, related models have developed in several new directions. ORANI's solution algorithm combined the efficiency of linearised algebra with the accuracy of multi-step solutions, allowing the development of ever more disaggregated and elaborate models. The GEMPACK software developed by Ken Pearson (1988) and colleagues in the mid-1980s simplified the specification of new models, while cheaper, more powerful computers allowed the development of computer-intensive multi-regional and dynamic models. On the demand side, these advances have been driven by the appetite of policy-makers for sectoral, temporal, and social detail in analyses of the effects of policy or external shocks. Since parliamentary representatives are elected by regions, demand for regional detail is particularly strong.

To meet this need, even early versions of ORANI (see Dixon *et al*. 1978) included a “top-down” regional module to work out the regional consequences of national economic changes: national results for quantity variables were broken down by region using techniques borrowed from input-output analysis. From 8 to 100 regions could easily be distinguished. Region-specific demand shocks could be simulated, but, since price variables were not given a regional dimension, there was little scope for region-specific supply shocks[2]. On the other hand, the “top-down” approach did not need much extra data or computer power.

A second generation of regional CGE models adapted ORANI by adding two regional subscripts (source and destination) to most variables and equations. In this “bottom-up” type of multi-regional CGE model, national results are driven by (ie, are additions of) regional results. Liew (1984), Madden (1989) and Naqvi and Peter (1995) describe several Australian examples. Dynamic versions of such models have followed (Giesecke 1997). The best-known example of this type of regional model is the Monash Multiregional Forecasting model, MMRF (Adams *et al.* 2002).

Bottom-up models allow simulations of policies that have region-specific price effects, such as a payroll tax increase in one region only. They also allow us to model imperfect factor mobility (between regions as well as sectors). Thus, increased labour demand in one region may be both choked off by a local wage rise and accommodated by migration from other regions. Unfortunately models like MMRF pose formidable data and computational problems—limiting the amount of sectoral and regional detail. Only 2 to 8 regions and up to 40 sectors could be distinguished[3]. Luckily, Australia has only 8 states, but size limitations have hindered the application of similar models to larger countries with 30 to 50 provinces, and have hitherto prevented us from distinguishing smaller, sub-state regions.

Finer regional divisions are desirable for several reasons. Policy-makers who are concerned about areas of high unemployment or about disparities between urban and rural areas desire more detailed regional results. Environmental issues, such as water management, often call for smaller regions that can map watershed or other natural boundaries more closely. Finally, more and smaller regions give CGE models a greater sense of geographical realism, closing the gap between CGE and LUTE (Land Use Transportation Energy) modelling.

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[2] Such limitations could be partially circumvented: see Higgs et al., 1988.
[3] More precisely, these 2nd-generation models (like MMRF) become rather large and slow to solve as the product: (number of regions) x (number of sectors) exceeds 300. TERM raises this limit to about 2500.

This paper outlines a new model with greater disaggregation of regional economies than previously available. The bottom-up TERM (The Enormous Regional Model) model allows us to analyse effects for each of 57 statistical divisions within Australia. Our application of the model in this paper is not to a policy scenario, but rather to a depiction of the Australian drought of 2002. Although widespread, the severity of the drought varied greatly between regions: rainfall ranged from 80% to 5% of the norm. As each region within the model has its own input-output database and agricultural product mix, TERM is uniquely equipped to estimate the varying impact of the drought on different regions. Our simulation depicts short-run effects, as we anticipate that most regions will recover from drought as the El Nino pattern breaks up.

2. The structure of TERM

The key feature of TERM, in comparison to predecessors such as MMRF, is its ability to handle a greater number of regions or sectors. The greater efficiency arises from a more compact data structure, made possible by a number of simplifying assumptions. For example, TERM assumes that all users in a particular region of, say, vegetables, source their vegetables from other regions according to common proportions. The data structure is the key to TERM's strengths.

Figure 1 is a schematic representation of the model's input-output database. It reveals the basic structure of the model. The rectangles indicate matrices of flows. Core matrices (those stored on the database) are shown in bold type; the other matrices may be calculated from the core matrices. The dimensions of the matrices are indicated by indices (c, s, i, m, etc) which correspond to the following sets:

Table 1: Main sets of the TERM model

Index	Set name	Description	Typical size
s	SRC	(dom,imp) Domestic or imported (ROW) sources	2
c	COM	Commodities	40
m	MAR	Margin commodities (Trade, Road, Rail, Boat)	4
i	IND	Industries	40
o	OCC	Skills	8
d	DST	Regions of use (destination)	30
r	ORG	Regions of origin	30
p	PRD	Regions of margin production	30
f	FINDEM	Final demanders(HOU, INV,GOV, EXP);	4
u	USER	Users = IND union FINDEM	44

The sets DST, ORG and PRD are in fact the same set, named according to the context of use.

The matrices in Figure 1 show the value of flows valued according to 3 methods:

1) Basic values = Output prices (for domestically-produced goods), or CIF prices (for imports)
2) Delivered values = Basic + Margins
3) Purchasers' values = Basic + Margins + Tax = Delivered + Tax

The matrices on the left-hand side of the diagram resemble (for each region) a conventional single-region input-output database. For example, the matrix USE at top left shows the delivered value of demand for each good (c in COM) whether domestic or imported (s in SRC) in each destination region (DST) for each user (USER, comprising the industries, IND, and 4 final demanders: households, investment, government, and exports). Some typical elements of USE might show:

USE("Wool","dom","Textiles","North") : domestically-produced wool used by the textile industry in North

USE("Food","imp","HOU","West") : imported food used by households in West

USE("Meat","dom","EXP","North") : domestically-produced meat exported from a port in North. Some of this meat may have been produced in another region.

USE("Meat","imp","EXP","North") : imported meat re-exported from a port in North

As the last example shows, the data structure allows for re-exports (at least in principle). All these USE values are "delivered": they include the value of any trade or transport margins used to bring goods to the user. Notice also that the USE matrix contains no information about regional sourcing of goods.

The TAX matrix of commodity tax revenues contains an element corresponding to each element of USE. Together with matrices of primary factor costs and production taxes, these add to the costs of production (or value of output) of each regional industry.

In principle, each industry is capable of producing any good. The MAKE matrix at the bottom of Figure 1 shows the value of output of each commodity by each industry in each region. A subtotal of MAKE, MAKE_I, shows the total production of each good (c in COM) in each region d.

TERM recognizes inventory changes in a limited way. First, changes in stocks of imports are ignored. For domestic output, stock changes are regarded as one destination for industry output (ie, they are dimension IND rather than COM). The rest of production goes to the MAKE matrix.

The right hand side of Figure 1 shows the regional sourcing mechanism. The key matrix is TRADE, which shows the value of inter-regional trade by sources (r in ORG) and destinations (d in DST) for each good (c in COM) whether domestic or imported (s in SRC). The diagonal of this matrix (r=d) shows the value of local usage which is sourced locally. For foreign goods (s="imp") the regional source subscript r (in ORG) denotes the port of entry. The matrix IMPORT, showing total entry of imports at each port, is simply an addup (over d in DST) of the imported part of TRADE.

The TRADMAR matrix shows, for each cell of the TRADE matrix the value of margin good m (m in MAR) which is required to facilitate that flow. Adding together the TRADE and TRADMAR matrix gives DELIVRD, the delivered (basic + margins) value of all flows of goods within and between regions. Note that TRADMAR makes no assumption about where a margin flow is produced (the r subscript refers to the source of the underlying basic flow).

Matrix SUPPMAR shows where margins are produced (p in PRD). It lacks the good-specific subscripts c (COM) and s (SRC), indicating that, for all usage of margin good m used to transport any goods from region r to region d, the same proportion of m is produced in region p. Summation of SUPPMAR over the p (in PRD) subscript yields the matrix SUPPMAR_P which should be identical to the subtotal of TRADMAR (over c in COM and S in SRC), TRADMAR_CS. In the model, TRADMAR_CS is a CES aggregation of SUPPMAR: margins (for a given good and route) are sourced according to the price of that margin in the various regions (p in PRD).

TERM assumes that all users of a given good (c,s) in a given region (d) have the same sourcing (r) mix. In effect, for each good (c,s) and region of use (d) there is a broker who decides for all users in d whence supplies will be obtained. Armington sourcing is assumed: the matrix DELIVRD_R is a CES composite (over r in ORG) of the DELIVRD matrix.

A balancing requirement of the TERM database is that the sum over user of USE, USE_U, shall be equal to the sum over regional sources of the DELIVRD matrix, DELIVRD_R.

It remains to reconcile demand and supply for domestically-produced goods. In Figure 1 the connection is made by arrows linking the MAKE_I matrix with the TRADE and SUPPMAR matrices. For non-margin goods, the domestic part of the TRADE matrix must sum (over d in DST) to the corresponding element in the MAKE_I matrix of commodity supplies. For margin goods, we must take into account both the margins requirement SUPPMAR_RD and direct demands TRADE_D.

At the moment, TERM distinguishes only 4 final demanders in each region:
(a) HOU: the representative household
(b) INV: capital formation
(c) GOV: government demand
(d) EXP: export demand.

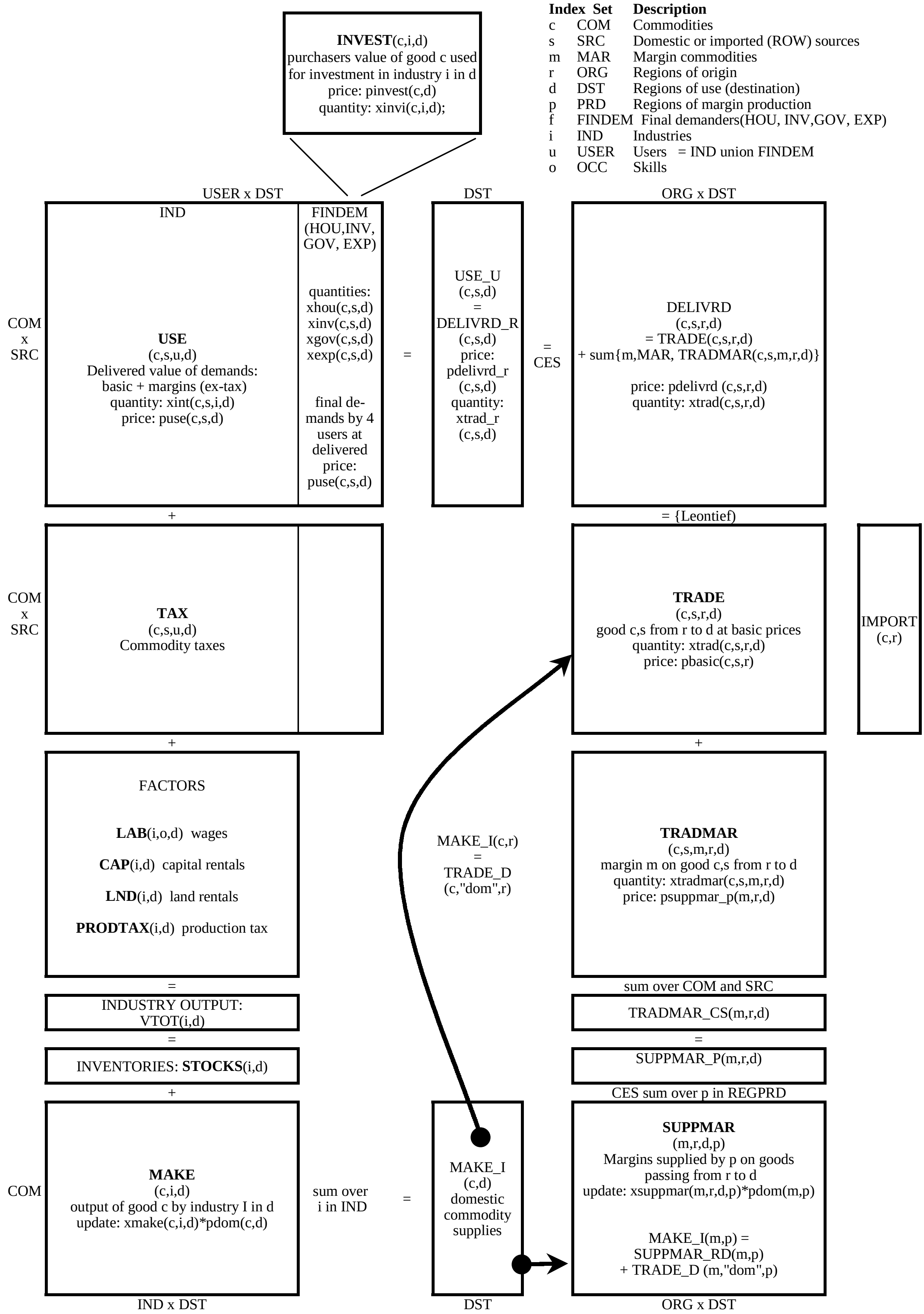

Figure 1: The TERM flows database

For many purposes it is useful to break down investment according to destination industry. The satellite matrix INVEST (subscripted c in COM, i in IND, and d in DST) serves this purpose. It allows us to distinguish the commodity composition of investment according to industry: for example, we would expect investment in agriculture to use more machinery (and less construction) than investment in dwellings.

MMRF includes SAM-like modelling of regional governments' income and expenditure. For the Australian[4] version of TERM, the 57 regions correspond to 'statistical divisions' which do not entirely correspond with administrative regions. Hence, regional government finances are not modelled in this version of TERM.

2.1. TERM sourcing mechanisms

Figure 2 illustrates the details of the TERM system of demand sourcing. Although the figure covers only the demand for a single commodity (Vegetables) by a single user (Households) in a single region (North), the same diagram would apply to other commodities, users and regions. The diagram depicts a series of 'nests' indicating the various substitution possibilities allowed by the model. Down the left side of the figure, boxes with dotted borders show in upper case the value flows associated with each level of the nesting system. These value flows may also be located in Figure 1. The same boxes show in lower case the price (p....) and quantity (x....) variables associated with each flow. The dimensions of these variables are critical both to the usefulness of the model and to its computational tractability; they are indicated by subscripts c, s, m, r, d and p, as explained in Table 1. Most of what is innovative in TERM could be reconstructed from Figures 1 and 2.

At the top level, households choose between imported (from another country) and domestic vegetables. A CES or Armington specification describes their choice—as pioneered by ORANI and adopted by most later CGE models. Demands are guided by user-specific purchasers' prices (the purchasers' values matrix PUR is found by summing the TAX and USE matrices of Figure 1). 2 is a typical value for the elasticity of substitution.

Demands for domestic vegetables in a region are summed (over users) to give total value USE_U (the "_U" suffix indicates summation over the user index u). The USE_U matrix is measured in "delivered" values—which include basic values and margins (trade and transport), but not the user-specific commodity taxes.

The next level treats the sourcing of USE_U between the various domestic regions. The matrix DELIVRD shows how USE_U is split between origin regions r. Again a CES specification controls the allocation; substitution elasticities range from 5 (merchandise) to 0.2 (services). The CES implies that regions which lower production costs more than other regions will tend to increase their market share. The sourcing decision is made on the basis of delivered prices—which include transport and other margin costs. Hence, even with growers' prices fixed, changes in transport costs will affect regional market shares. Notice that variables at this level lack a user (u) subscript—the decision is made on an all-user basis (as if wholesalers, not final users, decided where to source vegetables). The implication is that, in North, the proportion of vegetables which come from South is the same for households, intermediate, and all other users.

The next level shows how a "delivered" vegetable from, say, South, is a Leontief composite of basic vegetable and the various margin goods. The share of each margin in the delivered price is specific to a particular combination of origin, destination, commodity and source. For example, we should expect transport costs to form a larger share for region pairs which are far apart, or for heavy or bulky goods. The number of margin goods will depend on how aggregated is the model database. Under the Leontief specification we preclude substitution between Road and Retail margins, as well as between Road and Rail. For some purposes it might be worthwhile to construct a more elaborate nesting which accommodated Road/Rail switching.

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[4] TERM has also been applied to Brazil and Indonesia.

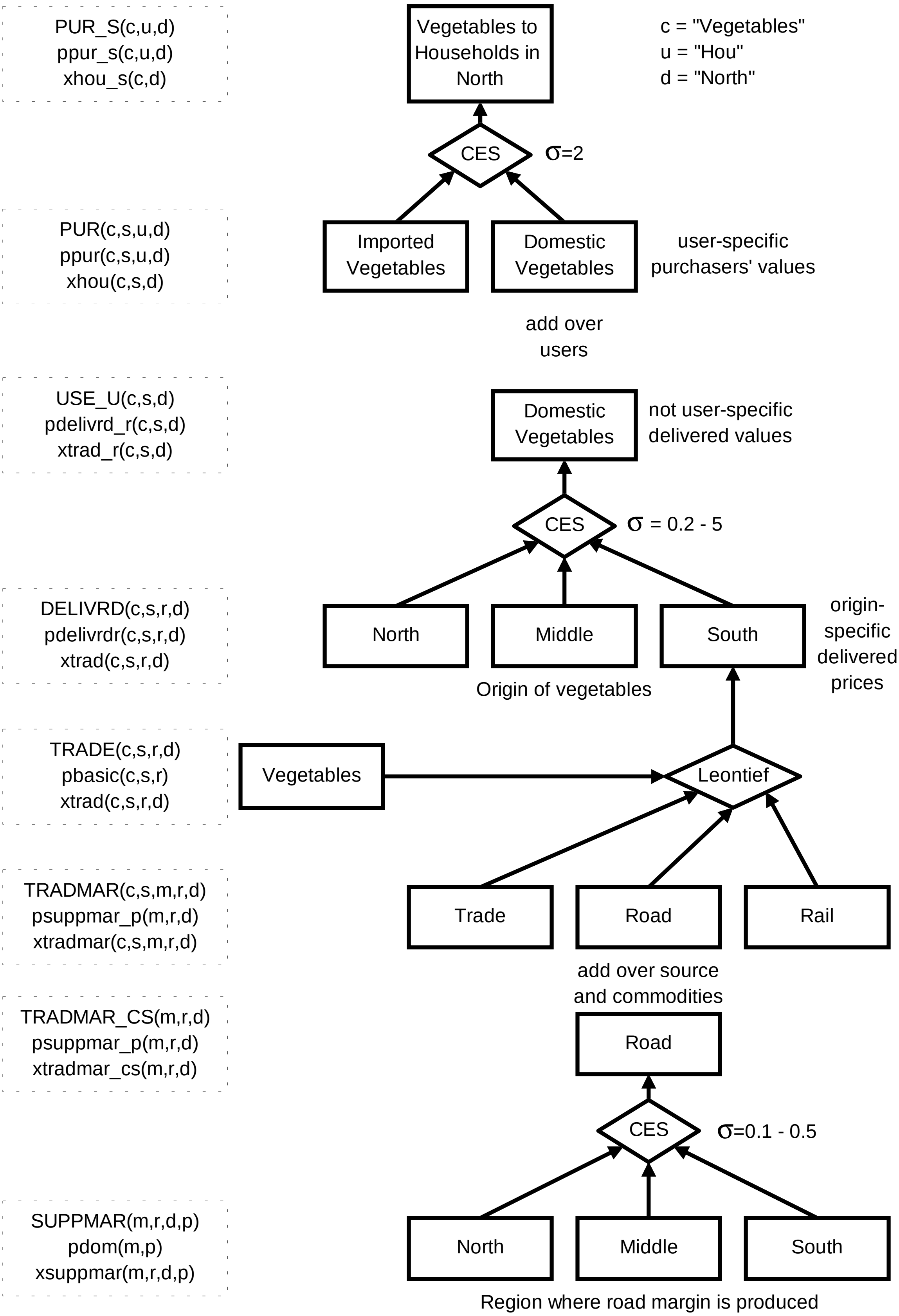

Figure 2: TERM sourcing mechanisms

The bottom part of the nesting structure shows that margins on vegetables passing from South to North could be produced in different regions. The figure shows the sourcing mechanism for the road margin. We might expect this to be drawn more or less equally from the origin (South), the destination (North) and regions between (Middle), There would be some scope (σ=0.5) for substitution, since trucking firms can relocate depots to cheaper regions. For retail margins, on the other hand, a larger share would be drawn from the destination region, and scope for substitution would be less (σ=0.1). Once again, this substitution decision takes place at an aggregated level. The assumption is that the share of, say, Middle, in providing Road margins on trips from South to North, is the same whatever good is being transported.

Although not shown in Figure 2, a parallel system of sourcing is also modelled for imported vegetables, tracing them back to port of entry instead of region of production.

2.2. Other features of TERM

The remaining features of TERM are common to most CGE models, and in particular to ORANI, from which TERM descends. Industry production functions are of the nested CES type: Leontief except for substitution between primary factors and between sources of goods. Exports from each region's port to the ROW face a constant elasticity of demand. The composition of household demand follows the linear expenditure system, while the composition of investment and government demands is exogenous. A variety of closures are possible. For the shortrun simulation we describe below, industry capital stocks and land endowments were held fixed, whilst labour was fully mobile between sectors within a region and partially mobile between regions. At the regional level, household consumption tended to follow regional income.

2.3. Comparison with the GTAP model

GTAP, a well-known model of the world economy, has a fairly similar structure to TERM. The "regions" of GTAP, however, are countries or groups of countries, whilst in TERM they are regions within a single country. In GTAP, regional trade deficits must sum to zero [the planet is a closed system] whilst in TERM a national trade deficit is possible. There are also differences in data structures: TERM models import/domestic substitution at the user level, whilst in GTAP this decision is modelled at a regional, all-user level. GTAP has a far more detailed representation of bilateral trade taxes than does TERM, reflecting the freer trade that is usually possible within a nation. TERM can accommodate commodity tax rates that vary between regions (North might tax whisky more than South) but it does not allow for regional tax discrimination (such as a tax, in North, that applied only to whisky from West). Inter-regional labour movements, a rarity in GTAP, are usual in TERM. Finally, TERM has a particularly detailed treatment of transport margins.

3. Gathering data for 144 sectors and 57 regions

As formidable as the computational demands of regional CGE models, are the data requirements—which usually far exceed what is available. Regional input-output tables and trade matrices, as depicted in Figure 1 are not available for Australia. Thus, a vital counterpart to TERM is a strategy, depicted in Figure 3, to estimate its database from very limited regional data. The key features of this strategy are:

(a) The process starts with a national input-output table and certain regional data. The *minimum* requirements for regional data are very modest: the distribution between regions of industry outputs and of final demand aggregates. Additional regional detail, such as region-specific technologies or consumption preferences may be added selectively, when available.

(b) The process is automated, so that additional detail can easily be added at a later stage.

(c) The database is constructed at the highest possible level of detail: 144 sectors and 57 regions. Aggregation (for computational tractability) takes place at the end of the process, not at the beginning. Perhaps surprisingly, the high level of disaggregation is often helpful in estimating missing data. When aggregated, the model database displays a richness of structure that belies the simple mechanical rules that were used to construct its disaggregated parent. For example, even though we normally assume that a given disaggregated sector has the same input-output coefficients wherever it is located, aggregated sectors display regional differences in technology. Thus, sectoral detail partly compensates for missing regional data.

3.1. The national input-out database

As shown in Figure 3, the TERM data process starts from the 1997 Australian input-output Tables, distinguishing 107 sectors. Our first step was to convert these tables to the file format of ORANI-G, a standard single-country CGE model. Next, working at the national level, we expanded the 107 sectors to 144. In choosing to split sectors, we hoped to avoid infelicities of classification that have caused problems in the past (such as the lumping together of exports of sugar, cotton and prawns) and also to split up sectors which showed regional differences in composition. For example, we split up electricity generation according to the fuel used (which differs among Australian regions) and added considerable agricultural detail. The interests of one collabarator led to a remarkably detailed treatment of the wine and grape sectors, which were divided according to quality (some regions produce high-quality wine for export, others a cheaper brew for local drinking).

The main source for the sectoral split was unpublished ABS commodity cards data. Such data provide a split of sales for approximately 1,000 commodities to 107 industries, plus final users. However, the cards data do not always provide a desirable split from the 107 industries to the eventual 144 sectors of the disaggregated database. For example, there are significant sales of sugarcane to the other food products sector (107-sector aggregation). We allocated all sugarcane sales to refined sugar and zero sales to the seafood and other food products in our 144-sector disaggregation. When the intermediate sales split was less obvious, we used activity weights of the purchasing sectors for the split.

The 144-sector national database has an independent value for our modelling work (for example, it forms the bulk of the MONASH database). For TERM purposes it was converted to a simpler format prior to the addition of regional detail.

3.2. Estimates of the regional distribution of output and final demands

The next step was to obtain, for each industry and final demander, an estimate of each statistical division's share of national activity (these shares are the R001, R002, etc, of Figure 3). To develop a full input-output table for each region, we required estimates of industry shares (i.e., each region's share of national activity for a given industry), industry investment shares, household expenditure shares, international export and import shares, and government consumption shares.

The main data sources for the industry split were:

- AgStats data from ABS, which details agricultural quantities and values at the SD level;
- employment data by industry at the SD level prepared by our colleague Tony Meagher from ABS census data and surveys;
- published ABS manufacturing census data (state level); and
- state yearbooks (for mining, ABS 1301.* and, for grapes and wine, ABS 1329.0).

Our sectoral split included a split of electricity into generation by fuel type plus a distribution sector. We relied on the internet sites of various electricity and energy agencies for capacity levels, on which shares of national activity were based.

Manufacturing, mining and services data disaggregated at the statistical division level were in quantities rather than values. These were adjusted these to fit state account sector aggregates (ABS 5220.0), as wages and industry composition vary between states. Industry investment shares are similar to industry activity shares for most sectors. Exceptions include residential construction input shares, set equal to ownership of dwellings investment shares in each statistical division.

Published ABS data (Tables 4 and 5, ABS 6530.0) provide sufficient commodity disaggregation for the task of splitting regional consumption aggregates into commodity shares. Such data also provide a split between capital city regions and other regions within each state.

In compiling international trade data by region, we first gathered trade data by port of exit or entry. For this task, we used both unpublished ABS trade data available for each state and territory plus the annual reports of various ports authorities. Queensland Transport's annual downloadable publication *Trade Statistics for Queensland Ports* gives enough data to estimate exports by port of exit with reasonable accuracy for that state. For other states, port activity is less complex, with most manufacturing trade passing through capital city ports and regional ports specialising in mineral and grain shipments.

State accounts data provide aggregated Commonwealth and state government spending in each region (ABS 5220.0). Employment numbers by statistical division for government administration and defence provide a useful split for these large public expenditure items. For other commodities, population shares by statistical division were used to calculate the distribution of Commonwealth and state government spending across regions.

By applying these shares to the national CGE database, we were able to compute the USE, FACTOR, and MAKE matrices on the left-hand side of Figure 1. None of these matrices distinguish the source region of inputs.

3.3. The TRADE matrix

The next stage was to construct the TRADE matrix on the right-hand side of Figure 1. For each commodity either domestic or imported, TRADE contains a 57x57 submatrix, where rows correspond to region of origin and columns correspond to region of use. Diagonal elements show production which is locally consumed. As shown in Figure 3 we already know both the row totals (supply by commodity and region) and the column totals (demand by commodity and region) of these submatrices. For Australia, hardly any detailed data on inter-regional state trade is available. We used the gravity formula (trade volumes follow an inverse power of distance) to construct trade matrices consistent with pre-determined row and column totals. In defence of this procedure, two points should be noted:

- Wherever production (or, more rarely, consumption) of a particular commodity is concentrated in one or a few regions, the gravity hypothesis is called upon to do very little work. Because our sectoral classification was so detailed, this situation occurred frequently.
- Outside of the state capitals, most Australian regions are rural, importing services and manufactured goods from the capital cities, and exporting primary products through a nearby port. For a given rural region, one big city is nearly always much closer than any others, and the port of exit for primary products is also well defined. These facts of Australian geography again reduce the weight borne by the gravity hypothesis.

3.4. Aggregation

Even though TERM is computationally efficient, it would be slow to solve if a full 144-sector, 57-region database were used. The next stage in the data procedure is to aggregate the data to a more manageable size. The aggregation choice is application-specific. For the simulation reported below, we distinguished 45 regions but only 38 sectors. The sectoral aggregation was most detailed in the agricultural and agriculture-related sectors, while manufacturing and service industries were grouped broadly.

As Figure 3 shows, we routinely aggregate TERM's 57 regions into the 8 Australian states. The resulting aggregated database forms the kernel of the MMRF database. MMRF is still the workhorse of regional CGE modelling at CoPS, since it incorporates features that TERM lacks, such as year-to-year dynamics, state government accounts, and emissions modelling. TERM is needed when sub-state detail is required, especially if supply-side shocks must be imposed which differ amongst regions within a state. The latter requirement is exemplified by the drought simulation described next.

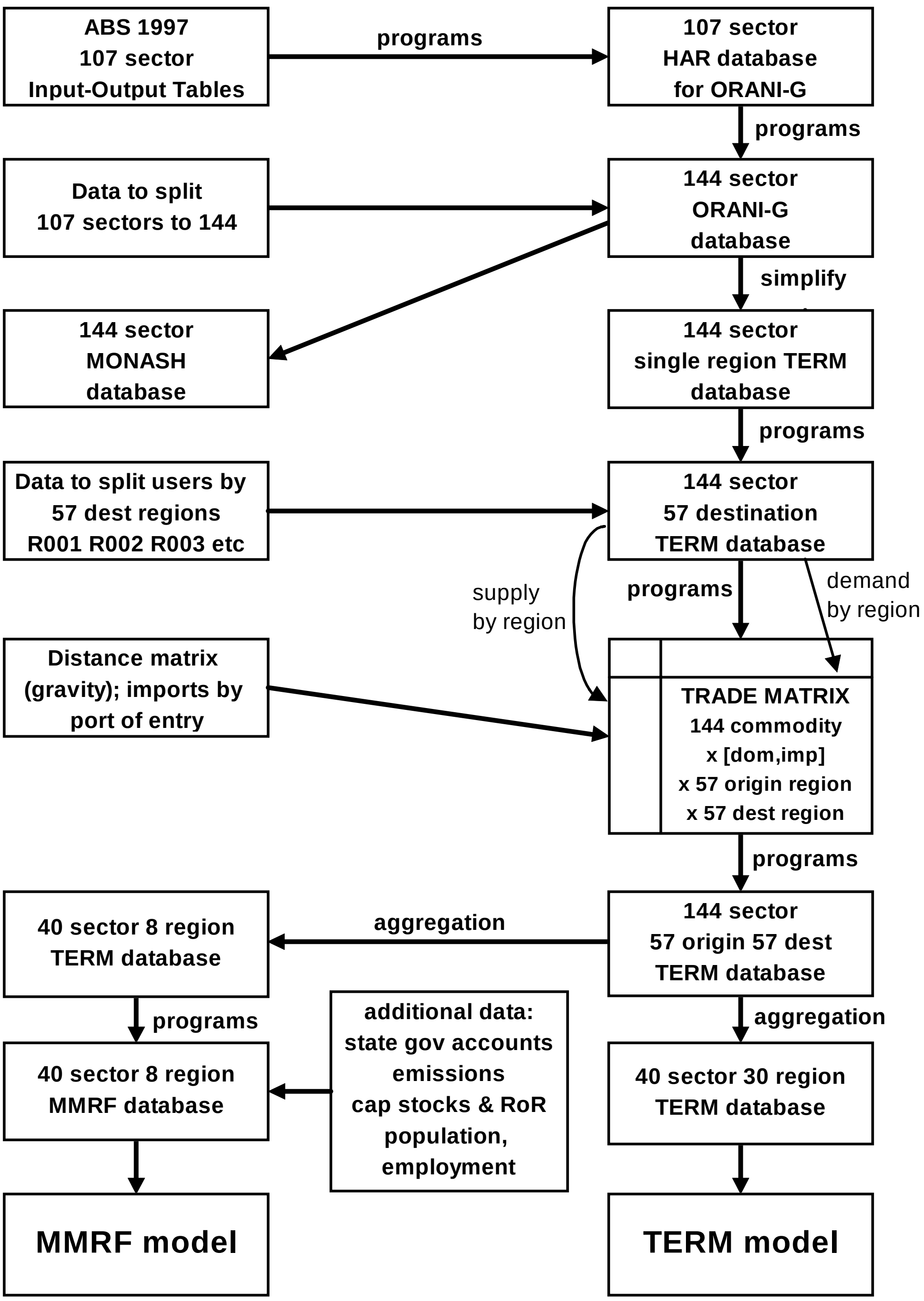

Figure 3: Producing regional databases for MMRF and TERM

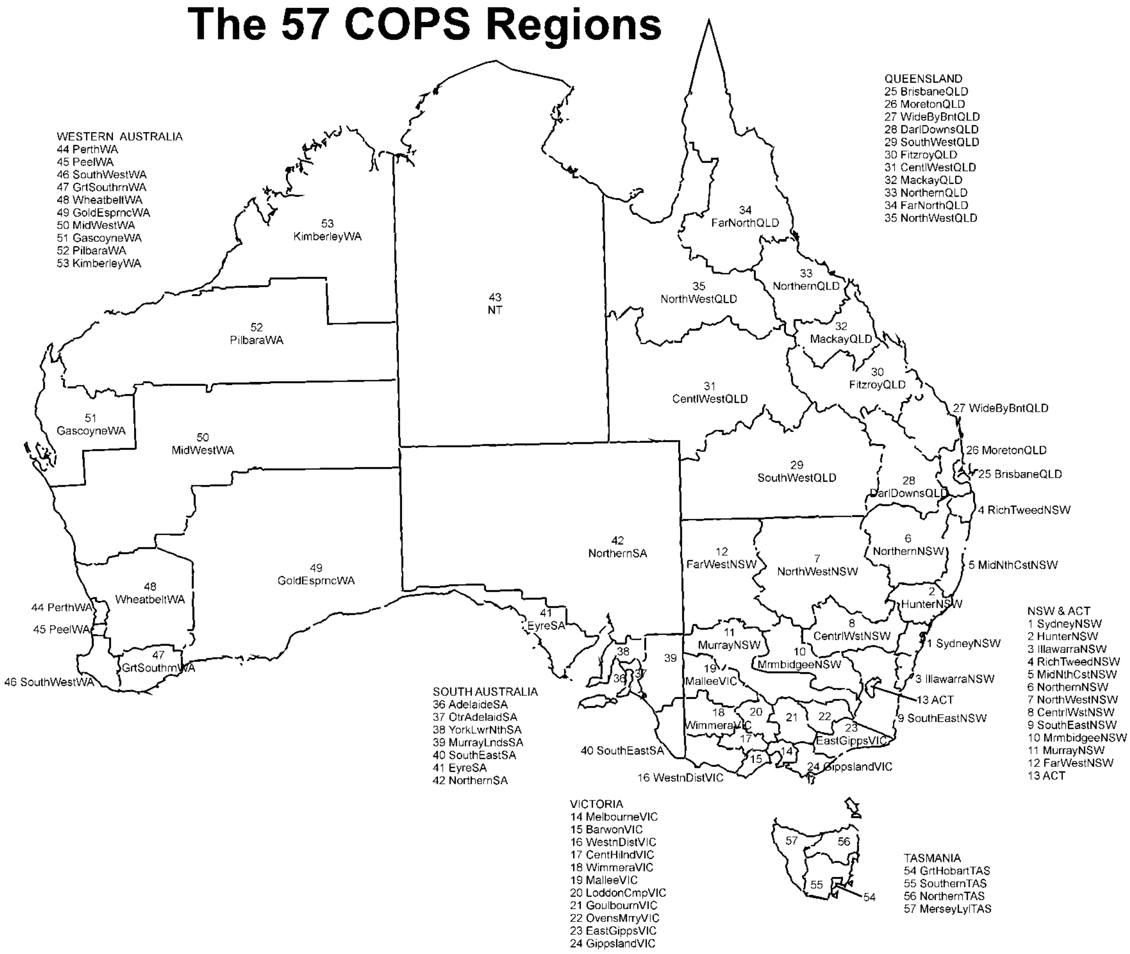

Figure 4: Statistical divisions in Australia

4. Background to the drought of 2002

Even in a drought as widespread as that of 2002, the impact on farmers varied widely across regions. For example, some grain growers around Adelaide, the south east of South Australia and south-western Victoria realised near-average harvests. Yet on eastern Eyre Peninsula, in the Murray districts and northerly grain growing areas of South Australia, in north-western Victoria and western New South Wales, many farmers suffered substantial or total crop failure.

Rainfall deficits generally have been worse in inland grain-growing regions than in coastal regions. This has meant a bleaker outlook for grains than some other crops, but it also has meant that the same agricultural product is likely to be affected differently in different regions. The level of industry and regional detail in the TERM model provides a unique tool for estimating both the regional and macroeconomic effects of the current drought. Regions are either statistical divisions or combinations of statistical divisions. Each region has its own CGE model; these are linked by matrices of trade flows. Of particular relevance for the current project was the formation of the agricultural component of the database, estimated using ABS agricultural output data at the statistical division level. The simulations reported here employ a 1996-97 database. Nineteen of the 38 industries are in the agricultural sector.

4.1. Estimating the direct impact of drought at the regional level

The Bureau of Meteorology (2002a) recorded April to December 2002 as one of the most severe and widespread droughts on record for a 9-month period. In terms of the proportion of the nation recording rainfall below the 10^{th} percentile for nine months, this period was the second worst on record. In terms of the mean percentile value, this period was the worst on record (Table 2). While few regions have registered record low rainfall totals, Figure 5 shows that a large area of Australia suffered severe rainfall deficiencies in 2002.

Table 2: The extent of the drought

Rank	**9-month period**	**% of Australia below 10th percentile**	**Rank**	**9-month period**	**Mean Australian percentile value**
1	Nov 1901–July 1902	58.9	**1**	April–Dec 2002	13.2
2	April–Dec 2002	58.6	**2**	March–Nov 1994	15.7
3	March–Nov 1994	52.6	**3**	April–Dec 1972	17.1
4	March–Nov 1940	49.9	**4**	March–Nov 1940	18.6
5	July 1951–Mar 1952	49.4	**5**	July 1951–Mar 1952	19.4

Source: Bureau of Meteorology (2002a)

In October ABARE (2002a) issued a special drought issue of its crop report further revising downwards its expectations for winter crop output and warning of an inauspicious outlook for summer crops. The grim 2002-03 outlook for Australian crops was confirmed in ABARE's (2002b) December crop report, with winter and summer crop output down on average on 2001-02 output by 56 per cent and 59 per cent respectively.

For the forecasting estimates reported above our concern was with such year-on-year estimates. In this section, however, we wish to compare the impact of the drought with what otherwise would have been the case. We assume the latter to be encapsulated in ABARE's earlier 2002-03 forecasts published in the first part of 2002, before it became apparent that Australia was facing a severe drought.

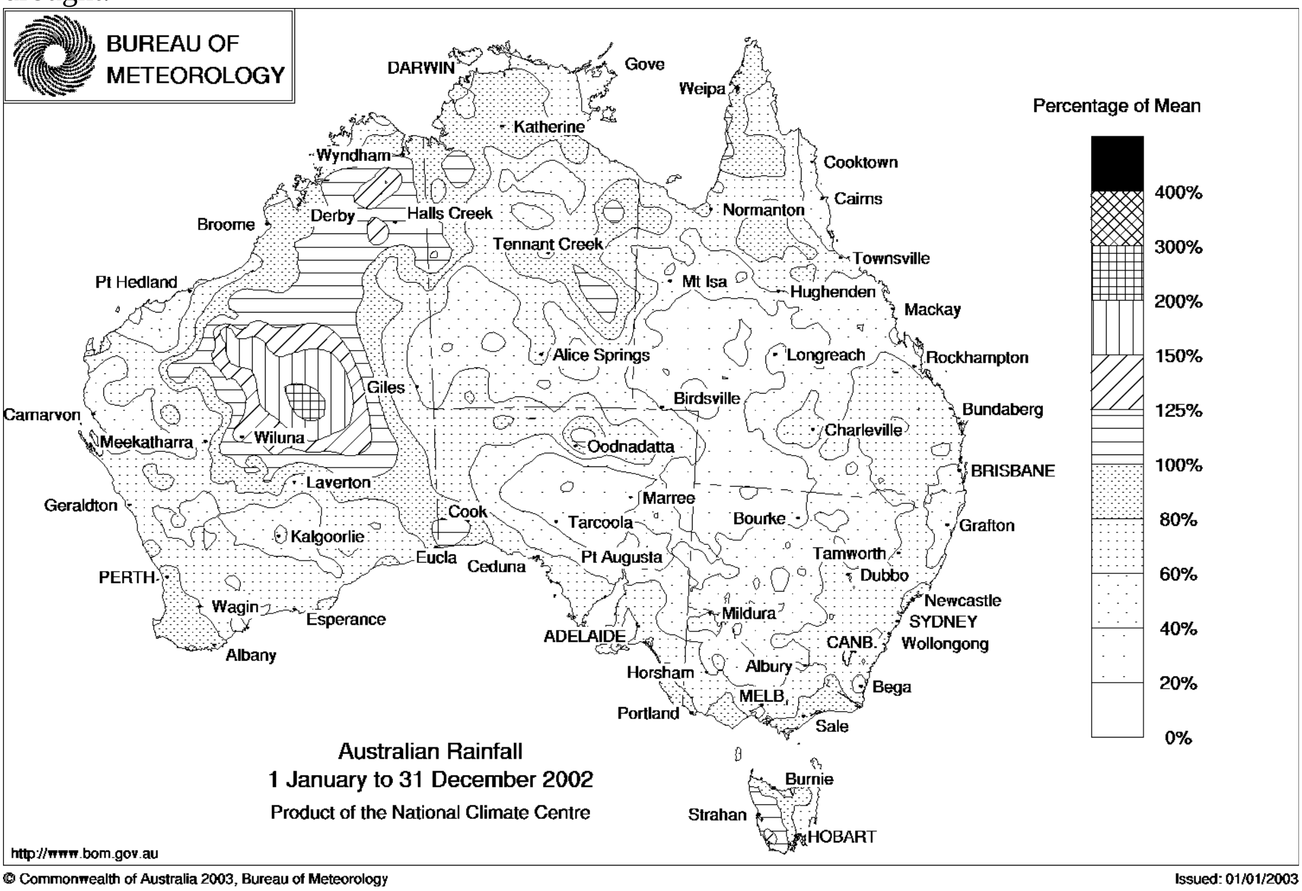

Figure 5: Rainfall deficits in Australia, 2002

To properly model the drought at the regional (statistical division) level it was important to make estimates of the direct effect of the drought on output for agricultural industries within individual statistical divisions. We did this by developing estimation formulae that computed productivity losses due to the drought for each agricultural industry in each region. The formulae related the productivity losses to rainfall deficits in individual regions which, in turn, were estimated from district rainfall deficit figures (for specific periods up to 31/10/02) available from the Bureau of Meteorology. Separate formulae were developed for different types of crops and for livestock. For example, for winter grains grown in southern Australia, we assumed that the productivity loss for the crop in a particular region was a progressively increasing function of the 3-month rainfall deficit, and was also affected to a lesser extent by the 6-month deficit. Thus as the severity of the 3-month rainfall deficit increased, productivity losses were estimated to become increasingly greater at the margin. Other crops were either linearly or progressively related to combinations of 3-month, 6-month and 18-month rainfall deficits. In each case, regional industry productivity losses were adjusted so that the simulation result for the effect of the drought on the Australia-wide output of the industry coincided with the difference between the latest ABARE 2002-03 output forecast and the Bureau's earlier forecast for the industry.

For cattle and sheep grazing, we used 18-month rainfall deficits to estimate the productivity impact of the drought. However, using ABARE's estimates for the Australia-wide output effects on the various livestock industry presented a particular difficulty. ABARE (2002c) forecasts a modest overall increase above the 2001-02 figure in the number of livestock slaughtered and also a small increase in meat produced. The latter increase is by only a slightly smaller percentage than the former, apparently indicating only limited deterioration in the quality of the livestock slaughtered. However, for the most severely affected regions, where the 18-month rainfall deficits have been extreme, it would appear that de-stocking may have been the dominant response to the drought. We adjusted the ABARE estimates to account for some of the livestock sales in the worst affected regions, treating these as disinvestment rather than increased production. Thus for regions such as Central West and South West Queensland we ascribed a near zero level of investment to livestock sectors. Our 2002-03 results may still not fully capture the negative effects of the drought on some livestock regions as it is not possible to gauge properly the degree to which maintaining livestock sales has been via de-stocking. Reduced herd numbers can also be expected to have an effect on certain regions well beyond 2002-03.

We also recognised in our modelling that in less severely affected livestock regions, especially with the expectation of the drought breaking relatively early in 2003, increased feed grain would be used to keep livestock alive. Feed-grain-using productivity losses in livestock industries were computed on the basis of rainfall deficits, in order to capture this effect.

5. Impacts at the regional and national levels and a historical comparison

Table 3 shows the results for the macroeconomic effects of the drought generated by the TERM simulation. It can be seen from the first row of the final column that we expect the drought to lower Australian GDP by 1.6 per cent. One percentage point of this relates to reductions in value added in the agriculture sector (row 2), while the remaining 0.6 percentage point (row 3) is contributed by other industries suffering negative multiplier effects.

The bottom two rows of Table 3 show that the drought is projected to have considerable adverse effects on the Australian labour market in 2002-03. It will be noticed that the drought is projected to cause a reduction both in employment and in the national real wage rate of a little under 1 per cent. This reflects our assumption that the temporary drought-induced reduction in the demand for labour will be shared between a decline in employment and a decline in real wages. Capital stocks are fixed in each sector in each region.

Our assumption regarding adjustment in the labour market limits the degree of multiplier effects of the drought. The fall in economy-wide employment accounts for only 0.4 percentage points of the projected negative effect of the drought on GDP, while reductions in the indirect tax base accounts for a further 0.2 per cent reduction in GDP.

Both real investment and real household consumption are projected to suffer a smaller percentage reduction than GDP. Again this reflects our assumptions about the macroeconomic environment. In the case of household consumption we expect reductions in expenditure to be ameliorated by increased borrowing (particularly given the current low interest rates), increased government benefits (e.g. unemployment benefits and government relief schemes) and, for severely-affected farmers, deferrals in investments in machinery. Using these considerations we set a particular ratio for the percentage change in real household expenditure to the percentage change in gross regional product (GRP) for each of the 45 regions. It can be seen from Table 3 that the drought-induced percentage decline in real consumption is slightly under half the percentage decline in GDP.

The reduction in real investment of 0.9 per cent is made up entirely of falls in investment in the agricultural sector, particularly the postulated marked reductions in investment in livestock in the sheep and cattle industries. We assume that, given widespread expectations that the drought will not continue very much longer, there will be no overall change in the non-agricultural level of real investment from what would otherwise have been the case.

Table 3: Macroeconomic impacts of drought, 2002-03

Percentage change relative to base case

	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	Aust
Real GDP (total)	-1.9	-1.2	-2.0	-1.9	-1.5	0.3	-0.1	-0.1	-1.6
-- Agriculture contribution	-1.2	-0.7	-1.2	-1.4	-1.2	0.3	-0.1	0.0	-1.0
-- Other industries contribution	-0.7	-0.5	-0.8	-0.5	-0.3	0.0	0.0	-0.1	-0.6
Real consumption	-0.9	-0.5	-0.9	-0.8	-0.6	0.1	0.0	-0.1	-0.7
Real investment	-1.6	-0.7	-1.2	-1.6	0.3	1.6	-0.5	2.1	-0.9
Export volume	-2.7	-4.3	-3.8	-12.1	-8.8	-3.0	0.5	-1.1	-5.0
Import volume	-0.4	0.1	-0.4	-0.4	0.1	1.3	0.3	0.5	-0.2
Export prices	0.7	1.2	1.0	2.8	1.8	0.8	-0.1	0.3	1.2
Employment	-0.9	-0.6	-1.1	-0.7	-0.5	0.1	-0.1	-0.2	-0.8
Average wage rate	-1.2	-0.7	-1.3	-0.8	-0.6	0.2	-0.1	-0.2	-0.9

The widespread nature of the drought can be seen through the substantial projected fall in gross state product (GSP) in all the mainland states. Queensland, New South Wales and South Australia are all projected to experience reductions in real GSP of approximately 2 per cent. New South Wales's agricultural sector is the hardest hit in percentage change terms with an overall agricultural production loss of around 45 per cent. However, NSW was the state least intensive in agriculture in 2001-02. Thus the decline in agriculture had only the same impact on GSP as it did in Queensland, where we project agriculture's output to fall by a quarter as a result of the drought. Queensland agriculture's 2001-02 share of GSP is 4.7 per cent compared with 2.5 per cent for NSW. The estimated reduction in agricultural output in both South Australia and Victoria is a little under 20 per cent, but their 2001-02 shares in total state output are 7.2 per cent and 3.6 per cent respectively. Hence, even a moderate drought has significant negative impacts on the economies of South Australia and Victoria. Western Australia with a projected reduction in overall agricultural output of around 30 per cent and a base-year agricultural share slightly above the Australian average of 3.6 per cent is projected to experience the same fall in GSP directly through agriculture's contraction as NSW and Queensland. However, the negative flow-on effects to the Western Australian economy are projected to be substantially smaller than the other two states. A major reason for this is that mining, which makes up a very large proportion of WA output relative to other states, is projected to increase its output slightly as a result of the drought-induced decline in the real wage rate.

Tasmania is the only state that is not negatively affected by the drought. While the state is quite agriculture intensive (with an agricultural share in output of over 4 per cent), it experienced a reasonable level of rainfall in 2002, with serious or severe rainfall deficits only being experienced on the east coast of the island. Tasmania is thus projected to gain from the beneficial effects of agricultural price rises without having to suffer output contractions in agricultural industries. The ACT has virtually no agricultural industry and thus suffers little from the drought. While agriculture, consisting largely of beef cattle, comprises 2.7 per cent of the Northern Territory economy, the rainfall deficit in the Territory was considered not to have had any major effect on that region's agricultural output.

A historical comparison of the effects of drought is shown in Table 4. In moving from 1982-83, when drought had a marked effect on agricultural output in all states other than Western Australia, to a good year in 1983-84, agriculture's contribution to GDP increased by 1.5 per cent. Given that downstream sectors also benefited from a seasonal recovery, that recovery in 1983-84 may have contributed as much as 2.5 per cent to GDP.[5] Our projection that real GDP declines by 1.6 per cent reflects both a drought that arguably was slightly less severe than that of 20 years ago combined with agriculture's share of national income declining in the interval.

In Table 5 we see that the effects of the drought are estimated to vary considerably across Australian regions. As expected, the largest negative effects of the drought are projected to occur outside the capital cities. Nevertheless, the capital cities are still affected by the drought, as the GRPs for Sydney/Illawarra, Melbourne/Barwon, Brisbane and Adelaide/Outer-Adelaide fall by around half a per cent.

Table 4: Agriculture's share of state factor income

	1981-82	1982-83	1983-84	2001-02	2002-03 (projected)
NSW	3.8	2.4	4.3	2.7	1.5
VIC	3.9	2.9	4.6	3.8	3.1
QLD	7.3	5.2	7.0	4.9	3.7
SA	8.2	4.9	7.3	7.5	6.2
WA	8.9	8.6	6.9	4.1	2.9
TAS	6.3	6.2	6.8	6.1	6.4
Aust	5.1	3.7	5.2	3.9	2.9

Source: ABS 5220.0; TERM projection.

While a small number of non-capital-city regions are projected to suffer smaller declines in their real GRP than the national GDP decline, rural Australia overall is projected to suffer severe output contractions in 2002-03. Eighteen out of the 45 regions in the model are projected to suffer GRP declines of over 5 per cent. A GRP reduction of greater than 10 per cent is projected for eleven of these. The 17 worst-affected regions include all 14 of Australia's regions that had 20 per cent or more of their output in the agricultural sector, reflecting the widespread nature of the drought.

The projected severity of the drought on a region can largely be explained as a combination of the region's reliance on agriculture and the severity of the drought in the region. The worst affected regions are South West Queensland (with a -21 per cent change in GRP), North West NSW (-18%), the WA Wheatbelt (-17%), the Victorian Mallee (-16%) and Northern NSW (-15%). The Wheatbelt has an agricultural share of output of 46 per cent, compared to the mid to high 20s for the other four regions. However, the other four regions have suffered an even more severe drought than the Wheatbelt.

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[5] During March to November 2002, Australia's average annual maximum temperatures were the highest ever recorded for those months, compounding the drought with extreme levels of evaporation (Karoly et al. 2003)..

Table 5: Impact of drought on major regional aggregates(a)

	Real Household consumption	Real Investment	Real GRP	Aggregate Employment	Real Wage Rate
New South Wales					
Sydney/Illawarra	-0.2	1.1	-0.5	-0.7	-0.8
Hunter	-0.3	0.9	-0.6	-0.6	-0.8
North NSW Coast	-0.7	-0.2	-1.3	-0.8	-1.0
Northern NSW	-8.0	-12.7	-15.4	-2.9	-3.7
North West NSW	-9.6	-19.3	-18.4	-5.1	-6.3
Central West NSW	-3.5	-8.1	-6.9	-2.4	-3.0
South East NSW	-1.2	-3.3	-2.3	-1.0	-1.2
Murrumbidgee	-5.8	-10.8	-11.4	-2.7	-3.4
Murray NSW	-6.7	-13.0	-13.0	-3.3	-4.2
Far West NSW	-2.8	-4.8	-5.5	-2.0	-2.5
Victoria					
Melbourne/Barwon	-0.2	1.4	-0.4	-0.4	-0.6
Western District	-1.8	-11.3	-3.5	-1.3	-1.7
Central Highlands	-0.7	-1.1	-1.4	-0.7	-0.9
Wimmera	-5.7	-9.6	-11.1	-2.2	-2.7
Mallee	-8.1	-13.1	-15.5	-3.3	-4.1
Loddon	-0.9	-1.2	-1.8	-0.8	-0.9
Goulburn	-2.6	-6.9	-5.1	-1.4	-1.8
Ovens Murray	-0.8	-1.6	-1.7	-0.7	-0.9
Gippsland/East Gippsland	-0.5	-1.4	-1.0	-0.2	-0.3
Queensland					
Brisbane	-0.3	0.8	-0.6	-0.8	-1.0
Moreton	-0.5	0.8	-1.0	-0.8	-1.0
Wide Bay-Burnett	-1.1	0.0	-2.1	-1.0	-1.2
Darling Downs	-4.4	-7.3	-8.6	-2.3	-2.9
South West Qld	-11.1	-24.1	-21.0	-5.5	-6.9
Fitzroy	-1.3	-0.6	-2.7	-1.3	-1.6
Central West Qld	-7.3	-19.0	-14.0	-4.6	-5.7
Mackay Qld	-1.8	0.8	-3.5	-1.6	-2.0
Northern Qld	-1.6	0.7	-3.3	-1.3	-1.6
Far North Qld	-1.0	1.0	-1.9	-0.9	-1.1
North West Qld	-1.1	-3.0	-2.3	-1.0	-1.3
South Australia					
Adelaide (&Outer Adelaide)	-0.3	1.1	-0.5	-0.5	-0.6
Yorke and Lower North	-5.4	-7.9	-10.5	-2.3	-2.9
Murray Lands SA	-5.0	-5.8	-9.7	-1.3	-1.6
South East SA	-1.3	-2.2	-2.6	-0.6	-0.8
Eyre SA	-6.8	-11.3	-13.2	-3.5	-4.3
Northern SA	-1.6	-1.7	-3.1	-1.3	-1.6
Western Australia					
Perth & Sth West WA	-0.2	1.4	-0.3	-0.4	-0.5
Great Southern WA	-3.7	-9.0	-7.3	-2.3	-2.8
Wheatbelt	-8.7	-11.7	-16.6	-2.6	-3.2
Goldfields Esperance	-1.0	0.5	-2.1	-0.5	-0.6
Mid West WA	-2.8	-1.8	-5.4	-0.9	-1.1
Northern WA(b)	0.0	2.8	-0.1	0.3	0.4

(a) Table excludes Tasmania, the Northern Territory and the Australian Capital Territory which are already covered in table 3. (b) Covers the areas of the Gascoyne, Pilbara and Kimberley.

Table 6: Effect of drought on selected industries for drier regions

listed in order of negative GRP effects (% change in output)

	Sheep	Barley	Wheat	Oth Broadacre	Beef Cattle	Dairy Cattle	Rice	Cotton	Fruit & Nuts	Grapes	Multi-Grape	Sugar Cane	PastureIrrig	Vegetables	Other Crops	Agric. Services	Meat Products	Dairy Products	Flour, Cereals	Wine	Fibre Woven	Construction	Trade	Transport	OtherSrvcs
South West Qld	-38	-63	-66	-42	-37	1	0	-71	-36	0	-37	0	4	7	-58	-19	-5	0	0	0	-5	-13	-7	-12	-6
Nrth West NSW	-30	-64	-67	-43	-29	-41	0	-67	-34	-32	-36	0	-36	-34	-52	-16	-3	-10	2	-5	-2	-12	-7	-11	-5
Wheatbelt	-11	-36	-41	-24	-11	0	0	0	-19	-9	-21	0	-22	-20	-20	-13	4	-5	0	0	0	-8	-6	-6	-4
Mallee	-12	-64	-67	-43	-12	-19	-50	0	-30	-16	-32	0	-30	-30	-31	-15	4	-9	0	-5	0	-8	-8	-10	-4
Northern NSW	-8	-42	-47	-28	-7	-14	0	-66	-22	11	0	0	-24	-22	-51	-15	4	-5	1	0	1	-9	-5	-6	-4
Central West Qld	-38	0	0	0	-38	0	0	0	0	0	0	0	0	0	0	-18	-7	0	0	0	0	-6	-5	-9	-3
Eyre SA	-5	-41	-45	-27	3	0	0	0	0	0	0	0	-17	0	-16	-14	5	0	-2	0	0	-8	-5	-7	-3
Murray NSW	-14	-65	-68	-44	-14	-23	-50	0	-33	-20	-35	0	-33	-33	-34	-14	1	-10	-1	-5	0	-7	-5	-9	-3
Murrumbidgee	-14	-62	-66	-42	-13	-22	-50	0	-29	-15	0	0	-30	-29	-30	-14	2	-6	-1	-5	-1	-5	-6	-7	-3
Wimmera	-9	-38	-43	-26	-7	0	0	0	-19	-17	0	0	-20	6	-20	-14	3	-7	0	-6	0	-5	-5	-9	-3
Yorke, LwrNorth	-4	-33	-39	-23	-4	-5	0	0	-12	-9	0	0	-13	0	-13	-14	3	0	-2	-6	-1	-4	-4	-7	-2
Murray Lnds SA	-9	-55	-59	-37	-8	-15	0	0	-24	-1	-6	0	-25	-24	-25	-15	1	-9	-2	-5	0	-4	-5	-7	-2
Darling Downs	-11	-42	-47	-28	-10	-18	0	-58	-20	-18	-23	0	-23	-21	-39	-14	-1	-9	-1	0	-3	-4	-4	-5	-2
Great Southern	-6	-34	-39	-23	-5	-10	0	0	-14	-11	0	0	-17	-15	-15	-13	4	-7	0	-6	0	-3	-5	-5	-2
CentWest NSW	-12	-64	-67	-43	-12	-20	0	0	-30	-27	0	0	-31	-31	-32	-15	0	-9	-2	-7	-2	-3	-4	-5	-2
Far West NSW	-30	-66	-69	0	-29	0	0	-72	-36	10	-38	0	0	0	5	-17	-7	0	0	-6	0	-3	-3	-5	-2
Mid West WA	-9	-17	-24	-14	-8	0	0	0	0	0	0	0	4	0	-15	-14	2	0	0	0	0	0	-4	-7	-1
Goulburn Vic	-12	-40	-45	-27	-11	-19	-50	0	-22	-17	-25	0	-24	-23	-24	-15	0	-11	-2	-7	-3	-2	-3	-3	-1

The next most affected region is Central West Queensland which has a projected GRP reduction of 14 per cent relative to the base case in 2002-03. It is likely that this region, among a number of other regions, will be slow to recover from the drought as its agricultural output consists of sheep and beef cattle, and it may therefore have been subject to significant destocking.

6. Impacts at the sectoral level

In Table 6 we show the percentage changes in the output of 25 selected industries for each of the 18 regions worst affected by the drought (in GRP terms) in 2002-03. Outputs for a number of agricultural industries decline dramatically. Negative flow-on effects, although not as large, can also be seen in those industries that process agricultural products. There are negative effects on trade and transport sectors that supply both margin services on the sales of agricultural products and form part of farmers' consumption expenditure. The construction industry contracts in these regions as investors, at least temporarily, transfer their investment activities to non-agricultural regions.

For the agricultural industries the large negative effects on output are not matched by similar reductions in employment. Indeed, employment in the agricultural industries is projected to change little due to the drought, for reasons discussed in the next section. However, the processing and service-sector industries shown to lose output in Table 6 reduce their employment by a slightly greater percentage than their output. Thus, there are only seven regions for which more than a fifth of the total number of jobs lost in the region are in the agricultural sector.

The limited contraction in agricultural employment explains why the rural regions suffer a much smaller percentage reduction in total employment than in GRP, while there is a slightly greater percentage contraction in aggregate employment than in GRP in the capital city regions.

7. Modelling issues arising from this application

Intermediate input usage with CGE models typically follows a “Leontief” structure – that is, the physical quantity of intermediate inputs used per unit of output is, at a given technology, constant and independent of price. Therefore, for commodities sold entirely to other industries, demand is rather inelastic. Inelastic demands created a major modelling problem in our drought scenario, as we combine extraordinary supply shocks with these inelastic demands. This results in very large price increases, beyond what we observe in practice. To deal with this, we allowed some substitution between different intermediate inputs. It does not make intuitive sense to allow much substitution; that would imply that we could convert base metal ores into gold with sufficient relative price changes without changing the technology, or reduce the grape content of wine below legal limits. In another sense, a little “alchemy” is quite reasonable: when an input becomes very scarce, we may put extra effort into minimising wastage. In our modelling, we settled on an intermediate input substitution parameter of 0.15.

Another way we adapted the model for drought was to increase the magnitude of the Armington or import substitution elasticities. Grain imports in Australia are usually negligible due to quarantine restrictions. Late in 2002, quarantine restrictions were temporarily relaxed to allow the importation of feed grain. This provides a real world justification for greatly enlarging the relevant elasticity in the model to deal with a drought scenario.

In our modelling of dairy cattle, the output declines are not large enough to exceed the additional labour hired per unit of output in response to productivity declines. That is, the percentage decline in output is less than the percentage decline in productivity, so the hiring of mobile factors increases. It is possible that own-labour inputs on dairy holdings may increase in a drought—because keeping livestock alive requires extra hours of work checking water supplies and hand feeding. However, the main reason for dairy cattle labour increasing within the model is that the sector sells almost entirely to the dairy products sector, and faces no import competition. With zero imports in the database, adjusting the Armington parameter has no effect, while adjusting the intermediate input substitution elasticity has negligible effect.

8. Conclusions

Fifty years ago, agriculture's share of GDP in Australia was around 20 per cent (Maddock and McLean, 1987). Now, it is less than 4 per cent (ABS 2002). Despite the relative decline of agriculture, a widespread drought can still have observable impacts on Australia's economy. Using a new CGE model of the statistical divisions of Australia, we have ascribed output shocks based on ABARE estimates, and productivity shocks related to rainfall deficits, in projecting the impacts on different regions of the Australian economy. The effect of the drought has been to reduce severely agricultural output in most regions. On average Australian agricultural output is estimated to be reduced by the drought by slightly under 30 per cent. Given agriculture's share of 3.6 per cent of Australian GDP, this projected contraction in agricultural output is estimated to reduce Australian GDP growth by 1 percentage point. A further 0.6 percentage points is expected to be cut from GDP growth due to negative multiplier effects.

Our modelling indicates that Australian employment will be almost 0.8 per cent lower on average in 2002-03 than would have been the case in the absence of the drought. While the greatest employment contractions are projected for rural regions, the bulk of the jobs losses occur in non-agricultural sectors. Employment within the agricultural sector is not expected to change much, relative to the large output contractions, due partly to the nature of agricultural employment (i.e. a large proportion of owner-operators) and partly to the drought-induced reduction in the productivity of labour. This drought, unlike that of 1982-83, comes at a time when jobs growth is relatively strong, so that drought-induced employment losses are unlikely to cause a national jobs crisis.

The effects of the drought are mainly temporary. The El Nino weather pattern appears to have ended. While the Bureau of Meteorology (2002b) is unable to forecast exactly when the drought will end, January to March is the most common period for the El Nino effect on Australian weather to ease. Some regions will recover fully with a return to more favourable seasonal conditions, aided by low interest rates. Recovery for other regions in which livestock herd numbers have declined sharply due to prolonged drought will be much slower.

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Using a highly disaggregated multi-regional single-country model to analyse the impacts of the 2002-03 drought on Australia

by

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Abstract

TERM (The Enormous Regional Model) is a "bottom-up" CGE model of Australia which treats each region as a separate economy. TERM was created specifically to deal with highly disaggregated regional data while providing a quick solution to simulations. This makes it a useful tool for examining the regional impacts of shocks that may be region-specific. We include some details of how we prepared the TERM database, using a national input-output table, together with regional data showing output (for agriculture) and employment (in other sectors) for each of 144 sectors and 57 regions [the Australian statistical divisions]. Using a 38-sector, 45-region aggregation of the model, we simulate the short-run effects of the Australian drought of 2002-03, which was the most widespread for 20 years. The effects on some statistical divisions are extreme, with income losses of up to 20 per cent. Despite the relatively small share of agriculture in Australian GDP, the drought reduces GDP by 1.6 per cent, and contributes to a decline in unemployment and to a worsening of the balance of trade.

JEL Classification: D58, R13, N57, O13.

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Using a highly disaggregated multi-regional single-country model to analyse the impacts of the 2002-03 drought on Australia

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1. Progress in Australian regional economic modelling

The ORANI model (Dixon et al., 1982), which distinguished over 100 sectors, introduced large-scale computable general equilibrium modelling in 1977. Since then, related models have developed in several new directions. ORANI's solution algorithm combined the efficiency of linearised algebra with the accuracy of multi-step solutions, allowing the development of ever more disaggregated and elaborate models. The GEMPACK software developed by Ken Pearson (1988) and colleagues in the mid-1980s simplified the specification of new models, while cheaper, more powerful computers allowed the development of computer-intensive multi-regional and dynamic models. On the demand side, these advances have been driven by the appetite of policy-makers for sectoral, temporal, and social detail in analyses of the effects of policy or external shocks. Since parliamentary representatives are elected by regions, demand for regional detail is particularly strong.

To meet this need, even early versions of ORANI (see Dixon *et al.* 1978) included a "top-down" regional module to work out the regional consequences of national economic changes: national results for quantity variables were broken down by region using techniques borrowed from input-output analysis. From 8 to 100 regions could easily be distinguished. Region-specific demand shocks could be simulated, but, since price variables were not given a regional dimension, there was little scope for region-specific supply shocks[2]. On the other hand, the "top-down" approach did not need much extra data or computer power.

A second generation of regional CGE models adapted ORANI by adding two regional subscripts (source and destination) to most variables and equations. In this "bottom-up" type of multi-regional CGE model, national results are driven by (ie, are additions of) regional results. Liew (1984), Madden (1989) and Naqvi and Peter (1995) describe several Australian examples. Dynamic versions of such models have followed (Giesecke 1997). The best-known example of this type of regional model is the Monash Multiregional Forecasting model, MMRF (Adams *et al.* 2002).

Bottom-up models allow simulations of policies that have region-specific price effects, such as a payroll tax increase in one region only. They also allow us to model imperfect factor mobility (between regions as well as sectors). Thus, increased labour demand in one region may be both choked off by a local wage rise and accommodated by migration from other regions. Unfortunately models like MMRF pose formidable data and computational problems—limiting the amount of sectoral and regional detail. Only 2 to 8 regions and up to 40 sectors could be distinguished[3]. Luckily, Australia has only 8 states, but size limitations have hindered the application of similar models to larger countries with 30 to 50 provinces, and have hitherto prevented us from distinguishing smaller, sub-state regions.

Finer regional divisions are desirable for several reasons. Policy-makers who are concerned about areas of high unemployment or about disparities between urban and rural areas desire more detailed regional results. Environmental issues, such as water management, often call for smaller regions that can map watershed or other natural boundaries more closely. Finally, more and smaller regions give CGE models a greater sense of geographical realism, closing the gap between CGE and LUTE (Land Use Transportation Energy) modelling.

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[2] Such limitations could be partially circumvented: see Higgs et al., 1988.

[3] More precisely, these 2nd-generation models (like MMRF) become rather large and slow to solve as the product: (number of regions) x (number of sectors) exceeds 300. TERM raises this limit to about 2500.

This paper outlines a new model with greater disaggregation of regional economies than previously available. The bottom-up TERM (The Enormous Regional Model) model allows us to analyse effects for each of 57 statistical divisions within Australia. Our application of the model in this paper is not to a policy scenario, but rather to a depiction of the Australian drought of 2002. Although widespread, the severity of the drought varied greatly between regions: rainfall ranged from 80% to 5% of the norm. As each region within the model has its own input-output database and agricultural product mix, TERM is uniquely equipped to estimate the varying impact of the drought on different regions. Our simulation depicts short-run effects, as we anticipate that most regions will recover from drought as the El Nino pattern breaks up.

2. The structure of TERM

The key feature of TERM, in comparison to predecessors such as MMRF, is its ability to handle a greater number of regions or sectors. The greater efficiency arises from a more compact data structure, made possible by a number of simplifying assumptions. For example, TERM assumes that all users in a particular region of, say, vegetables, source their vegetables from other regions according to common proportions. The data structure is the key to TERM's strengths.

Figure 1 is a schematic representation of the model's input-output database. It reveals the basic structure of the model. The rectangles indicate matrices of flows. Core matrices (those stored on the database) are shown in bold type; the other matrices may be calculated from the core matrices. The dimensions of the matrices are indicated by indices (c, s, i, m, etc) which correspond to the following sets:

Table 1: Main sets of the TERM model

Index	Set name	Description	Typical size
s	SRC	(dom,imp) Domestic or imported (ROW) sources	2
c	COM	Commodities	40
m	MAR	Margin commodities (Trade, Road, Rail, Boat)	4
i	IND	Industries	40
o	OCC	Skills	8
d	DST	Regions of use (destination)	30
r	ORG	Regions of origin	30
p	PRD	Regions of margin production	30
f	FINDEM	Final demanders(HOU, INV,GOV, EXP);	4
u	USER	Users = IND union FINDEM	44

The sets DST, ORG and PRD are in fact the same set, named according to the context of use.

The matrices in Figure 1 show the value of flows valued according to 3 methods:

1) Basic values = Output prices (for domestically-produced goods), or CIF prices (for imports)
2) Delivered values = Basic + Margins
3) Purchasers' values = Basic + Margins + Tax = Delivered + Tax

The matrices on the left-hand side of the diagram resemble (for each region) a conventional single-region input-output database. For example, the matrix USE at top left shows the delivered value of demand for each good (c in COM) whether domestic or imported (s in SRC) in each destination region (DST) for each user (USER, comprising the industries, IND, and 4 final demanders: households, investment, government, and exports). Some typical elements of USE might show:

USE("Wool","dom","Textiles","North") : domestically-produced wool used by the textile industry in North

USE("Food","imp","HOU","West") : imported food used by households in West

USE("Meat","dom","EXP","North") : domestically-produced meat exported from a port in North. Some of this meat may have been produced in another region.

USE("Meat","imp","EXP","North") : imported meat re-exported from a port in North

As the last example shows, the data structure allows for re-exports (at least in principle). All these USE values are "delivered": they include the value of any trade or transport margins used to bring goods to the user. Notice also that the USE matrix contains no information about regional sourcing of goods.

The TAX matrix of commodity tax revenues contains an element corresponding to each element of USE. Together with matrices of primary factor costs and production taxes, these add to the costs of production (or value of output) of each regional industry.

In principle, each industry is capable of producing any good. The MAKE matrix at the bottom of Figure 1 shows the value of output of each commodity by each industry in each region. A subtotal of MAKE, MAKE_I, shows the total production of each good (c in COM) in each region d.

TERM recognizes inventory changes in a limited way. First, changes in stocks of imports are ignored. For domestic output, stock changes are regarded as one destination for industry output (ie, they are dimension IND rather than COM). The rest of production goes to the MAKE matrix.

The right hand side of Figure 1 shows the regional sourcing mechanism. The key matrix is TRADE, which shows the value of inter-regional trade by sources (r in ORG) and destinations (d in DST) for each good (c in COM) whether domestic or imported (s in SRC). The diagonal of this matrix (r=d) shows the value of local usage which is sourced locally. For foreign goods (s="imp") the regional source subscript r (in ORG) denotes the port of entry. The matrix IMPORT, showing total entry of imports at each port, is simply an addup (over d in DST) of the imported part of TRADE.

The TRADMAR matrix shows, for each cell of the TRADE matrix the value of margin good m (m in MAR) which is required to facilitate that flow. Adding together the TRADE and TRADMAR matrix gives DELIVRD, the delivered (basic + margins) value of all flows of goods within and between regions. Note that TRADMAR makes no assumption about where a margin flow is produced (the r subscript refers to the source of the underlying basic flow).

Matrix SUPPMAR shows where margins are produced (p in PRD). It lacks the good-specific subscripts c (COM) and s (SRC), indicating that, for all usage of margin good m used to transport any goods from region r to region d, the same proportion of m is produced in region p. Summation of SUPPMAR over the p (in PRD) subscript yields the matrix SUPPMAR_P which should be identical to the subtotal of TRADMAR (over c in COM and S in SRC), TRADMAR_CS. In the model, TRADMAR_CS is a CES aggregation of SUPPMAR: margins (for a given good and route) are sourced according to the price of that margin in the various regions (p in PRD).

TERM assumes that all users of a given good (c,s) in a given region (d) have the same sourcing (r) mix. In effect, for each good (c,s) and region of use (d) there is a broker who decides for all users in d whence supplies will be obtained. Armington sourcing is assumed: the matrix DELIVRD_R is a CES composite (over r in ORG) of the DELIVRD matrix.

A balancing requirement of the TERM database is that the sum over user of USE, USE_U, shall be equal to the sum over regional sources of the DELIVRD matrix, DELIVRD_R.

It remains to reconcile demand and supply for domestically-produced goods. In Figure 1 the connection is made by arrows linking the MAKE_I matrix with the TRADE and SUPPMAR matrices. For non-margin goods, the domestic part of the TRADE matrix must sum (over d in DST) to the corresponding element in the MAKE_I matrix of commodity supplies. For margin goods, we must take into account both the margins requirement SUPPMAR_RD and direct demands TRADE_D.

At the moment, TERM distinguishes only 4 final demanders in each region:

(a) HOU: the representative household
(b) INV: capital formation
(c) GOV: government demand
(d) EXP: export demand.

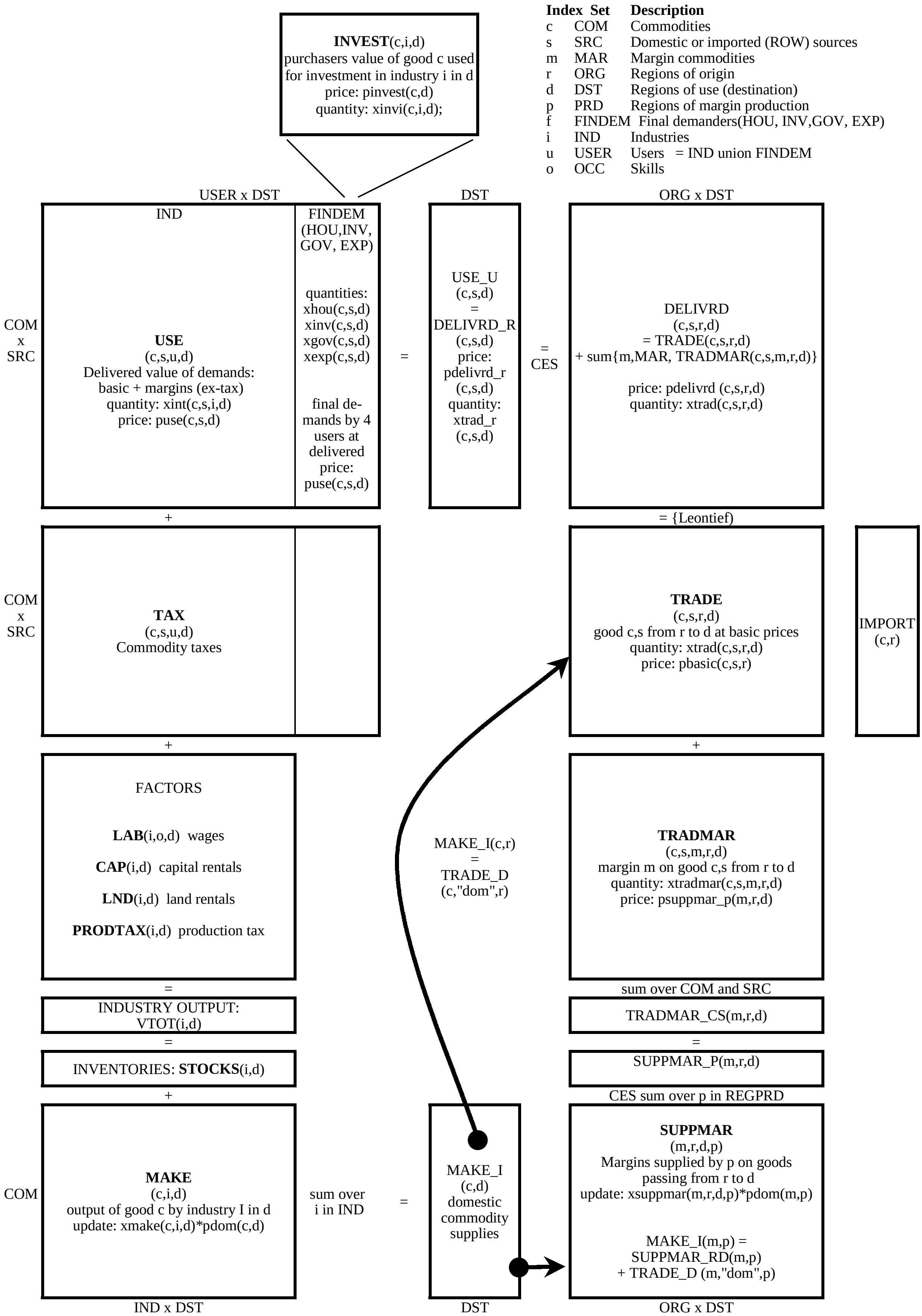

Figure 1: The TERM flows database

For many purposes it is useful to break down investment according to destination industry. The satellite matrix INVEST (subscripted c in COM, i in IND, and d in DST) serves this purpose. It allows us to distinguish the commodity composition of investment according to industry: for example, we would expect investment in agriculture to use more machinery (and less construction) than investment in dwellings.

MMRF includes SAM-like modelling of regional governments' income and expenditure. For the Australian[4] version of TERM, the 57 regions correspond to 'statistical divisions' which do not entirely correspond with administrative regions. Hence, regional government finances are not modelled in this version of TERM.

2.1. TERM sourcing mechanisms

Figure 2 illustrates the details of the TERM system of demand sourcing. Although the figure covers only the demand for a single commodity (Vegetables) by a single user (Households) in a single region (North), the same diagram would apply to other commodities, users and regions. The diagram depicts a series of 'nests' indicating the various substitution possibilities allowed by the model. Down the left side of the figure, boxes with dotted borders show in upper case the value flows associated with each level of the nesting system. These value flows may also be located in Figure 1. The same boxes show in lower case the price (p....) and quantity (x....) variables associated with each flow. The dimensions of these variables are critical both to the usefulness of the model and to its computational tractability; they are indicated by subscripts c, s, m, r, d and p, as explained in Table 1. Most of what is innovative in TERM could be reconstructed from Figures 1 and 2.

At the top level, households choose between imported (from another country) and domestic vegetables. A CES or Armington specification describes their choice—as pioneered by ORANI and adopted by most later CGE models. Demands are guided by user-specific purchasers' prices (the purchasers' values matrix PUR is found by summing the TAX and USE matrices of Figure 1). 2 is a typical value for the elasticity of substitution.

Demands for domestic vegetables in a region are summed (over users) to give total value USE_U (the "_U" suffix indicates summation over the user index u). The USE_U matrix is measured in "delivered" values—which include basic values and margins (trade and transport), but not the user-specific commodity taxes.

The next level treats the sourcing of USE_U between the various domestic regions. The matrix DELIVRD shows how USE_U is split between origin regions r. Again a CES specification controls the allocation; substitution elasticities range from 5 (merchandise) to 0.2 (services). The CES implies that regions which lower production costs more than other regions will tend to increase their market share. The sourcing decision is made on the basis of delivered prices—which include transport and other margin costs. Hence, even with growers' prices fixed, changes in transport costs will affect regional market shares. Notice that variables at this level lack a user (u) subscript—the decision is made on an all-user basis (as if wholesalers, not final users, decided where to source vegetables). The implication is that, in North, the proportion of vegetables which come from South is the same for households, intermediate, and all other users.

The next level shows how a "delivered" vegetable from, say, South, is a Leontief composite of basic vegetable and the various margin goods. The share of each margin in the delivered price is specific to a particular combination of origin, destination, commodity and source. For example, we should expect transport costs to form a larger share for region pairs which are far apart, or for heavy or bulky goods. The number of margin goods will depend on how aggregated is the model database. Under the Leontief specification we preclude substitution between Road and Retail margins, as well as between Road and Rail. For some purposes it might be worthwhile to construct a more elaborate nesting which accommodated Road/Rail switching.

[4] TERM has also been applied to Brazil and Indonesia.

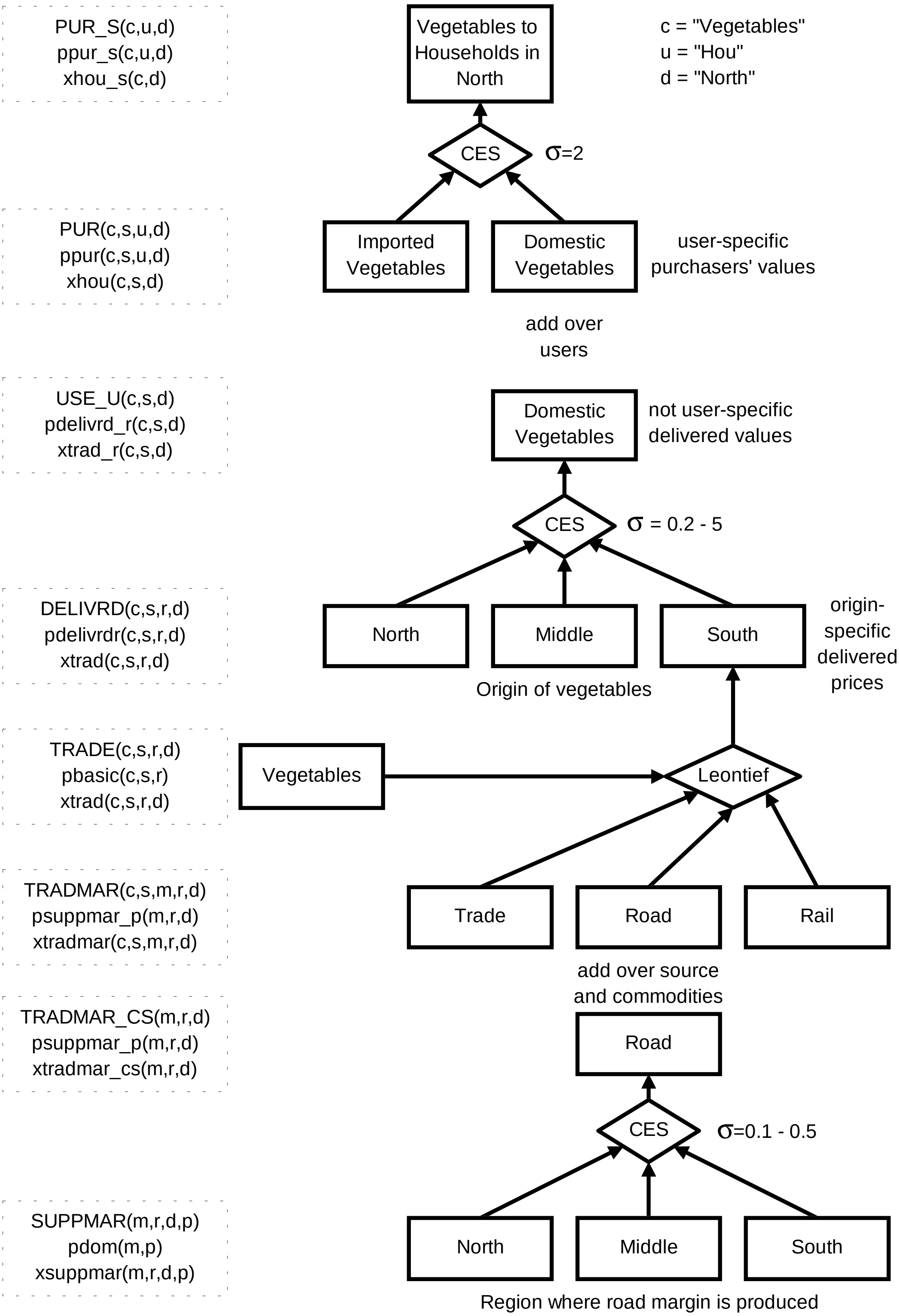

Figure 2: TERM sourcing mechanisms

The bottom part of the nesting structure shows that margins on vegetables passing from South to North could be produced in different regions. The figure shows the sourcing mechanism for the road margin. We might expect this to be drawn more or less equally from the origin (South), the destination (North) and regions between (Middle), There would be some scope (σ=0.5) for substitution, since trucking firms can relocate depots to cheaper regions. For retail margins, on the other hand, a larger share would be drawn from the destination region, and scope for substitution would be less (σ=0.1). Once again, this substitution decision takes place at an aggregated level. The assumption is that the share of, say, Middle, in providing Road margins on trips from South to North, is the same whatever good is being transported.

Although not shown in Figure 2, a parallel system of sourcing is also modelled for imported vegetables, tracing them back to port of entry instead of region of production.

2.2. Other features of TERM

The remaining features of TERM are common to most CGE models, and in particular to ORANI, from which TERM descends. Industry production functions are of the nested CES type: Leontief except for substitution between primary factors and between sources of goods. Exports from each region's port to the ROW face a constant elasticity of demand. The composition of household demand follows the linear expenditure system, while the composition of investment and government demands is exogenous. A variety of closures are possible. For the shortrun simulation we describe below, industry capital stocks and land endowments were held fixed, whilst labour was fully mobile between sectors within a region and partially mobile between regions. At the regional level, household consumption tended to follow regional income.

2.3. Comparison with the GTAP model

GTAP, a well-known model of the world economy, has a fairly similar structure to TERM. The "regions" of GTAP, however, are countries or groups of countries, whilst in TERM they are regions within a single country. In GTAP, regional trade deficits must sum to zero [the planet is a closed system] whilst in TERM a national trade deficit is possible. There are also differences in data structures: TERM models import/domestic substitution at the user level, whilst in GTAP this decision is modelled at a regional, all-user level. GTAP has a far more detailed representation of bilateral trade taxes than does TERM, reflecting the freer trade that is usually possible within a nation. TERM can accommodate commodity tax rates that vary between regions (North might tax whisky more than South) but it does not allow for regional tax discrimination (such as a tax, in North, that applied only to whisky from West). Inter-regional labour movements, a rarity in GTAP, are usual in TERM. Finally, TERM has a particularly detailed treatment of transport margins.

3. Gathering data for 144 sectors and 57 regions

As formidable as the computational demands of regional CGE models, are the data requirements—which usually far exceed what is available. Regional input-output tables and trade matrices, as depicted in Figure 1 are not available for Australia. Thus, a vital counterpart to TERM is a strategy, depicted in Figure 3, to estimate its database from very limited regional data. The key features of this strategy are:

(a) The process starts with a national input-output table and certain regional data. The *minimum* requirements for regional data are very modest: the distribution between regions of industry outputs and of final demand aggregates. Additional regional detail, such as region-specific technologies or consumption preferences may be added selectively, when available.

(b) The process is automated, so that additional detail can easily be added at a later stage.

(c) The database is constructed at the highest possible level of detail: 144 sectors and 57 regions. Aggregation (for computational tractability) takes place at the end of the process, not at the beginning. Perhaps surprisingly, the high level of disaggregation is often helpful in estimating missing data. When aggregated, the model database displays a richness of structure that belies the simple mechanical rules that were used to construct its disaggregated parent. For example, even though we normally assume that a given disaggregated sector has the same input-output coefficients wherever it is located, aggregated sectors display regional differences in technology. Thus, sectoral detail partly compensates for missing regional data.

3.1. The national input-out database

As shown in Figure 3, the TERM data process starts from the 1997 Australian input-output Tables, distinguishing 107 sectors. Our first step was to convert these tables to the file format of ORANI-G, a standard single-country CGE model. Next, working at the national level, we expanded the 107 sectors to 144. In choosing to split sectors, we hoped to avoid infelicities of classification that have caused problems in the past (such as the lumping together of exports of sugar, cotton and prawns) and also to split up sectors which showed regional differences in composition. For example, we split up electricity generation according to the fuel used (which differs among Australian regions) and added considerable agricultural detail. The interests of one collabarator led to a remarkably detailed treatment of the wine and grape sectors, which were divided according to quality (some regions produce high-quality wine for export, others a cheaper brew for local drinking).

The main source for the sectoral split was unpublished ABS commodity cards data. Such data provide a split of sales for approximately 1,000 commodities to 107 industries, plus final users. However, the cards data do not always provide a desirable split from the 107 industries to the eventual 144 sectors of the disaggregated database. For example, there are significant sales of sugarcane to the other food products sector (107-sector aggregation). We allocated all sugarcane sales to refined sugar and zero sales to the seafood and other food products in our 144-sector disaggregation. When the intermediate sales split was less obvious, we used activity weights of the purchasing sectors for the split.

The 144-sector national database has an independent value for our modelling work (for example, it forms the bulk of the MONASH database). For TERM purposes it was converted to a simpler format prior to the addition of regional detail.

3.2. Estimates of the regional distribution of output and final demands

The next step was to obtain, for each industry and final demander, an estimate of each statistical division's share of national activity (these shares are the R001, R002, etc, of Figure 3). To develop a full input-output table for each region, we required estimates of industry shares (i.e., each region's share of national activity for a given industry), industry investment shares, household expenditure shares, international export and import shares, and government consumption shares.

The main data sources for the industry split were:

- AgStats data from ABS, which details agricultural quantities and values at the SD level;
- employment data by industry at the SD level prepared by our colleague Tony Meagher from ABS census data and surveys;
- published ABS manufacturing census data (state level); and
- state yearbooks (for mining, ABS 1301.* and, for grapes and wine, ABS 1329.0).

Our sectoral split included a split of electricity into generation by fuel type plus a distribution sector. We relied on the internet sites of various electricity and energy agencies for capacity levels, on which shares of national activity were based.

Manufacturing, mining and services data disaggregated at the statistical division level were in quantities rather than values. These were adjusted these to fit state account sector aggregates (ABS 5220.0), as wages and industry composition vary between states. Industry investment shares are similar to industry activity shares for most sectors. Exceptions include residential construction input shares, set equal to ownership of dwellings investment shares in each statistical division.

Published ABS data (Tables 4 and 5, ABS 6530.0) provide sufficient commodity disaggregation for the task of splitting regional consumption aggregates into commodity shares. Such data also provide a split between capital city regions and other regions within each state.

In compiling international trade data by region, we first gathered trade data by port of exit or entry. For this task, we used both unpublished ABS trade data available for each state and territory plus the annual reports of various ports authorities. Queensland Transport's annual downloadable publication *Trade Statistics for Queensland Ports* gives enough data to estimate exports by port of exit with reasonable accuracy for that state. For other states, port activity is less complex, with most manufacturing trade passing through capital city ports and regional ports specialising in mineral and grain shipments.

State accounts data provide aggregated Commonwealth and state government spending in each region (ABS 5220.0). Employment numbers by statistical division for government administration and defence provide a useful split for these large public expenditure items. For other commodities, population shares by statistical division were used to calculate the distribution of Commonwealth and state government spending across regions.

By applying these shares to the national CGE database, we were able to compute the USE, FACTOR, and MAKE matrices on the left-hand side of Figure 1. None of these matrices distinguish the source region of inputs.

3.3. The TRADE matrix

The next stage was to construct the TRADE matrix on the right-hand side of Figure 1. For each commodity either domestic or imported, TRADE contains a 57x57 submatrix, where rows correspond to region of origin and columns correspond to region of use. Diagonal elements show production which is locally consumed. As shown in Figure 3 we already know both the row totals (supply by commodity and region) and the column totals (demand by commodity and region) of these submatrices. For Australia, hardly any detailed data on inter-regional state trade is available. We used the gravity formula (trade volumes follow an inverse power of distance) to construct trade matrices consistent with pre-determined row and column totals. In defence of this procedure, two points should be noted:

- Wherever production (or, more rarely, consumption) of a particular commodity is concentrated in one or a few regions, the gravity hypothesis is called upon to do very little work. Because our sectoral classification was so detailed, this situation occurred frequently.
- Outside of the state capitals, most Australian regions are rural, importing services and manufactured goods from the capital cities, and exporting primary products through a nearby port. For a given rural region, one big city is nearly always much closer than any others, and the port of exit for primary products is also well defined. These facts of Australian geography again reduce the weight borne by the gravity hypothesis.

3.4. Aggregation

Even though TERM is computationally efficient, it would be slow to solve if a full 144-sector, 57-region database were used. The next stage in the data procedure is to aggregate the data to a more manageable size. The aggregation choice is application-specific. For the simulation reported below, we distinguished 45 regions but only 38 sectors. The sectoral aggregation was most detailed in the agricultural and agriculture-related sectors, while manufacturing and service industries were grouped broadly.

As Figure 3 shows, we routinely aggregate TERM's 57 regions into the 8 Australian states. The resulting aggregated database forms the kernel of the MMRF database. MMRF is still the workhorse of regional CGE modelling at CoPS, since it incorporates features that TERM lacks, such as year-to-year dynamics, state government accounts, and emissions modelling. TERM is needed when sub-state detail is required, especially if supply-side shocks must be imposed which differ amongst regions within a state. The latter requirement is exemplified by the drought simulation described next.

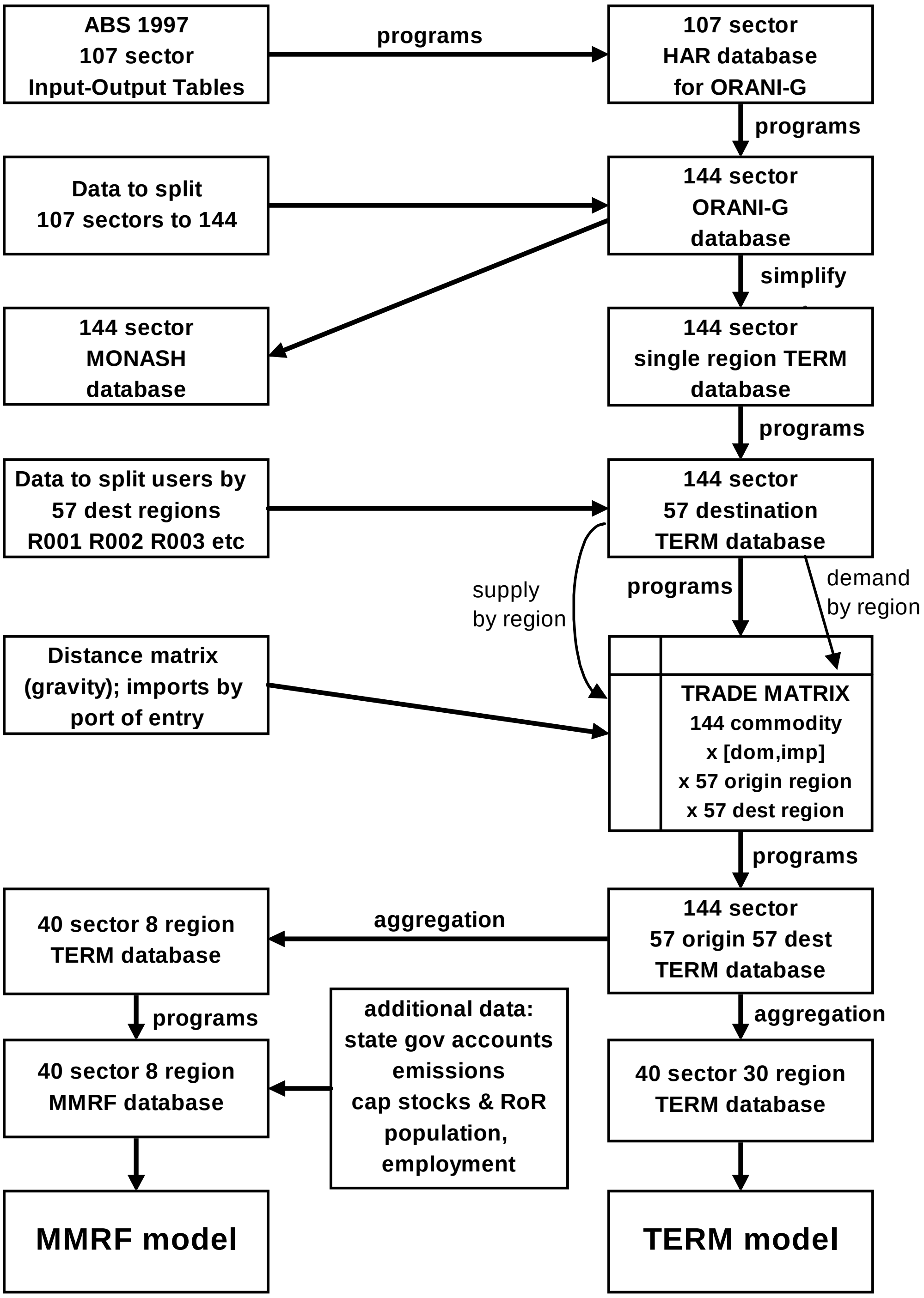

Figure 3: Producing regional databases for MMRF and TERM

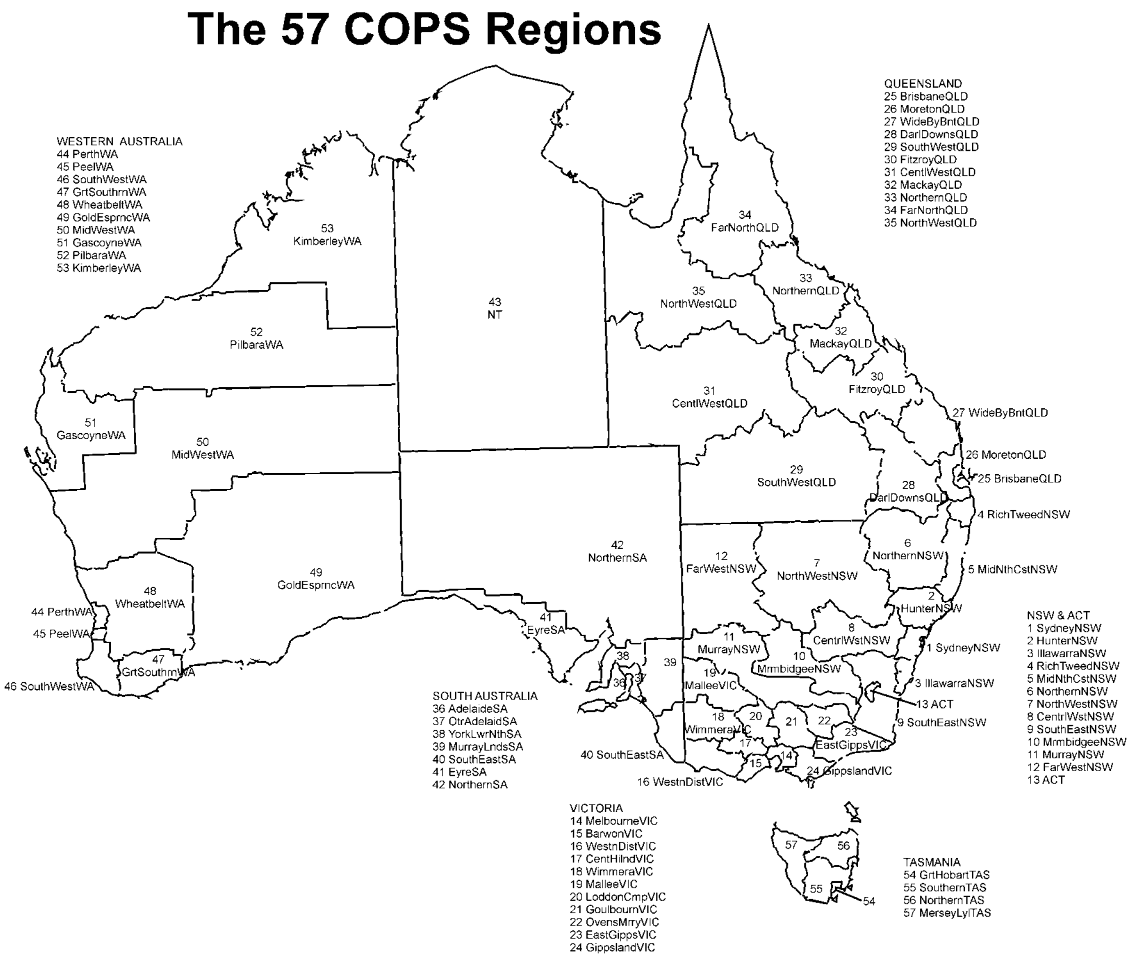

Figure 4: Statistical divisions in Australia

4. Background to the drought of 2002

Even in a drought as widespread as that of 2002, the impact on farmers varied widely across regions. For example, some grain growers around Adelaide, the south east of South Australia and south-western Victoria realised near-average harvests. Yet on eastern Eyre Peninsula, in the Murray districts and northerly grain growing areas of South Australia, in north-western Victoria and western New South Wales, many farmers suffered substantial or total crop failure.

Rainfall deficits generally have been worse in inland grain-growing regions than in coastal regions. This has meant a bleaker outlook for grains than some other crops, but it also has meant that the same agricultural product is likely to be affected differently in different regions. The level of industry and regional detail in the TERM model provides a unique tool for estimating both the regional and macroeconomic effects of the current drought. Regions are either statistical divisions or combinations of statistical divisions. Each region has its own CGE model; these are linked by matrices of trade flows. Of particular relevance for the current project was the formation of the agricultural component of the database, estimated using ABS agricultural output data at the statistical division level. The simulations reported here employ a 1996-97 database. Nineteen of the 38 industries are in the agricultural sector.

4.1. Estimating the direct impact of drought at the regional level

The Bureau of Meteorology (2002a) recorded April to December 2002 as one of the most severe and widespread droughts on record for a 9-month period. In terms of the proportion of the nation recording rainfall below the 10th percentile for nine months, this period was the second worst on record. In terms of the mean percentile value, this period was the worst on record (Table 2). While few regions have registered record low rainfall totals, Figure 5 shows that a large area of Australia suffered severe rainfall deficiencies in 2002.

Table 2: The extent of the drought

Rank	9-month period	% of Australia below 10th percentile	Rank	9-month period	Mean Australian percentile value
1	Nov 1901–July 1902	58.9	**1**	April–Dec 2002	13.2
2	April–Dec 2002	58.6	**2**	March–Nov 1994	15.7
3	March–Nov 1994	52.6	**3**	April–Dec 1972	17.1
4	March–Nov 1940	49.9	**4**	March–Nov 1940	18.6
5	July 1951–Mar 1952	49.4	**5**	July 1951–Mar 1952	19.4

Source: Bureau of Meteorology (2002a)

In October ABARE (2002a) issued a special drought issue of its crop report further revising downwards its expectations for winter crop output and warning of an inauspicious outlook for summer crops. The grim 2002-03 outlook for Australian crops was confirmed in ABARE's (2002b) December crop report, with winter and summer crop output down on average on 2001-02 output by 56 per cent and 59 per cent respectively.

For the forecasting estimates reported above our concern was with such year-on-year estimates. In this section, however, we wish to compare the impact of the drought with what otherwise would have been the case. We assume the latter to be encapsulated in ABARE's earlier 2002-03 forecasts published in the first part of 2002, before it became apparent that Australia was facing a severe drought.

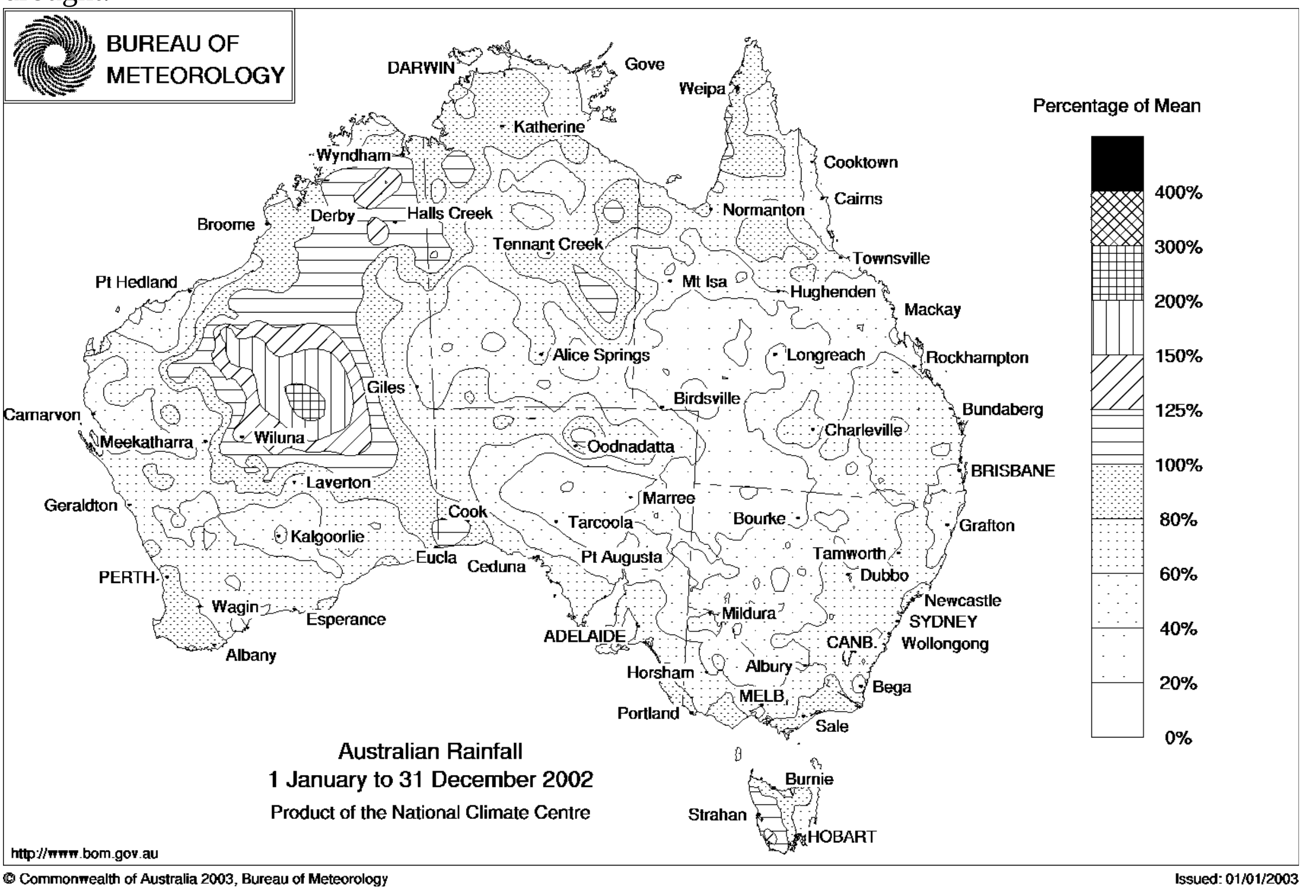

Figure 5: Rainfall deficits in Australia, 2002

To properly model the drought at the regional (statistical division) level it was important to make estimates of the direct effect of the drought on output for agricultural industries within individual statistical divisions. We did this by developing estimation formulae that computed productivity losses due to the drought for each agricultural industry in each region. The formulae related the productivity losses to rainfall deficits in individual regions which, in turn, were estimated from district rainfall deficit figures (for specific periods up to 31/10/02) available from the Bureau of Meteorology. Separate formulae were developed for different types of crops and for livestock. For example, for winter grains grown in southern Australia, we assumed that the productivity loss for the crop in a particular region was a progressively increasing function of the 3-month rainfall deficit, and was also affected to a lesser extent by the 6-month deficit. Thus as the severity of the 3-month rainfall deficit increased, productivity losses were estimated to become increasingly greater at the margin. Other crops were either linearly or progressively related to combinations of 3-month, 6-month and 18-month rainfall deficits. In each case, regional industry productivity losses were adjusted so that the simulation result for the effect of the drought on the Australia-wide output of the industry coincided with the difference between the latest ABARE 2002-03 output forecast and the Bureau's earlier forecast for the industry.

For cattle and sheep grazing, we used 18-month rainfall deficits to estimate the productivity impact of the drought. However, using ABARE's estimates for the Australia-wide output effects on the various livestock industry presented a particular difficulty. ABARE (2002c) forecasts a modest overall increase above the 2001-02 figure in the number of livestock slaughtered and also a small increase in meat produced. The latter increase is by only a slightly smaller percentage than the former, apparently indicating only limited deterioration in the quality of the livestock slaughtered. However, for the most severely affected regions, where the 18-month rainfall deficits have been extreme, it would appear that de-stocking may have been the dominant response to the drought. We adjusted the ABARE estimates to account for some of the livestock sales in the worst affected regions, treating these as disinvestment rather than increased production. Thus for regions such as Central West and South West Queensland we ascribed a near zero level of investment to livestock sectors. Our 2002-03 results may still not fully capture the negative effects of the drought on some livestock regions as it is not possible to gauge properly the degree to which maintaining livestock sales has been via de-stocking. Reduced herd numbers can also be expected to have an effect on certain regions well beyond 2002-03.

We also recognised in our modelling that in less severely affected livestock regions, especially with the expectation of the drought breaking relatively early in 2003, increased feed grain would be used to keep livestock alive. Feed-grain-using productivity losses in livestock industries were computed on the basis of rainfall deficits, in order to capture this effect.

5. Impacts at the regional and national levels and a historical comparison

Table 3 shows the results for the macroeconomic effects of the drought generated by the TERM simulation. It can be seen from the first row of the final column that we expect the drought to lower Australian GDP by 1.6 per cent. One percentage point of this relates to reductions in value added in the agriculture sector (row 2), while the remaining 0.6 percentage point (row 3) is contributed by other industries suffering negative multiplier effects.

The bottom two rows of Table 3 show that the drought is projected to have considerable adverse effects on the Australian labour market in 2002-03. It will be noticed that the drought is projected to cause a reduction both in employment and in the national real wage rate of a little under 1 per cent. This reflects our assumption that the temporary drought-induced reduction in the demand for labour will be shared between a decline in employment and a decline in real wages. Capital stocks are fixed in each sector in each region.

Our assumption regarding adjustment in the labour market limits the degree of multiplier effects of the drought. The fall in economy-wide employment accounts for only 0.4 percentage points of the projected negative effect of the drought on GDP, while reductions in the indirect tax base accounts for a further 0.2 per cent reduction in GDP.

Both real investment and real household consumption are projected to suffer a smaller percentage reduction than GDP. Again this reflects our assumptions about the macroeconomic environment. In the case of household consumption we expect reductions in expenditure to be ameliorated by increased borrowing (particularly given the current low interest rates), increased government benefits (e.g. unemployment benefits and government relief schemes) and, for severely-affected farmers, deferrals in investments in machinery. Using these considerations we set a particular ratio for the percentage change in real household expenditure to the percentage change in gross regional product (GRP) for each of the 45 regions. It can be seen from Table 3 that the drought-induced percentage decline in real consumption is slightly under half the percentage decline in GDP.

The reduction in real investment of 0.9 per cent is made up entirely of falls in investment in the agricultural sector, particularly the postulated marked reductions in investment in livestock in the sheep and cattle industries. We assume that, given widespread expectations that the drought will not continue very much longer, there will be no overall change in the non-agricultural level of real investment from what would otherwise have been the case.

Table 3: Macroeconomic impacts of drought, 2002-03

Percentage change relative to base case

	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	Aust
Real GDP (total)	-1.9	-1.2	-2.0	-1.9	-1.5	0.3	-0.1	-0.1	-1.6
-- Agriculture contribution	-1.2	-0.7	-1.2	-1.4	-1.2	0.3	-0.1	0.0	-1.0
-- Other industries contribution	-0.7	-0.5	-0.8	-0.5	-0.3	0.0	0.0	-0.1	-0.6
Real consumption	-0.9	-0.5	-0.9	-0.8	-0.6	0.1	0.0	-0.1	-0.7
Real investment	-1.6	-0.7	-1.2	-1.6	0.3	1.6	-0.5	2.1	-0.9
Export volume	-2.7	-4.3	-3.8	-12.1	-8.8	-3.0	0.5	-1.1	-5.0
Import volume	-0.4	0.1	-0.4	-0.4	0.1	1.3	0.3	0.5	-0.2
Export prices	0.7	1.2	1.0	2.8	1.8	0.8	-0.1	0.3	1.2
Employment	-0.9	-0.6	-1.1	-0.7	-0.5	0.1	-0.1	-0.2	-0.8
Average wage rate	-1.2	-0.7	-1.3	-0.8	-0.6	0.2	-0.1	-0.2	-0.9

The widespread nature of the drought can be seen through the substantial projected fall in gross state product (GSP) in all the mainland states. Queensland, New South Wales and South Australia are all projected to experience reductions in real GSP of approximately 2 per cent. New South Wales's agricultural sector is the hardest hit in percentage change terms with an overall agricultural production loss of around 45 per cent. However, NSW was the state least intensive in agriculture in 2001-02. Thus the decline in agriculture had only the same impact on GSP as it did in Queensland, where we project agriculture's output to fall by a quarter as a result of the drought. Queensland agriculture's 2001-02 share of GSP is 4.7 per cent compared with 2.5 per cent for NSW. The estimated reduction in agricultural output in both South Australia and Victoria is a little under 20 per cent, but their 2001-02 shares in total state output are 7.2 per cent and 3.6 per cent respectively. Hence, even a moderate drought has significant negative impacts on the economies of South Australia and Victoria. Western Australia with a projected reduction in overall agricultural output of around 30 per cent and a base-year agricultural share slightly above the Australian average of 3.6 per cent is projected to experience the same fall in GSP directly through agriculture's contraction as NSW and Queensland. However, the negative flow-on effects to the Western Australian economy are projected to be substantially smaller than the other two states. A major reason for this is that mining, which makes up a very large proportion of WA output relative to other states, is projected to increase its output slightly as a result of the drought-induced decline in the real wage rate.

Tasmania is the only state that is not negatively affected by the drought. While the state is quite agriculture intensive (with an agricultural share in output of over 4 per cent), it experienced a reasonable level of rainfall in 2002, with serious or severe rainfall deficits only being experienced on the east coast of the island. Tasmania is thus projected to gain from the beneficial effects of agricultural price rises without having to suffer output contractions in agricultural industries. The ACT has virtually no agricultural industry and thus suffers little from the drought. While agriculture, consisting largely of beef cattle, comprises 2.7 per cent of the Northern Territory economy, the rainfall deficit in the Territory was considered not to have had any major effect on that region's agricultural output.

A historical comparison of the effects of drought is shown in Table 4. In moving from 1982-83, when drought had a marked effect on agricultural output in all states other than Western Australia, to a good year in 1983-84, agriculture's contribution to GDP increased by 1.5 per cent. Given that downstream sectors also benefited from a seasonal recovery, that recovery in 1983-84 may have contributed as much as 2.5 per cent to GDP.[5] Our projection that real GDP declines by 1.6 per cent reflects both a drought that arguably was slightly less severe than that of 20 years ago combined with agriculture's share of national income declining in the interval.

In Table 5 we see that the effects of the drought are estimated to vary considerably across Australian regions. As expected, the largest negative effects of the drought are projected to occur outside the capital cities. Nevertheless, the capital cities are still affected by the drought, as the GRPs for Sydney/Illawarra, Melbourne/Barwon, Brisbane and Adelaide/Outer-Adelaide fall by around half a per cent.

Table 4: Agriculture's share of state factor income

	1981-82	1982-83	1983-84	2001-02	2002-03 (projected)
NSW	3.8	2.4	4.3	2.7	1.5
VIC	3.9	2.9	4.6	3.8	3.1
QLD	7.3	5.2	7.0	4.9	3.7
SA	8.2	4.9	7.3	7.5	6.2
WA	8.9	8.6	6.9	4.1	2.9
TAS	6.3	6.2	6.8	6.1	6.4
Aust	5.1	3.7	5.2	3.9	2.9

Source: ABS 5220.0; TERM projection.

While a small number of non-capital-city regions are projected to suffer smaller declines in their real GRP than the national GDP decline, rural Australia overall is projected to suffer severe output contractions in 2002-03. Eighteen out of the 45 regions in the model are projected to suffer GRP declines of over 5 per cent. A GRP reduction of greater than 10 per cent is projected for eleven of these. The 17 worst-affected regions include all 14 of Australia's regions that had 20 per cent or more of their output in the agricultural sector, reflecting the widespread nature of the drought.

The projected severity of the drought on a region can largely be explained as a combination of the region's reliance on agriculture and the severity of the drought in the region. The worst affected regions are South West Queensland (with a -21 per cent change in GRP), North West NSW (-18%), the WA Wheatbelt (-17%), the Victorian Mallee (-16%) and Northern NSW (-15%). The Wheatbelt has an agricultural share of output of 46 per cent, compared to the mid to high 20s for the other four regions. However, the other four regions have suffered an even more severe drought than the Wheatbelt.

[5] During March to November 2002, Australia's average annual maximum temperatures were the highest ever recorded for those months, compounding the drought with extreme levels of evaporation (Karoly et al. 2003)..

Table 5: Impact of drought on major regional aggregates[(a)]

	Real Household consumption	Real Investment	Real GRP	Aggregate Employment	Real Wage Rate
New South Wales					
Sydney/Illawarra	-0.2	1.1	-0.5	-0.7	-0.8
Hunter	-0.3	0.9	-0.6	-0.6	-0.8
North NSW Coast	-0.7	-0.2	-1.3	-0.8	-1.0
Northern NSW	-8.0	-12.7	-15.4	-2.9	-3.7
North West NSW	-9.6	-19.3	-18.4	-5.1	-6.3
Central West NSW	-3.5	-8.1	-6.9	-2.4	-3.0
South East NSW	-1.2	-3.3	-2.3	-1.0	-1.2
Murrumbidgee	-5.8	-10.8	-11.4	-2.7	-3.4
Murray NSW	-6.7	-13.0	-13.0	-3.3	-4.2
Far West NSW	-2.8	-4.8	-5.5	-2.0	-2.5
Victoria					
Melbourne/Barwon	-0.2	1.4	-0.4	-0.4	-0.6
Western District	-1.8	-11.3	-3.5	-1.3	-1.7
Central Highlands	-0.7	-1.1	-1.4	-0.7	-0.9
Wimmera	-5.7	-9.6	-11.1	-2.2	-2.7
Mallee	-8.1	-13.1	-15.5	-3.3	-4.1
Loddon	-0.9	-1.2	-1.8	-0.8	-0.9
Goulburn	-2.6	-6.9	-5.1	-1.4	-1.8
Ovens Murray	-0.8	-1.6	-1.7	-0.7	-0.9
Gippsland/East Gippsland	-0.5	-1.4	-1.0	-0.2	-0.3
Queensland					
Brisbane	-0.3	0.8	-0.6	-0.8	-1.0
Moreton	-0.5	0.8	-1.0	-0.8	-1.0
Wide Bay-Burnett	-1.1	0.0	-2.1	-1.0	-1.2
Darling Downs	-4.4	-7.3	-8.6	-2.3	-2.9
South West Qld	-11.1	-24.1	-21.0	-5.5	-6.9
Fitzroy	-1.3	-0.6	-2.7	-1.3	-1.6
Central West Qld	-7.3	-19.0	-14.0	-4.6	-5.7
Mackay Qld	-1.8	0.8	-3.5	-1.6	-2.0
Northern Qld	-1.6	0.7	-3.3	-1.3	-1.6
Far North Qld	-1.0	1.0	-1.9	-0.9	-1.1
North West Qld	-1.1	-3.0	-2.3	-1.0	-1.3
South Australia					
Adelaide (&Outer Adelaide)	-0.3	1.1	-0.5	-0.5	-0.6
Yorke and Lower North	-5.4	-7.9	-10.5	-2.3	-2.9
Murray Lands SA	-5.0	-5.8	-9.7	-1.3	-1.6
South East SA	-1.3	-2.2	-2.6	-0.6	-0.8
Eyre SA	-6.8	-11.3	-13.2	-3.5	-4.3
Northern SA	-1.6	-1.7	-3.1	-1.3	-1.6
Western Australia					
Perth & Sth West WA	-0.2	1.4	-0.3	-0.4	-0.5
Great Southern WA	-3.7	-9.0	-7.3	-2.3	-2.8
Wheatbelt	-8.7	-11.7	-16.6	-2.6	-3.2
Goldfields Esperance	-1.0	0.5	-2.1	-0.5	-0.6
Mid West WA	-2.8	-1.8	-5.4	-0.9	-1.1
Northern WA[(b)]	0.0	2.8	-0.1	0.3	0.4

(a) Table excludes Tasmania, the Northern Territory and the Australian Capital Territory which are already covered in table 3. (b) Covers the areas of the Gascoyne, Pilbara and Kimberley.

Table 6: Effect of drought on selected industries for drier regions
listed in order of negative GRP effects (% change in output)

	Sheep	Barley	Wheat	Oth Broadacre	Beef Cattle	Dairy Cattle	Rice	Cotton	Fruit & Nuts	Grapes	Multi-Grape	Sugar Cane	PastureIrrig	Vegetables	Other Crops	Agric. Services	Meat Products	Dairy Products	Flour, Cereals	Wine	Fibre Woven	Construction	Trade	Transport	OtherSrvcs
South West Qld	-38	-63	-66	-42	-37	1	0	-71	-36	0	-37	0	4	7	-58	-19	-5	0	0	0	-5	-13	-7	-12	-6
Nrth West NSW	-30	-64	-67	-43	-29	-41	0	-67	-34	-32	-36	0	-36	-34	-52	-16	-3	-10	2	-5	-2	-12	-7	-11	-5
Wheatbelt	-11	-36	-41	-24	-11	0	0	0	-19	-9	-21	0	-22	-20	-20	-13	4	-5	0	0	0	-8	-6	-6	-4
Mallee	-12	-64	-67	-43	-12	-19	-50	0	-30	-16	-32	0	-30	-30	-31	-15	4	-9	0	-5	0	-8	-8	-10	-4
Northern NSW	-8	-42	-47	-28	-7	-14	0	-66	-22	11	0	0	-24	-22	-51	-15	4	-5	1	0	1	-9	-5	-6	-4
Central West Qld	-38	0	0	0	-38	0	0	0	0	0	0	0	0	0	0	-18	-7	0	0	0	0	-6	-5	-9	-3
Eyre SA	-5	-41	-45	-27	3	0	0	0	0	0	0	0	-17	0	-16	-14	5	0	-2	0	0	-8	-5	-7	-3
Murray NSW	-14	-65	-68	-44	-14	-23	-50	0	-33	-20	-35	0	-33	-33	-34	-14	1	-10	-1	-5	0	-7	-5	-9	-3
Murrumbidgee	-14	-62	-66	-42	-13	-22	-50	0	-29	-15	0	0	-30	-29	-30	-14	2	-6	-1	-5	-1	-5	-6	-7	-3
Wimmera	-9	-38	-43	-26	-7	0	0	0	-19	-17	0	0	-20	6	-20	-14	3	-7	0	-6	0	-5	-5	-9	-3
Yorke, LwrNorth	-4	-33	-39	-23	-4	-5	0	0	-12	-9	0	0	-13	0	-13	-14	3	0	-2	-6	-1	-4	-4	-7	-2
Murray Lnds SA	-9	-55	-59	-37	-8	-15	0	0	-24	-1	-6	0	-25	-24	-25	-15	1	-9	-2	-5	0	-4	-5	-7	-2
Darling Downs	-11	-42	-47	-28	-10	-18	0	-58	-20	-18	-23	0	-23	-21	-39	-14	-1	-9	-1	0	-3	-4	-4	-5	-2
Great Southern	-6	-34	-39	-23	-5	-10	0	0	-14	-11	0	0	-17	-15	-15	-13	4	-7	0	-6	0	-3	-5	-5	-2
CentWest NSW	-12	-64	-67	-43	-12	-20	0	0	-30	-27	0	0	-31	-31	-32	-15	0	-9	-2	-7	-2	-3	-4	-5	-2
Far West NSW	-30	-66	-69	0	-29	0	0	-72	-36	10	-38	0	0	0	5	-17	-7	0	0	-6	0	-3	-3	-5	-2
Mid West WA	-9	-17	-24	-14	-8	0	0	0	0	0	0	0	4	0	-15	-14	2	0	0	0	0	0	-4	-7	-1
Goulburn Vic	-12	-40	-45	-27	-11	-19	-50	0	-22	-17	-25	0	-24	-23	-24	-15	0	-11	-2	-7	-3	-2	-3	-3	-1

The next most affected region is Central West Queensland which has a projected GRP reduction of 14 per cent relative to the base case in 2002-03. It is likely that this region, among a number of other regions, will be slow to recover from the drought as its agricultural output consists of sheep and beef cattle, and it may therefore have been subject to significant destocking.

6. Impacts at the sectoral level

In Table 6 we show the percentage changes in the output of 25 selected industries for each of the 18 regions worst affected by the drought (in GRP terms) in 2002-03. Outputs for a number of agricultural industries decline dramatically. Negative flow-on effects, although not as large, can also be seen in those industries that process agricultural products. There are negative effects on trade and transport sectors that supply both margin services on the sales of agricultural products and form part of farmers' consumption expenditure. The construction industry contracts in these regions as investors, at least temporarily, transfer their investment activities to non-agricultural regions.

For the agricultural industries the large negative effects on output are not matched by similar reductions in employment. Indeed, employment in the agricultural industries is projected to change little due to the drought, for reasons discussed in the next section. However, the processing and service-sector industries shown to lose output in Table 6 reduce their employment by a slightly greater percentage than their output. Thus, there are only seven regions for which more than a fifth of the total number of jobs lost in the region are in the agricultural sector.

The limited contraction in agricultural employment explains why the rural regions suffer a much smaller percentage reduction in total employment than in GRP, while there is a slightly greater percentage contraction in aggregate employment than in GRP in the capital city regions.

7. Modelling issues arising from this application

Intermediate input usage with CGE models typically follows a “Leontief” structure – that is, the physical quantity of intermediate inputs used per unit of output is, at a given technology, constant and independent of price. Therefore, for commodities sold entirely to other industries, demand is rather inelastic. Inelastic demands created a major modelling problem in our drought scenario, as we combine extraordinary supply shocks with these inelastic demands. This results in very large price increases, beyond what we observe in practice. To deal with this, we allowed some substitution between different intermediate inputs. It does not make intuitive sense to allow much substitution; that would imply that we could convert base metal ores into gold with sufficient relative price changes without changing the technology, or reduce the grape content of wine below legal limits. In another sense, a little “alchemy” is quite reasonable: when an input becomes very scarce, we may put extra effort into minimising wastage. In our modelling, we settled on an intermediate input substitution parameter of 0.15.

Another way we adapted the model for drought was to increase the magnitude of the Armington or import substitution elasticities. Grain imports in Australia are usually negligible due to quarantine restrictions. Late in 2002, quarantine restrictions were temporarily relaxed to allow the importation of feed grain. This provides a real world justification for greatly enlarging the relevant elasticity in the model to deal with a drought scenario.

In our modelling of dairy cattle, the output declines are not large enough to exceed the additional labour hired per unit of output in response to productivity declines. That is, the percentage decline in output is less than the percentage decline in productivity, so the hiring of mobile factors increases. It is possible that own-labour inputs on dairy holdings may increase in a drought—because keeping livestock alive requires extra hours of work checking water supplies and hand feeding. However, the main reason for dairy cattle labour increasing within the model is that the sector sells almost entirely to the dairy products sector, and faces no import competition. With zero imports in the database, adjusting the Armington parameter has no effect, while adjusting the intermediate input substitution elasticity has negligible effect.

8. Conclusions

Fifty years ago, agriculture's share of GDP in Australia was around 20 per cent (Maddock and McLean, 1987). Now, it is less than 4 per cent (ABS 2002). Despite the relative decline of agriculture, a widespread drought can still have observable impacts on Australia's economy. Using a new CGE model of the statistical divisions of Australia, we have ascribed output shocks based on ABARE estimates, and productivity shocks related to rainfall deficits, in projecting the impacts on different regions of the Australian economy. The effect of the drought has been to reduce severely agricultural output in most regions. On average Australian agricultural output is estimated to be reduced by the drought by slightly under 30 per cent. Given agriculture's share of 3.6 per cent of Australian GDP, this projected contraction in agricultural output is estimated to reduce Australian GDP growth by 1 percentage point. A further 0.6 percentage points is expected to be cut from GDP growth due to negative multiplier effects.

Our modelling indicates that Australian employment will be almost 0.8 per cent lower on average in 2002-03 than would have been the case in the absence of the drought. While the greatest employment contractions are projected for rural regions, the bulk of the jobs losses occur in non-agricultural sectors. Employment within the agricultural sector is not expected to change much, relative to the large output contractions, due partly to the nature of agricultural employment (i.e. a large proportion of owner-operators) and partly to the drought-induced reduction in the productivity of labour. This drought, unlike that of 1982-83, comes at a time when jobs growth is relatively strong, so that drought-induced employment losses are unlikely to cause a national jobs crisis.

The effects of the drought are mainly temporary. The El Nino weather pattern appears to have ended. While the Bureau of Meteorology (2002b) is unable to forecast exactly when the drought will end, January to March is the most common period for the El Nino effect on Australian weather to ease. Some regions will recover fully with a return to more favourable seasonal conditions, aided by low interest rates. Recovery for other regions in which livestock herd numbers have declined sharply due to prolonged drought will be much slower.

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