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# STATE-LEVEL DYNAMIC CGE MODELING FOR FORECASTING AND POLICY ANALYSIS

by

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# State-level dynamic CGE modeling for forecasting and policy analysis

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**Abstract**

In computable general equilibrium (CGE) modeling there are two broad approaches to generating regional results: bottoms-up and tops-down. We describe both, providing illustrative examples from our experience in Australia. We then describe USAGE, a 500-order dynamic CGE model of the US that we are developing in collaboration with the US International Trade Commission. Tops-down State results from USAGE will be available in a relatively short time. With a longer time horizon, it will be possible to create a bottoms-up version of USAGE. Tops-down applications will be adequate for analysis of economy-wide shocks such as changes in Federal policies. Bottoms-up modeling will be required for analysis of shocks in which the essence is a change in relative costs across regions.

## 1. Introduction

In federations such as Australia and the US, economic projections for individual States are of considerable policy interest.

In CGE modeling there are two strategies for generating results at the sub-national level: tops-down and bottoms-up. Under the tops-down strategy, results are first generated by a national model and then disaggregated to regions. Under the bottoms-up strategy, results are generated directly at the regional level and, where national results are required, they are derived by aggregating across regions.

The tops-down approach was pioneered by Leontief, Morgan, Polenske, Simpson and Tower (LMPST, 1965) who disaggregated results from an input-output model to the fifty US States. Their method was adapted to CGE modeling by Dixon, Parmenter and Sutton (1978) who disaggregated results from a CGE model to the six Australian States. The bottoms-up approach evolved from the multi-country model developed at the IMF by Armington (1969, 1970). The first policy-relevant bottoms-up regional CGE model was created by Liew (1981, 1984) for Australia.

In sections two and three of this paper we describe both strategies for regional CGE modeling and give examples of recent applications in Australia. From the Australian experience we draw out the strengths and limitations of the two strategies. Then in section 4 we discuss strategies for regional aspects of USAGE, a 500-sector dynamic CGE model of the US economy being developed by Monash University and the United States International Trade Commission (ITC). At this stage, USAGE produces results at the national level.

## 2. Tops-down regional modeling

### *2.1 Theory*

The simplest approach to regional modeling involves running a national model and then disaggregating the results to the regional level by assuming that percentage changes in employment by industry at the national level apply at the regional level. Thus it is assumed that

$$l(r) = \sum_{i} S(i,r) * l(i,\cdot) \tag{2.1}$$

where

$l(i,\cdot)$ is the result from the national model for the percentage change in employment in industry i caused by the shock under consideration;

S(i,r) the share of industry i in employment in region r; and

$l(r)$ is the percentage change in employment in region r.

Implementation of equation (2.1) requires a minimum of regional data and computational effort. The only data requirement is the industry profile of employment in each region. Computationally, all that is required is a trivial calculation after the solution of the national model.

A more elaborate, although still simple, tops-down regional computation was formulated and applied by LMPST (1965). Their method involves a partition of goods into two groups: national and local. National goods are those that are readily tradable across regional boundaries. Where the regions are the six States of Australia, the set of national goods includes nearly all agricultural, mineral and manufactured products. Local goods are those that are not readily tradable across regional boundaries. These include goods that must consumed at or close to the point of production. Examples are services such as hair cuts, restaurant meals and financial advising, and perishable goods such as bread. With goods classified as national and local, an LMPST computation proceeds as follows:

$$x(i,r) = x(i,\cdot) + q(i,r) \qquad i \in \text{NATIONAL} \tag{2.2}$$

$$x(i,r) = \sum_{j} \beta(i,j,r) * x(j,r) + \beta_f(i,r)c(i,r) \qquad i \in \text{LOCAL} \tag{2.3}$$

$$c(i,r) = \alpha * l(r) \qquad i \in \text{LOCAL} \tag{2.4}$$

$$l(r) = \sum_{i} S(i,r) * l(i,r) \tag{2.5}$$

$$l(i,r) = l(i,\cdot) + [x(i,r) - x(i,\cdot)] \qquad i \in NATIONAL \cup LOCAL \qquad (2.6)$$

where

$x(i,\cdot)$ is the result from the national model for the percentage change in output in industry i caused by the shock under consideration;

x(i,r) and $l(i,r)$ are the percentage changes in output and employment in industry i in region r;

q(i,r) the percentage change in the share of region r in the production of national good i;

c(i,r) is the percentage change in final demand (public and private consumption and investment) for local good i in region r;

$\beta_f(i,r)$ and $\beta(i,j,r)$ are the shares of the sales of local good i in region r that are absorbed in final demand and in industry j as an intermediate input;

$\alpha$ is a positive parameter (possibly one) relating percentage changes in final demands for local goods in a region to percentage changes in aggregate employment in the region; and

$l(i,\cdot)$, $l(r)$ and S(i,r) are as defined in connection with (2.1).

Denoting the numbers of national goods, local goods and regions by N, L and R, we see that (2.2) to (2.6) provide 2(N+L)R+LR+R equations. With q(i,r) set exogenously and $l(i,\cdot)$ and $x(i,\cdot)$ given by the national model, these equations can be used to compute movements in an equal number of regional variables, x(i,r), $l(i,r)$, c(i,r) and $l(r)$. In most LMPST computations, q(i,r) is set at zero, implying that the shock under consideration does not affect the regional allocation of production of national good i. However, other settings can be used.[1] For example, in a study of the effects of cuts in protection for the Australian car industry, we assumed that Mitsubishi (the financially weakest of Australia's four producers) would close down its Australian operations. Because Mitsubishi's plant is located entirely in South Australia, we adopted a negative value for q(Car, SA) and positive values for q(Car, r) for $r \neq SA$.

Relative to (2.1), LMPST computations require slightly more computational effort. However, the computations remain trivial because they can be performed separately from those required to solve the national model. The LMPST method also requires slightly more data effort than (2.1). Not only do we need values for the industry profile of employment in each region [S(i,r)], but we also need values for the sales profile of local goods [$\beta_f(i,r)$, $\beta(i,j,r)$]. Ideally, the sales profiles should be estimated from regional input-output tables. In the absence of a useable set of such tables[2], satisfactory estimates of sales profiles at the regional level can be obtained using data in national input-output tables. This is done by assuming that regional industry technologies and final demand proportions (the structures of the columns of the input-output tables) are the same as at the national

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[1] For each national good i, the q(i,r)s must be set so that their weighted average over r is zero where the weights [usually assumed to be the S(i,r)s] are regional shares in the output of i. Otherwise the regional computation will imply an output movement for commodity i that is inconsistent with that implied by the national computation

[2] We have found that tables developed for different regions by different research teams are not normally useable because of incompatibilities in industry/commodity classifications and accounting conventions.

level.[3] Under this assumption, differences between regions in the estimated sales profiles of a given local commodity arise from differences in the industrial composition of activity. Differences in cost structures within industries are ignored. In the Australian context, our experience suggests that these ignored differences are of minor importance.

The advantage of the LMPST method over (2.1) is that it introduces local multiplier effects. Assume that region r specialises in the production of national commodity i [i.e., S(i,r) is high relative to S(i,rr) for rr ≠ r]. Now assume that the national model shows strongly positive results for output and employment in national industry i [strongly positive values for $x(i,\cdot)$ and $l(i,\cdot)$]. With q(i,r) set on zero, the strongly positive national result for employment in industry i feeds through to the regional level for the industry via (2.2) and (2.6). Then via (2.5), employment is stimulated in region r relative to other regions through r's high value for S(i,r). The relative stimulation of employment in region r then gives a relative stimulation to final demand for all local goods in region r via (2.4). This leads to relative stimulation of output in local industries in region r via (2.3). Then, via (2.6) and (2.5) there is further stimulation of employment in region r (a multiplier effect).

### *2.2 Tops-down disaggregation of results from ORANI and MONASH*

Since the late 1970's, LMPST calculations have been used frequently in conjunction with ORANI simulations. ORANI is a large-scale comparative-static computable general equilibrium model of Australia.[4] ORANI/LMPST calculations were particularly effective in the Australian tariff debate. For the national level, ORANI indicated that reduced tariffs would harm employment in Australia's import-competing industries such as Motor vehicles and Textiles, clothing and footwear. On the other hand, reduced tariffs would stimulate employment in export industries such as Mining, Agriculture, Tourism and Food processing. Via (2.2) to (2.6), these ORANI results were translated into a significant shift in employment from Victoria to Queensland and Western Australia. Victorian employment was relatively heavily concentrated in import-competing industries whereas Queensland and Western Australia had a heavy concentration of employment in export-oriented industries. Results generated by these tops-down calculations helped persuade the Governments of Queensland and Western Australia to oppose actively Australia's policy of high protection. The attitudes of these State Governments were important in the eventual move by the Federal Government to a regime of low protection.

While the ORANI/LMPST conclusions on tariffs were immediately understandable, this is not true for all ORANI/LMPST studies. Occasionally, quite surprising, but eventually understandable

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[3] As explained in Dixon *et al.* (1982, ch. 6), an advantage of the national technology assumption is that it produces $\beta$ coefficients in (2.3) that guarantee consistency between the results from the regional and national computations for output and for employment in local industries.

[4] Dixon *et al.* (1982).

results have been generated. An example was a study of the effects of stimulating foreign tourism in Australia (Adams and Parmenter, 1993, 1995). This was commissioned by the Australian Bureau of Tourism Research (BTR). With Queensland being the favorite holiday destination for visitors to Australia, the BTR anticipated a strongly positive result for Queensland. They were incredulous when it was reported that a general stimulation of tourism in Australia would slightly reduce Gross State Product (GSP) and employment in Queensland. The ORANI/LMPST calculations picked up two key effects. First, although visitors to Australia spend a lot of time in Queensland, they fly into and out of Sydney (in New South Wales) and do most of their shopping in Sydney. Second, general stimulation of tourism strengthens Australia's real exchange rate and thereby crowds out other export activities, principally mining and agriculture. The Queensland economy has a strong concentration of both mining and agriculture. The negative effects for Queensland's GSP and employment of appreciation-induced reductions in mining and agriculture slightly outweighed the direct positive effects of increased tourism.

Since the mid 1990s, we have used LMPST calculations to generate regional results from MONASH,[5] the dynamic successor to ORANI. In standard applications, MONASH is run with 112 industries. Via two-tier LMPST calculations, results can be generated first for Australia's eight States and Territories and then for 57 sub-state regions (statistical divisions). In the first tier, (2.2) to (2.6) are applied with inputs from the national model (MONASH) to generate results for the States and Territories. In the second tier, (2.2) to (2.6) are reapplied with inputs from the first tier calculation to generate results for regions within States and Territories. Between the two tiers we vary the Local/National partition of commodities, recognizing that less commodities can be considered Local as we move to a finer regional disaggregation.

An example of a recent consultancy project using a two-tier MONASH/LMPST calculation is our study of the effects of eCommerce on the Australian economy.[6] This work was commissioned by the National Office for the Information Economy (NOIE, part of the Federal Government). NOIE's objective was to reduce resistance to eCommerce by showing that the benefits are widespread across the Australian community. They were also interested in convincing the Finance Department to allocate money to a government-sponsored education program on eCommerce.

As part of the study, we participated in a series of meetings for people from business and government who were knowledgeable in the area of eCommerce. The aim of these meetings was to obtain a picture of the direct effects of adoption of eCommerce on the conduct of business. Our task was to lead the participants in the meetings towards a quantification of their views in terms of effects on MONASH variables describing technologies and preferences. This involved an iterative process,

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[5] Dixon and Rimmer (2002).

consisting of *qualitative* discussion by participants, *quantitative* suggestions from us and further discussion by participants. What emerged was an agreed list of shocks to MONASH representing the likely direct effects of eCommerce over the next ten years.[7] These shocks included: reductions in retail and wholesale facilitation of sales to households and businesses by an amount worth about 0.9 per cent of GDP; reductions in household shopping time allowing an increase in productive work time by an amount worth about 0.12 per cent of GDP; increases in foreign awareness of Australian manufactured commodities and of tourism services allowing a 5 per cent upward movements in foreign demand curves for these products; and an average reduction of 0.76 per cent in the foreign currency prices of imported products arising from increased ability by Australian consumers to get a good deal by shopping around. In total the direct effects on Australia's ability to produce and consume were equivalent to increases in GDP and consumption (private and public) of 1.6 and 2.8 per cent. Through the MONASH national calculation we found that these direct effects would attract foreign capital, allowing long-run increases in real GDP and real private and public consumption of about 2.7 and 3.0 per cent.[8] The eCommerce-induced long-run increase in the average after-tax real wage rate was nearly 4 per cent.

To help NOIE show that these favourable macro outcomes would generate widespread benefits, we applied a two-tier LMPST calculation, obtaining regional results for each year out to 2016. The long-run GSP results (for 2016) generated for States and Territories in the first-tier calculation are presented in Chart 1. The long-run employment results generated for the sub-state regions in the second-tier calculation are presented in Chart 2.

Chart 1 shows that eCommerce will cause output to increase in all States and Territories.

The least-stimulated State is Western Australia which suffers relative to other States/Territories because of the heavy representation of mining in its economy. Output in the Mining sector is reduced by eCommerce. Whereas eCommerce is likely to increase foreign awareness of Australia's manufactures and tourism, it is unlikely to have similar effects for Australia's traditional mining and agriculture exports. The world is already well aware of these traditional products. The main effect from eCommerce for mining and agriculture is likely to be an increase in costs through the eCommerce-induced increase in real wage rates with no compensating increase in foreign demand.

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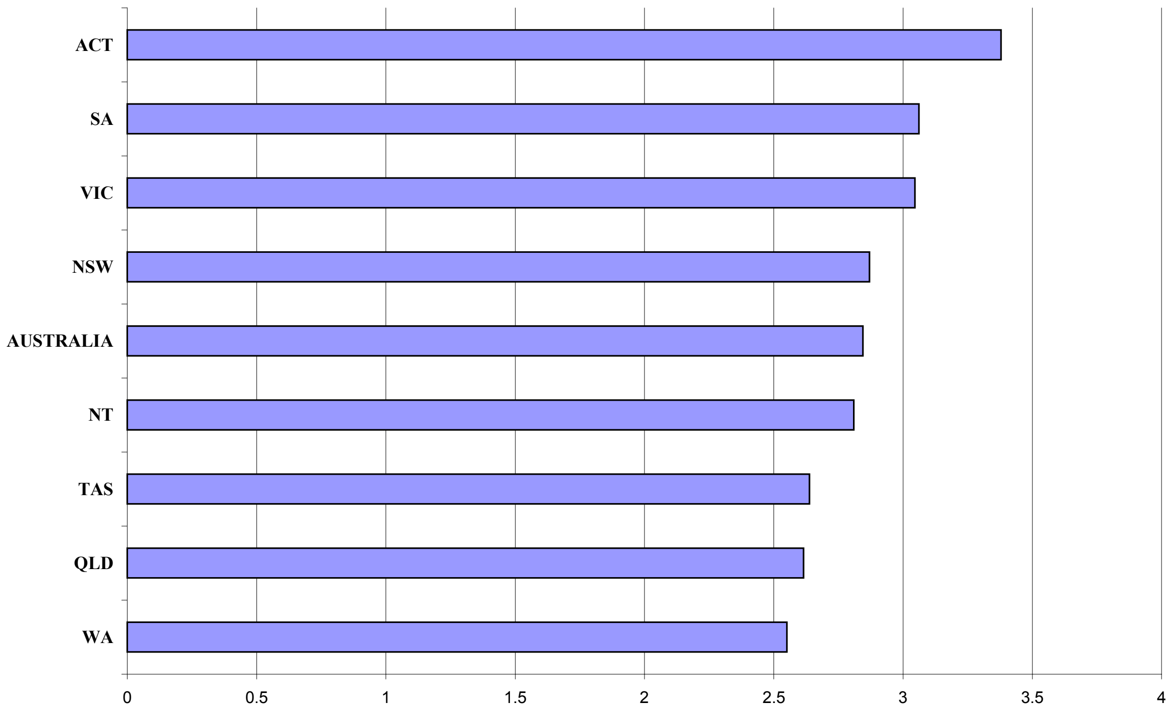
[6] Dixon and Rimmer (2003) and National Office for the Information Economy (2000 a & b, 2001).

[7] Litan and Rivlin (2001) describe a rather similar process for finding out about the direct effects of eCommerce in the United States. However, they stopped with the direct technology effects. They did not use an economic model to translate these effects into ultimate effects.

[8] Capital inflow has a much more pronounced effect in MONASH on GDP than on consumption. Extra capital acts directly to increase GDP through the production function. Because most of the extra GDP must be paid to foreign investors, the effect on GNP and therefore consumption is muted.

***Chart 1. GSPs for States and Territories and GDP for Australia in 2016***
***(% deviation from basecase forecasts caused by eCommerce)***




Queensland has a heavy concentration of mining and export-oriented agriculture. This explains its relatively low ranking in Chart 1. An offset for Queensland, which means that it performs better than Western Australia, is its well developed tourism industry.

Like Queensland, Tasmania has over-representations in its economy of traditional exports and of tourism. This gives it a performance under eCommerce similar to that of Queensland. The Northern Territory also has over-representations of traditional exports and of tourism. Its output deviation under the eCommerce shocks is larger than those of Queensland and Tasmania because the Territory, which has a relatively large government sector, benefits from an eCommerce-induced expansion in public consumption.

The industrial composition of the New South Wales economy is close to that of Australia. Thus the deviation for GSP in NSW is close to that for Australia's GDP.

Victoria and South Australia have above average prospects under eCommerce because neither state has a heavy reliance on traditional exporting. The ACT is the region of Australia with least reliance on traditional exporting and the heaviest reliance on public consumption. These characteristics give the ACT the top ranking in Chart 1.

***Chart 2. Employment by Statistical Division in 2016***
***(% deviation from basecase forecasts caused by eCommerce)***

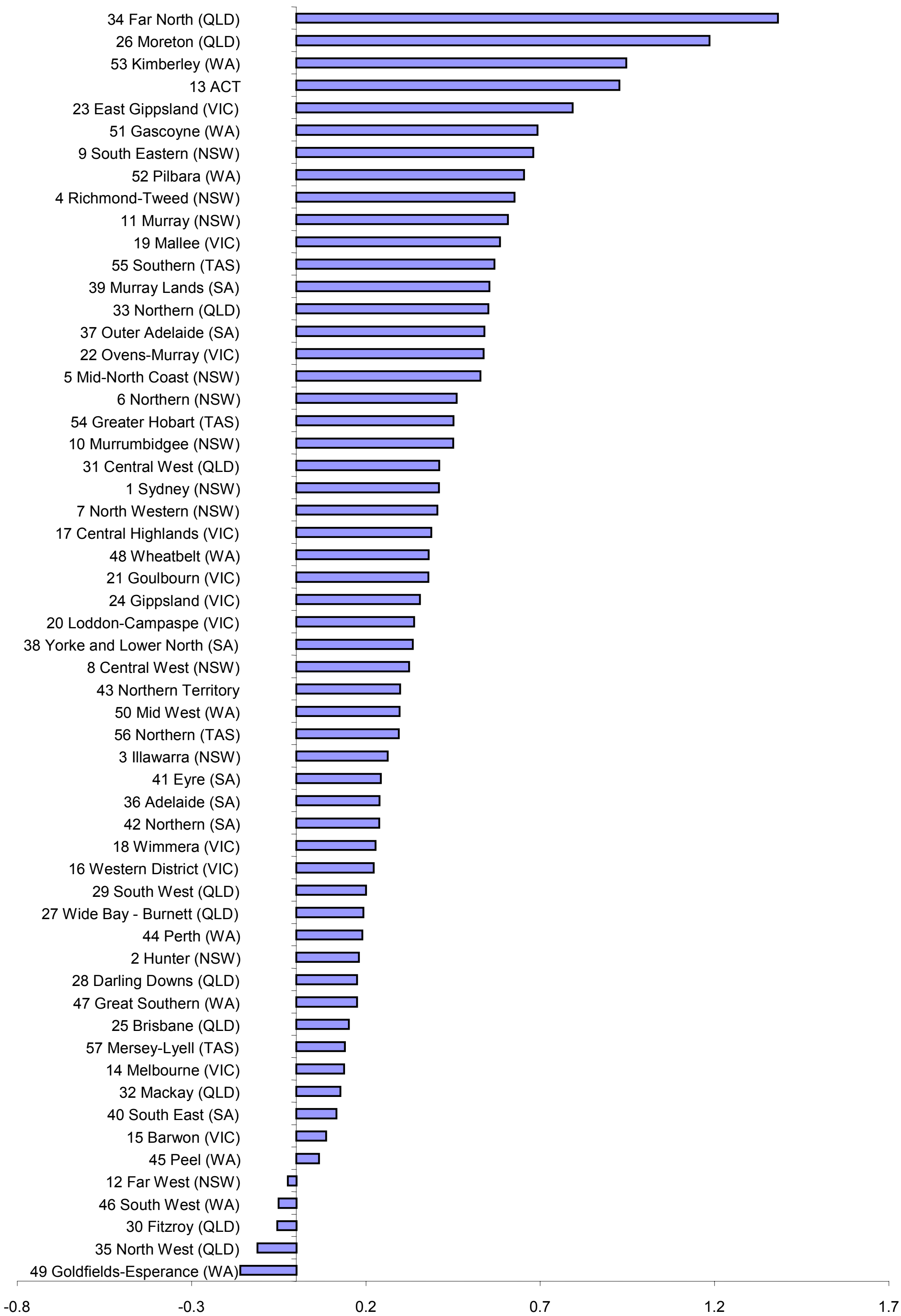


Chart 2 shows long-run employment deviations for Statistical Divisions. These are relatively uniform, all lying in the range -0.16 to 1.38 per cent. The position of a Statistical Division within this range is determined mainly by the shares of its economic activity accounted for by tourism and traditional exports. The top three Statistical Divisions shown in Chart 2, Far North (QLD), Morton (QLD) and Kimberley (WA), all have heavy reliance on tourism. At the other end of Chart 2, we find Mackay (QLD), South East (SA), Barwon (VIC), Peel (WA), Far West (NSW), South West (WA), Fitzroy (QLD), North West (QLD) and Goldfields-Esperance (WA). All of these areas rely heavily on either export-oriented agriculture or export-oriented mining, activities which have least to gain from eCommerce.

While Charts 1 and 2 show distinct differences in outcomes across regions, to us the differences seem quite small. We have found that a narrow spread is a feature of LMPST disaggregations of many sets of results from ORANI and MONASH simulations. The reason is that Australia's regional economies are structurally quite similar. The main differences in their industrial structures are in their levels of reliance on traditional exporting activities and import-competing activities. However, these activities account for rather small shares of employment in nearly all regions. In each of the 57 Statistical Divisions, more than 60 per cent of employment occurs in the Service and Construction sectors and in most regions these two sectors account for about 80 per cent of employment. Thus, tops-down calculations [with the q(i,r)s in (2.2) set at zero] show a narrow spread of regional results even for simulations in which there is a relatively broad spread of industry results.

A conclusion that we can draw for Australia is that economy-wide shocks have differential impacts across regions but that there will be few cases in which regions are decimated by such shocks. Economy-wide shocks include changes in technologies (e.g. eCommerce), changes in Federal Government policies (e.g. cuts in tariffs) and changes in world trading conditions. The only shocks that are likely to have disruptive differential impacts across regions are those that are region specific. Examples are: financial mismanagement by local government in a particular region; relocation out of a region of a government department; and closure of a major plant in one region associated with regional rationalization of an industry's activity.

For analyzing the effects of some region-specific shocks we can use the LMPST method with the q(i,r)s set at non-zero values. However, with the tops-down method we have difficulties in simulating shocks that cause cost differences between regions. For example, how do we simulate the effects of a financial mismanagement that causes an increase in taxes in a region and a reduction in local government services? Industries and households in the region have an incentive to relocate. To analyze this situation we need a model in which the q(i,r)s are effectively endogenous rather than exogenous. This leads us to bottoms-up modeling.

## 3. Bottoms-up regional modeling

### *3.1 Theory*

Bottoms-up models are so named because they explain economic activity at the regional level and derive economy-wide results by aggregation. In these models, the regions are treated as a group of separate trading economies. The theoretical structure of bottoms-up regional CGE models is much the same as that of multi-country CGE models such as GTAP (Hertel, 1997). Bottoms-up regional models can be thought of as multi-country models but with higher levels of trade and of factor mobility, with more coordinated tax and wage movements and with fixed rather than variable exchange rates. A strength of multi-country CGE models is their capacity to shed light on the effects of policies that affect relative costs across countries. Similarly, a strength of multi-regional CGE models is their capacity to shed light on the effects of policies that affect relative costs across regions.

Over the last 20 years, several bottoms-up models have been constructed for Australia.[9] Our experience suggests that, compared with tops-down methods such as LMPST, a convincing bottoms-up model is difficult to implement. The bottoms-up approach imposes heavy requirements for explicit judgments about initial values for interregional trade flows. The bottoms-up approach also imposes considerable computational burdens. Here we discuss both these aspects of bottoms-up modeling. Then in the next subsection we illustrate the pay-off from bottoms-up modeling by working through a recent application of Australia's MMRF model.

*Interregional trade flows*

In Australia the distinction between Local and National goods is tenable for LMPST disaggregation to the State/Territory level. This is because most of Australia's economic activity takes place in the capital cities of each State and these cities are far from State/Territory borders. This means that there are many goods that are barely traded across State/Territory borders and can therefore be classified as Local without too much loss of realism. At the same time, there are many goods for which the State/Territory distribution of production seems to be independent of the State/Territory distribution of absorption. It is reasonable to classify these goods as National. However, when we move to the Statistical Division level, there are few goods that can be classified comfortably as Local. Even hair cuts are exported from one Statistical Division to residents of another Statistical Division. This problem is not solved satisfactorily simply by reclassifying goods from the Local to the National categories. While many services and perishables may be traded across Statistical Division borders, it

[9] These include MRSMAE (Liew, 1981, 1984), FEDERAL (Madden, 1990, 1996 and Dixon *et al.* 1993), FEDERAL-F (Giesecke, 1997). MMRF (Naqvi and Peter, 1996, and Adams *et al.* 2000b) and TERM (Horridge *et al.* 2003). For an overview of Australian muti-regional modeling, see Madden and Giesecke (1999). For a more general overview of regional CGE modelling, see Partridge and Rickman (1998).

is clear that these goods do not meet the National criterion of independence of location of production and location of absorption.

Under the LMPST method, it is assumed implicitly that all users of Local good i in region d source good i from region d, and that all users of National good i in region d source good i from regions in proportion to these regions' shares in national production of good i. That is,

$$\text{for } i \in \text{Local}, \quad H(i,s,d) = 1 \quad \text{if } s = d$$
$$= 0 \quad \text{if } s \neq d \qquad (3.1)$$

$$\text{and for } i \in \text{National}, \quad H(i,s,d) = Q(i,s) \quad \text{for all s, d}, \qquad (3.2)$$

where

H(i,s,d) is the share of good i from region s in the absorption of good i in region d; and
Q(i,s) is the share of region s in the production of good i.

With tops-down modeling we are able to make more realistic (and explicit) assumptions about the H(i,s,d)s than those in (3.1) and (3.2). With more realistic assumptions we can recognize that the effect on the production of i in region s of increased demand for i in region d depends on the proximity of s to d.

Ideally, assumptions about the H(i,s,d)s should reflect data on interregional flows of goods. In practice, interregional flow data is usually fragmentary. In many cases, what is available for each commodity are data on outputs in each region and estimates of absorption. The absorption estimates are often generated by assuming that regional industrial technologies and regional consumption structures are the same as national industrial technologies and consumption structures. With given values for output and demand for commodity i in each region, various common-sense procedures can be used to estimate interregional trade flows in i. For example, a stripped-down version of the procedure used by our colleague Mark Horridge to estimate the base-period interregional trade flows for the 57 region, 144 commodity bottoms-up TERM model of Australia is as follows[10]:

$$H_1(i,s,d) = \left\{ \frac{V(i,s,\cdot)^{\lambda}}{G(i,s,d)} \right\} \qquad \text{for } s \neq d \qquad (3.3)$$

$$H_2(i,d,d) = \text{MIN}\left\{ \frac{V(i,d,\cdot)}{V(i,\cdot,d)}, 1 \right\} * F(i) \qquad \text{for all d} \qquad (3.4)$$

$$H_2(i,s,d) = H_1(i,s,d) * \left\{ \frac{1 - H_2(i,d,d)}{\sum\limits_{q \neq d} H_1(i,q,d)} \right\} \qquad \text{for } s \neq d \qquad (3.5)$$

$$V_1(i,s,d) = H_2(i,s,d) * V(i,\cdot,d) \qquad \text{for all s, d} \qquad (3.6)$$

[10] See Horridge *et al.* (2003). In (3.3) to (3.8) we strip-down Horridge's method for estimating interregional trade flows by leaving out his treatment of complications associated with international trade and margins.

$$V_{final}(i,s,d) = RAS_{i,s,d}\left\{V_1(i)\,;\,V^s(i), V^d(i)\right\} \qquad \text{for all s, d} \qquad (3.7)$$

$$H_{final}(i,s,d) = \frac{V_{final}(i,s,d)}{V(i,\cdot,d)} \qquad \text{for all s, d} \qquad (3.8)$$

where

$H_1(i,s,d)$, s≠d, is an initial estimate of the share of region s in satisfying region d's demand for commodity i;

$H_2(i,d,d)$ is an initial estimate of the share of region d in satisfying region d's demand for commodity i;

$V(i,s,\cdot)$ is the given value for production of good i in region s;

$V(i,\cdot,d)$ is the given value for demand of good i in region d;

λ is a positive parameter (assumed by Horridge to be 0.5);

$G(i,s,d)$ is a parameter reflecting the distance between s and d and the extent to which i is tradable;

F(i) is a parameter valued between 0.5 and 1, with a value close to 1 if i is not readily tradable;

$H_2(i,s,d)$, s≠d, is a revised estimate of the share of region s in satisfying region d's demand for commodity i;

$V_1(i,s,d)$ is an initial estimate of the value of the flow of good i from region s to region d;

$V_{final}(i,s,d)$ is the final estimate of the value of the flow of good i from region s to region d;

$V_1(i)$ is the region by region matrix formed by the $V_1(i,s,d)$s;

$V^s(i)$ is the vector of regional supplies of good i, that is [$V(i,1,\cdot)$, $V(i,2,\cdot)$, …];

$V^d(i)$ is the vector of regional demands for good i, that is [$V(i,\cdot,1)$, $V(i,\cdot,2)$, …]; and

$H_{final}(i,s,d)$ is the final estimate of the share of region s in satisfying region d's demand for commodity i.

In (3.3) and (3.4) Horridge makes initial judgments concerning the $H(i,s,d)$s. For good i, he sets a high initial value for the own-share in region d [$H_2(i,d,d)$] if d is a major producer of i [$V(i,d,\cdot) > V(i,\cdot,d)$] and he judges good i not to be readily traded [F(i) close to one]. He sets a high initial value for H(i,s,d), s ≠ d, if s and d are geographically close and i is readily tradable [G(i,s,d) is small] and if region s is a significant producer of good i [$V(i,s,\cdot)$ is large]. In (3.5) he refines his initial guesses of the off-diagonal shares [H(i,s,d), s ≠ d] so that he has a set of shares that satisfy

$$\sum_s H_2(i,s,d) = 1 \qquad \text{for all d .} \qquad (3.9)$$

In (3.6) he uses the refined shares in calculating initial values [$V_1(i,s,d)$] for the flows of good i from source-regions to destination-regions. These initial values are refined in (3.7) by a RAS procedure to obtain a flow matrix which is close to the initial flow matrix but satisfies the adding up constraints:

$$\sum_s V_{final}(i,s,d) = V(i,\cdot,d) \qquad \text{for all d .} \qquad (3.10)$$

$$\sum_d V_{final}(i,s,d) = V(i,s,\cdot) \qquad \text{for all s .} \qquad (3.11)$$

The final estimates of the H(i,s,d)s are calculated in (3.8) from the final estimates of the V(i,s,d)s.

By using procedures such as (3.3) to (3.8) we can implement bottoms-up models with no more data than is required for tops-down modeling. These procedures allow us to make better use of the available data than is possible under tops-down methods involving implicit assumptions such as (3.1) and (3.2).

*Computational complexity*

Bottoms-up models can impose considerable computational burdens. For example, in its full dimensionality (57 regions and 144 commodities), the TERM model is inconveniently slow to solve. In its present form, TERM is a single-period (comparative-static) model. The computational burden in bottoms-up modeling is even more acute with a dynamic model such as MMRF.[11] The potential commodity dimension in MMRF is 144 and the although the potential regional dimension is only 8 (the States and Territories) the computational difficulties are magnified by the need to solve over a number of years, usually 20.

The computational problem of bottoms-up multi-regional modeling has been mitigated by the creation, at the Centre of Policy Studies, of flexible aggregation programs.[12] These programs take an initial database and associated model and aggregate them in any desired way. For example, in the study to be described in subsection 3.2, we are concerned with a problem in the Victorian construction industry. For analyzing this problem we used a version of MMRF that distinguished just 20 commodities and 2 regions. Little relevant detail was lost because in our commodity categories we retained all of the available detail on Construction and construction-related commodities, and in our regional categories we recognized Victoria separately while aggregating the rest of Australia.

### *3.2 A bottoms-up study: an MMRF simulation of a strike in the Victorian construction industry*

Large-scale bottoms-up regional CGE models are shown to best advantage in studies concerned with highly specific shocks that operate differentially across regions. Here we give an example: an MMRF consultancy study of the effects of a strike in the Victorian construction industry.[13] The policy relevance of the study arose from Australia's *Workplace Relations Act 1996*. A clause in this act requires Australia's Industrial Relations Commission to restrain participants in a wage bargaining round from undertaking strikes and lockouts if a potentially injured party can demonstrate that these actions threaten "to cause significant damage to the Australian economy or an important part of it". For this clause to be invoked, the Industrial Relations Commission would need

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[11] Naqvi and Peter (1996) and Adams *et al.* (2000).

**[12]** These are the work of our colleagues Mark Horridge and Glyn Wittwer.

[13] See Dixon and Wittwer (2003).

to be presented with a projection of economic damage that would follow from a specific planned strike or lockout.

The consultancy study was undertaken for a client who was considering an appearance before the Industrial Relations Commission to seek an injunction against a union threatening a strike. The strike was to be carried out in February 2003 against a Victorian company involved in non-residential construction. The client estimated that the strike would cause $A30 million loss of wages in the company and an associated direct wastage of capital input worth $A12 million. Our task was to estimate the effects of the strike on the Victorian and Australian economies.

We simulated these effects by introducing two shocks into MMRF in 2003. The first was a reduction in primary factor productivity in the Victorian non-residential construction industry designed to represent idle labor and capital. The second was an increase in required rates of return on capital throughout Victorian industries designed to ration demand for non-residential construction services to be compatible with the strike-reduced capacity of the non-residential construction industry to supply these services. Both shocks were temporary. For 2004 onwards, we reset required rates of return and primary factor productivity to their basecase forecast paths.

The most important assumption underlying our MMRF results relates to the labor market. We assumed that workers throughout Australia are concerned with the real wage rate, that is, the average wage rate in Australia deflated by the CPI. If the labor market weakens, then we assume that the real wage rate declines sluggishly in response to reduced worker bargaining power. More technically, we assume that the deviation in the real wage rate from its basecase forecast level increases in proportion to the deviation in employment from its basecase forecast level. The coefficient of proportionality was chosen so that the employment effects of a shock such as a strike in the Victorian non-residential construction industry are largely eliminated after 5 years. This labor market assumption is consistent with conventional macro-economic modeling in which the NAIRU is exogenous.

As shown in Chart 3, MMRF implies that the strike in Victoria would reduce Australia-wide employment. Inefficiencies introduced by the strike reduce the level of employment that can be sustained at any given real wage rate. Under our labor-market assumption, wage adjustment is too sluggish to prevent an increase in short-run unemployment. Eventually, wage rates fall sufficiently to allow employment to return to its basecase forecast path.

Charts 4 and 5 give results for Victoria and the rest of Australia. Employment in Victoria is reduced in 2003 by 0.162 per cent or 3900 full-time equivalent jobs (Chart 4). In the rest of Australia, employment rises by 0.051 per cent, or 3600 full-time equivalent jobs (Chart 5).

***Chart 3. Effects of strike on employment and wage rates: Australia (% deviations from basecase forecasts)***

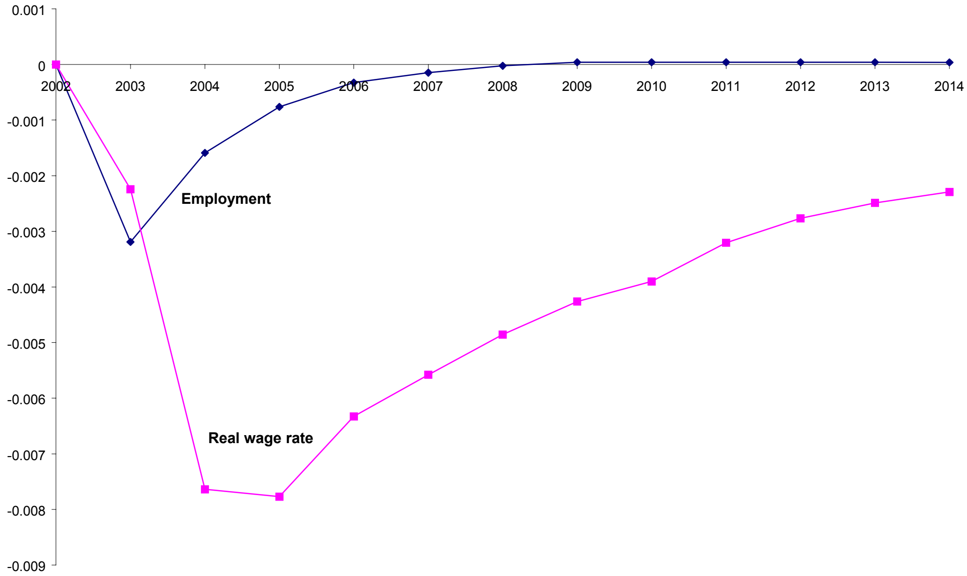



***Chart 4. Effects of strike on Victoria's employment, capital stock and real GSP (% deviations from basecase forecasts)***

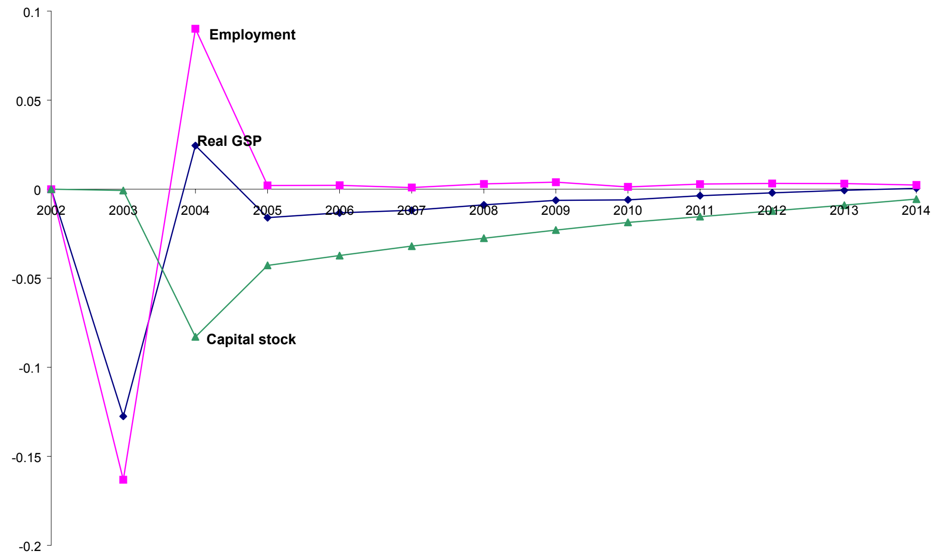
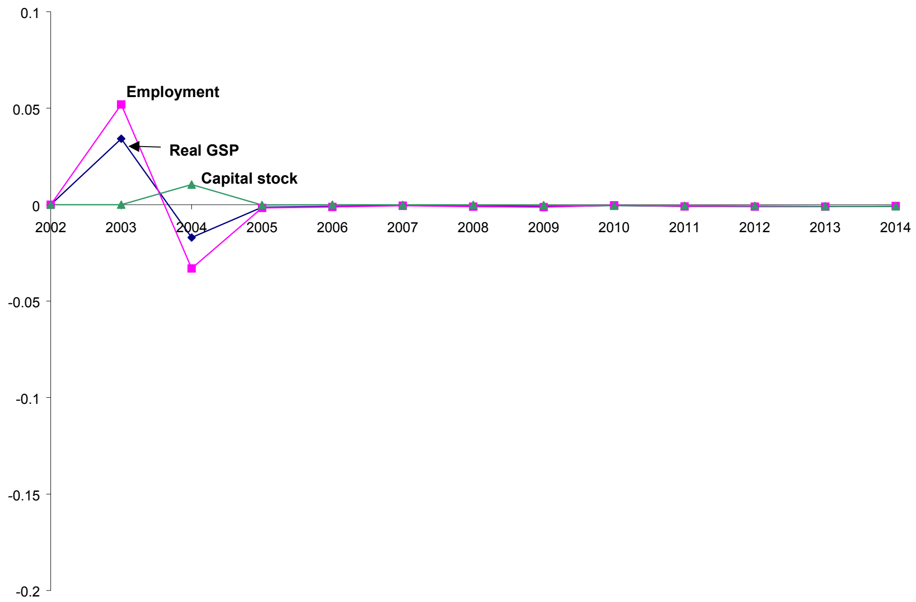


***Chart 5. Effects of strike on Rest of Australia's employment, capital stock and real GSP (% deviations from basecase forecasts)***




The strike reduces Victoria's competitiveness by causing cost increases. The rest of Australia gains from reduced real wages without offsetting losses in efficiency. In effect, resources flow from Victoria to the rest of Australia. This does not necessarily require physical movements of people. It is consistent with unemployment rising in Victoria and falling in the rest of Australia.

In 2004, Victoria's finds itself with lowered real wage rates and a shortage of capital. With the elimination of the inefficiency (the strike), the ratios of actual to required rates of return increase in Victoria, causing a strong recovery in investment. Catch-up investment in 2004 causes Victorian employment to move above control by 0.09 per cent or 2160 jobs. Beyond 2004, Victorian employment returns approximately to control. Overall, Victoria experiences an employment loss of about 1740 person-years. This is made up of 3900 jobs lost in 2003 with a partial offset of 2160 jobs gained in 2004.

On processing all of the relevant results from MMRF we were able to report to our client that the present value of the Australia-wide welfare loss from the strike would be $A93 million, slightly more than twice the direct wastage of $A42 million. Most of the unfavorable effects of the strike would occur in the year of the strike. However, national employment would remain below its basecase forecast path for several years. In the year of the strike, Victoria would suffer a considerable loss in employment. In other states, there would be an increase in employment. In the year following the strike, the regional employment situation would be reversed. Victoria would benefit from an employment increase reflecting catch-up investment, while employment in other states would fall.

## 4. Concluding remarks: regional extension of the USAGE model of the US

In collaboration with the ITC, we are developing a dynamic general equilibrium model of the US economy. Dynamic aspects of the model include specifications of capital flows into and out of the United States together with relationships between capital flows, the balance of payments, the public sector budget and US foreign assets and liabilities.

The model, known as USAGE, is built at the 500 industry level and allows for multiple trading partners. These features will be appealing to people concerned with environmental and trade issues. The industry detail will allow pollution coefficients to be sharply associated with the activities that produce the pollution and the trade-partner detail will facilitate analysis of trade agreements.

USAGE shares many features with the MONASH and ORANI models of Australia. Over the last twenty-five years, these models have applied to a wide range of issues and are the basis for several hundred published papers. In common with MONASH, USAGE will have 4 modes:

*Historical,* where we estimate changes in technology and consumer preferences;

*Decomposition,* where we explain periods of economic history in terms of driving factors such as changes in technology and consumer preferences;

*Forecast,* where we derive basecase forecasts for industries, occupations and regions that are consistent with trends from historical simulations and with available expert opinions; and

*Policy,* where we derive deviations from basecase forecast paths caused by assumed policies.

For USAGE, we have completed: (a) the development of a database for 1992; (b) the development of historical shocks for 1992 to 1998; (c) an historical simulation for 1992 to 1998 that reveals for this period detailed estimates of changes in technology and consumer preferences; and (d) a decomposition simulation for 1992 to 1998 that explains the development of the US economy for this period in terms of exogenous driving factors including changes in technology and consumer preferences. From here it will be a relatively short step to forecast simulations (which rely heavily on results from historical simulations) and policy simulations (which require the basecase forecasts).

As with MONASH, USAGE will have several add-on programs, that is programs that process results from the main model but do not affect those results. The first of these will allow results to be generated for the State economies. Subsequent add-ons will deal with occupations, income distribution and adjustment costs. USAGE has the four ingredients required for analyses of adjustment costs: dynamics; detail; economy-wide focus; and forecasting capability.

We have chosen disaggregation to the States as our first add-on program because of the immense interest in the implications for the States of policy and other shocks to the economy. We intend to implement the LMPST method. This is relatively easy to do and will produce acceptable results for the effects on the States of a wide range of economy-wide shocks such as changes in: Federal taxes and expenditures; tariffs and other trade policies; Federal environmental regulations;

Federal consumer and competition regulations; industry technologies and consumer preferences; world commodity prices and trading conditions; and investor confidence in US industries.

To disaggregate USAGE results to the State level using the LMPST method we need data on output and/or employment by State and 500-order industries. We also need to classify commodities as either Local or National. Our colleagues at the ITC have supplied us with 500-order data for the States on output, employment and other variables. We are in the process of analyzing these data. This involves the time-consuming work of correcting mismatches between the industrial/commodity classification in the regional data and that in USAGE. These mismatches go both ways. In some cases the regional data have finer industrial detail than the USAGE data. For example, the regional data distinguishes: Copper ores; Lead and zinc ores; Gold ores; Silver ores; and Uranium-radium-vanadium ores. The USAGE data distinguishes only Copper ores and Other nonferrous ores. On the other hand the USAGE data distinguishes: Petroleum and natural gas well drilling; Petroleum, natural gas and solid mineral exploration; and Access structures for solid mineral development. The regional data distinguishes only New mineral extraction facilities.

Another time-consuming data task is the resolution of problems that have arisen when we have tried to allocate commodities to the Local and National categories. Consider for example the case of Laundry. This is an obvious candidate for the Local category. However, our initial estimates of supplies and demands show considerable excess supply in California and excess demands in Virginia, Maryland and the District of Columbia. In estimating household demands our first approach was to distribute national demands to States according to population shares. In the Laundry case, more plausible but still unsatisfactory results were obtained when we distributed national demands to States in accordance with their shares in household disposable income. Further refinements will be required, possibly involving estimates of expenditure elasticities of demand that differ from one.

Eventually we hope to implement a bottoms-up regional version of USAGE, along the lines of Australia's MMRF and TERM models. With a bottoms-up approach, we will be able to extend the range of regional applications of USAGE to include those in which the essence is a change in relative costs across regions. Such applications include the effects of local disasters and the effects of changes in: State taxes; State environmental regulations; State consumer and competition regulations; and investor confidence in the industries of particular States. As explained in section 3, the bottoms-up approach does not necessarily require more data than tops-down methods but it does require more ingenious use of the data. Relative to tops-down modeling, bottoms-up modeling presents challenging computer problems. Our colleague Mark Horridge reports that 50-region-50-commodity one-period solutions for CGE models like TERM, GTAP and MMRF can be generated accurately in about 6 hours on a modern PC. For experimental and consulting work, we require faster turnaround. This can be achieved by using aggregations that eliminate regional and commodity detail of low relevance to the application at hand.

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