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DISAGGREGATION OF RESULTS FROM A DETAILED GENERAL EQUILIBRIUM MODEL OF THE US TO THE STATE LEVEL

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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.

Abstract

This paper describes the regional extension of USAGE-ITC, a 500-order dynamic CGE model of the US that we are developing in collaboration with the International Trade Commission. With the regional extension, USAGE-ITC can project the effects on employment and output by state of policy and other shocks to the economy. The paper describes the theory and data underlying the regional extension, and provides an illustrative application concerned with the effects of elimination of US restraints on imports.

In CGE modeling there are two broad approaches to generating regional results: bottoms-up and tops-down. Our approach here is tops-down with emphasis on the estimation of inter-regional flows of goods and services. As explained in the paper, the tops-down approach is 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.

JEL Classification: C68, D58, F14, R1.

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Disaggregation of results from a detailed general equilibrium model of the US to the State level

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1. Introduction

This paper describes the disaggregation of results from a national CGE model of the US, USAGE-ITC, to the states.

USAGE-ITC is a detailed dynamic model being developed at the Centre of Policy Studies in collaboration with the US International Trade Commission. Dynamic aspects of the model include investment/capital-accumulation relationships for industries, and specifications of financial capital flows into and out of the US together with relationships between capital flows, the balance of payments, the public sector budget and US foreign assets and liabilities. The model 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-ITC shares many features with the MONASH and ORANI models of Australia [Dixon and Rimmer, 2002 and Dixon *et al.*, 1982]. Over the last twenty-five years, these models have been applied to a wide range of issues and are the basis for several hundred published papers. In common with MONASH, USAGE-ITC 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-ITC, 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-ITC will have several add-on programs, that is programs that process results from the main model but do not affect those results. Here we describe the first of these, the regional add-on. Subsequent add-ons will deal with occupations, income distribution and adjustment costs. 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.

The rest of the paper consists of five sections.

Section 2 describes the theory of the regional add-on. The main features of the theory are:

(a) It gives roles to a large number of the national variables in determining regional results. These variables include: employment and output by industry; intermediate usage by commodity and industry; consumption, exports and government expenditure by commodity; and various macro variables such as real GDP.

(b) It specifies the movement for many of the regional variables as being determined by the movement in the corresponding national variable plus a regional deviation term. The regional deviation term is the gap between the movement in a relevant region-specific variable and the average of these relevant variables across regions. For example, the percentage movement in region r's consumption of good i is specified as the percentage movement in national consumption of good i plus the gap between the percentage movements in household disposable income in region r and household disposable income in the nation.

(c) It provides a detailed treatment of regional demands for margin services: transport, wholesale trade and retail trade.

(d) It ensures that the regional results for all variables add up to the national results for the corresponding national variables.

Section 3 describes the computing strategy. With 51 regions (the states plus DC) and about 500 commodities each with two varieties (domestic and imported), the regional extension is a very large equation system. Solving the system involves the inversion of a matrix of size 51x2x500 squared. This is far too big for routine applications of standard CGE software. One possibility is to reduce the dimensions of the equation system by aggregation of either the commodity/industry dimension or the regional dimension. We tried this approach but were disappointed with the loss of information and the consequent adverse effects on the realism of our results. As documented in section 3, we eventually computed full-dimension regional results by a tailor-made algorithm (one that exploited special features of our regional system) applied with GEMPACK software.

Section 4 describes the coefficients and parameters for the regional system. The main novelty of this section is the application of formulas devised by Mark Horridge for estimating interregional flows of commodities. Earlier tops-down regional add-ons have often used the LMPST method in which each commodity is classified as either local or national. For local commodities it is assumed that there is no interregional trade, implying that output in a region depends entirely on demand in the region. For national commodities, it is assumed that the regional distribution of output is independent of the regional distribution of demand. These extreme assumptions are unsuitable for the US. As shown in section 4, they can be avoided by using the Horridge formulas.

Section 5 provides an illustrative application of the regional add-on concerned with the effects on states of elimination of US restraints on imports.

Concluding remarks including plans for future research are in section 6.

2. The theory of the regional extension

The equations for the regional extension of USAGE-ITC are listed in Table 2.1. Tables 2.2, 2.3 and 2.4 define sets, variables, and coefficients and parameters. In looking at these tables, it will be helpful to keep in mind the following conventions.

- Sets, coefficient and parameters are denoted by upper-case symbols. The names of all variables in the regional extension start with lower-case symbols. As explained below, the names of some variables also include an underscore followed by some upper-case letters.
- With two minor exception, all the variables in the regional extension are percentage changes, that is percentage deviations from base-case levels caused by the shocks under consideration. The exceptions are d_x6cs(i,s) and d_x6_csr(i,s,r). These are changes (not percentage changes) in the rates of inventory accumulation. In general it is convenient to deal with percentage changes because they are easy to interpret. However, for variables such as rates of inventory accumulation, in which the initial level can be negative or zero, percentage changes must be avoided.
- Variables from the national model are shown in the equations in bold typeface. For example, **x0ind(j)** in equation T1 is the percentage change in the national output of industry j.
- The sets over which variables with a regional dimension are defined are indicated in their names by upper-case letters following an underscore. For example, x0ind_IR refers to output by industry (denoted by I) and region (denoted by R).
- USAGE-ITC distinguishes commodities by source (domestic or imported). We often refer to commodity i from source s as commodity i,s.

Table 2.1. Equations in the regional extension of USAGE-ITC

Equation T1: ***Output by industry j in region r***

(All,j,IND)(All,r,REG)

$$\mathrm{x0ind\_IR}(j,r) = \mathbf{x0ind(j)} + \sum_{i\in COM} \mathrm{H0CI}(i,j) * \mathrm{x0\_CSR}(i,\text{"dom"},r) - \sum_{g\in REG} \mathrm{JOBSH}(j,g) * \sum_{i\in COM} \mathrm{H0CI}(i,j) * \mathrm{x0\_CSR}(i,\text{"dom"},g)$$

Equation T2: ***Disposable income in region r***

(All,r,REG)

$$\mathrm{dispy\_R}(r) = \mathbf{hdy} + \mathrm{GAMMA} * \sum_{j\in IND} \mathrm{LABSH}(j,r) * [\mathbf{labind(j)} + \mathrm{x0ind\_IR}(j,r) - \mathbf{x0ind(j)}]$$
$$- \mathrm{GAMMA} * \sum_{g\in REG} \mathrm{SHLAB}(g) \sum_{j\in IND} \mathrm{LABSH}(j,g) * [\mathbf{labind(j)} + \mathrm{x0ind\_IR}(j,g) - \mathbf{x0ind(j)}]$$

Equation T3: ***Demand for commodity i from source s by households in region r***

(All,i,COM)(All,s,SOURCE)(All,r,REG)

$$\mathrm{x3\_CSR}(i,s,r) = \mathbf{x3cs(i,s)} + \mathrm{dispy\_R}(r) - \sum_{g\in REG} \mathrm{REGSH3}(i,g) * \mathrm{dispy\_R}(g)$$

Equation T4: ***Demand for commodity i to be delivered from region r to export (demand for i by region of exit)***

(All,i,COM)(All,r,REG)

$$\mathrm{x4\_CR}(i,r) = \mathbf{x4(i)} + \mathrm{reg4\_CR}(i,r) - \sum_{g\in REG} \mathrm{REGSH4}(i,g) * \mathrm{reg4\_CR}(i,g)$$

… Table 2.1 continued

Table 2.1 continued

Equation T5: ***Demand for commodity i from source s to be delivered from region r to governments***

(All,i,COM)(All,s,SOURCE)(All,r,REG)

$$x5\_CSR(i,s,r) = \mathbf{x5cs(i,s)}$$

Equation T6: ***Demand for commodity i from source s to be delivered from region r to inventories***

(All,i,COM)(All,s,SOURCE)(All,r,REG)

$$d\_x6\_CSR(i,s,r) = SUPSH(i,s,r) * \mathbf{d\_x6cs(i,s)}$$

Equation T7: ***Gross Regional product***

(All,r,REG)

$$gspreal\_R(r) = \mathbf{gdpreal} + \sum_{j \in IND} VADSH(j,r) * x0ind\_IR(j,r) - \sum_{g \in REG} SHVAD(g) \sum_{j \in IND} VADSH(j,g) * x0ind\_IR(j,g)$$

Equation T8: ***Employment by region***

(All,r,REG)

$$emp\_R(r) = \mathbf{emp\_hours} + \sum_{j \in IND} LABSH(j,r) * [\mathbf{labind(j)} + x0ind\_IR(j,r) - \mathbf{x0ind(j)}] - \sum_{g \in REG} SHLAB(g) \sum_{j \in IND} LABSH(j,g) * [\mathbf{labind(j)} + x0ind\_IR(j,g) - \mathbf{x0ind(j)}]$$

… *Table 2.1 continued*

Table 2.1 continued

Equation T9: ***Demand for non-margin commodity i from source s by agents in r***

(All,i,NMARG)(All,s,SOURCE)(All,r,REG)

$$
\begin{aligned}
\mathrm{dem\_CSR}(i,s,r) = \frac{1}{\mathrm{TOTDEMREG}(i,s,r)} * \Big\{ & \sum_{j \in IND} \mathrm{JOBSH}(j,r) * \mathrm{BAS1}(i,s,j) * [\mathbf{x1csi(i,s,j)} + \mathrm{x0ind\_IR}(j,r) - \sum_{g \in REG} \mathrm{JOBSH}(j,g) * \mathrm{x0ind\_IR}(j,g)] \\
+ & \sum_{j \in IND} \mathrm{JOBSH}(j,r) * \mathrm{BAS2}(i,s,j) * [\mathbf{x2csi(i,s,j)} + \mathrm{x0ind\_IR}(j,r) - \sum_{g \in REG} \mathrm{JOBSH}(j,g) * \mathrm{x0ind\_IR}(j,g)] \\
+ & \ \mathrm{REGSH3}(i,r) * \mathrm{BAS3}(i,s) * \mathrm{x3\_CSR}(i,s,r) \\
+ & \ \mathrm{SOURCEDOM}(s) * \mathrm{REGSH4}(i,r) * \mathrm{BAS4}(i) * \mathrm{x4\_CR}(i,r) \\
+ & \ \mathrm{REGSH5}(i,r) * \mathrm{BAS5}(i,s) * \mathrm{x5\_CSR}(i,s,r) \\
+ & \ 100 * \mathrm{d\_x6\_CSR}(i,s,r) \Big\}
\end{aligned}
$$

Equation T10: ***Use of margin commodity m to facilitate flows of i,s from r***

(All,m,MARG)(All,i,NMARG)(All,s,SOURCE)(All,r,REG)

$$
\mathrm{xmargf\_MNSR}(m,i,s,r) = \mathbf{xmarg\_MCS(m,i,s)} + \mathrm{x0\_CSR}(i,s,r) - \sum_{g \in REG} \mathrm{WTF}(m,i,s,g) * \mathrm{x0\_CSR}(i,s,g)
$$

Equation T11: ***Use of margin commodity m to facilitate flows of i,s to r***

(All,m,MARG)(All,i,NMARG)(All,s,SOURCE)(All,r,REG)

$$
\mathrm{xmargt\_MNSR}(m,i,s,r) = \mathbf{xmarg\_MCS(m,i,s)} + \mathrm{dem\_CSR}(i,s,r) - \sum_{g \in REG} \mathrm{WTT}(m,i,s,g) * \mathrm{dem\_CSR}(i,s,g)
$$

… Table 2.1 continued

Table 2.1 continued

Equation T12: ***Margin demand for margin commodity m by agents in r***

(All,m,MARG)(All,r,REG)

$$\text{xmarg\_MR}(m,r) = \frac{1}{\text{DM}(m,r)} * \sum_{i \in \text{NMARG}} \sum_{s \in \text{SOURCE}} \Big\{ \text{BETA}(m) * \text{DMF}(m,i,s,r) * \text{xmargf\_MNSR}(m,i,s,r) + (1 - \text{BETA}(m)) * \text{DMT}(m,i,s,r) * \text{xmargt\_MNSR}(m,i,s,r)] \Big\}$$

Equation T13: ***Demand for margin commodity i from source s by agents in r***

(All,i,MARG)(All,s,SOURCE)(All,r,REG)

$$\begin{aligned}\text{dem\_CSR}(i,s,r) = \frac{1}{\text{TOTDEMREG}(i,s,r)} * \Big\{ & \sum_{j \in \text{IND}} \text{JOBSH}(j,r) * \text{BAS1}(i,s,j) * [\mathbf{x1csi(i,s,j)} + \text{x0ind\_IR}(j,r) - \sum_{g \in \text{REG}} \text{JOBSH}(j,g) * \text{x0ind\_IR}(j,g)] \\ & + \sum_{j \in \text{IND}} \text{JOBSH}(j,r) * \text{BAS2}(i,s,j) * [\mathbf{x2csi(i,s,j)} + \text{x0ind\_IR}(j,r) - \sum_{g \in \text{REG}} \text{JOBSH}(j,g) * \text{x0ind\_IR}(j,g)] \\ & + \text{REGSH3}(i,r) * \text{BAS3}(i,s) * \text{x3\_CSR}(i,s,r) \\ & + \text{SOURCEDOM}(s) * \text{REGSH4}(i,r) * \text{BAS4}(i) * \text{x4\_CR}(i,r) \\ & + \text{REGSH5}(i,r) * \text{BAS5}(i,s) * \text{x5\_CSR}(i,s,r) \\ & + 100 * \text{d\_x6\_CSR}(i,s,r) \\ & + \text{SOURCEDOM}(s) * \text{DM}(i,r) * \text{xmarg\_MR}(i,r) \Big\}\end{aligned}$$

… Table 2.1 continued

Table 2.1 continued

Equation T14: ***Supply of commodity i from source s out of region r***

(All,i,COM)(All,s,SOURCE)(All,r,REG)

$$x0\_CSR(i,s,r) = \frac{1}{SCSR(i,s,r)} * \sum_{g \in REG} SHIN(i,s,r,g) * TOTDEMREG(i,s,g) * \left\{ dem\_CSR(i,s,g) + shin\_CSRR(i,s,r,g) - \sum_{k \in REG} SHIN(i,s,k,g) * shin\_CSRR(i,s,k,g) \right\}$$

Table 2.2. Sets in the regional extension

Name	Description
COM	Commodities, 503 in USAGE-ITC
IND	Industries, 513 in USAGE-ITC
SOURCE	Domestic and imported
MARG	Margin commodities, a subset of COM, 10 elements
NMARG	Non-margin commodities, a subset of COM, 493 elements
REG	Regions, 50 states plus the District of Columbia

Table 2.3. Variables in the regional extension

Name	Domain	Description
National variables		
x0ind(j)	$j \in$ IND	Output by industry
hdy	scalar	Household disposable income
labind(j)	$j \in$ IND	Employment by industry
x3cs(i,s)	$i \in$ COM, $s \in$ SOURCE	Consumption by households of i,s
x4(i)	$i \in$ COM	Exports of commodity i
x5cs(i,s)	$i \in$ COM, $s \in$ SOURCE	Consumption by governments of i,s
d_x6cs(i,s)	$i \in$ COM, $s \in$ SOURCE	Inventory accumulation of i,s
gdpreal	scalar	Real GDP
emp_hours	scalar	Aggregate employment
x1csi(i,s,j)	$i \in$ COM, $s \in$ SOURCE, $j \in$ IND	Intermediate demand for i,s by industry j
x2csi(i,s,j)	$i \in$ COM, $s \in$ SOURCE, $j \in$ IND	Investment demand for i,s by industry j
xmarg_MCS(m,i,s)	$m \in$ MARG, $i \in$ COM, $s \in$ SOURCE,	Margin demand for m to facilitate flows of i,s
Regional variables		
x0ind_IR(j,r)	$j \in$ IND, $r \in$ REG	Output by industry and region
x0_CSR(i,s,r)	$i \in$ COM, $s \in$ SOURCE, $r \in$ REG	Supply of i,s from region r
dispy_R(r)	$r \in$ REG	Disposable income in region r
x3_CSR(i,s,r)	$i \in$ COM, $s \in$ SOURCE, $r \in$ REG	Consumption of i,s by households in r
x4_CR(i,r)	$i \in$ COM, $r \in$ REG	Exports of i leaving US from region r
reg4_CR(i,r)	$i \in$ COM, $r \in$ REG	Share of US exports of i leaving from r (usually exogenous)
x5_CSR(i,s,r)	$i \in$ COM, $s \in$ SOURCE, $r \in$ REG	Consumption of i,s in r by governments
d_x6_CSR(i,s,r)	$i \in$ COM, $s \in$ SOURCE, $r \in$ REG	Inventory accumulation of i,s in r
gspreal_R(r)	$r \in$ REG	Gross State product in r
emp_R(r)	$r \in$ REG	Employment in r
dem_CSR(i,s,r)	$i \in$ COM, $s \in$ SOURCE, $r \in$ REG	Demand for i,s in region r
xmargf_MNSR(m,i,s,r)	$m \in$ MARG, $i \in$ NMARG $s \in$ SOURCE, $r \in$ REG	Use of margin commodity m to facilitate the flow of i,s from r
xmargt_MNSR(m,i,s,r)	$m \in$ MARG, $i \in$ NMARG $s \in$ SOURCE, $r \in$ REG	Use of margin commodity m to facilitate the flow of i,s to r
xmarg_MR(m,r)	$m \in$ MARG, $r \in$ REG	Margin demand for m by agents in r
shin_CSRR(i,s,r,g)	$i \in$ COM, $s \in$ SOURCE, $r \in$ REG, $g \in$ REG	Share of region r in satisfying region g's demand for i,s (usually exogenous)

Table 2.4. Coefficients and parameters in the regional extension

Name	Domain	Description
H0CI(i,j)	i∈COM, j∈IND	Share of commodity i in the output of industry j
JOBSH(j,r)	j∈IND, r∈REG	Share of region r in employment and output in industry j
GAMMA	scalar	Parameter, controls sensitivity of regional disposable income to regional employment
LABSH(j,r)	j∈IND, r∈REG	Share of industry j in r's labor income
SHLAB(r)	r∈REG	Share of region r in national labor income
REGSH3(i,r)	i∈COM, r∈REG	Share of region r in consumption of i
REGSH4(i,r)	i∈COM, r∈REG	Share of region r as a port for exports of i
REGSH5(i,r)	i∈COM, r∈REG	Share of region r in govt. consumption of i
SUPSH(i,s,r)	i∈COM, s∈SOURCE, r∈REG	Share of region r in the supply of i,s
VADSH(j,r)	j∈IND, r∈REG	Share of industry j in value-added in region r
SHVAD(r)	r∈REG	Share of region r in national value-added
TOTDEMREG(i,s,r)	i∈COM, s∈SOURCE, r∈REG	Demand for i,s in region r
BAS1(i,s,j)	i∈COM, s∈SOURCE, j∈IND	Intermediate use of i,s by industry j, national
BAS2(i,s,j)	i∈COM, s∈SOURCE, j∈IND	Investment use of i,s by industry j, national
BAS3(i,s)	i∈COM, s∈SOURCE	Household use of i,s, national
BAS4(i)	i∈COM	Exports of i, national
BAS5(i,s)	i∈COM, s∈SOURCE	Government consumption of i,s, national
SOURCEDOM(s)	s∈SOURCE	One for s = domestic, zero for s = imported
WTF(m,i,s,r)	m∈MARG, i∈NMARG, s∈SOURCE, r∈REG	Share of the margin use of m on flows of i,s associated with i,s flows *from* r
WTT(m,i,s,r)	m∈MARG, i∈NMARG, s∈SOURCE, r∈REG	Share of the margin use of m on flows of i,s associated with i,s flows *to* r
DM(m,r)	m∈MARG, r∈REG	Margin demand for m by agents in r
DMF(m,i,s,r)	m∈MARG, i∈NMARG, s∈SOURCE, r∈REG	Margin use of m on flows of i,s *from* r
DMT(m,i,s,r)	m∈MARG, i∈NMARG, s∈SOURCE, r∈REG	Margin use of m on flows of i,s *to* r
BETA(m)	m∈MARG	Fraction of the margin use of m on flows from a region that is organised by agents in the region
SCSR(i,s,r)	i∈COM, s∈SOURCE, r∈REG	Supply of i,s from region r
SHIN(i,s,r,g)	i∈COM, s∈SOURCE, r∈REG, g∈REG	Share of region r in satisfying region g's demand for i,s

As will be apparent in section 3, the ordering of the equations in Table 2.1 reflects our computing strategy. For explaining the equations it is easiest to start with those for total demands for commodities by demanding regions, T9 and T13. Then we look at the specifications of the components of these demands.

Demand for commodity i from source s by agents in region r, T9 and T13

Equation T9 determines the percentage changes in total demands [dem_CSR(i,s,r)] for non-margin commodities in regions as weighted averages of percentage changes in intermediate, investment, consumption, export, government and inventory demands. Equation T13, for margin commodities, has an extra term covering demands in region r for commodity i from the domestic source (s = dom) to be used as a margin service. Margin services connect producers (or ports of entry in the case of imports) to users. Margin commodities include transport, retail trade and wholesale trade. In USAGE-ITC, there are 10 margin commodities and 493 non-margin commodities. All demands for margin services are satisfied by domestic production and margin commodities can be used not only as margin services but also directly (e.g. air transport used to move employees between work sites).

The weights applied to different demands on the RHSs of T9 and T13 are the shares of each demand in total demand. For example, the weight given to the percentage change in region r's household demand for i,s [x3_CSR(i,s,r)] in determining the percentage change in r's total demand for i,s is the share of household consumption in r's total demand for i,s. This share is calculated as

$$\text{HHShare}(i,s,r) = \frac{\text{REGSH3}(i,r) * \text{BAS3}(i,s)}{\text{TOTDEMREG}(i,s,r)} \quad . \tag{2.1}$$

As can be seen from Table 2.4, REGSH3(i,r) is the share of region r in national household consumption of i [1] and BAS3(i,s) is national household consumption of i,s. Thus, the numerator on the RHS of (2.1) is household consumption of i,s in r. The denominator is the total demand for i,s in r.

The only exceptions to the use of shares as weights on the RHSs of T9 and T13 are for inventories. Because the inventory variable [d_x6_CSR(i,s,r)] refers to a change (not a percentage change), the appropriate coefficients in T9 and T13 are 100/TOTDEMREG(i,s,r).

Finally with regard to T9 and T13, we note that percentage changes in intermediate and investment demands for i,s by industry j in region r are given by:

$$\text{intermediate}(i,s,j,r) = \mathbf{x1csi(i,s,j)} + \text{x0ind\_IR}(j,r) - \sum_{g \in REG} \text{JOBSH}(j,g) * \text{x0ind\_IR}(j,g) \tag{2.2}$$

and

$$\text{investment}(i,s,j,r) = \mathbf{x2csi(i,s,j)} + \text{x0ind\_IR}(j,r) - \sum_{g \in REG} \text{JOBSH}(j,g) * \text{x0ind\_IR}(j,g) \quad . \tag{2.3}$$

In (2.2) we assume that the percentage change in intermediate demand for i,s by industry j in region r varies from that by industry j for the nation to the extent that the percentage change in j's output in region r [x0ind_IR(j,r)] varies from the percentage change in j's output for the nation. The percentage change in industry j's output for the nation is calculated as a weighted average of the percentage changes in j's outputs in the regions. Similarly, in (2.3) we assume that the differences between the percentage changes in j's investment demands for i,s at the regional level reflect differences between percentage changes in j's output at the regional and national levels.

---

[1] We assume that r's shares of household consumption of domestic and imported i are the same.

Equations (2.2) and (2.3) are examples of a general form that is applied several times in our regional extension:

$$\text{var\_R}(r) = \mathbf{var} \quad + \quad \text{relevant\_R}(r) - \sum_{g \in REG} \text{SHVAR}(g) * \text{relevant\_R}(g) \qquad . \tag{2.4}$$

In (2.4),

var_R is a regional variable and **var** is the corresponding national variable, e.g. percentage changes in intermediate demands at the state and national levels;

relevant_R is a regional variable relevant to determining the gap between var_R and **var**, e.g. the percentage change in output at the state level; and

SHVAR(g) is the coefficient giving the share of region g in the national level of **var**, e.g. state shares in national output.

By using equations such as (2.4) we ensure that the regional extension produces results that aggregate to those in the national model:

$$\sum_{g \in REG} \text{SHVAR}(g) * \text{var\_R}(g) = \mathbf{var} \qquad . \tag{2.5}$$

Demand for commodity i from source s by households in r and household disposable income in r, T3 and T2

Equation T3, which determines the demand for i,s by households in region r, is a straightforward application of (2.4). The "relevant" variable is household disposable income [dispy_R(r)].

Household disposable income at the state level is determined in T2 by another application of (2.4). This time the "relevant" variable is a modified measure of employment in region r:

$$\text{relevant\_R}(r) = \text{GAMMA} * \sum_{j \in IND} \text{LABSH}(j,r) * [\mathbf{labind(j)} + \text{x0ind\_IR}(j,r) - \mathbf{x0ind(j)}] \quad . \tag{2.6}$$

In (2.6) we assume that the percentage change in employment in industry j in region r is determined by the percentage change in national employment in industry j and by the deviation between the percentage changes in j's output in region r and j's national output. The parameter GAMMA is set at one for the illustrative application in section 3. However, values of less than one may be appropriate. This would be the case if the effects of employment changes in region r on household consumption are softened by social security payments, other non-labor incomes and changes in savings behavior.

Demand for commodity i to be exported from region r, T4

Equation T4 specifies percentage movements in exports of i from ports in state r. Again we adopt a form consistent with (2.4). The "relevant" variable [reg4_CR(i,r)] is simply the percentage change in r's share of the exports of i. It will normally be exogenous.

Demand for commodity i from source s to be delivered from region r to governments, T5

In T5 we assume that the percentage changes across all states in government demands for i,s are in line with percentage changes at the national level. We have not included a "relevant" variable for government consumption, although it may be a good idea to do so. For example, we may want to recognise that state and local government demand in a region depends on income in the region.

Demand for commodity i from source s to be delivered from region r for inventories , T6

The change in inventory demand for i,s at the regional level is modeled in T6 as a share of the change at the national level. SUPSH(i,s,r) is the share of region r in the supply of i,s. For domestic good i, SUPSH(i,s,r) is r's output share. For imported good i, SUPSH(i,s,r) is the share of the nation's imports of i that arrive through ports in region r.

Demand for margins by agents in r, T10, T11 and T12

Equations T10 and T11 follow the (2.4)-format in specifying the demands for margin service m in facilitating flows of i,s *from* region r and *to* region r. In T10 the "relevant" variable is the supply of i,s in r and in T11 the "relevant" variable is the demand for i,s in r.

We assume that agents in each region r are responsible for organising the fraction BETA(m) of the margin services of type m required on the flows of i,s *from* r. Consequently we assume that agents in each region r are responsible for organising the fraction [1-BETA(m)] of the margin services of type m required on the flows of i,s *to* r. In the illustrative application in section 3, BETA(m) is 0.5 for all m expect retail trade. For retail trade we assume that all the margin service is organised by the receiving region, i.e. BETA(retail) = 0. With the BETA(m)s assumed constant, we obtain T12, in which the percentage change in the demand for margin service m by agents in region r is a weighted average of the percentage changes in the demands for m to be used in facilitating flows from and to region r. The weights, BETA(m)*DMF(m,i,s,r)/DM(m,r) and (1-BETA(m))*DMT(m,i,s,r)/DM(m,r), are the shares of the total margin demand for m in r that are associated with flows of i,s from r and flows of i,s to r.

Output by industry j in region r, T1

To determine the percentage change in the output of industry j in region r [x0ind_IR(j,r)] we again adopt the (2.4)-format. The "relevant" variable is a weighted average of the percentage changes in the outputs of commodities in r [x0_CSR(i,"dom",r)] with the weights being commodity shares in the national output of industry j. Thus the "relevant" variable is an estimate of the percentage change in industry j's output in region r based on movements in commodity outputs in region r.

Supply of commodity i from source s out of region r, T14

T14 determines the percentage change in the supply of i,s from region r. For domestic commodities, supply is output in region r. For imported commodities, supply is the volume of imports of i coming into the US via ports in region r.

In T14 we assume that the percentage change in the demand for i,s from r by region g is given by:

$$\mathrm{dem}(i,s,r,g) = \mathrm{dem\_CSR}(i,s,g) + \mathrm{shin\_CSRR}(i,s,r,g) - \sum_{k \in REG} \mathrm{SHIN}(i,s,k,g) * \mathrm{shin\_CSRR}(i,s,k,g) \quad , \quad (2.7)$$

that is, g's demand for i,s from r moves with g's demand for i,s [dem_CSR(i,s,g)] and with percentage changes [shin_CSRR(i,s,r,g)] in the share of g's demands for i,s satisfied from r. The share changes, shin_CSRR(i,s,r,g), are normally set exogenously. The final term on the RHS of (2.7) ensures that exogenous movements in the shin_CSRR(i,s,r,g)s cannot lead to a violation of the adding-up condition:

$$\sum_{r \in REG} SHIN(i,s,r,g) * dem(i,s,r,g) = dem\_CSR(i,s,g) \quad . \tag{2.8}$$

With the dem(i,s,r,g)s given by (2.7), T14 determines the percentage change in the supply of i,s from r as a weighted average of the dem(i,s,r,g)s across all regions g. The weights, SHIN(i,s,r,g)*TOTDEMREG(i,s,g)/SCSR(i,s,r), are regional shares in the demand for i,s supplied from r.

Gross regional product and employment by region, T7 and T8

These equations define percentage movements in regional gross product and employment. Neither of these variables feeds back into any of the other equations in Table 2.1. However, both variables are important in the presentation of results. In T7 and T8 we follow the familiar (2.4)-format. In T7 the "relevant" variable is the percentage change in regional value added, calculated as a weighted average of percentage changes in regional industry outputs. In T8 the "relevant" variable is the percentage change in regional employment, calculated as in T2.

3. Computing regional solutions

Initially we attempted to compute regional solutions by attaching the regional equations (Table 2.1) to the GEMPACK[2] representation of the national USAGE-ITC model. This approach failed because the national-plus-regional equation system required far more memory than we had available. We then tried to solve the regional system as a standard set of GEMPACK equations with the national variables being exogenous and given shocks reflecting results from the national model. Again we failed to obtain regional results because of size/memory problems. With a standard GEMPACK representation, our regional system involves effective inversion of coefficient matrices of size 503x2x51 squared (503 commodities by 2 sources by 51 regions). Matrices of this size are far too large for inversion with the hardware normally available to economic modelers.

Our third approach was to undertake the regional computations in stand-alone mode with the commodity dimension reduced from 503 to 88. Aggregation of the commodity dimension allowed us to obtain solutions. However, these solutions had unrealistic features. For example, we found that our regional computation with aggregated commodities implied a large flow of Food Grain from producing states such as Kansas and Texas to Alaska. This was caused by Alaska having a large Other Food industry. With aggregated commodities and industries, the Other Food industry is an amalgam of twenty-one 500-order industries including Flour, Cereal, Noodles, Canned Fish and Prepared Fish. It is the fish-related component that gives Alaska a substantial Other Food industry. At the national level, Other Food absorbs considerable inputs of Food Grain. Because in our regional calculations we assume that the national technology for each industry applies in all regions, our aggregated calculations imply that the Alaskan Other Food industry uses large amounts of Food Grain which must be shipped from producing states. These unrealistic implications are avoided in computations using the 500-order industry/commodity dimension. At the 500 level, we recognize that the Alaskan component of Other Food is Fish-related activities which do not use Food Grain. Examples such as this convinced us that we should try harder to perform our regional computations with the full commodity/industry dimension.

Still using GEMPACK code, we finally succeeded in generating full-dimension regional solutions by a tailor-made algorithm. This algorithm exploits the near lower-triangular structure of the equations in the regional extension. We start by making an initial guess of percentage changes in regional supplies of commodities [x0_CSR(i,s,r)] according to

$$\mathrm{x0\_CSR(i,s,r)} = \mathbf{x0(i,s)} \quad , \qquad \mathrm{i} \in \mathrm{COM},\ \mathrm{s}, \mathrm{SOURCE}, \mathrm{r} \in \mathrm{REG} \quad . \tag{3.1}$$

where x0(i,s) is the USAGE-ITC result for the percentage change in the national supply of commodity i from source s. With this guess, we can use T1 to compute percentage changes in output by industry and region [x0ind_IR(j,r)]. T2 then generates percentage changes in disposable income by region [dispy_R(r)]. Moving to T3 we can compute percentage changes in household consumption by commodity, source and region. With reg4_CR(i,r) set exogenously, T4 reveals percentage changes in exports by commodity and region of exit [x4_CR(i,r)]. Proceeding in this way we can work through each of the equations in Table 2.1 solving for the left hand variables. Eventually we arrive at T14 where we obtain new values for percentage changes in commodity supplies by region.[3] If the new values contradict those given by (3.1), we adopt the new values in T1 and proceed through the equations again. We have found that the process converges very rapidly, probably because (3.1) is a reasonable starting guess.

While this iterative process produces full-dimension regional results with trivial computing requirements, it is not ideal. Being tailor-made, it does not currently allow us to exploit all of the valuable features of GEMPACK, including procedures for eliminating linearization errors and for disaggregating changes in endogenous variables into the parts attributable to changes in each of the exogenous variables. We expect that these drawbacks of our current iterative process will be overcome in future research.

4. The coefficients of the regional extension

To implement the regional extension we need values for the 26 arrays of coefficients and parameters listed in Table 2.4. This subsection describes how these coefficients have been estimated for the illustrative application in section 3. The estimates of some coefficients depend on estimates of other coefficients. Our

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[2] GEMPACK is well-known CGE software created by Ken Pearson and his colleagues, see for example, Pearson (1988) and Harrison and Pearson (1996).

description of the estimation procedures follows a particular sequence that avoids circularity, whereby the estimation of each coefficient depends only on known data and previously estimated coefficients. *Parameters: GAMMA, SOURCEDOM, BETA*

As mentioned in subsection 2.1, in our illustrative application GAMMA is set at one, BETA(m) = 0.5 for all m except retail trade and BETA(retail) = 0. The setting of SOURCEDOM is specified in Table 4.

National coefficients: H0CI, BAS1 … BAS5

Values for these coefficients are available in the national model. In our illustrative application we used values for 1998.

Output and employment by industry and State: JOBSH

The main regional data ingredient in our calculations is the JOBSH matrix showing the shares of each industry located in each region. We assume that these shares refer to industry outputs. We also use them as shares in industry employment.

The starting point for developing the JOBSH matrix is IMPLAN data for 1998 showing numbers of jobs (wage and salary plus self-employed) for 528 industries and 51 states (we treat the District of Colombia as a state). These data were supplied to us for construction of USAGE-ITC by the USITC.

The first task in using the IMPLAN data to develop the JOBSH matrix was the time-consuming work of correcting mismatches between the industrial/commodity classifications in the IMPLAN regional data and in USAGE-ITC data. These mismatches go both ways. In some cases the IMPLAN data have finer industrial detail than the USAGE-ITC data. For example, the IMPLAN data distinguishes: Copper ores; Lead and zinc ores; Gold ores; Silver ores; and Uranium-radium-vanadium ores, whereas the USAGE-ITC data distinguishes only Copper ores and Other nonferrous ores. On the other hand the USAGE-ITC data distinguishes: Petroleum and natural gas well drilling; Petroleum, natural gas and solid mineral exploration; and Access structures for solid mineral development, whereas the IMPLAN data distinguishes only New mineral extraction facilities. At the end of the matching process we were able to develop JOBSH rows for 506 of the 513 USAGE-ITC industries. The remaining seven industries have no direct employment. For these industries the IMPLAN jobs data do not provide a basis for estimating the regional distribution of industry outputs.

The first of the zero-employment industries is Ownership of Dwellings. We assumed that the regional distribution of its output reflects the regional distribution of total jobs. Thus we assumed that the distribution across states of rental incomes (explicit and imputed) on the housing stock is the same as that of total jobs.

[3] We assume that shin_CSRR(i,s,r,g) is exogenous.

The next two zero-employment industries are Export Tourism and Holidays. In USAGE-ITC these industries sell packages consisting mainly of hotels, travel and entertainment to foreign tourists and to domestic tourists. For working out the regional distribution of activity for Export Tourism we used estimates for 1997 of the regional distribution of expenditures by foreign tourists prepared by the Travel Industry Association of America (1999, Table 10). We were unable to find direct estimates of the regional distribution of expenditures by domestic tourists. For the Holiday row of the JOBSH matrix we relied on a formula that takes account of holiday use of hotels in each region estimated by deducting business and foreign demand for hotels from regional hotel outputs [details are in Dixon and Rimmer (2003)].

For Export Education, which sells a package of services to foreign students, we adopted a state distribution of activity reflecting the state distribution of output from the higher education industries.

For Foreign Holiday and Other Non-Residential we assumed that the state distributions of activity reflect the state distribution of disposable income. Foreign Holiday is an industry in USAGE-ITC that puts together services, predominantly imported, that make up holidays in foreign countries for US residents. Other Non-Residential is an industry that sells packages of goods and services to foreign workers in the US.

The final zero-employment industry is General Government, which sells a package of services to the public sector. In USAGE-ITC we have modeled most government services as produced by more specific industries such as Federal Government Defense. Thus, General Government is very small. We assume that its output is distributed across the states in the same way as the outputs of the rest of the government sector.

Regional supplies of commodities and regional shares in commodity supplies: SCSR and SUPSH

We estimate the supply of commodity i,s from region r according to:

$$SCSR(i,"dom",r) = \sum_{j \in IND} JOBSH(j,r) * MAKE(i,j) \tag{4.1}$$

and

$$SCSR(i,"imp",r) = SH\_M(i,r) * IMPORTS(i) \tag{4.2}$$

where

MAKE(i,j) is the output of domestic commodity i by industry j at the national level;
IMPORTS(i) is imports of commodity i at the national level; and
SH_M(i,r) is the share of imports of i that enter the US through region r.

Values for MAKE and IMPORTS are available from the national model. To estimate SH_M(i,r) we used data on goods imports by port from American Association of Port Authorities (2003). If ports in region r account for *x* per cent of US goods imports, then we assumed that *x* per cent of the imports of each good arrive in the US at a port in region r. For service imports, we assumed the same regional distribution as for demand. Given more research time we could improve the estimate of SH_M by taking account of differences in the composition of goods imports by port.

Regional shares in national supply are calculated as:

$$\text{SUPSH}(i,s,r) = \frac{\text{SCSR}(i,s,r)}{\sum_{g\in \text{REG}} \text{SCSR}(i,s,g)} \tag{4.3}$$

Regional shares in household, export and government demands: REGSH3, REGSH4 and REGSH5

For REGSH3 we assumed that households in region r account for *x* per cent of national household consumption of commodity i (domestic and imported) if region r accounts for *x* per cent of national disposable income. In developing REGSH4 we used data from the American Association of Port Authorities (2003) on goods exports by port of exit. If ports in region r account for *x* per cent of US goods exports, then we assumed that *x* per cent of the exports of each good leave the US from region r. The estimates of REGSH3 and REGSH4 could be improved by taking account of interregional differences in consumption patterns and in the goods composition of exports by port. For service exports, we assumed the same regional distribution as that for output. Similarly, for REGSH5, we used regional output shares. Thus, for both service exports and government demands we assumed that demands for delivery from region r are satisfied by production in region r.

Regional demands for non-margin commodities: TOTDEMREG(i,s,r), i,s a non-margin

The demand for non-margin commodity i,s for use in region r is estimated as:

$$\begin{aligned}\text{TOTDEMREG}(i,s,r) = & \sum_{j\in \text{IND}} \text{JOBSH}(j,r) * [\text{BAS1}(i,s,j) + \text{BAS2}(i,s,j) + \text{REGSH3}(i,r) * \text{BAS3}(i,s) \\ & + \text{SOURCEDOM}(s) * \text{REGSH4}(i,r) + \text{REGSH5}(i,r) * \text{BAS5}(i,s) + \text{SUPSH}(i,s,r) * \text{BAS6}(i,s) \quad .\end{aligned} \tag{4.4}$$

All of the notation in (4.4) has already been defined. The estimation of TOTDEMREG(i,s,r) where i,s is a margin commodity is discussed later in this subsection.

Regional shares in satisfying regional demands: SHIN

For each commodity i,s, SHIN contains a region by region (51 by 51) matrix, $\text{SHIN}_{i,s}$. The columns of $\text{SHIN}_{i,s}$ each add to one and the (r,g)-th component is the share of g's requirements for i,s that is satisfied by shipments from region r.

Ideally, SHIN matrices should be developed from detailed information on interregional commodity flows. However, such data are scarce and often difficult to use.[4] In these circumstances, the tradition in regional modeling is to generate SHIN matrices by formulas.

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[4] The US Department of Transportation (1996) has published statistics by mode of transport on flows in broad commodity classifications between US states. In future research we hope to use these statistics to improve our estimation of the SHIN matrices.

The first SHIN formula used in interregional modeling was that of Leontief, Morgan, Polenske, Simpson and Tower (LMPST, 1965) in an input-output study of the regional effects of defense spending. LMPST divided commodities into two groups: national and local. National commodities include all imports and domestic commodities that are extensively traded across state borders. Local commodities are those that are not readily tradeable across state borders. They 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. For national commodities, LMPST assumed, in effect, that the SHIN matrix for commodity i,s has 51 identical columns with each column showing regional output shares in the case of domestic goods and regional entry shares in the case of imports. Thus, LMPST assumed that if region r is responsible for 10 per cent of the supply of national commodity i,s, then each region g satisfies 10 per cent of its demands for i,s by shipments from r. Under the LMPST assumption, the state distribution of supply of a national commodity is independent of the state distribution of demand for the commodity. For local commodities, LMPST assumed that SHIN is the identity matrix. Thus, they assumed that region g's requirements for local good (i,"dom") are satisfied entirely by shipments from region g.

The LMPST approach for estimating SHIN was adapted for CGE modelling by Dixon, Parmenter and Sutton (1978) who disaggregated results from a CGE model to the six Australian States. In Australia, LMPST's distinction between local and national goods is tenable for disaggregation to the state level. This is because most of Australia's economic activity takes place in the capital cities of the states and these cities are far from state borders. Thus, there are many goods that are barely traded across state 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 distribution of production seems to be independent of the state distribution of absorption. It is reasonable to classify these goods as national.

Although first applied in the US, the LMPST approach does not seem particularly suitable for the US. Many major cities are near state borders and almost all commodities are traded between states. Thus in the US there are few local goods. In looking at US data, we found that even strong candidates for the local category (e.g. laundry services) are traded between neighbouring regions such as Virginia, Maryland and Washington DC. 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 state borders, it is clear that these goods do not meet the national criterion of independence of location of production and location of absorption.

In developing SHIN matrices for the US, we adopted formulas invented by our colleague Mark Horridge for use in the TERM model, a 57 region CGE model of Australia, see Horridge *et al.* (2003). These formulas allow us to recognise that nearly all of the 503 commodities in USAGE-ITC fall between the LMPST extremes of national and local. For nearly all commodities, there is interstate trade and the regional allocation of supply responds to changes in the regional allocation of demand.

We started by implementing the Horridge formulas for non-margin commodities. As we will see, the formulas require estimates of regional demands and supplies by commodity (TOTDEMREG and SCSR). At this stage we have not worked out regional demands for margin commodities.

The first step in the Horridge procedure is to make a preliminary estimate (denoted by a superscript 1) of the $SHIN_{i,s}$ matrix by computing:

$$SHIN^1(i,s,g,g) = MIN\left\{\frac{SCSR(i,s,g)}{TOTDEMREG(i,s,g)}\ ,1\right\} * F(i,s) \quad , \quad (i,s) = \text{non-margin},\ g \in REG \tag{4.5}$$

and

$$SHIN^1(i,s,r,g) = \left\{\frac{1}{Dist(r,g)} * \frac{SCSR(i,s,r)}{\sum_{q \in REG} SCSR(i,s,q)}\right\} * \left\{\frac{1 - SHIN^1(i,s,g,g)}{\sum_{v \neq g}\left[\frac{1}{Dist(v,g)} * \frac{SCSR(i,s,v)}{\sum_{q \in REG} SCSR(i,s,q)}\right]}\right\}, \tag{4.6}$$

$$(i,s) = \text{non-margin},\ r \in REG,\ g \in REG,\ r \neq g$$

where

F(i,s) is a parameter valued between 0.5 and 1, with a value close to 1 if i,s is not readily tradeable;
Dist(r,g) for $r \neq g$ is the distance between central points in regions r and g ; and
Dist(g,g) is half the distance between g and its nearest neighbour.[5]

Together these two formulas produce share estimates that satisfy the condition $\sum_r SHIN^1(i,s,r,g) = 1$.

Via (4.5) we set a high initial value for the (i,s)-own-share in region g [$SHIN^1(i,s,g,g)$] if g is a major supplier of i,s [SCSR(i,s,g) >TOTDEMREG(i,s,g)] and we judge commodity i,s to be not readily traded [F(i,s) close to one]. Via (4.6), we set a high initial value for $SHIN^1(i,s,r,g)$, $r \neq g$, if r and g are geographically close, i,s is readily traded and region r is a significant supplier of good i,s [Dist(r,g) and $SHIN^1(i,s,g,g)$ are small and SCSR(i,s,r) is large].

In setting the values for F(i,s), we looked at the proportionate demand-supply gaps in each region for commodity i,s defined by

$$GAP(i,s,g) = ABS\left(\frac{TOTDEMREG(i,s,g) - SCSR(i,s,g)}{[TOTDEMREG(i,s,g) + SCSR(i,s,g)]/2}\right) \quad . \tag{4.7}$$

[5] Values for Dist(g,g) are not needed immediately. However, it is convenient to record them here. They are needed in (4.18) and (4.19).

If i,s is not readily tradeable, then we would expect GAP(i,s,g) for most g to be close to zero. On the other hand, if i,s is readily tradeable, then we would expect GAP(i,s,g) to be close to 2 for a significant number of g's. Having computed the GAPs, we calculated F(i,s) according to

$$F(i,s) = \frac{1 + 0.5 * \exp[5 * (aveGAP(i,s) - 1)]}{1 + \exp[5 * (aveGAP(i,s) - 1)]} \quad . \tag{4.8}$$

where aveGAP(i,s) is the average of GAP(i,s,g) over g. Formula (4.8) ensures that F(i,s) lies between 0.5 and 1, and will be close to 0.5 if aveGAP(i,s) is close to its upper limit (2) and will be close to 1 if aveGAP(i,s) is close to its lower limit (0).

The next step in the Horridge procedure is to calculate initial values for the flows of i,s between states r and g:

$$FLOW^1(i,s,r,g) = SHIN^1(i,s,r,g) * TOTDEMREG(i,s,g) \quad . \tag{4.9}$$

The $FLOW^1_{i,s}$ matrix is then refined by a RAS procedure to achieve a final estimate that satisfies the conditions:

$$\sum_{r \in REG} FLOW(i,s,r,g) = TOTDEMREG(i,s,g) \quad . \tag{4.10}$$

and

$$\sum_{g \in REG} FLOW(i,s,r,g) = SCSR(i,s,r) \quad . \tag{4.11}$$

The final estimate for $SHIN_{i,s}$ is obtained from these refined FLOW estimates as:

$$SHIN(i,s,r,g) = FLOW(i,s,r,g) / TOTDEMREG(i,s,g) \quad , (i,s) = \text{non-margin}, r \in REG, g \in REG \quad . \tag{4.12}$$

For seeing how the Horridge procedure works, it is helpful to look at Tables 4.1 and 4.2. These show parts of the FLOW and SHIN matrices for domestically produced Fruit and Coal. The row totals in Table 4.1 indicate that California, Florida and Washington are the major US producers of Fruit. Under the Horridge procedure, demands in these major supplying regions are satisfied predominantly from within the region: the diagonal elements for California, Florida and Washington in the SHIN matrix are 0.70, 0.53 and 0.55. In regions with little fruit production, nearby supplying regions are over-represented in satisfying demands. Thus we see that 92 per cent of demand in Nevada is satisfied from California. On the other hand, the Californian share in flows to the District of Columbia is only 44 per cent, considerably less than the Californian share in total supply (54 per cent). Because it is closer to Florida than to California, the District of Columbia has an above average share of its fruit demands satisfied from Florida (19 per cent compared with the national average of 13 per cent).

Table 4.1. Estimated flows ($m) for 1998 and shares in state demands: US Fruit

Demand Supply	California	Florida	Georgia	Nevada	New York	Utah	Washing-ton	Dist. of Columbia	Other	Total supply
FLOW										
California	1924	232	137	75	136	43	199	7	2801	5554
Florida	134	365	73	1	53	2	8	3	711	1350
Washington	455	33	20	4	22	6	314	1	475	1330
Other	234	60	63	2	183	7	46	5	1460	2061
Total demand	2747	691	293	81	394	58	569	15	5447	10294
SHIN										
California	0.70	0.34	0.47	0.92	0.35	0.75	0.35	0.44	0.51	0.54
Florida	0.05	0.53	0.25	0.01	0.13	0.03	0.01	0.19	0.13	0.13
Washington	0.17	0.05	0.07	0.04	0.06	0.10	0.55	0.07	0.09	0.13
Other	0.09	0.09	0.22	0.02	0.46	0.12	0.08	0.30	0.27	0.20
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

The row totals in Table 4.2 indicate that Alabama, Kentucky, New Mexico, Pennsylvania, Utah, Virginia and West Virginia are the major US producers of Coal. The major demanding states are California, Florida, Illinois, New York, Ohio and Texas. Under the Horridge procedure, Utah and New Mexico are over-represented in supplies to nearby California; Kentucky is over-represented in supplies to nearby Florida; Pennsylvania is over-represented in supplies to nearby New York; Alabama is over-represented in supplies to nearby Texas; and West Virginia is over-represented in supplies to nearby Ohio. All of the major supplying states are under-represented in coal sales to Illinois. This is because Illinois is a significant supplier of coal and satisfies much of its own demand.

While it will require considerable effort to justify the Horridge procedure empirically, on the evidence of Tables 4.1 and 4.2, it appears to produce results that are considerably more plausible than those obtained under the LMPST method. LMPST would classify both fruit and coal as national commodities. Thus, under the LMPST method: the Utah share of Coal sales to California would be the same as the Utah share of Coal sales to New York; the Californian share in Fruit sales to Nevada would be the same as the Californian share of Fruit sales to New York; etc.

Table 4.2. Estimated flows ($m) for 1998 and shares in state demands: US Coal

Demand / Supply	California	Florida	Illinois	New York	Ohio	Texas	Other	Total supply
FLOW								
Alabama	92	87	24	34	13	89	1063	1401
Kentucky	348	276	168	185	158	256	3457	4847
New Mexico	123	16	5	7	2	35	335	523
Pennsylvania	135	119	33	644	27	82	2076	3117
Utah	148	12	4	6	2	21	339	531
Virginia	87	94	20	140	17	56	1229	1643
West Virginia	323	286	119	256	200	223	3367	4772
Other	520	188	546	130	436	573	3434	5827
Total demand	1776	1076	920	1402	854	1335	15299	22662
SHIN								
Alabama	0.05	0.08	0.03	0.02	0.02	0.07	0.07	0.06
Kentucky	0.20	0.26	0.18	0.13	0.18	0.19	0.23	0.21
New Mexico	0.07	0.01	0.01	0.01	0.00	0.03	0.02	0.02
Pennsylvania	0.08	0.11	0.04	0.46	0.03	0.06	0.14	0.14
Utah	0.08	0.01	0.00	0.00	0.00	0.02	0.02	0.02
Virginia	0.05	0.09	0.02	0.10	0.02	0.04	0.08	0.07
West Virginia	0.18	0.27	0.13	0.18	0.23	0.17	0.22	0.21
Other	0.29	0.17	0.59	0.09	0.51	0.43	0.22	0.26
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Margin use of m on flows of i,s to and from region r: DMT and DMF

Again reflecting the ideas of Mark Horridge, we estimated the components of DMT and DMF for non-margin commodities i,s according to:

$$DMT(m,i,s,r) = DG\_IN(m,i,s,r) * MAR\_MCS(m,i,s) * \frac{TOTDEMREG(i,s,r)}{\sum_{q \in REG} TOTDEMREG(i,s,q)}$$

$$m \in MARG,\ r \in REG \qquad (4.13)$$

and

$$DMF(m,i,s,r) = DG\_OUT(m,i,s,r) * MAR\_MCS(m,i,s) * \frac{SCSR(i,s,r)}{\sum_{q \in REG} SCSR(i,s,q)},$$

$$m \in MARG,\ r \in REG \qquad (4.14)$$

where

MAR_MCS(m,i,s) is the national value (available from the USAGE-ITC database) of margin service m used in facilitating flows of i,s;

DG_IN(m,i,s,r) is a coefficient reflecting the distance travelled by the units of i,s absorbed in r and the sensitivity of requirements for margin m to distance travelled; and

DG_OUT(m,i,s,r) is a coefficient reflecting the distance travelled by the units of i,s supplied from r and the sensitivity of requirements for margin m to distance travelled.

For m = Wholesale Trade and Retail Trade, we assume that there is no sensitivity of m-requirements to distance travelled. Thus we set

$$DG\_IN(m,i,s,r) = DG\_OUT(m,i,s,r) = 1 \quad , \quad \text{for all i,s,r when m= Wholesale and Retail.} \tag{4.15}$$

In this case, if region r is responsible for *x* per cent of the nation's demand for i,s, then we assume that *x* per cent of margin service m (Wholesale and Retail) used in facilitating flows of i,s is associated with flows of i,s to r. Similarly, if region r is responsible for *x* per cent of the nation's supply of i,s, then we assume that *x* per cent of margin service m (Wholesale and Retail) used in facilitating flows of i,s is associated with flows of i,s from r.

For the remaining margin commodities, mainly transport services, we set the DG_INs so that the amount of margin service m associated with flows of i,s to r is relatively high if i,s flows to r travel a long way. Similarly, we set the DG_OUTs so that the amount of margin service m associated with flows of i,s from r is relatively high if i,s flows from r travel a long way. Specifically, we set the DG_INs and DG_OUTs according to:

$$DG\_IN(m,i,s,r) = \frac{aveDist\_IN(i,s,r)}{\sum_{g\in REG} \frac{TOTDEMREG(i,s,g)}{\sum_{q\in REG} TOTDEMREG(i,s,q)} * aveDist\_IN(i,s,g)} ,$$

for all i,s,r and m ≠Wholesale or Retail (4.16)

and

$$DG\_OUT(m,i,s,r) = \frac{aveDist\_OUT(i,s,r)}{\sum_{g\in REG} \frac{SCSR(i,s,g)}{\sum_{q\in REG} SCSR(i,s,q)} * aveDist\_OUT(i,s,g)} ,$$

for all i,s,r and m ≠Wholesale or Retail, (4.17)

where

aveDist_IN(i,s,r) and aveDist_OUT(i,s,r) are the average distances travelled by units of i,s absorbed in r and sent from r, computed as

$$aveDist\_IN(i,s,r) = \frac{\sum_{g\in REG} FLOW(i,s,g,r) * Dist(g,r)}{\sum_{q\in REG} FLOW(i,s,q,r)} , \tag{4.18}$$

and

$$\text{aveDist\_OUT}(i,s,r) = \frac{\sum_{g \in REG} FLOW(i,s,r,g) * Dist(r,g)}{\sum_{q \in REG} FLOW(i,s,r,q)} \quad . \tag{4.19}$$

With the DG_INs and DG_OUTs set according to (4.15), (4.16) and (4.17), it is easy to check that (4.13) and (4.14) satisfy the adding-up conditions

$$\sum_{r \in REG} DMT(m,i,s,r) = MAR\_MCS(m,i,s) \tag{4.20}$$

and

$$\sum_{r \in REG} DMF(m,i,s,r) = MAR\_MCS(m,i,s) \quad . \tag{4.21}$$

Margin demands and total demands for margin commodities at the regional level, and SHIN matrices for margin commodities: DM(m,r), TOTDEMREG(m,dom,r) and $SHIN_{m,dom}$ for $m \in MARG$

With DMT and DMF in place, we estimate the total demand for margin use of commodity m by agents in r as

$$DM(m,r) = \sum_{i \in NMARG} \sum_{s \in SOURCE} [BETA(m) * DMF(m,i,s,r) + (1 - BETA(m)) * DMT(m,i,s,r)]$$

$$m \in MARG,\ r \in REG. \tag{4.22}$$

In (4.22), we assume realistically that margin services are not used on flows of margin commodities. Thus the first summation on the RHS is restricted to $i \in NMARG$.

Now we can complete the estimation of total demands for commodities by regions. We compute

$$TOTDEMREG(m,s,r) = \sum_{j \in IND} JOBSH(j,r) * [BAS1(m,s,j) + BAS2(m,s,j) + REGSH3(m,r) * BAS3(m,s)$$
$$+ SOURCEDOM(s) * REGSH4(m,r) + REGSH5(m,r) * BAS5(m,s) + SUPSH(m,s,r) * BAS6(m,s) + DM(m,r)$$

$$\text{for } m \in MARG,\ s = dom \text{ and } r \in REG \quad . \tag{4.23}$$

With TOTDEMREG now in place for margin commodities, we can complete the estimation of the SHIN matrices by computing $SHIN_{m,dom}$, $m \in MARG$, using the procedures described by (4.5) to (4.12).

Tables 4.3 and 4.4 give parts of the FLOW and SHIN matrices for two margin commodities: Retail trade and Trucking services. The SHIN matrix for Retail trade is close to the identity matrix: our implementation of the Horridge procedure implies that each regions satisfies its own demand for Retail trade. The SHIN matrix for Trucking services is strongly diagonal but not nearly as close to the identity matrix as that for Retail trade. For example, New York has a diagonal SHIN element of only 0.70. The Horridge procedure implies that a significant share (17 per cent) of New York's trucking requirements are supplied

Table 4.3. Estimated flows ($m) for 1998 and shares in state demands: US Retail trade

Supply \ Demand	Alabama	Alaska	Arizona	Arkansas	Other	Total
FLOW						
Alabama	9908	1	1	1	530	10442
Alaska	0	1570	0	0	31	1601
Arizona	0	1	10113	0	1160	11275
Arkansas	1	0	1	6236	380	6619
Other	67	34	81	37	640414	640633
Total	9977	1605	10197	6275	642516	670571
SHIN						
Alabama	0.99	0.00	0.00	0.00	0.00	0.02
Alaska	0.00	0.98	0.00	0.00	0.00	0.00
Arizona	0.00	0.00	0.99	0.00	0.00	0.02
Arkansas	0.00	0.00	0.00	0.99	0.00	0.01
other	0.01	0.02	0.01	0.01	1.00	0.96
Total	1.00	1.00	1.00	1.00	1.00	1.00

Table 4.4. Estimated flows ($m) for 1998 and shares in state demands: US Trucking services

Supply \ Demand	California	Hawaii	New Jersey	New York	Dist. of Columbia	Other	Total
FLOW							
California	20868	67	0	31	4	745	21717
Hawaii	5	399	0	0	0	5	408
New Jersey	62	9	4800	1805	15	557	7247
New York	79	12	32	7537	18	748	8427
Dist. Columbia	1	0	0	2	125	11	140
Other	3536	373	20	1421	246	180271	185868
Total	24551	860	4852	10797	409	182337	223806
SHIN							
California	0.85	0.08	0.00	0.00	0.01	0.00	0.10
Hawaii	0.00	0.46	0.00	0.00	0.00	0.00	0.00
New Jersey	0.00	0.01	0.99	0.17	0.04	0.00	0.03
New York	0.00	0.01	0.01	0.70	0.04	0.00	0.04
Dist. of Columbia	0.00	0.00	0.00	0.00	0.31	0.00	0.00
Other	0.14	0.43	0.00	0.13	0.60	0.99	0.83
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00

from nearby New Jersey. The low diagonal number for Hawaii (0.46 per cent) in the SHIN matrix for Trucking services reveals a mistake in our application of the Horridge procedure. As can be seen from (4.13) and (4.14), in estimating the use of Trucking services for facilitating flows of commodities into and out of Hawaii we have not recognized that Hawaii is an island. This has led us to over-estimate the Hawaiian responsibility for Trucking services, leading to the erroneous conclusion that Hawaiian demand for

Trucking services far outweighs Hawaiian supply. This error and a corresponding error concerning water transport should be corrected in future research.

Coefficients derived from earlier regional coefficients and national coefficients

The six remaining coefficients in Table 2.4 are derived by straightforward formulas relying on regional coefficients to which values have already been assigned and on the national coefficients LABIND(j) and VADD(j) $j \in IND$. These two national coefficients are the values of labor input and value-added in industry j, available from the USAGE-ITC database. The formulas for the six remaining regional coefficients are:

$$LABSH(j,r) = \frac{JOBSH(j,r) * LABIND(j)}{\sum_{k \in IND} JOBSH(k,r) * LABIND(k)} \tag{4.24}$$

$$SHLAB(r) = \frac{\sum_{j \in IND} JOBSH(j,r) * LABIND(j)}{\sum_{k \in IND} LABIND(k)} \tag{4.25}$$

$$VADSH(j,r) = \frac{JOBSH(j,r) * VADD(j)}{\sum_{k \in IND} JOBSH(k,r) * VADD(k)} \tag{4.26}$$

$$SHVAD(r) = \frac{\sum_{j \in IND} JOBSH(j,r) * VADD(j)}{\sum_{k \in IND} VADD(k)} \tag{4.27}$$

$$WTT(m,i,s,r) = \frac{DMT(m,i,s,r)}{\sum_{d \in REG} DMT(m,i,s,d)} \tag{4.28}$$

$$WTF(m,i,s,r) = \frac{DMF(m,i,s,r)}{\sum_{d \in REG} DMF(m,i,s,d)} \tag{4.29}$$

5. Illustrative application: the regional effects of the removal of import restraints

This section provides an illustrative application of USAGE-ITC and its regional extension. We look at the effects of removing import restraints (tariffs and quotas).

Our colleagues at the USITC have calculated the tariff equivalents of US import restraints. These are shown in Table 5.1 for the commodities with the highest equivalent rates. The table also shows imports and implied tariff revenue, that is imports multiplied by the equivalent tariff rate.

Table 5.1. Imports and related data for 1998, and effects of tariff removal

USAGE-ITC Commodity	Tariff rate equivalents	Imports (c.i.f., $m)	Implied revenue ($m)	USAGE-ITC results *Percentage changes* imports	output	Arming -ton
78 Sugar	83.79	634	531	52.78	-7.18	1.7
55 Butter	52.96	133	70	25.82	-1.55	1
113 Hosierynec	33.08	279	92	20.80	-2.42	1.6
115 Apparel	33.06	44563	14732	14.66	-4.71	1.6
112 Womenhosiery	33.05	392	129	21.53	-1.47	1.6
56 Cheese	25.13	488	123	17.28	-0.53	1
209 Luggage	20.25	2547	516	11.43	-13.03	2.9
210 WmnsHandbag	20.24	1141	231	10.62	-10.13	2.9
211 PerLeathrGds	20.23	535	108	16.69	-8.93	2.9
58 Icecream	16.78	5	1	21.74	-0.04	1.7
116 Curtains	13.72	176	24	6.84	-0.27	1.1
117 Housefurnish	13.72	2160	296	6.48	-0.62	1.1
208 Leathrgloves	12.71	317	40	5.26	-3.08	1.4
217 CeramicTile	11.35	795	90	4.63	-5.23	1.7
102 Broadfabric	11.22	3843	431	8.92	-3.07	1.5
199 RubPlFootwr	10.69	4493	480	3.01	-0.49	1.1
206 ShoesExrub	10.69	11034	1180	3.23	-1.15	1.1
207 Slippers	10.65	99	10	4.80	-0.85	1.1
98 Cigarettes	9.55	94	9	17.81	0.31	2.7
101 TobStmRedry	8.76	573	50	10.43	-0.14	1.6
114 Knitfabric	8.46	807	68	16.72	-6.17	3.6
66 Frozenfruit	7.82	1031	81	15.14	-1.74	3.5
59 Fluidmilk	7.22	17	1	4.87	-0.21	1
221 VitChinaTble	7.02	318	22	6.12	-4.76	2.4
222 Earthenware	7.02	483	34	2.32	-3.25	2.4
383 CostumJewel	6.34	922	58	2.44	-0.38	1
306 Ballbearings	6.01	1630	98	5.79	-1.17	1.8
105 Threadmills	5.64	51	3	2.56	-1.80	1.5
104 YarnFinish	5.56	608	34	1.79	-3.68	1.5
103 Narrowfabric	5.28	472	25	-0.46	-0.96	1
373 Watches	5.28	2628	139	1.35	-0.49	1.8
High-tariff coms. (>5%)	23.67	83269	19709			
All other commodities	0.72	1043128	7465			
All commodities	2.41	1126397	27174			

In our simulation we assume in 1998 that import restraints operated purely as tariffs and that the implied revenue was fully collected. Then we simulate the long-run effects of reducing all tariff rates to zero. As mentioned in section 1, the USAGE-ITC forecasting mode has not yet been developed. Consequently, the exercise reported here is comparative static. We assume that without the tariff changes the economy would remain perpetually in its 1998 situation. In future applications of USAGE-ITC it will be possible to generate the effects of policy changes, such as tariff removal, as deviations around explicit and realistic forecast paths.

Apart from the static base-case, the main assumptions underlying our illustrative application are as follows.

(1) The cut in tariffs has no effect on the ratio of nominal consumption (private plus public) to nominal GNP.
(2) The ratio of real public consumption to real private consumption is unaffected by tariff cuts. Both types of consumption adjust together to maintain the consumption/GNP ratio.
(3) The ratio of investment to capital in each industry is held constant. Nevertheless, aggregate investment can move relative to aggregate capital because of variations between industries in their I/K ratios.
(4) The average rate of return on capital across industries is assumed to be unaffected by tariff cuts. However, we allow for increases in rates of return on capital in industries favored by tariff cuts and decreases in industries that are harmed. The rate-of-return assumptions mean that our simulation depicts long-run effects. The parameters of the model were set to give effects after about seven years.
(5) Real wage rates adjust so that there is no effect on aggregate employment.
(6) The change in tariffs has no effect on technology or consumer preferences.
(7) The change in tariffs has no effect on the price deflator for GDP at factor cost, that is we treat this price deflator as the numeraire.

5.1 Macro results

The most obvious macro effect of tariff cuts is to stimulate imports. Thus we find a positive entry (1.046 per cent) in row 10 of Table 5.2. For understanding the size of the import effect it is useful to start with a stylized version of the import-demand equation for a typical agent (industry, capital creator, household, government) in USAGE-ITC:

$$x_m = z - \theta * S_d * (1 - S_{marg}) * (p_m - p_d) \,, \qquad (5.1)$$

where

x_m is the percentage change in the agent's demand for the imported variety of a commodity;
p_m and p_d are the percentage changes in the basic prices of the imported and domestically produced varieties of the commodity (basic prices of imports are landed-duty-paid prices and those of domestic products are prices at the factory door or farm gate);
z is the percentage change in the agent's activity level (industry output, level of capital creation, aggregate real consumption);
θ is the agent's substitution elasticity (Armington elasticity) between the imported and the domestically produced varieties;
S_d is the share of the agent's expenditure on the commodity that is accounted for by the domestic variety; and
S_{marg} is the margin share in purchasers' prices, i.e. the combined share of wholesale, retail and transport costs.

In using (5.1), we start by noting that implied tariff revenue and imports in 1998 were \$27.2b and \$1126.4b (see Table 5.1). Thus the impact effect of removing tariffs is to reduce landed-duty-paid import prices by 2.4 per cent (= 100*27/1126). This is partially offset by nominal devaluation of 0.450 per cent (row 2, Table 5.2) leaving a net reduction in landed-duty-paid import prices of about 1.95 per cent (p_m = 1.95). By assumption, there is little change in domestic prices (the price deflator for GDP at factor cost is the numeraire) so that p_d is approximately zero. Margin costs represent about 25 per cent of purchasers' costs of imports and their domestic competitor products (S_{marg} = 0.25). As indicated by the GDP result in row 7 of Table 5.2, the tariff cuts generate an increase in real GDP of 0.042 per cent, implying an average value for z of about 0.042. An import-weighted average of the Armington elasticities is 2.1 (θ = 2.1) and an import-weighted average of the domestic shares (S_d) in the USAGE-ITC database is 0.63.[6] Putting all these numbers into equation (5.1) gives the percentage change in imports as 1.97 per cent [x_m = 0.042 −2.1*0.63*0.75(-1.95)]. This is nearly twice the result in row 10 of Table 5.2.

On investigation we found that the use of averages in (5.1) is too crude. Commodities for which our simulation gives a large negative value for $p_m - p_d$ happen to have small values for $\theta S_d(1-S_{marg})$. For example, Apparel, which contributes over half the overall increase in imports in our simulation, has a low Armington elasticity (θ = 1.6), a low domestic share (S_d = 0.59) and a very high margin share (S_{marg} = 0.53). With a strong negative correlation between $\theta S_d(1-S_{marg})$ and the absolute values of $p_m - p_d$, the use of averages in (5.1) leads to a substantial overestimate of the simulated increase in imports.

The tariff cut has a small positive effect on capital stocks and investment (lines 4 and 5 of Table 5.2). The positive effects arise because the industries that are harmed by tariff cuts have low capital intensity. For example, the capital share of primary-factor input in the Apparel industry is only 10 per cent whereas for the whole economy the capital share is 27 per cent.

The tariff cut also has a small positive effect on real GDP, 0.042 per cent, row 7 of Table 5.2. To check how much of this is contributed by the traditional welfare triangles, we computed

$$\text{Area of welfare triangles} = \sum_{i \in COM} 0.5 * \text{Tariff Revenue}(i) * \%\Delta\,\text{Imports}(i)/100 \quad .$$

This calculation gives $1.34 billion or 0.016 per cent of GDP. Thus the welfare triangles account for only about 40 per cent of the gain in real GDP (0.016 out of 0.042). The increase in capital stock (0.011 per cent) contributes about 0.003 percentage points (= 0.011*0.27) to the growth in real GDP. This still leaves an increase of 0.023 per cent (= 0.042 – 0.019) in real GDP unexplained. We found that most of this unexplained increase was associated with the modeling of other costs. This item in USAGE-ITC coves costs not explicitly modeled, e.g. the cost of holding inventories. These costs act like production taxes. It happens in the tariff-cut simulation that industries with high other costs are stimulated relative to industries with low or negative other costs. This produces most of the unexplained increase in real GDP. In future research we should eliminate GDP and welfare increases that flow simply from expedient modeling of other costs.

The percentage increases in real private and public consumption (0.022 per cent, rows 8 & 9, Table 5.2) are less than that in real GDP (0.042 per cent). There are two obvious factors that reduce consumption relative to GDP. First, as will be explained shortly, the tariff cut causes a decline in the terms of trade (0.465

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6 This may seem low. However, when we use import weights we give heavy weight to low domestic shares.

per cent, row 12 of Table 5.2). This reduces the purchasing power of real GDP by reducing the prices of commodities produced in the US relative to the prices of commodities absorbed in the US. Second, with an increase in the capital stock (row 4, Table 5.2) and no corresponding increase in US saving (we assume that the average propensity to save out of GNP is constant), there is an increase in US foreign liabilities (row 14). This reduces US consumption relative to GDP because an increase in foreign liabilities reduces GNP relative to GDP. While these two factors provide a qualitative explanation of the reduction in (C+G)/GDP, they seem too strong to provide a quantitative explanation. The terms of trade effect alone could be expected to reduce C+G by 0.064 per cent. This is worked out as follows: exports and C+G are about 11and 80 per cent of GDP implying that a reduction in the terms of trade of 0.465 per cent reduces the purchasing power of GDP by 0.051 per cent (= 0.465*0.11) which translates into a reduction in C+G of 0.064 per cent (= 0.051/0.80). However, our results show a reduction in C+G relative to GDP of only 0.020 per cent (= 0.042 – 0.022). The explanation is that via assumption (1) we fixed the ratio of *nominal* C+G to *nominal* GNP and because US tariffs fall predominantly on consumption goods (e.g. Apparel) our simulation produces a sharp reduction in the price deflator for private consumption relative to the price deflator for investment. With the savings-to-GNP ratio fixed in nominal terms, our simulation leads to a reduction in the ratio of *real* US-financed investment (= real saving) to *real* GDP. In future research we should run a simulation in which US-financed real investment is fixed. In such a simulation, the movement in real C+G would be a legitimate indicator of the welfare effect of the cut in tariffs. By allowing a squeeze in US-financed real investment, the present simulation produces an increase in real C+G that overestimates the welfare advantage of the policy change.

Because C, I and G all decline in real terms relative to GDP, there must be an increase in real exports relative to real imports. In Table 5.2 the percentage increase in exports is 1.336 per cent, exceeding that in imports of 1.046 per cent. The increase in exports is facilitated by real devaluation (row 1). Despite the increase in real exports relative to real imports, there is a deterioration in the balance of trade (row 13). The improvement in the real balance is more than offset by the deterioration in the terms of trade. With an increase in exports, terms-of-trade decline is inevitable. We assume that foreign demand curves for US products slope down with an elasticity of 3. Consistent with this elasticity value, the export expansion shown in Table 5.2 is accompanied by a terms-of-trade decline of about one third of the percentage increase in exports (0.465is approximately 0.333*1.336). The terms-of-trade decline is limited to 0.465 per cent because we assume that expansion of US imports does not cause a rise in import prices. For a country as economically dominant as the US, our assumption of fixed foreign-currency c.i.f. import prices may be too optimistic.

The final result in Table 5.2 worthy of comment is the 0.472 per cent increase in the real wage rate (CPI deflated). With a terms-of-trade decline and no improvement in technology, we would normally expect a reduction in real wage rates. The increase shown in Table 5.2 reflects the removal of indirect taxes (tariffs) with no explicit modeling of the replacement taxes. The wage increase should not be interpreted as meaning

Table 5.2 Macro effects of removing import restraints: USAGE-ITC results

Percentage changes		
1	Real exchange rate	-0.792
2	Nominal exchange rate	-0.450
3	Real wage rate (before tax)	0.472
4	Capital stock	0.011
5	Real investment	0.034
6	Employment	0.000
7	Real GDP	0.042
8	Real private consumption	0.022
9	Real public consumption	0.022
10	Imports, volume	1.046
11	Exports, volume	1.336
12	Terms of trade	-0.465
Changes expressed as per cent of GDP		
13	Balance of trade	-0.050
14	Net foreign liabilities	0.273

that workers would be better off with reduced tariffs. In 1998, labor income was $5,564b.[7] To replace $27.2b of lost tariff revenue would require a tax of 0.498 per cent on labor income (=100*26.7/5564). Thus, if a labor tax were used for revenue replacement, then the effect of the tariff cut on real *after-tax* wage rates would be a small negative.

5.2 The effects of tariff cuts on outputs by commodity

Table 5.1 shows the effects of the tariff cuts on the outputs and imports of the 31 USAGE-ITC commodities with the highest tariff rates (more than 5 per cent). These 31 commodities account for only 7.4 per cent of the c.i.f. value of imports (= $83.3b out of $1126.4b) but 72 per cent of the implied tariff collection ($19.7b out of $27.2b). As can be seen from Table 5.1, the average rate of tariff on the 31 heavily protected commodities is 23.24 per cent whereas it is less than one per cent on the remaining commodities.

A good starting point for understanding the USAGE-ITC results for the effects of tariff removal on the outputs of heavily protected commodities is the equation

$$x_d = z - \theta * S_m * (1 - S_{marg}) * (p_d - p_m) \quad . \qquad (5.2)$$

[7] This includes wages and salaries and imputed labor income of the self employed.

This is a stylized version of the demand by a typical agent in USAGE-ITC for the domestic variety of a commodity. In the equation x_d is the percentage change in the agent's demand for the domestic variety; S_m is the share of the agent's expenditure on the commodity that is accounted for by the imported variety; and the remaining notation is the same as that in equation (5.1). To illustrate the use of equation (5.2) in explaining output results, we start by working through two straight-forward cases: Luggage and Ceramic tiles, commodities 209 and 217 in Table 5.1.

The principal users of Luggage are households. They have an import share (S_m) for this commodity of 0.77 and an Armington elasticity (θ) of 2.9. The tariff equivalent on Luggage in 1998 was 20.25 per cent. Thus the removal of tariffs has an impact effect on the landed-duty-paid price of Luggage of -16.83 per cent (=-20.25/1.2025). Part of this is offset by the exchange rate movement (-0.450 per cent), leaving the final change in the landed-duty-paid price of Luggage at –16.38 per cent. Our results show little change in the basic price of domestic Luggage. Thus the increase in the domestic/import basic price ratio for the commodity is about 16 per cent. This shrinks to 8.9 per cent when we move to purchasers' prices for households. In common with other consumer goods, the sale of Luggage to households incurs considerable margins costs. These costs are barely affected by changes in tariffs. With the value of$(1- S_{marg})*(p_d – p_m)$ at 8.9 and with S_m = 0.77 and θ = 2.9, the substitution term on the RHS of (5.2) gives a reduction in household demand for domestically produced Luggage of 19.9 per cent. Because Luggage becomes cheaper (the overall purchasers' price to consumers of domestic and imported luggage falls by 7.4 per cent), households buy more of it. The household elasticity of demand for Luggage in USAGE-ITC is about 0.76. Thus the reduction in the price of Luggage boosts demand by 5.6 per cent (= 0.76*7.4). In terms of equation (5.2), z = 5.6 per cent where z is the percentage change in household demand for the Luggage import-domestic composite. Combining the activity effect with the substitution effect gives a reduction in household demand for domestic Luggage of 14.3 per cent (= 5.6 – 19.9). The reduction in total output of domestic Luggage (13.03 per cent, Table 5.2) is a little smaller than the reduction in household demand for domestic Luggage. This is because there are significant exports of Luggage (about 19 per cent of total sales). Exports of Luggage are stimulated by the devaluation that accompanies the tariff cuts.

The principal users of Ceramic tiles are the construction industries. Imports represent about 53 per cent of their purchases of Ceramic tiles (S_m = 0.53) and the relevant Armington elasticity is 1.7. The tariff in 1998 was 11.35 per cent. Thus the removal of tariffs has an impact effect on the basic price of imports of –10.19 per cent (=-11.35/1.1135). By taking account of margins (about 40 per cent of purchasers' prices) and the movement in the exchange rate (-0.450 per cent), we expect USAGE-ITC to project reductions in the purchasers' prices of the imported Ceramic tiles of about 5.8 per cent [= -(10.19-0.450)*0.6]. With little movement in the purchasers' prices of domestic Ceramic tiles, the substitution term on the RHS of (5.2) gives a reduction in demand for the domestic product of 5.2 per cent. Because the cut in tariffs has little effect on activity in the construction industries and because there is very little export of ceramic tiles, the substitution effect is close to the total effect on output shown in Table 5.1.

For Luggage and Ceramic tiles, substitution effects are dominant in determining the reduction in domestic output. For some other negatively affected commodities, activity effects are dominant. Consider for example Knit fabric mills (commodity 114, Table 5.2). Imports of this commodity are small, giving an S_m of about 0.09. Although margins are quite small (S_{marg} =0.063 per cent) and the Armington elasticity is high, the low import share limits the substitution effect on domestic demand for the domestic product to about –2 per cent. Most of the reduction of 6.17 per cent in domestic output of Knit fabric mills arises from activity contraction in the industries that use Knit fabric mills as an intermediate input, particularly the Apparel producers. As can be seen from Table 5.1, the tariff cut reduces output of Apparel by 4.71 per cent. For Knit fabric mills, this represents a contraction in the relevant activity level of about 4 per cent.

Some of the commodities in Table 5.1 show negligible output contraction (or even a small expansion in the case of Cigarettes) despite suffering significant tariff reductions. These commodities fall into two groups. The first group has very small import shares (S_m) in their domestic markets. Members of this group include Fluid milk and Icecream. The second group has significant exports. Output of these commodities benefits from devaluation. Members of this group include Cigarettes and Tobacco stem redry.

Table 5.3 shows that a high export share (greater than 20 per cent) is a common feature of nearly all the commodities for which USAGE-ITC projects an output increase of more than 0.5 per cent. The five exceptions are: Water transport international; Chocolate; Air transport international; Retail trade; and Water transport domestic.

Water transport international is the provision by US companies of shipping services outside the US. These services are used mainly to facilitate flows of goods into and out of the US. They are modeled in USAGE-ITC as margins on imports and exports, not as direct exports. In the tariff-cut simulation, output of Water transport international is stimulated by expansion in US trade, both exports and imports.

US Chocolate production benefits in the tariff-cut simulation from a sharp reduction in the price of sugar, one of its principal inputs. As can be seen from Table 5.1, sugar is the commodity with the highest tariff (83.79 per cent).

Air transport international is the provision by US carriers of airline services outside the US. In USAGE-ITC, these services are not directly exported. They are modeled as inputs to several export activities that benefit in the tariff-cut simulation from devaluation. Export activities that use Air transport international include the provision of holidays and education to foreigners (Export tourism and Export education) and the facilitation of flows of US goods exports. Air transport international also benefits in the tariff-cut simulation from its role in facilitating the flow of US imports.

Retail trade benefits in the tariff-cut simulation from a shift in consumer expenditure towards products that happen to carry high retail margins. These include Apparel and other textile products. Substitution towards these products is caused in the tariff-cut simulation by reductions in their prices.

Table 5.3. Exports shares of domestic output in 1998, and the effects of tariff removal

USAGE-ITC Commodity	Export share	USAGE-ITC results *Percentage changes* x0dom
500 ExpEdu	100	1.86
205 BootCutStock	88	1.83
502 WaterTrans international	0	1.49
499 ExpTour	100	1.44
286 OilGsFldMach	80	1.32
79 Chocolate	19	0.98
23 Nonferrores	71	0.98
280 Turbines	63	0.86
503 AirTrans international	0	0.84
356 Aircraft	50	0.81
416 RetailTrade	0	0.80
358 AircrftEquip	44	0.75
285 MiningMachin	51	0.73
351 ElectMachnec	62	0.69
152 Pulpmills	41	0.69
100 tobaccoSnuff	39	0.68
310 IndMachEquip	55	0.68
202 RubPlHose	30	0.67
320 VendingMach	21	0.66
357 AircrftEngin	32	0.64
232 AsbestosPrd	45	0.60
479 Scrap	84	0.60
292 MachToolForm	51	0.59
377 InstrumElec	45	0.58
375 ElctroMedApp	46	0.57
402 WaterTrans, dom	0	0.57
15 OilBearCrops	32	0.55
376 LabInstrum	46	0.55
18 ComFishing	48	0.55
175 NitPhosFert	21	0.53
303 PrintMach	41	0.53
48 Tanks	35	0.52
184 SyntheticRub	21	0.51

Water transport domestic appears in Table 5.3 because one of its principal constituents is the provision by US companies of wharf services to ships involved in international trade.

5.3 The effects of tariff cuts on employment by state

The last column of Table 5.4 shows percentage effects on employment by state calculated by applying the regional extension to the USAGE-ITC results generated in the tariff-removal simulation.

The most striking feature of these results is the narrowness of their range. The worst affected state, North Carolina, loses 0.323 per cent of its jobs while the most favored state, Washington, obtains a 0.247 per cent increase in jobs. North Carolina is relatively badly affected because it has a high share of its employment in the production of high-tariff commodities (those listed in Table 5.1), mainly textiles. However, as shown in the first column of Table 5.4, even for North Carolina, the share of employment in the production of these commodities is only 5.78 per cent. In the tariff-cut simulation, North Carolina loses about 4 per cent of its high-tariff jobs imposing a total job loss of 0.23 per cent (= 5.78*0.04). This is magnified by multiplier effects. On the other hand, North Carolina, in common with other states, benefits form export expansion. As can be seen from the second column of Table 5.4, North Carolina has 6.46 per cent of its employment in the production of the high-export commodities listed in Table 5.3. North Carolina's share in export-oriented activities is only a little less than that of the nation (6.46 per cent compared with 7.62 per cent, see Table 5.4).

At the other end of Table 5.4, Washington is the most advantaged state because it has a high share (14.29 per cent) of its production in export-oriented commodities, particularly aircraft. However, as can be seen from Table 5.3, the tariff cuts generate an output expansion for the typical export-oriented commodity of only about 1 per cent. For Washington, this generates an employment increase of about 0.1429 per cent. Multiplier effects take this up to the 0.247 per cent shown in Table 5.4 as Washington's employment result.

Do employment shares in the production of high-tariff and export-oriented commodities explain all of our regional employment results? To answer this question we regressed the employment results in the last column of Table 5.4 against the employment shares in the first two columns. The outcome of this regression was:

$$\text{Emp}(r) = -0.099 - 0.053 * \text{HTS}(r) + 0.019 * \text{EXS}(r), \quad r \in \text{REG} \tag{5.3}$$

R-squared = 0.68

where

Exp(r) is the percentage change in employment in state r (last column of Table 5.4);

HTS(r) is the share of employment in state r accounted for by production of high-tariff commodities (the first column of Table 5.4); and

EXS(r) is the share of employment in state r accounted for by production of export-oriented commodities (the second column of Table 5.4).

In (5.3), the coefficients on HTS and EXS have the expected signs. However, these two variables explain only 68 per cent of the variation across the states in the USAGE-ITC employment results. As illustrated in Figure 5.1, there must be other factors contributing to the state employment effects.

On studying Figure 5.1, we saw that regression equation (5.3) strongly under predicts the USAGE-ITC employment results for Washington, California and South Carolina. A factor that these three states have in common is major ports. In our computations, a state benefits from having a major port via the trade-expanding effects of tariff cuts. The idea that ports are the missing factor in the HTS-EXS explanation of the

USAGE-ITC state employment results is strengthened by (5.3)'s over prediction of North Carolina's employment result. North Carolina has no major port. On the other hand, the Delaware result is over predicted by (5.3) even though Delaware has a significant port. Despite the Delaware counterexample, we decided to add a port index to our regression explanation of the USAGE-ITC results. The index we chose was a ratio of two shares: the state's share of trade going through its ports and the state's share of national employment. The values of this index are in the third column of Table 5.4. With the port index included, our regression equation becomes:

$$Emp(r) = -0.068 - 0.061 * HTS(r) + 0.015 * EXS(r) + 0.030 * Port(r), \quad r \in REG \qquad (5.4)$$

R-squared = 0.80

where

Port(r) is state r's port index (third column of Table 5.4).

The port index enters the regression with the expected sign and raises R-squared to 0.80. Nevertheless, as can be seen from Figure 5.2, our explanation of the state employment results is still incomplete. For example, regression equation (5.4) strongly under predicts the USAGE-ITC employment results for Hawaii and Oregon and strongly over predicts the result for Delaware.

The under and over predictions suggested to us that proximity to growth areas may be a missing factor. Both Hawaii and Oregon are close to California, a major state economy that benefits from tariff cuts. Delaware is close to New York and Pennsylvania, major state economies that contract with tariff cuts. With the Horridge formulas applied in the regional extension, we model Hawaii and Oregon as having strong trade connections with California and Delaware as having strong trade connections with New York and Pennsylvania.

To test the theory that proximity is the missing factor we added to the regression a proximity variable defined as

$$Prox(r) = \sum_{g \neq r} ShOUT(r, g) * gspreal(g) \qquad (5.5)$$

where

ShOUT(r,g) is the share of r's sales to other states that are accounted for by state g; and

gspreal(g) is the percentage change in g's state product projected by USAGE-ITC and the regional extension in the tariff-cut simulation.

When we added Prox(r) to the regression we obtained:

$$Emp(r) = -0.082 - 0.060 * HTS(r) + 0.014 * EXS(r) + 0.031 * Port(r) + 0.351 * Prox(r), \quad r \in REG \qquad (5.6)$$

R-squared = 0.81 .

Table 5.4. State characteristics and effects of tariff removal

State	Employment shares: High-tariff activities	Employment shares: Export activities	Port index	Proximity variable	USAGE-ITC results *Percentage change* Employment
33 North Carolina	5.78	6.46	0.12	0.05	-0.323
1 Alabama	2.99	7.33	0.00	0.05	-0.203
39 Rhode Island	3.50	6.56	0.00	0.04	-0.193
42 Tennessee	1.81	7.37	0.00	0.06	-0.110
12 Idaho	1.88	7.72	0.00	0.10	-0.104
34 North Dakota	0.92	6.96	0.00	0.07	-0.090
30 New Jersey	0.95	6.56	0.00	0.01	-0.075
40 South Carolina	4.55	7.09	4.43	0.02	-0.072
32 New York	1.37	5.79	1.98	0.03	-0.072
8 Delaware	0.37	7.80	1.96	0.02	-0.059
17 Kentucky	1.89	7.18	0.00	0.04	-0.052
38 Pennsylvania	1.18	7.45	0.21	0.03	-0.046
21 Massachusetts	0.99	7.51	0.16	0.04	-0.043
24 Mississippi	1.73	6.66	0.25	0.05	-0.043
29 New Hampshire	1.57	9.00	0.00	0.03	-0.043
19 Maine	2.10	8.62	0.00	0.04	-0.041
10 Georgia	2.49	7.51	1.88	0.04	-0.036
6 Colorado	0.41	6.98	0.00	0.08	-0.034
23 Minnesota	0.72	7.18	0.00	0.06	-0.021
46 Virginia	1.95	6.28	2.07	0.03	-0.018
25 Missouri	0.86	8.21	0.00	0.06	-0.014
51 Dist. of Columbia	0.06	1.80	0.00	0.03	-0.012
50 Wyoming	0.49	7.36	0.00	0.07	-0.007
13 Illinois	0.54	6.24	0.00	0.05	-0.006
27 Nebraska	0.51	6.92	0.00	0.07	-0.006
4 Arkansas	1.09	7.82	0.00	0.06	-0.004
49 Wisconsin	1.15	6.97	0.00	0.05	-0.003
45 Vermont	1.21	7.80	0.00	0.04	-0.002
26 Montana	0.39	7.79	0.00	0.08	0.002
20 Maryland	0.50	6.82	0.82	0.03	0.006
41 South Dakota	0.66	7.79	0.00	0.07	0.008
15 Iowa	0.70	7.66	0.00	0.06	0.009
31 New Mexico	0.48	6.97	0.00	0.08	0.019
36 Oklahoma	0.57	7.64	0.00	0.07	0.020
22 Michigan	0.37	6.90	0.00	0.05	0.025
2 Alaska	0.07	8.37	0.00	0.08	0.027
18 Louisiana	0.70	8.61	0.82	0.06	0.028
44 Utah	0.59	8.82	0.00	0.10	0.036

… Table 5.4 continued

Table 5.4 continued

State	Employment shares: High-tariff activities	Employment shares: Export activities	Port index	Proximity variable	USAGE-ITC results *Percentage change*: Employment
35 Ohio	0.60	7.81	0.00	0.05	0.041
7 Connecticut	0.77	11.51	0.00	0.03	0.045
43 Texas	0.74	7.58	0.69	0.06	0.047
14 Indiana	0.48	7.84	0.00	0.05	0.049
48 West Virginia	0.55	7.23	0.00	0.04	0.057
3 Arizona	0.25	8.98	0.00	0.09	0.059
5 California	1.26	8.00	3.52	0.08	0.080
37 Oregon	0.90	7.49	0.93	0.14	0.081
9 Florida	0.61	8.76	1.75	0.04	0.088
16 Kansas	0.30	13.03	0.00	0.07	0.094
28 Nevada	0.26	8.74	0.00	0.07	0.094
11 Hawaii	0.59	7.05	0.36	0.06	0.111
47 Washington	0.60	14.29	4.14	0.08	0.247
All states	1.20	7.62	1.00	0.04	0.000

Equation (5.6) is only a slight improvement on (5.4). As can be seen from Figure 5.3, the USAGE-ITC results for Hawaii, Nevada, Delaware and several other states remain largely unexplained.

At this stage, it is necessary to look at the difficult states one at a time. For Hawaii and Nevada, we think that the gap between the regression fit and the USAGE-ITC result in Figure 5.3 is explained by tourism. In the USAGE-ITC simulation, tariff cuts are good for domestic tourist activities. This is because devaluation makes holidays abroad expensive for US residents causing substitution in our model towards holidays at home. This is a favorable effect for tourist destinations such as Hawaii and Nevada that is taken into account in USAGE-ITC but not in regression equation (5.6). For Delaware, we think that the gap between the regression fit and the USAGE-ITC result is explained by Manmade fibers. This is a major industry in Delaware. It fairs poorly in the USAGE-ITC simulation because its main customers are textile industries that are adversely affected by tariff cuts. However, because it has low protection, Manmade fibers is not included in Table 5.1 and consequently is not included in HTS. Thus, we suspect that HTS underestimates Delaware's exposure to tariff reductions, causing our regression equations to over predict Delaware's performance. In future research we will check these explanations of our results and continue the process until all results are explained satisfactorily.

6. Concluding remarks

There are many directions in which we hope to improve and extend the research presented in this paper. Perhaps the most ambitious is to use interregional trade-flow data to validate and calibrate the

Horridge estimation procedures. Other future research tasks that were alluded to in the paper include: improvement in the long-run macro policy closure of USAGE-ITC to avoid overstatement of consumption effects arising from reductions in the price deflator for consumption relative to that for investment; elimination of spurious welfare effects arising from the modeling of unidentified costs as though they are equivalent to production taxes; recognition of Hawaii as an island economy implying zero use of trucking and rail services across its state border; introduction of data on the composition of commodity flows through US ports; introduction of data identifying different consumption patterns across states; and provision of complete explanations of results for each state.

Our approach to regional modeling in this paper has been tops-down. The fundamental simplification in top-down methods is exogeneity of sourcing shares. These are the shares in a region's use of a good that are accounted for by flows from producers within the region and by flows from producers in each of the other regions (the SHIN matrices). The adoption of exogenous sourcing shares is not satisfactory in analyses of issues in which the essence is changes in relative costs across regions. Thus, tops-down methods are not satisfactory for analyses of 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. On the other hand, tops-down methods give satisfactory results in the analyses of a broad range of economy-wide shocks such as changes in tariffs and other Federal policies.

The alternative to tops-down modeling is bottoms-up. 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 theory of bottoms-up modeling is very much the same as that of multi-country modeling (e.g. the GTAP model of Hertel, 1997). In common with multi-country models, bottoms-up regional models emphasize endogenous price-sensitive determination of sourcing shares. Experience in Australia with detailed bottoms-up models [for example, Federal, MMRF and TERM, see Madden, 1996; Naqvi and Peter, 1996; and Horridge *et al.* 2003] suggests that it will be possible eventually to create a bottoms-up version of USAGE-ITC. However, before this is done there are many improvements and applications of the tops-down version that should be undertaken.

Figure 5.1. Employment effects of tariff removal explained by a two-variable regression: equation (5.3)

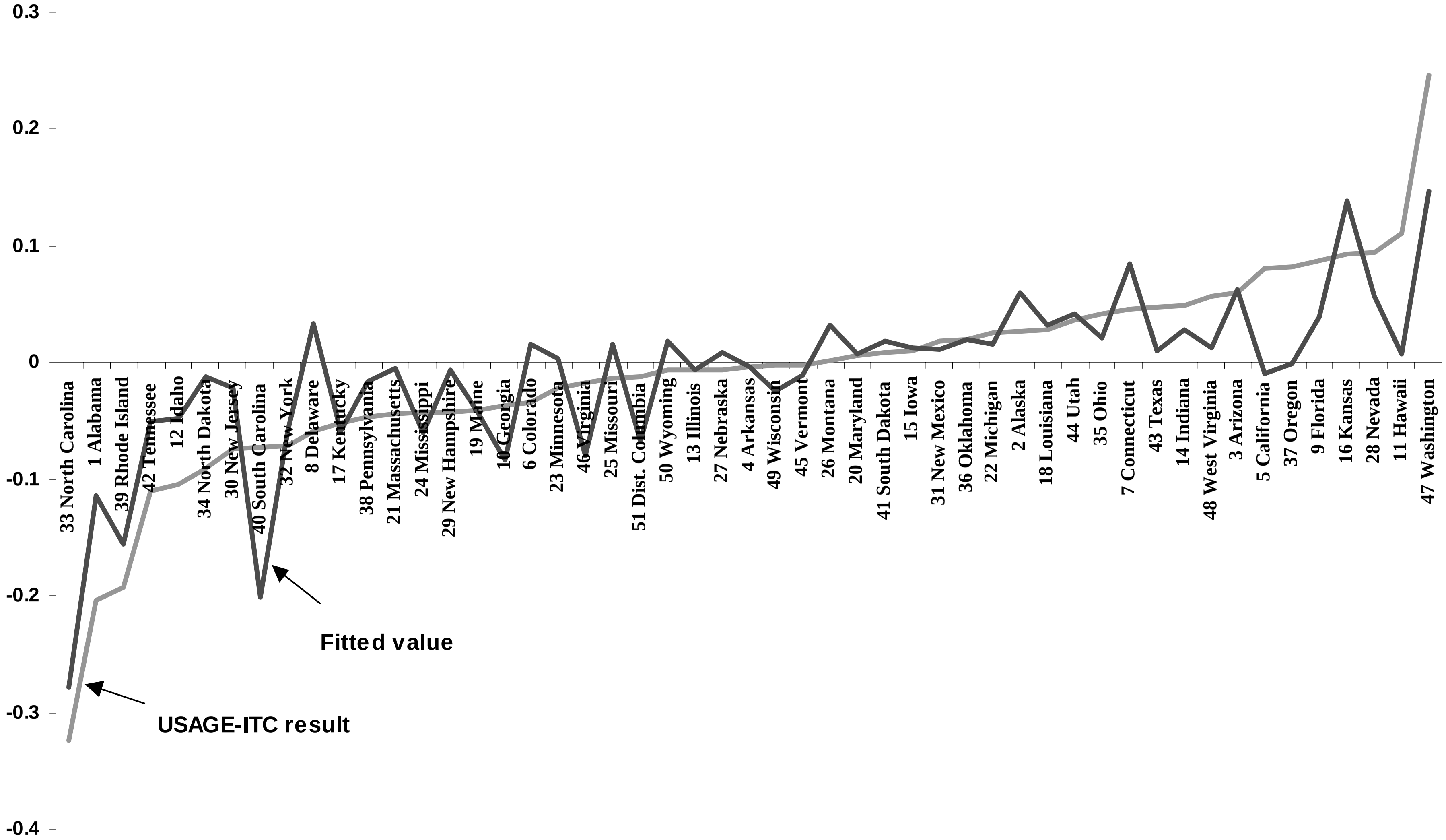


Figure 5.2. Employment effects of tariff removal explained by a three-variable regression: equation (5.4)

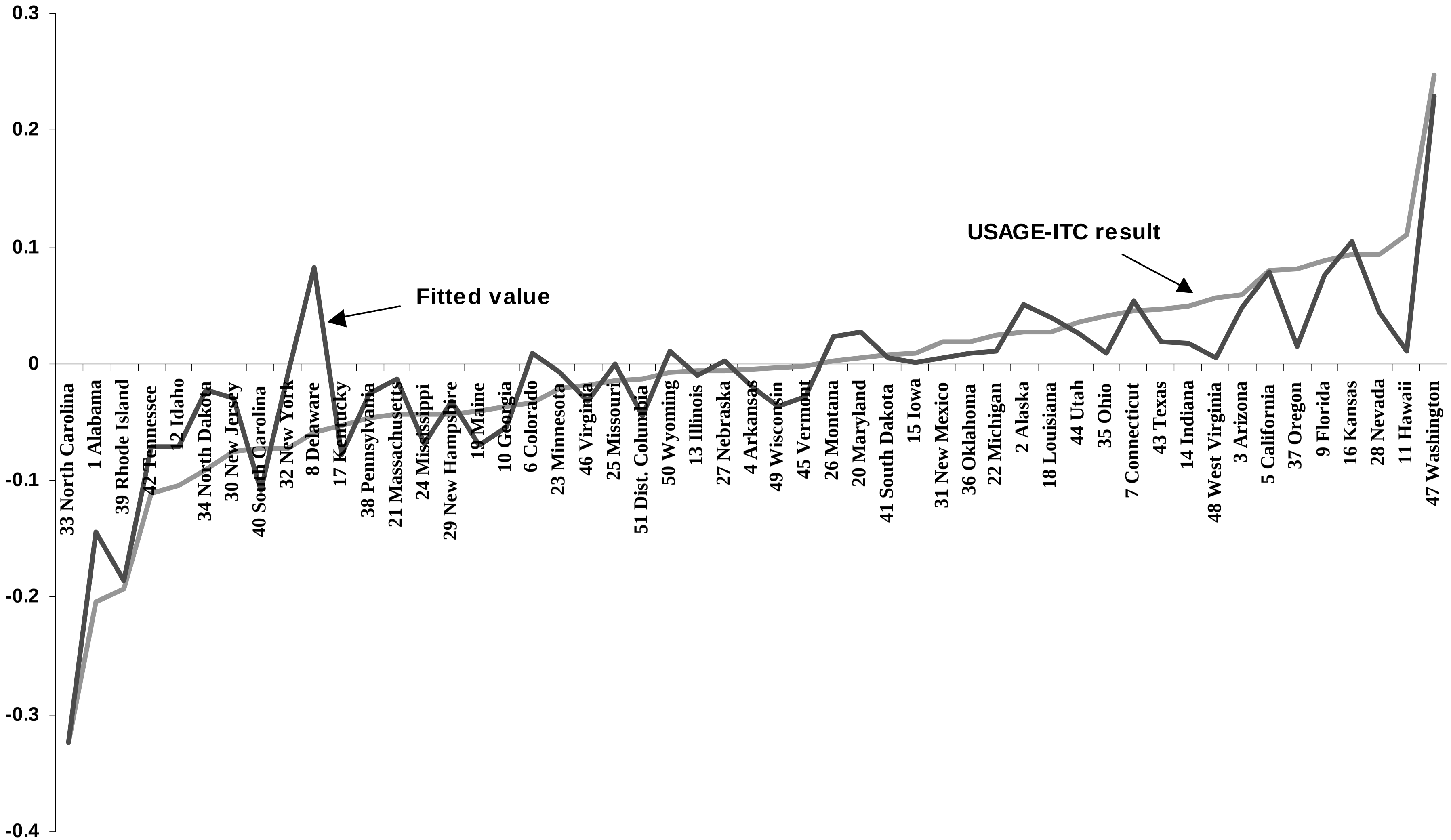
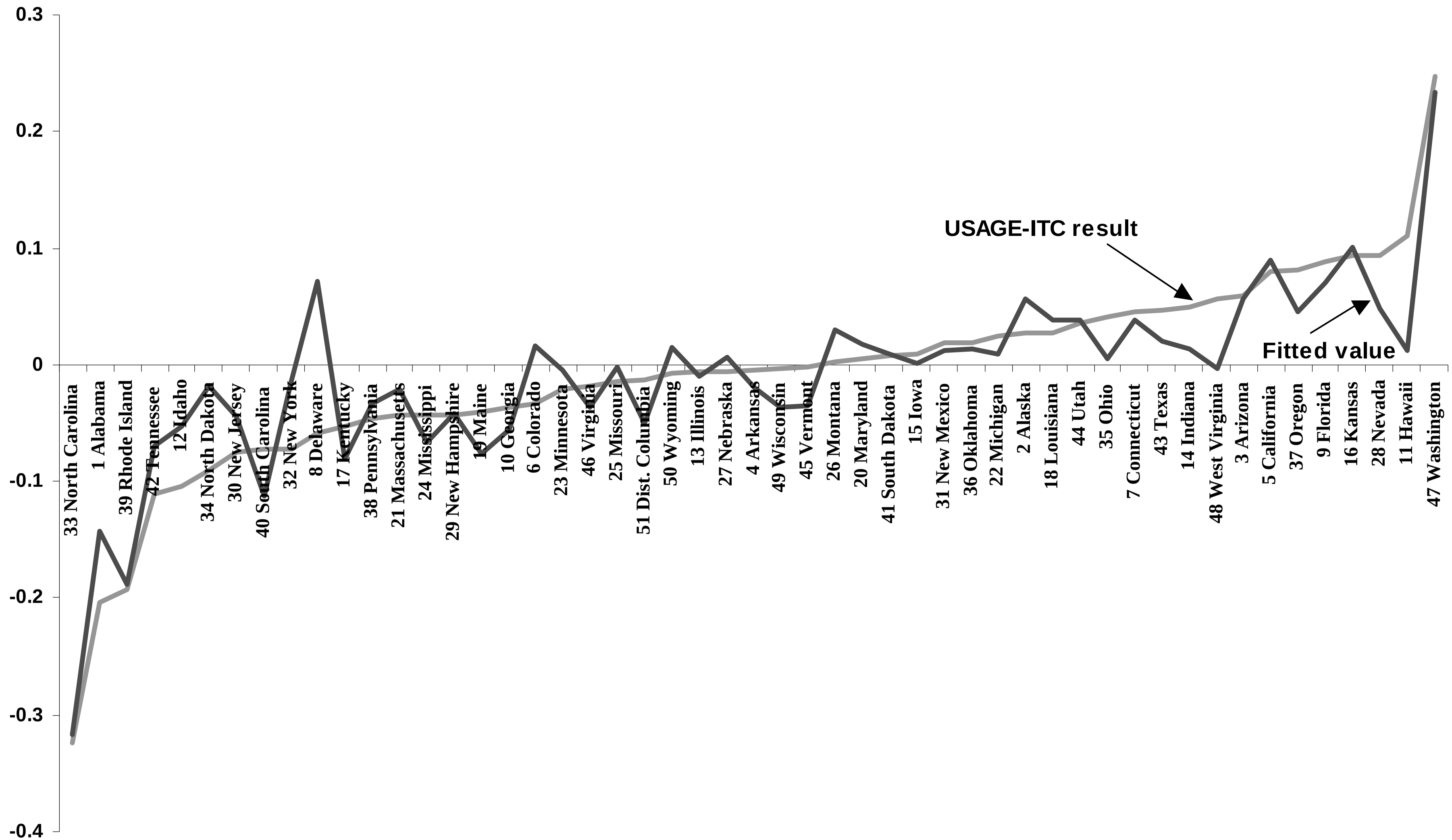


Figure 5.3. Employment effects of tariff removal explained by a four-variable regression: equation (5.6)



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