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**Este arquivo inclui os seguintes itens bibliográficos:**

**Haddad, E. A. Computing Guide for the CEER Model Using Customized RunGEM, 2011, mimeo.**

**Haddad, E. A.; Perobelli, F. S.; Domingues, E. P.; Aguiar, M.. Assessing the ex ante Economic Impacts of Transportation Infrastructure Policies in Brazil. Journal of Development Effectiveness, v. 3, no.1, p. 44-61, 2011.**

**Haddad, E. A., Hewings, G. J. D., Perobelli, F. S. e dos Santos, R. A. C.. Regional Effects of Port Infrastructure: A Spatial CGE Application to Brazil. International Regional Science Review, v. 33, p. 239-263, 2010.**

**Haddad, E. A. e Hewings, G. J. D.. Handling Market Imperfections in a Spatial Economy: Some Experimental Results. The Quarterly Review of Economics and Finance, v. 45, 2005.**

**Haddad, E. A., Bonet, J., Hewings, G.J.D. e Perobelli, F.S.. Spatial Aspects of Trade Liberalization in Colombia: A General Equilibrium Approach. Papers in Regional Science, v. 88, p. 699-732, 2009.**

**Peter, M. W. et alli The Theoretical Structure of MONASH-MRF, Centre of Policy Studies Working Paper OP-85, Monash University, 1996.**

# Computing Guide for the CEER Model Using Customized RunGEM

Eduardo Haddad

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## 1. Introduction

This document explains how to use the Customized RunGEM program to work with the CEER model. It was originally designed for use at the short course to be held in Banco de la República, Cartagena, Colombia. It draws on the document “Computing Guide for MINIMAL Using Customized RunGEM”, by **Mark Horridge**, March 2001.

GEMPACK is a system of software for implementing and solving computable general equilibrium (CGE) models. The CEER model is a spatial CGE model, implemented using GEMPACK and designed for policy analysis in Colombia. RunGEM is a windows program that makes it easy for you to run any CGE model created with GEMPACK. Customized RunGEM is a special version of RunGEM that has been hard-wired to work only with one or a few particular models (such as CEER). In this document, references to *RunGEM* mean *Customized RunGEM*, tailored for use with the CEER model.

This document assumes that you have installed on your computer a recent version of Customized RunGEM (dated March 2001 or later) that contains the CEER model. Instructions for doing this are in Appendix 1.

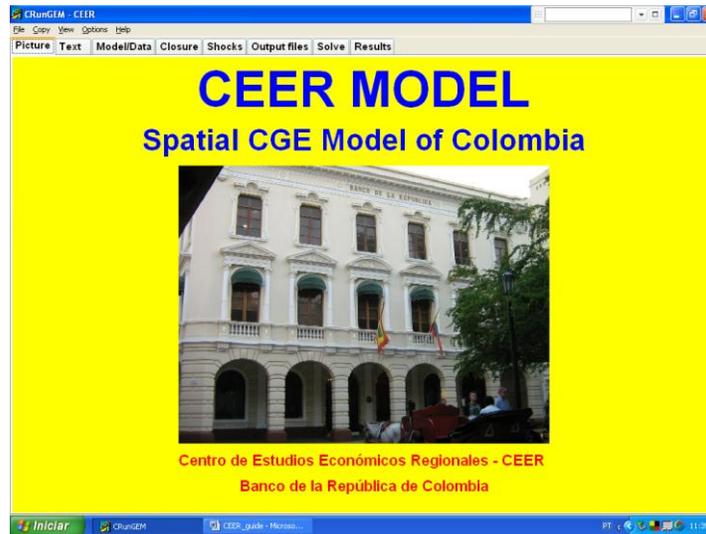
You should also have studied the CoPS working paper OP-85, *The Theoretical Structure of MONASH-MRF*, by Peter *et al.* (1996), the book *Regional Inequality and Structural Changes: Lessons from the Brazilian Economy*, by Haddad (1999), and the article by Haddad and Hewings (2005), *Market Imperfection in a Spatial Economy: Some Experimental Results*, published in the Quarterly Review of Economics and Finance, Vol. 45. They describe the underlying economic theory of the CEER model.

As you read this document, you will use RunGEM to work through examples designed to familiarize you with the software and, perhaps more importantly, the CEER model. The instructions are quite detailed. Our aim is to give sufficient detail to enable a new RunGEM user to work through the examples relying solely on this document.

A series of numbered questions appear throughout the text. Write your answers in the margin.

## 2. Starting RunGEM

To see RunGEM in action, double-click on the Customized RunGEM (CEER Model) icon on your desktop. You should see the following screen:



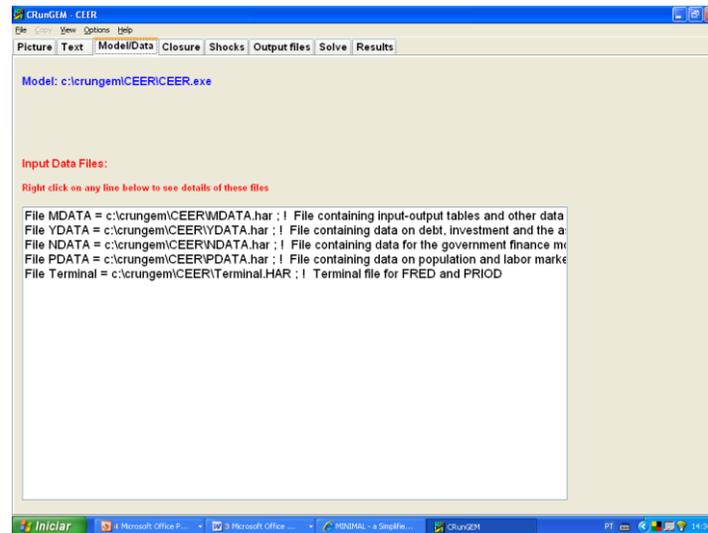
RunGEM uses a tabbed notebook or card index interface. The first 2 pages (**Picture** and **Text**) contain general information. The 3rd page (**Model/Data**) contains information about files used by the CEER model. The remaining 5 pages relate to simulations – we explain those in Part 5 below.

The **Help** menu item gives access to extensive online-help about RunGEM. **Customized RunGEM** is a slightly simplified version of RunGEM, so some of the options described there may not apply. There is a special Help menu item, “Customized RunGEM Help”, dealing with these differences.

### 3. The Model/Data page

Have a look at RunGEM's **Model/Data** page. It gives two pieces of information:

- The *model* is CEER.EXE, an executable program. This has been produced by the GEMPACK program **TABLO** using, as input, the text file CEER.TAB. To change the model specifications, you need to (a) edit CEER.TAB, and (b) run TABLO to make CEER.EXE. That procedure is not covered in this introductory document, and TABLO is not supplied with the **Customized RunGEM** package.
- There are five input data files, MDATA.HAR, which corresponds to the logical file MDATA which is mentioned in CEER.TAB. Similarly, YDATA.HAR corresponds to the logical file, YDATA, NDATA.HAR to NDATA, PDATA.HAR to PDATA, and Terminal.HAR to Terminal.



RunGEM, and the programs that come with it (TABmate, ViewHAR and others) are parts of the standard GEMPACK system, which allows you to create and modify economic models and data. The customized version of the CEER model is designed as an introduction to the CEER model itself, using GEMPACK: therefore the Customized version of RunGEM does not allow you to alter the model equations or database. To change the equations or data, you would need other GEMPACK components (such as the TABLO program) not supplied with Customized RunGEM. See Section 8 for more information.

#### 4. Looking at the data

The data files are given the logical names **MDATA**, **YDATA**, **NDATA**, **PDATA** and **Terminal** in the TAB file **CEER.TAB** which lays down the theory of CEER. To see what information is on the MDATA file, for instance, select

*View / Input Data files / Original MDATA*

in RunGEM's menu. ["Original MDATA" appears to the side of "Input Data files"].

This will start up **ViewHAR**, a windows program for viewing and modifying data held in GEMPACK Header Array files. It will open the MDATA file and show a Contents screen.<sup>1</sup>

<sup>1</sup> The top of the ViewHAR window shows the actual name (MDATA.HAR) and location of the file which has logical name MDATA in the TAB file.

## Computing Guide for CEER

Header	Type	Dimension	Coeff	Total	Name
1 BAS1	RE	COM*ALLSOURCE*IND*REGDEST	BAS1	18895920.00	Commodity inputs to the production process: basic values
2 BAS2	RE	COM*ALLSOURCE*IND*REGDEST	BAS2	44612880.00	Commodity inputs to capital creation: basic values
3 BAS3	RE	COM*ALLSOURCE*REGDEST	BAS3	157449936.00	Commodity demands by regional households: basic values
4 BAS4	RE	COM*REGSOURCE	BAS4	30146452.00	Commodity demands by foreigners: basic values
5 BAS5	RE	COM*ALLSOURCE*REGDEST	BAS5	11572076.00	Regional
6 BAS6	RE	COM*ALLSOURCE*REGDEST	BAS6	33561798.00	Federal
7 MAR1	RE	COM*ALLSOURCE*IND*REGDEST*MARGCOM	MAR1	125574.50	Demands for margins: user 1
8 MAR2	RE	COM*ALLSOURCE*IND*REGDEST*MARGCOM	MAR2	177095.50	Demands for margins: user 2
9 MAR3	RE	COM*ALLSOURCE*REGDEST*MARGCOM	MAR3	561398.44	Demands for margins: user 3
10 MAR4	RE	COM*REGSOURCE*MARGCOM	MAR4	168924.25	Demands for margins: exports
11 MAR5	RE	COM*ALLSOURCE*REGDEST*MARGCOM	MAR5	0.01	Margins regional
12 MAR6	RE	COM*ALLSOURCE*REGDEST*MARGCOM	MAR6	0.01	Margins federal
13 TAX1	RE	COM*ALLSOURCE*IND*REGDEST	TAX1	6736186.50	Taxes on inputs to the production process
14 TAX2	RE	COM*ALLSOURCE*IND*REGDEST	TAX2	1021572.88	Taxes on inputs to capital creation
15 TAX3	RE	COM*ALLSOURCE*REGDEST	TAX3	5753212.00	Taxes on commodities demanded by regional households
16 TAX4	RE	COM*REGSOURCE	TAX4	1447048.13	Taxes on commodities demanded by foreigners
17 TAX5	RE	COM*ALLSOURCE*REGDEST	TAX5	0.79	Taxes on commodities demanded by regional gov
18 TAX6	RE	COM*ALLSOURCE*REGDEST	TAX6	0.79	Taxes on commodities demanded by federal gov
19 LABR	RE	OC*IND*REGDEST	LAB_OCC_IND	121466296.00	Regional Wage Bill
20 CPTL	RE	IND*REGDEST	CAPITAL	112936800.00	Regional returns to capital
21 LAND	RE	IND*REGDEST	LAND	0.00	Regional returns to land
22 CNTS	RE	IND*REGDEST	OTH_COST	2038263.88	Regional other cost tickets
23 TARI	RE	COM*REGDEST	TARIFF	3133190.50	Regional tariff of imported commodities
24 QO27	RE	IND*REGDEST	QCOEF	277.20	Default investment parameter Q()
25 PO18	RE	COM	EXP_ELAST	-14.00	Default gamma (long-run)
26 PO28	RE	IND*REGDEST	SIGMAIFAC	115.50	Primary-factor elasticity of substitution
27 SLAB	RE	IND*REGDEST	SIGMALAB	115.50	Labor-labor substitution (CES)
28 PO15	RE	COM	SIGMALO	9.24	Elasticity of substitution: domestic/foreign import Armington: user 1
29 PO16	RE	COM	SIGMAO	9.24	Elasticity of substitution: domestic/foreign import Armington: user 2
30 PO17	RE	COM	SIGMAO	9.24	Elasticity of substitution: domestic/foreign import Armington: user 3
31 BETR	RE	IND*REGDEST	BETA_R	924.00	Rates of return on capital
32 BO15	RE	COM	SIGMA1C	9.24	Elasticity of substitution: interregional Armington: user 1
33 BO16	RE	COM	SIGMA2C	9.24	Elasticity of substitution: interregional Armington: user 2

Each of the rows corresponds to a different array of data on the file. Look at the **Name** column to see what these arrays are.<sup>2</sup> Use the buttons at bottom right to set your preferred font size.

You can see that array number 19 is the data at Header “LABR”. The data at this header is the value of labor payments, measured in millions of 2004 Colombian pesos. To see the actual data, double-click on the LABR row.

Q1. What is the value of wages in manufacturing (IND) in Bolívar (D4)?

Now click on **Contents** in ViewHAR’s main menu to return to the list of contents. Similarly, the array number 20 is the data at Header “CPTL”. The data at this header is the value of capital payments, measured in millions of 2004 Colombian pesos. To see the actual data, double-click on the CPTL row.

Q2. What is the value of capital payments in the construction sector (CNT) in Nariño (D17)?

Click on the small yellow rectangle near the top left of the ViewHAR window to transpose the matrix (exchange rows and columns). This makes it easier to see.

<sup>2</sup> The arrays may be ordered differently from the list in the text. You can set ViewHAR up to either list the headers alphabetically, or to list them in the order they were written to file. ViewHAR’s **File...Options** menu command can be used to customize the display in various ways.

The screenshot shows the ViewHAR application window titled 'NDATA.har in c:\crangm\CEER'. The main area displays a table with the following structure:

	1 AGR	2 MNE	3 IND	4 ENT	5 TRN	6 ADP	7 OTS	TOTAL
1 D1	56227.125000	1036154.000000	4996656.000000	1596757.500000	322239.000000	732523.500000	8049562.000000	17314840.000000
2 D2	51165.304668	50399.039063	1636744.375000	261062.625000	135388.359375	263344.437500	3082254.500000	5500478.500000
3 D3	17302.732422	264422.250000	6683205.000000	2114626.500000	632657.500000	1284563.625000	16299232.000000	27296010.000000
4 D4	127630.718750	173789.328125	1893673.375000	200960.937500	89940.453125	331787.375000	1543573.000000	4361225.000000
5 D5	148893.890625	224941.250000	582549.500000	17857.531250	66936.132813	211875.062500	1117467.250000	2531200.500000
6 D6	143127.259375	54165.888133	554066.437500	121256.546875	87720.937500	127540.062500	1096788.875000	2185375.000000
7 D7	17641.656250	1966.775391	26266.361328	39191.367188	5570.344238	68073.726563	210134.109375	422846.343750
8 D8	101593.148438	31019.667500	610655.250000	134238.906250	20853.032003	130917.617188	730258.562500	1749536.250000
9 D9	137175.843750	1293753.625000	173424.000000	109522.507813	43171.132813	61748.937500	541621.187500	2380417.250000
10 D10	17426.000000	152729.250000	151423.281250	211249.656250	73040.281250	119637.796875	851894.875000	3107721.250000
11 D11	457397.437500	142079.562500	1913563.625000	260936.203125	97125.578125	340974.656250	1817125.250000	5026612.500000
12 D12	22720.064493	112925.576125	4083.469258	70435.000000	11036.793125	47682.679688	150782.156250	419665.656250
13 D13	151528.437500	651050.250000	110062.460938	227500.859375	31811.843750	157828.437500	748081.562500	2077863.875000
14 D14	27056.156250	1318059.375000	14521.279297	67005.640625	15274.571289	47004.406250	493475.343750	1942846.750000
15 D15	139504.859375	11472.041992	102076.273438	90523.570313	57463.453125	141874.343750	770172.125000	1313086.625000
16 D16	195360.906250	587101.667500	208196.312500	128481.632813	53882.160196	88223.140625	693954.687500	1910600.500000
17 D17	175662.546875	41173274219	114375.259375	279661.927500	36168.583031	137169.859375	887718.125000	1671331.000000
18 D18	87143.578125	84907.765625	185093.662500	111286.30313	58944.921875	234007.734375	954105.375000	1712388.750000
19 D19	47538.426562	8113.448242	80337.156250	75063.359375	40683.675781	62975.226563	452792.406250	772923.750000
20 D20	52187.558994	28240.859469	417084.281250	247275.359375	62090.972656	110931.375000	937232.500000	1859042.875000
21 D21	246221.734375	261763.300625	2064109.000000	633569.187500	162138.562500	323347.656250	2423267.250000	6114417.000000
22 D22	74002.437500	13896.991211	37132.839844	68252.625000	12782.026367	62552.890625	436519.312500	705341.125000
23 D23	188077.103375	221755.781250	375977.531250	226407.625000	53448.219338	163133.531250	1163878.125000	2401678.000000
24 D24	256102.781250	188583.804668	3752618.500000	643278.875000	321037.562500	695853.187500	6470659.000000	12248434.000000
25 D25	4958.826172	40.261257	1647.639648	1322.860229	1993.109521	17047.693359	40296.578125	67306.968750
26 D26	61252.609375	520867.506250	9818.041992	43187.933594	7420.618164	54840.812500	138023.406250	835411.312500
27 D27	73602.078125	3708420.750000	34354.589398	190245.593750	18207.478516	30835.634766	200799.015625	4256555.000000
28 D28	2349.631348	4622.341309	877.234558	5586.239258	993.848328	6436.979492	15983.724609	37150.000000
29 D29	17300.511719	13.688827	822.590881	13816.983978	2416.199463	22388.609375	36943.020781	94590.609375
30 D30	19316.449219	87900.734375	6843.251465	15221.289603	3571.243896	28790.031250	100449.750000	263882.750000
31 D31	2665.951660	34.624680	2844.677979	3552.504883	14000.576172	14831.644531	217787.765625	255797.750000
32 D32	6833.133789	403.417736	529.353882	2288.826660	654.879639	7634.406738	14604.728516	33128.746094
33 D33	21750.568359	399.391663	782.731567	7134.862793	1031.504561	10254.992188	31014.773438	72369.242188

ViewHAR is able to show you some shares, as well as the actual data. To see this, click the drop-down list boxes near the top left-hand corner of the ViewHAR window, which at present probably says **None** [we call it the **shares list box**]. Select the **row share**.

Q3. What is Bogotá’s (D3) share in capital payments to manufacturing (IND)?

Q4. And in agriculture (AGR)?

Q5. What is Bogotá’s share in the economy-wide payments to capital?

Q6. In which Department the agriculture sector is responsible for the highest share of labor payments?

Q7. Which sector is most capital-intensive in Colombia?

Shares like these are often useful for explaining simulation results.

Now click again on **Contents** in ViewHAR’s main menu to return to the list of contents. Look at the BAS1 row (array number 1). You can see that this is a 4-dimensional array of size **COMxALLSOURCExINDxREGDEST**. The data at this header is the basic value of commodity inputs to the production process, also measured in millions of 2004 Colombian pesos. To see the actual data, double-click on this BAS1 row. You see a 7x33 matrix of data (plus a totals row and a totals column); the rows have commodity labels and the columns are labelled “D1” up to “D33” plus a 34<sup>th</sup> column labelled “foreign”. These must be the elements of the sets COM (commodities) and ALLSOURCE (source), respectively. What about the 3<sup>rd</sup> dimension IND and the 4<sup>th</sup> dimension REGDEST of this data array? The clue is given by the 4 drop-down lists near the top right-hand corner of the screen which say **All COM; All ALLSOURCE; Sum IND; Sum REGDEST** respectively. Because your computer screen is 2-dimensional, what you are seeing are the IND and REGDEST values **summed across sectors and regions**.

	27 D27	28 D28	29 D29	30 D30	31 D31	32 D32	33 D33	34 D34	All IND	Sum REGDEST
<b>1 AGR</b>	362417.625000	8674.690430	75769.273438	81795.625000	8601.575195	34138.608594	99427.007813	197123	1	97711874.000000
<b>2 MNE</b>	1596965.750000	1916.137476	5.700947	39896.788291	14.954394	162.639433	166.183947	270743	2	5665630.000000
<b>3 IND</b>	55578.718750	1085.628906	1383.175781	7404.861328	6395.980469	853.351440	1411.764648	21379468	3	94325630.000000
<b>4 CNT</b>	95162.523438	2040.603394	5454.857910	7914.299805	5338.531250	1410.597534	2801.493652	4 CNT	4	34805694.000000
<b>5 TRN</b>	96881.289063	3103.674561	6847.076660	9870.201172	82798.000000	3079.385986	2894.891846	1996338	5	14668758.000000
<b>6 ADP</b>	0	0	0	0	0	0	0	0	6	0
<b>7 OTS</b>	384344.406250	10900.916992	22943.958664	71346.117188	349646.781250	9636.857422	20837.621094	1653842.125000	7	70744040.000000
<b>Total</b>	26110930.250000	27721.550781	112404.046875	214217.843750	452795.812500	49281.628906	127538.960938	27271624.000000		188593520.000000

Q8. What is the total across all sectors of the value of manufacturing goods produced in Bogotá (D3) and sold in César (D9)?

Q9. What is the total across all sectors and across all regions of the value of imported manufactured inputs?

How can you see the value of purchases of one specific input (say IND) by just one sector, for example, other services (OTS), in a given location (e.g. Valle, D24)? To see this, click on the **All COM** drop-down list box near the top right-hand side and select “IND” from the options. Then, click on the **All IND** drop-down list box and select “OTS” from the options. Finally, select “D24” from the drop-down list **All REGDEST**. The data will change and now you are seeing how much is purchased just of manufactured inputs by the other services sector in Valle.

Q10. How much imported manufactured inputs is purchased in Valle by the sector other services?

Q11. What are the three main sources of manufactured inputs to other services in Valle?

Q12. And the two main sources of agricultural inputs to Bogotá’s manufacturing sector?

Now click again on **Contents** in ViewHAR’s main menu to return to the list of contents. Look at the rows BAS2, BAS3, BAS4, BAS5 and BAS6. They represent commodity demands by the other users in the CEER model, namely, investors, households, foreigners, regional government, and Central government. Let us take a look at household demand (BAS3). You can see that this is a 3-dimensional array of size **COMxALLSOURCExREGDEST**. There are lots of ways of viewing 2-dimensional slices of a multi-dimensional array.

## Computing Guide for CEER

REG	1 REG	2 MNE	3 IND	4 CNT	5 TRN	6 ADP	7 OIS	Total
1 D1	128072.425000	131.447199	679215.500000	51632.519311	1294913.750000	0	7899302.500000	1630000.000000
2 D2	82660.671875	7.615392	2512763.000000	14739.401367	531742.812500	0	4381084.000000	742297.500000
3 D3	9586.285136	36.712294	1127284.000000	123194.370000	3004904.500000	0	27811976.000000	4238943.000000
4 D4	284147.812500	25.360712	2417900.750000	11087.648262	370894.186250	0	2694138.875000	5137797.000000
5 D5	446750.968750	31.644428	375377.000000	8259.845703	289072.968750	0	1593759.500000	2713252.000000
6 D6	432876.437500	6.624624	926314.812500	6536.794434	364562.093750	0	1581460.250000	3311761.000000
7 D7	238769.494375	0.346242	49191.152394	1671.049340	26910.846703	0	30603.375000	62068.250000
8 D8	265986.562500	4.107509	873603.625000	6032.426270	94636.843750	0	1058299.625000	2298563.250000
9 D9	456904.000000	184.520396	215870.093750	4702.059082	188463.718750	0	792434.687500	168559.125000
10 D10	487242.562500	200.282463	228510.968750	6015.230957	238996.437500	0	1139732.500000	2150725.000000
11 D11	287917.125000	18.645727	2194046.750000	14104.582031	404929.312500	0	2488689.250000	5389795.500000
12 D12	73617.140625	15.738053	4368.267090	1341.404119	47249.050781	0	203923.259375	330614.968750
13 D13	494146.125000	105.656133	159796.421075	6234.450694	151853.671075	0	1134041.750000	1943318.000000
14 D14	103342.926688	186.466878	19724.383303	2408.310099	60340.917969	0	608979.937500	794663.062500
15 D15	459895.187500	1.567261	185132.234375	4914.015137	248724.703125	0	1159456.750000	2058124.500000
16 D16	687511.312500	101.837212	250373.78625	4423.092515	226178.984375	0	918894.687500	207183.625000
17 D17	474328.000000	4.146447	182417.109375	6786.421875	156233.101250	0	1324944.000000	2124201.750000
18 D18	286284.875000	13.270529	222562.953125	5419.132813	233641.250000	0	1290123.000000	2038044.500000
19 D19	153883.000000	1.246240	13741.609375	3197.798096	192226.820125	0	702795.437500	1189245.875000
20 D20	125399.703125	3.738629	649451.437500	6653.070313	246771.171875	0	1333867.875000	2357867.000000
21 D21	570638.687500	33.500358	1415264.125000	15991.478516	602689.625000	0	3016601.250000	5621218.500000
22 D22	235958.562500	2.018565	58713.435994	2764.143066	57777.398438	0	667273.562500	1022489.125000
23 D23	679426.437500	32.823200	438915.593750	8184.241197	825853.546875	0	1172328.250000	2966037.750000
24 D24	699144.750000	16.694109	5940041.000000	32259.835984	1256801.375000	0	8866315.000000	16788578.000000
25 D25	22407.314453	0.012426	4888.927734	310.594208	11871.472656	0	71411.750000	110893.070313
26 D26	188553.171875	66.343781	10327.075395	1700.468693	37981.164863	0	195867.846875	420465.250000
27 D27	253078.431875	578.274868	37336.282969	2462.418989	84737.015625	0	286944.000000	564618.375000
28 D28	11555.663086	1.957524	2259.798340	280.641907	6262.682617	0	31011.544922	51372.289663
29 D29	75244.625000	0.003092	1756.145142	844.440002	15914.006914	0	70881.269598	164640.896262
30 D30	80906.078125	20.968173	11454.526387	1893.086436	2388.119922	0	22253.250000	346701.875000
31 D31	13268.253945	0.005765	5676.119629	337.588745	50301.042969	0	273449.750000	343232.812500
32 D32	25287.152344	0.172393	1319.002686	196.966880	5013.481445	0	22243.433994	54033.210938
33 D33	90111.687500	0.134026	1722.328987	602.601318	6821.381268	0	44968.919531	165027.816250
34 Foreign	886500.187500	101.544243	20547472.000000	0	1705897.875000	0	1506747.250000	24646718.000000
Total	10854781.000000	1939.604248	57125364.000000	357324.218750	12534689.000000	0	76575948.000000	157449962.000000

To see another, click on the **ALLSOURCE** drop-down list box (the 2nd of the three) and select **foreign**, so that only foreign purchases are shown. Now click on the 3rd, **REGDEST**, list box and select **All REGDEST**.

REG	1 REG	2 MNE	3 IND	4 CNT	5 TRN	6 ADP	7 OIS	Total
1 D1	150995.187500	3.294510	76795.500000	0	22972.828125	0	316780.718750	1474247.500000
2 D2	39875.128906	4.650032	423378.031250	0	75702.351563	0	4893.605469	543853.750000
3 D3	190929.406250	70.351067	19641790.000000	0	598941.062500	0	246441.125000	17017872.000000
4 D4	9821.825195	7.607465	323786.200000	0	57962.312500	0	1846.398279	393335.000000
5 D5	134.669998	0.184413	15339.969180	0	40883.208594	0	0	92558.074219
6 D6	1135.200684	0.683339	43347.191406	0	33176.375000	0	1796.748901	79456.003125
7 D7	0	0	56.711929	0	8076.114023	0	0	8132.829598
8 D8	5943.737793	0.026789	46534.390625	0	28956.664963	0	0	60984.320313
9 D9	186.760254	0.000352	126610.312500	0	23160.619141	0	0	149957.687500
10 D10	2949.444580	0.138032	8578.966094	0	26815.072266	0	860.362793	39204.016625
11 D11	138207.531250	3.008918	1774931.625000	0	7022.273438	0	24263.673828	2007388.125000
12 D12	0	0	6.787982	0	5632.930509	0	0	5639.732910
13 D13	2561.054443	0.022666	5197.118164	0	26609.125000	0	0	34367.320313
14 D14	299.520844	0.220099	89713.889388	0	11396.882773	0	201432.268625	213832.250000
15 D15	1523.902954	0.025511	127149.523438	0	25756.644531	0	95.699104	154525.796875
16 D16	946.734436	0	2254.641113	0	20956.023911	0	0	23787.400391
17 D17	67910.304688	0.226467	12611.648625	0	27914.503906	0	0	221096.671875
18 D18	14125.481445	0.599111	42365.962188	0	27965.695547	0	251.236374	84619.984375
19 D19	1177.307983	0	4198.114746	0	15240.883789	0	11.103938	20627.410156
20 D20	1772.408325	0.002777	118881.954688	0	27916.773438	0	3099.888887	152670.593750
21 D21	90771.312500	0.033130	31125.293469	0	46683.889388	0	184766.268625	313845.937500
22 D22	121.640495	0.008842	964.296204	0	13304.125977	0	0	14390.274844
23 D23	4306.644043	0.000954	56509.792669	0	36575.078125	0	0	97791.515625
24 D24	191957.871875	10.020113	688327.312500	0	184560.431875	0	528537.562500	1292389.000000
25 D25	1.104966	0.015286	967.851440	0	2463.972412	0	44.065666	3477.009521
26 D26	167.616023	0.143499	11325.754983	0	8583.895886	0	0	20077.365234
27 D27	0	0.008973	9473.212111	0	9973.127920	0	0	19448.878906
28 D28	0	0	11.438824	0	1319.629403	0	0	1331.049516
29 D29	0	0	50.182243	0	4087.899170	0	0	4138.081543
30 D30	78.599670	0	318.124115	0	11607.796875	0	0	12004.520508
31 D31	0	0	19.684947	0	3259.824349	0	0	2574.431885
32 D32	0	0	0	0	1021.692810	0	0	1021.692810
33 D33	0	0	760.836609	0	2946.132324	0	0	3706.969994
Total	886500.187500	101.544243	20547472.000000	0	1705897.875000	0	1506747.250000	24646718.000000

Q13. What is the value of imported agricultural goods consumed by households in Atlántico (D2)?

Q14. What is the total value of imported manufactured goods consumed by Colombian households?

Let's look now at the structure of household consumption embedded in the model. First, click on the **ALLSOURCE** drop-down list box and select **Sum ALLSOURCE**, so that only total purchases are shown. Click on the **REGDEST** drop-down list box and select **ALLREGDEST**. Click on the small yellow rectangle near the top left of the ViewHAR window to transpose the

matrix (exchange rows and columns). From the shares list box, select **row** shares. Now you are seeing consumption shares.

Q15. What do you notice about regional structure of consumption?

Q16. What commodity is responsible for the highest share of household expenses in Colombia?

We saw that all regions have the same structure of consumption. This is a hypothesis used to construct the database of the CEER model. However the model allows for different structures of regional dependence on suppliers. Let's check it!

Q17. What share of household consumption of agricultural goods in Bogotá is supplied by producers within the Capital? And what is the share of agricultural products consumed by households in Antioquia (D1) is supplied regionally?

In the CEER model, domestic output is directed to sales to intermediate use (BAS1), capital creation (BAS2), household consumption (BAS3), exports (BAS4), regional governments (BAS5), and sales to Central government (BAS6). In addition, transportation services (TRN) are also consumed as a margin-commodity, used to facilitate trade between origin-destination pairs. Total sales for margin usage, by different users, are found in the arrays MAR1, MAR2, MAR3 and MAR4. Notice that there is no margin consumption associated with the consumption of public goods.

To answer the following questions, you may use Excel to help you. You can easily copy from ViewHAR and paste to Excel. Note in the main menu that you can decide whether or not to export details from the arrays [*Export /Options (labels, totals)*].

Q18. Which sector has the highest export share in the country?

Q19. Which sector sells the greatest proportion of its output to households?

Q20. And which is most investment-oriented in its sales pattern?

Q21. What is the total output of transportation? Do not forget to add margin sales!

Q22. If exports of agriculture increased by 10%, what would be the percent increase in agriculture output (assuming other sales unchanged)?

Q23. What might happen to manufacturing output if its exports went up 10%?

Just to refresh, answer the following:

Q24. Which sector uses the greatest proportion of imports in its material inputs?

<i>Sector</i>	<i>Import share</i>
AGR	
MNE	
IND	
CNT	
TRN	
ADP	
OTS	

Q25. And which final demander?

<i>Sector</i>	<i>Import share</i>
Investors	
Households	
Exports	
Regional government	
Central government	

Now close the ViewHAR window by selecting **File / Exit** from ViewHAR's (not RunGEM's) menu.

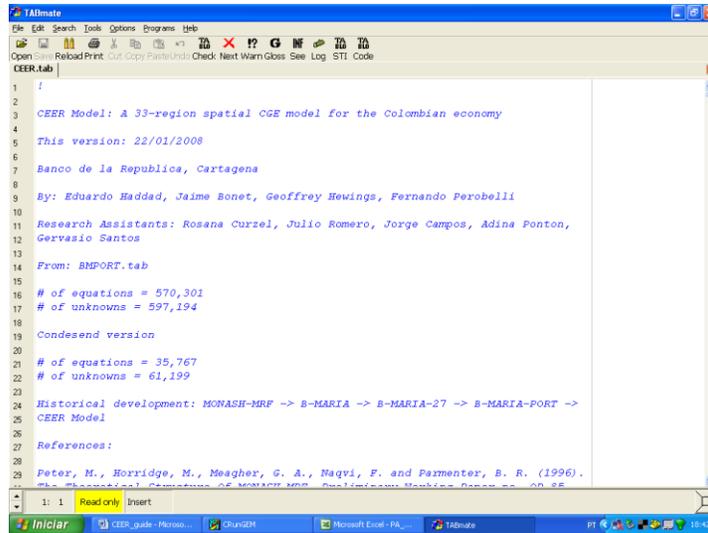
Binary files (such as Header Array files) cannot be looked at in a text editor. To see this, select **View / Other Text File** from RunGEM's main menu and select CEER.HAR (the data file). RunGEM tells you that it is unable to open this as a text file (and even suggests that you try to open it with ViewHAR).

### 5. Looking at the TAB file<sup>3</sup>

To see the model equations use the **View** menu item at the top of the **RunGEM** window and select

**View / Main TABLO file**

<sup>3</sup> The term **TAB file** is shorthand for **TABLO input file**.



A text editor will appear, with the file CEER.TAB visible. This will probably be the TABmate editor used by GEMPACK. It will be in read-only mode, so that you cannot change the TAB file. The TAB file uses the TABLO language to specify the equations and variables of the CEER model.

TABmate colours items in the TAB file according to their function:

- black for words that are part of the TABLO language;
- green for variables and other items that are specific to this model;
- blue for comments which GEMPACK ignores;
- *italics* for strings that GEMPACK uses as labels or descriptions.

You might also see line numbers in the left hand margin.

Now search for MDATA. Select **Search / Find...** from the editor’s menu, type in “MDATA”, and click **OK** (or press Enter). To search again after you have found the first occurrence, you can either again click OK, or you can close the Search dialog and touch the **F3** key (near the top of your keyboard). Close the Search dialog and press **F3** to see the first 3-4 occurrences of MDATA. You will see that various pieces of data are read from this file. [Note: where several Read statements occur together, the keyword “Read” is only needed for the first Read statement in the group.]

Click in the word MDATA, then click the button above marked **Gloss**. A window will appear, showing each line that contains that word. Line numbers appear in red – you can click on these red numbers to go to that line. Click to go to the line where **LAB\_OCC\_IND** is read from file.

You will see that the matrix LAB\_OCC\_IND is read from the header “LABR”. The **header** is a short key (up to 4 letters) which identifies the location of LAB\_OCC\_IND, within the MDATA file (in fact you previously used ViewHAR to examine the values of LAB\_OCC\_IND in that

file). Now click in the word LAB\_OCC\_IND, then again click the **Gloss** button to see all occurrences of it. You will see that LAB\_OCC\_IND is declared as a **COEFFICIENT** and that it holds the value of labor payments. It is used in numerous equations and formulae. Click on the line number for equation E\_p0a (zero pure profits in current production) to go there. Click on the word “Equation” and press **Gloss** again. This time you get a list defining all the variables and coefficients in the equation. Press spacebar to close the Gloss window.

You have learned two ways to use the **Gloss** button:

- click on a variable, coefficient or filename: **Gloss** shows every occurrence of that symbol;
- click elsewhere in a statement: **Gloss** shows the first occurrence of each symbol used there.

Both techniques can be very useful to find your way about the TAB file.

Now close TABmate (click the X button at top right of window) and return to RunGEM

## 6. Running a *numéraire* simulation

In this simulation the usual *numéraire*, **natphi** (the exchange rate), is increased by 10 per cent.

For simulations, the last pages **Closure - Shocks - Output files - Solve - Results** are usually accessed in that order (from left to right).

First click on the **Closure** page of RunGEM. You will see a list of the exogenous variables in the currently selected closure. You can choose between several different closures when running a simulation. The panel below shows which variables are exogenous in the selected closure. RunGEM allows you to load different closures already prepared.<sup>4</sup> To see this, use the **Load Closure** button to load the **SHORTRUN** closure file. Notice that **natphi** is one of the exogenous variables.

Now go to the **Shocks** page. Click on the **Clear Shocks List** button to remove whatever shocks are shown. Now you will specify a shock to variable **natphi**. To do this, click on the **down arrow** to the right of the label **Variable to shock** near the top of the Shocks page. A drop-down list of all the exogenous variables in this standard closure will appear. Click on **natphi**. A new edit box entitled **% Change Shock** will appear. Click in this and type in **10**. Then click on the button **Add to Shock List**. The line

**Shock natphi = 10;**

should appear in the Shocks memo which occupies the bottom half of the Shocks page. This is the only shock for the *numéraire* simulation.

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<sup>4</sup> You can also edit the closure shown on the Closure page, and can save this edited closure.

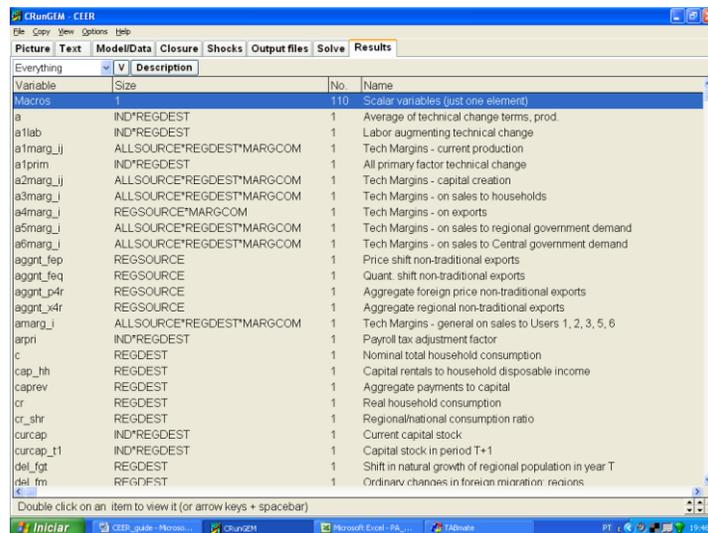
Have a look at the **Output files** page. It controls the names of output files produced by the simulation. Don't change anything now. Go to the **Solve** page of RunGEM.

- 1 First click on the topmost **Change** button (the one with **Solution method** before it). Click on **Johansen** to select Johansen's method. You will learn more about the different solution methods available later in this document.
- 2 If it is not already there, insert the text **Numéraire simulation** in the text box labelled **Verbal description**.
- 3 Now click on the **Solve** button. A "Please Wait" window will appear while the model is solved. Then RunGEM will show you a box telling you how long the solution took. Just press OK.

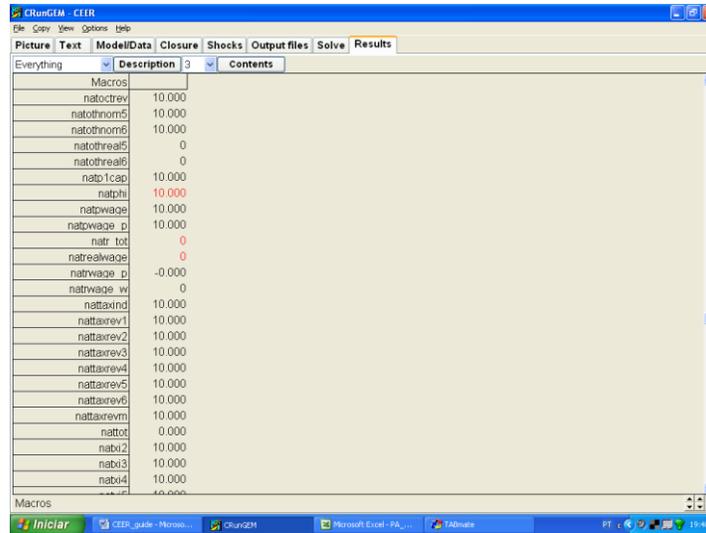
The next natural step is to look at the results.

## 7. Looking at the results

Click on the **Results** page of RunGEM. This page allows you to inspect the variable values computed during the **last** successful solution process. You will see the Contents page listing many of the variables of the model. The first row, **Macros**, refers to the rows which have no subscripts (i.e., just one element). The other rows correspond to individual vector and matrix variables. Slowly move the mouse pointer (without clicking) over the various buttons and controls to get a hint about their purpose.



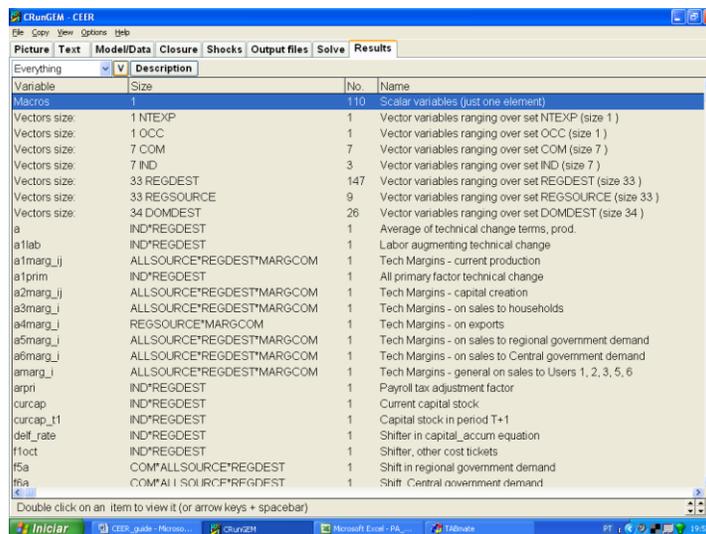
Double-click on the **macros** row to see the results for these variables. Select 3 decimal places.



Exogenous variables are shown in red, including the shocked variable, **natphi**. Notice that all the quantity variables are unchanged (zero), while variables measured in currency units such as prices and values have all increased by 10%. In other words, the single exogenous price (called *numéraire*) serves to determine the absolute level of prices but does not affect relative prices or, therefore, the behaviour of any agents.

Click the **Contents** button to return to the contents list.

To see the effects of another useful way of listing the variables in the **Contents** page, click on the **V** between the two drop-down list boxes near the top of the screen. You should see something like:



To see the results for all variables with a single argument ranging over the set **IND**, double-click on the fifth of the rows above (Vectors size: 7 IND). This time you will see the percent-change results for the 3 such variables (**natlabind**, **naty** and **natz**). When you have finished looking at

these results, double-click on any number to return to the Contents list. Return to the other view of the Contents list by clicking again on the **V** button.

Q26. Which variable shows percentage changes in industry output (activity level)?

**7.1. Looking at the updated data**

As well as producing percent change simulation results, the simulation above produced an updated version of the MDATA file for the model (and also for YDATA, NDATA, and PDATA). This updated database reflects the state of the economy as it would be after the shock (10 per cent increase in the *numéraire*). You can see this updated data by selecting

**View / Updated Data / Updated MDATA**

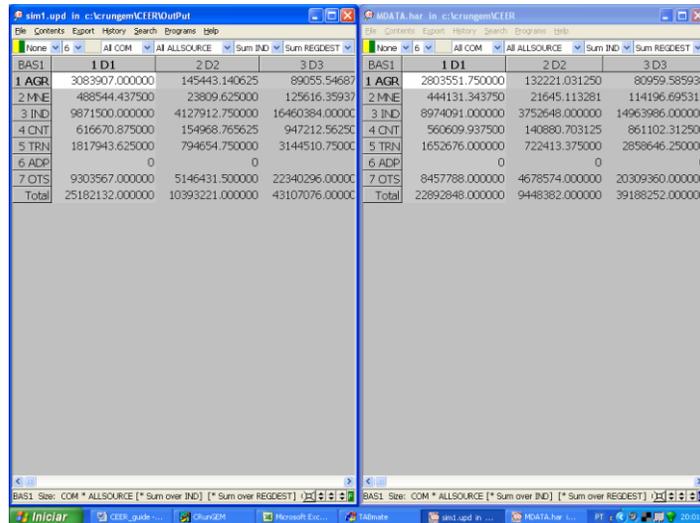
from the RunGEM menu. As usual, RunGEM opens ViewHAR to show you this data set. Double-click on the first Contents row (BAS1). You should see the values of intermediate consumption of inputs from different sources, summed over all sectors and destination regions. Now click (**carefully**) in the **left** side of the  button near the bottom right-hand corner of the ViewHAR window, to make this occupy just the **left** half of the screen.

Now, for the original (pre-simulation) version of this data, go back to RunGEM and select

**View / Input Data / Original MDATA.**

Again double-click to select the **USE** data and this time click carefully on the **right** side of the  button to make this ViewHAR occupy the right-hand half of your screen.

Then (via the **Taskbar** or **Alt+Tab**), bring the other ViewHAR window (the one in the left hand half of the screen) to th''e top.



When you have got both the original and the updated data side-by-side on your screen, take a moment to pat yourself on the back. You are truly a Windows wizard! Now look at a particular cell, say that corresponding to the value of intermediate usage of agriculture product from Antioquia (the top-left cell). Think what has happened to prices and to quantities in this simulation, and hence deduce what must have happened to values. Check that the pre- and post-simulation BAS1 values are consistent with this.<sup>5</sup> You might like to repeat this for some other cells in this or other headers. Close the two ViewHAR windows when you are finished.

Remember that the flows in the updated data are measured in terms of post-simulation prices. By comparing original and updated data, we can make deductions about values, but not about quantities.

## 8. Simulating the short-run effects of a drought in Antioquia

Most years, one or more regions of Colombia suffer from low rainfall. As a continuing result of climate change, during 2008 an unusually severe drought in Antioquia is expected to affect farmers all over the Department. Agricultural outputs will fall sharply. We simulate the effects of such a drought using the CEER model. Questions are scattered through the instructions. Write down answers to the questions onto the instruction sheet.

The simulation in the next example is one in which the shock is a

### 10% decrease in technical efficiency

Now look again at the TABLO Input file for the CEER model.

*Search / Find* for the variable name **a1**. The first occurrence is the variable definition:

```
(a1, j, IND) (a1, q, REGDEST)
a1(j, q) # All input augmenting technical change #;
```

The “(a1,j,IND) (a1,q,REGDEST)” means that **a1** is a vector variable with one value for each sector in each region. Click on **a1** and press the *Gloss* button (at top middle of the screen). You can see that a1prim appears in 4 equations: the three demand equations E\_x1o, E\_x1oct and E\_x1prim, and later on the long E\_a equation. Click on the red line number at left of equation E\_x1o and you should see:

---

<sup>5</sup> You should be able to confirm that the post-simulation value is exactly 10% greater than the original value. Right-click on the original value. A small window should appear: click first the **Copy** button, then the **Close** button. This puts the number in the Windows clipboard. Now use ViewHAR’s **Help...Calculator** menu command to launch the Windows calculator, then **Edit...Paste** to enter in the number from ViewHAR. Multiply by 1.1 (\*1.1=) and you should see the same number as in the updated data. You can also do this in Excel.

```
E_x1o # Demand for dom./for. composite inputs, User 1 #
(all,i,COM)(all,j,IND)(all,q,REGDEST)
x1o(i,j,q)=z(j,q)+a1(j,q);
```

Click on the = sign in the equation above and press the **Gloss** button to see a definition of each symbol that is used.

The terms “(all,i,COM)(all,j,IND)(all,q,REGDEST)” mean that Equation E\_x1o is actually a group or block of equations: there is one equation for each “commodity composite”<sup>6</sup> used by each industry in each region. So if there were 7 commodities, 7 industries and 33 regions in the database there would be 1617 (=7\*7\*33) separate equations. Each of the variables **x1o**, **a1**, and **z** is a percentage change: if **z**(“IND”,“D3”) had value 5, that would mean that output of the manufacturing sector in Bogotá would be 5% greater than in the initial equilibrium described by the input data files. The “a” variables are technological change variables, normally exogenous (values fixed outside the model). Suppose output were fixed (**z**=0), a shock of 10% to **a1**(“IND”,“D3”) would mean that for each commodity c, the values of **x1o**(c,“IND”,“D3”) must also increase 10% to keep the equation balanced. If you looked at the other equations where **a1** appears, you would find that a shock of 10% to **a1**(“IND”,“D3”) would mean that 10% less of *all* inputs were needed to produce a given IND output in Bogotá [note: positive **a1** implies technical *regress*].

Press ESC or spacebar to close the Gloss window.

Exit from TABmate in the usual Windows way by **File / Exit**. (There are usually alternatives in terms of keystrokes instead of the mouse action. For example you can use keystrokes **Alt** followed by **F** followed by **X** in order to exit.)

## 8.1. Implementing the shock

Start up RunGEM with the CEER model. Go to the **Closure** page. As in the previous example, use the **Load closure** button to select the **SHORTRUN** closure. Notice that the variable **a1** (all input augmenting technical change) is exogenous.

In this simulation we shock the variable **a1** to increase by 10% for the agricultural sector (**AGR**) in Antioquia (**D1**). **a1** is a measure of overall technical efficiency – the 10% means either that with inputs held constant output will be 10% less, or that 10% more inputs will be needed to produce the original output. This shock is used to simulate the main effect of the drought: agricultural productivity in Antioquia is reduced.

---

<sup>6</sup> An example of a “commodity composite” might be mining used by the manufacturing industry. Mining is potentially a mixture of local and imported mining products, so we call it a “dom/imp composite”.

Go to the *Shocks* page and delete any existing shocks by clicking **Clear Shocks List**. Then specify the shock as follows:

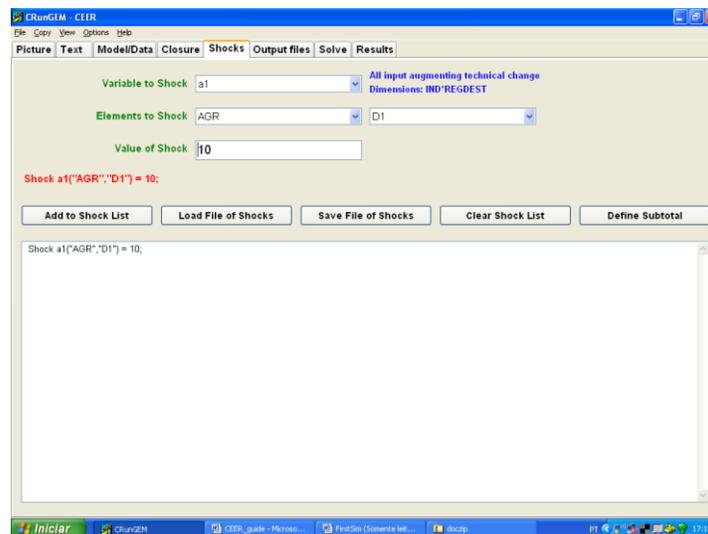
- 1 Use the combo box<sup>7</sup> at the top to choose which **variable to shock**: click on the arrow at the right. This will show you a list of variables. Click on **a1**.<sup>8</sup> This variable has dimensions **INDxREGDEST**.
- 2 Select the elements to shock: from the **ALL IND** drop-down list box choose **AGR**. And from the **ALL REGDEST** list box, select **D1** (Antioquia).
- 2 In the edit box labelled **value of shock**, type 10, meaning a 10% decrease in primary factors technical efficiency in the agriculture sector in Antioquia. Then click the *Add to shock list* button.

In this simulation, only one variable is shocked. If you wanted more shocks you would repeat steps A and B for each variable that was to be shocked.

The shock list underneath should now contain:

***Shock a1("AGR", "D1") = 10;***

You may edit it directly if necessary



When you have finished with the shocks, go to the Output Files page.

## 8.2. Choosing a special name for output files

Later, we want you to compare the solution file from this simulation with another solution file. If

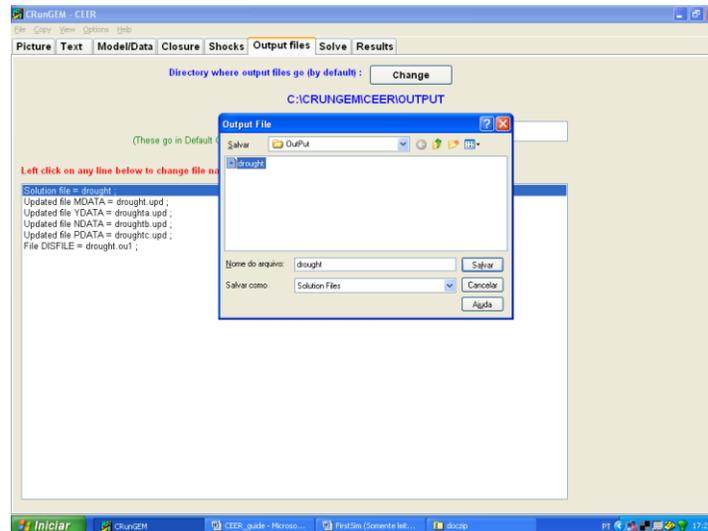
<sup>7</sup> A **drop-down list box** is also called a **combo box**.

<sup>8</sup> For some versions of the CEER.EXE file, one should shock **a1prim** instead.

you want to preserve solution files for later reference, you have to give a unique name for simulation output files. To do this, go to the Output Files page, and click on the line beginning

**solution file =**.

A file dialog will appear; type in a new name. This time, type **drought.SL4** [the suffix SL4 is compulsory]. Then click Save.



When you have set the name for output files, go to the Solve page.

### 8.3. Choosing the solution method and running the simulation

From the Solve page:

- 1 First select the solution method to use. To do this, you would need to click on the **Change** button to the right of the **Solution method** label. [This button is the top-most button on the page.] Do not change the solution method this time. In the **Method** part select **Euler**. [We will discuss the alternative methods later.]
- 2 Next notice the **Verbal description** label and the edit box to its right. It is good practice to enter a few words summarizing the simulation you are about to carry out. So first select the existing entry with your mouse and then replace it by

**10% decrease in productivity in the agricultural sector in Antioquia**

- 3 Now click the Solve button to start the solution process.

RunGEM runs the TABLO-generated program CEER.EXE to solve CEER.

Once it has solved, RunGEM displays an accuracy summary chart showing how many variables

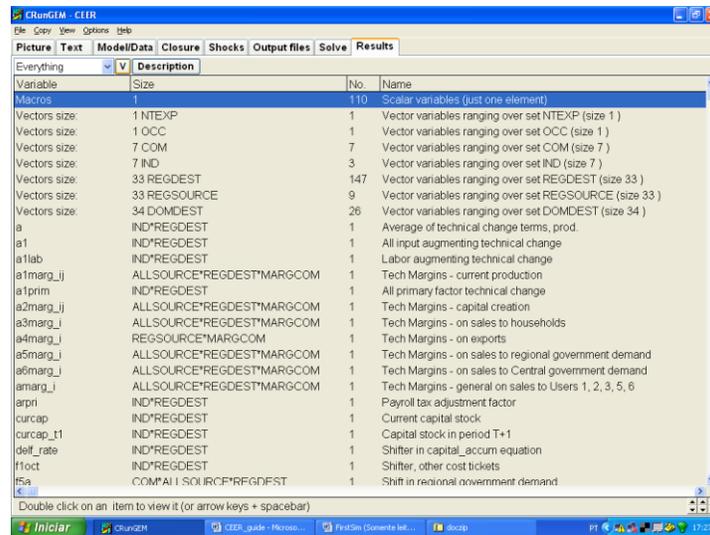
are accurate in the levels to 1, 2, 3, 4, 5, or 6 figures. A little face summarizes overall accuracy – hopefully it is smiling. Accuracy of the updated data is summarized in the same way. Click **Help** to learn more, then **OK** to proceed. Another message now tells how long the solution took.

### 8.4. Looking at the results

When the solution has been obtained, RunGEM will present you with a box telling you how long it took to obtain the solution. Close this and go directly to the **Results** page.

This page allows you to inspect the variable values computed during the **last** successful solution process. Initially a **Contents** window is displayed, listing the model variables. You can double-click on the row containing the variable you are interested in to see its results in this simulation. As you saw previously, you can also use the button marked “**V**” to arrange the contents list in two ways:

- variables listed individually;
- variables ranging over the same set grouped together.



You can also look at the results using ViewSOL. First click on the button

#### View / Solution via ViewSOL

The Contents screen shows the names of the variables. To see the values of a variable, double-click on its name. To return to the Contents screen, double-click on any number (or select Contents in the ViewSOL menu).

Start by double clicking on the first Contents row: **Macros** (Macros are scalar variables or variables with just one component). You should see a list of macro variables and the value of their changes. You can click on the variable names – a description will appear at the bottom of

ViewSOL . Use the decimal places combo box at top right to set the number of decimal places to 3.

Most of the variables are percentage changes, but some are ordinary changes, measured in million-pesos. Values for exogenous variables are shown in red. Scroll down the list to find price indices, nominal values, and quantity indices.

Q26. Write down below what happened to:

---

**natexpvol**: export volumes  
**natgdpreal**: real GDP from expenditure side  
**natemploy**: national employment  
**natimpvol**: import volume  
**natxi4**: exports price index  
**natxi3**: consumer price index  
**natpwage**: aggregate nominal wages to workers

---

Double-click on any number to return to the Contents screen. Then scroll down till you find the variable **natz** (activity level). Double-click to view the numbers.

Q27. Which non-agricultural industry was most affected?

Return to Contents and view regional results for:

**x4r**: export volume  
**xi3**: regional consumer price index

Q28. Compare the results for **dompq110** (private consumption) and **hhldy000** (disposable income). What do they suggest? Can you find in the CEER.TAB file the relevant equation?

Q29. Look at the results for **yr\_r** (real GRP), **I** (aggregate employment) and **z** (activity level by sector). Which Department is the main loser? Which Departments gained in real GDP terms? Can you think why?

## 8.5. Changing the solution method

In this example, you will tell RunGEM to solve the model using Johansen's method. With Johansen's method, only approximate solutions are obtained to the nonlinear levels equations of the model. GEMPACK also provides multi-step solution procedures referred to as **Euler's** and **Gragg's solution methods**. Coupled with **extrapolation** (a standard numerical method used in various branches of science and engineering), these are able to provide accurate solutions of the levels equations of the model, as was the case in the example above.

To change the solution method in RunGEM go to *Solve* and click on the *Change* button to the right of the **Solution method** label. [This button is the top-most button on the page.] In the *Method* part select **Johansen**. Then click *Ok*, and go to the Output Files page.

### 8.6. Choosing a special name for output files

Later we want you to compare results from this simulation with those from the previous simulation that used the **Euler** solution method. This means that you must specify a unique name for the output files that the next simulation will produce. To do this, go to the Output Files page, and click on the line beginning **solution file** =. A file dialog will appear; type in the name droughtj.SL4. Then click Save.<sup>9</sup>

### 8.7. Running the Johansen simulation

Now go to the *Solve* page and click the *Solve* button. A “Please Wait” window will appear while the model is solved. Then RunGEM will show you a box telling you how long the solution took. Just press OK.

### 8.8. Using ViewSOL to compare two sets of results

The RunGEM Results page lets you see only the most recently-computed solution. Sometimes you want to view 2 solutions at once. You can do that using the ViewSOL program which comes with RunGEM.

We assume that RunGEM is open and you have just successfully completed the steps described in previous sections.

Now select the menu item *View / Solution via ViewSOL*. The ViewSOL program will open the most recent solution<sup>10</sup> and show a Contents page. In general, ViewSOL works very like the **Results** page of RunGEM. For example, you can double-click on a variable to see its values.

Now, use the ViewSOL menu command *File / Open* to open the solution file **drought.SL4**. This ought to contain results from the previous, Euler 1-2-4, simulation.

ViewSOL Contents will again appear. ViewSOL offers a choice of formats for this Contents list. Select *Format*. from ViewSOL’s main menu and there click on *Arrange vectors by name* (in the panel headed Vector options); also click the button *Order Variables alphabetically*; then click *Ok* which will put you back to the Contents list. Now double-click on the **macros** row and you should be able see both solutions together.

---

<sup>9</sup> If you do not give a new name for the SL4 file, RunGEM uses the same name as before, and so overwrites the previous solution file. This might be annoying! You can use Explorer to delete files in the Output directory (maybe to save disk space).

<sup>10</sup> ViewSOL displays a short quotation (either inspiring or corny) while it is loading the solution file.

Macros	drought1	drought2
beta1	-0.031	-0.031
del_fmtd	0	0
del_natfm	0	0
del_natq	0	0
del_naturr	-0.008	-0.010
delbt	79261.195	74885.883
deldbt	39630.598	37442.941
deldbt_ratio	0.001	0.001
deldfudae	0	0
delf_rm	0	0
delf_rm_0	0	0
delfkfudae	0	0
delpopfudae	0	0
delunty	0	0
ev_boq	-406024.938	-388184.094
ev_car	-133474.109	-128612.766
ev_nor	-160155.453	-155082.219
ev_nue	37935.633	35873.367
ev_ooe	-829715.938	-777142.563
ev_pac	-119694.023	-115003.406
ev_r	-158314.000	-1501195.250
ev_sur	28014.795	26956.340
iq	0.070	0.071
interest	0	0
lp	0.070	0.071
levdabt_ratio	0.001	0.001
miscf002	0	0
natic	-0.163	-0.152
natzaprev	-0.287	-0.271

Q30. Do you think that the differences between Johansen and Euler solutions are significant?

Go back to the ViewSQL contents list and double click on the row for **z**, a matrix variable (this will be near the end of the contents list). This time you will only see results for one simulation. But you can use the **solution list box** (see picture) to switch between the two solutions. The Description menu item gives details of the currently selected solution.

z	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14	D15
AGR	-9.176	0.581	0.417	0.924	0.584	0.707	0.694	0.579	0.523	1.069	0.074	1.594	0.752	0.805	0.698
MNE	0.009	-0.007	-0.010	-0.004	-0.009	-0.003	-0.004	-0.009	-0.015	-0.004	-0.010	0.002	-0.017	-0.021	-0.008
IND	-0.332	-0.092	-0.066	-0.165	-0.041	-0.066	0.034	-0.027	-0.006	-0.080	-0.029	-0.125	-0.005	-0.046	-0.008
ONT	-0.014	-0.011	-0.008	-0.013	-0.007	-0.012	-0.003	-0.005	-0.005	-0.008	-0.003	-0.006	-0.003	-0.007	-0.008
TRN	-0.289	-0.161	-0.159	-0.177	-0.079	-0.097	0.076	-0.048	-0.009	-0.082	-0.064	-0.011	0.033	-0.037	-0.064
ADP	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
OTS	-0.144	-0.131	-0.132	-0.137	-0.065	-0.050	0.061	-0.031	-0.027	-0.026	-0.056	0.007	0.026	-0.049	-0.010

Now use the Filtering list box to select only the **D1** (Antioquia) component of matrices. This takes you back to the contents screen. Double-click on the **z[\*;D1]** row (probably the last row). You should see results for the Euler and Johansen simulations side-by-side:

The screenshot shows a ViewSOL window with the following data:

z\*D1	drought	drought
AGR	-10.184	-9.176
MNE	0.009	0.009
IND	-0.338	-0.332
CNT	-0.015	-0.014
TRN	-0.307	-0.289
ADP	-0.000	-0.000
OTS	-0.150	-0.144

When you have finished looking at the results, exit from ViewSOL.

### 8.9. Copying results into a spreadsheet

RunGEM makes it easy for you to copy simulation results (or data) into other windows programs such as spreadsheets or word processors. You will find this invaluable when you are preparing reports.

As an example, below we set out the simple steps needed to copy the **yr\_r** results from the previous simulation into Excel (or another spreadsheet).

Go to the Contents page of the **Results** and then select the **yr\_r** results

You should see something like:

The screenshot shows the RunGEM window with the following data:

yr_r	Description
D1	-1.656
D2	-0.108
D3	-0.108
D4	-0.058
D5	0.094
D6	0.071
D7	0.282
D8	0.078
D9	0.092
D10	0.203
D11	-0.024
D12	0.291
D13	0.157
D14	0.006
D15	0.198
D16	0.182
D17	0.152
D18	0.059
D19	0.070
D20	-0.017
D21	0.010
D22	0.444
D23	0.204
D24	-0.041
D25	0.031

Now click on **Copy** from RunGEM's main menu. A message **Data copied to Clipboard** will appear for a moment.

Now start Excel (or your favourite spreadsheet program) running. In a new sheet, click on the top left-hand cell and then select **Edit / Paste** from the main menu. You should see the above table appear in Excel. Note that the number of decimal places selected in RunGEM affects the exact numbers copied.

[If you want to check whether there is a correlation between regional performance in terms of GRP and the share of agriculture in total GRP, as suggested in Q29, open the file **Shares.xls** and create a scatter plot using the appropriate variables].

Close Excel.

In ViewHAR and ViewSOL, the **Export** command lets you copy data to Excel in just the same way.

When you have finished looking at the results, exit from RunGEM and other related programs.

## **9. An experiment with more complicated shocks: trade liberalization in Colombia**

General equilibrium modellers need to explain their results. A general equilibrium model has various main mechanisms that produce the results. The modeller is required to identify and quantify the mechanisms that are important for a particular simulation. To analyse the results in this way, the modeller must bring together details of several different information sources: the equations of the model, the base data, consequences of that data such as totals and shares, and the simulation results (percentage changes or ordinary changes). For this exercise, you can find the story behind the simulation in the companion paper "Spatial Aspects of Trade Liberalization in Colombia: A General Equilibrium Approach", by Haddad, Bonet, Hewings and Perobelli.

This section presents another example with the CEER model: a tariff cut simulation. The example is presented as exercises for the reader to follow.

### **9.1. Preparing the shock file**

The simulation shows the short-run effects of a 25% across-the-board reduction in the tariff rates on imported goods. Tariff rates are set by the Central government in Colombia, so that they vary only across products in the CEER model.

Trade liberalization is an important element of the range of structural changes foreseen by the Colombian government. To explore the effects of such policies, the CEER model is used to simulate the impacts of tariff changes in the Colombian economy. The model is applied to analyze the effects of a uniform 25% decrease in all tariff rates. All exogenous variables are set equal to zero, except the changes in the power of tariffs, i.e., one plus the tariff rates, which were set such that the percentage change decrease in each tariff rate was 25%.

To calculate the size of the shocks, we need to know two important pieces of information in the original database.

Q31. What are the total basic values of imported goods in the Colombian economy? We will need the totals, by product, across different users.

Q32. What is the total tariff revenue, by product?

Q33. What are the implicit tariff rates in Colombia in 2004?

<i>Product</i>	<i>Basic value of imports</i> (Q31)	<i>Tariff revenue</i> (Q32)	<i>Tariff rate</i> (Q33)
AGR			
MNE			
IND			
CNT			
TRN			
ADP			
OTS			

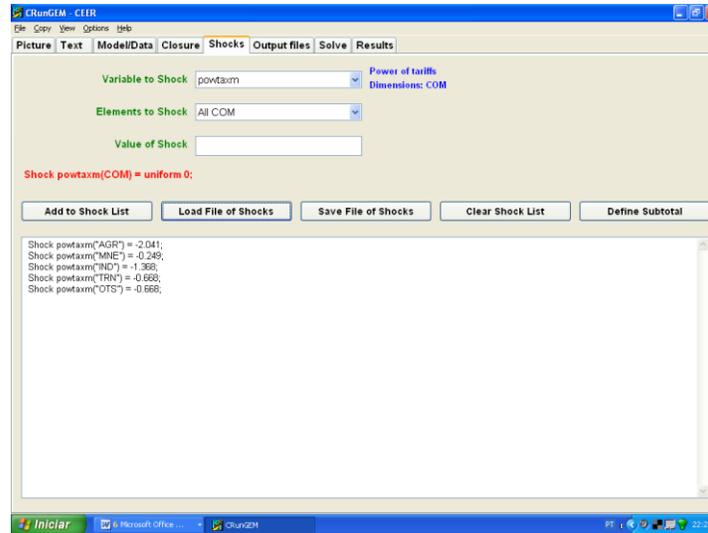
In the CEER model, tariffs are treated as ad valorem on basic values, with the tariff variables **powtaxm** in the linearized model being percentage changes in the powers of tariffs (the power of a tariff is one plus the ad valorem rate).

The details of the shock sizes are contained in the file TARF.SHF.

## 9.2. Implementing the shocks and running the simulation

Start up RunGEM with the CEER model. Go to the *Closure* page. As in the previous example, use the *Load closure* button to select the **SHORTRUN** closure. Notice that the variable **powtaxm** is exogenous:

Then go to the *Shocks* page and delete any existing shocks by clicking **Clear Shocks List**. Then specify the shocks as follows: click on **Load File of Shocks** and select the previously prepared shock file **tarf.SHF**.



The shock list underneath should now contain:

***Shock powtaxm(“AGR”) = -2.041;***  
***Shock powtaxm(“MNE”) = -0.249;***  
***Shock powtaxm(“IND”) = -1.368;***  
***Shock powtaxm(“TRN”) = -0.668;***  
***Shock powtaxm(“OTS”) = -0.668;***

When you have finished with the shocks, go to the Output Files page. There, click on the line there that begins **solution file =**. In the file dialog; type in the name **tarfsr.SL4**. Then click Save.

Now go to the *Solve* page:

- First select the solution method to use. To do this, click on the **Change** button to the right of the **Solution method** label. In the **Method** part select **Euler** and then make sure that you have **3 solutions** and **1,2,4 steps**. [Select these if they do not become selected after you click on “Euler”]. Check also the radio button **Automatic Accuracy**. Then click **Ok**.
- Next notice the **Verbal description** label and the edit box to its right. It is good practice to enter a few words summarizing the simulation you are about to carry out. So first select the existing entry with your mouse and then replace it by

**25% across-the-board tariff cut**

- Now click the **Solve** button to start the solution process.

RunGEM runs the TABLO-generated program CEER.EXE to solve CEER.

### 9.3. Looking at the results

When the solution has been obtained, RunGEM will present you with an accuracy summary and a box telling you how long it took to obtain the solution.

Once it has solved, RunGEM displays an accuracy summary chart showing how many variables are accurate in the levels to 1, 2, 3, 4, 5, or 6 figures. A little face summarizes overall accuracy – hopefully it is smiling. Accuracy of the updated data is summarized in the same way. Click **Help** to learn more, then **OK** to proceed.

Another message now tells how long the solution took. Click **OK** then select **View / XAC** file. TABmate will show you the Extrapolation Accuracy File where you can see the effect of the solution method and the extrapolation. To be specific, search for **natxigdp** (GDP price index, expenditure side). This row of the XAC file is

```
-0.190474  -0.190402  -0.190365  -0.190329      CX 5  L6
```

Here the results are respectively the 1-step (-0.190474), the 2-step (-0.190402), the 4-step (-0.190365) and the extrapolated result (-0.190329), with two sub-intervals. The notation CX 5 means that you can be **C**onfident in the **eX**trapolated result (this is the CX) and you can be confident that at least 5 of the figures (that is, at least the -0.1903 part) in the extrapolated result are accurate. The L6 means that at least 6 figures in the corresponding levels result (as distinct from the percent-change result) are accurate.

Close this and go directly to the **Results** page.

Look first at the results for **powtaxm** (power of tariffs). Check that the relevant components of the variable were indeed shocked.

Then look at the macro results.

Q34. What variable is the *numéraire* in this simulation? The exchange rate (**natphi**) or the CPI (**natxi3**)?

Q35. What was the effect on the variables listed below?

---

Real GDP  
Real Household Consumption  
Activity Level  
Employment: Persons  
Unemployment Rate (% point change)  
Nominal Wage Paid by Producers  
GDP Price Index  
Consumer Price Index  
Export Volume  
Import Volume  
Balance of Trade (percentage of GDP)

---

Q36. As expected, the tariff cut caused imports to increase – all bad for GDP. Yet, employment and real GDP expanded – why?

Look over the real GRP results (**yr\_r**).

Q37. Which regions are the main losers and gainers? Can you say anything about the short-run effects of trade liberalization on regional inequality?

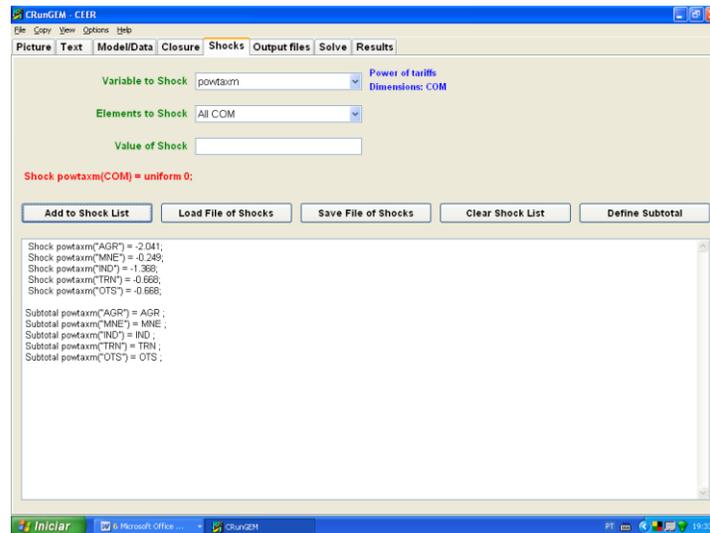
#### 9.4. Using Subtotals to divide up the effects of the shocks

If your simulation involves several different shocks, GEMPACK offers you a very powerful facility known as “subtotals”. This allows you to divide the total change in any endogenous variable between the various shocks.

Try it out using the tariffs reduction described above [if necessary, use **Load file of shocks** on the Shocks page to reload the **tarf.SHF** shock file that you saved, and rerun the simulation]. Go to the **Shocks** page and carefully type the following three lines underneath the list of shocks:

***Subtotal powtaxm(“AGR”) = AGR ;***  
***Subtotal powtaxm(“MNE”) = MNE ;***  
***Subtotal powtaxm(“IND”) = IND ;***  
***Subtotal powtaxm(“TRN”) = TRN ;***  
***Subtotal powtaxm(“OTS”) = OTS ;***

Then go to the **Solve** page and click the **Solve** button.



When the solution has been calculated, examine the macro results. You should see 6 columns of numbers. The first column shows the same changes that were calculated before. The next 5 columns show how much of the total change in each variable may be attributed to the exogenous increases in, respectively, tariff reduction on imported agricultural goods, mining goods, manufactured goods, transportation services, and other services. Click on the *Description* button above the results to verify this.

The subtotals columns show that the manufacturing (IND) shock accounts for most of the change. The last 2 columns are rather similar, except that the liberalization of services has slightly stronger impacts than liberalization of transportation services. Finally, the results associated with the mining sector are practically irrelevant.

Q38. Which kind of liberalization produces the biggest impact on national GDP?

Q39. In relative terms, which region benefits most from liberalization of agricultural products? And which region benefits least?

Q40. Why is the liberalization of manufactures worse for the balance of trade?

Go back to the Shocks page and click the Define Subtotal button. This launches a window which can help you compose subtotal statements like the five that you added before. Use the Help button to find out how to use this window, and to find out more about the theory behind subtotals.

## 10. Customized RunGEM and the complete GEMPACK system

The *Customized RunGEM with CEER* package that you have been using is especially arranged and simplified to suit newcomers to CGE modelling using GEMPACK, in general, and the CEER model, specifically. You might wonder how similar using the full GEMPACK system would be.

One difference is that RunGEM looks after *file management*: it controls the names and locations of the dozen or more files used for each GEMPACK simulation. An advanced GEMPACK user has to assume more of this responsibility.

Another difference is that users of the full GEMPACK system often wish to alter the data and specifications of the model. So they have to:

- use ViewHAR to create and modify the HAR files that contain data;
- edit the TAB file, then run the TABLO program to turn the TAB file into a model-solution program.

This document does not describe the many features of ViewHAR and TABmate that are aimed at these tasks. Also, you must buy a GEMPACK licence to run TABLO, to run larger models, or to modify larger data files. Finally, the full GEMPACK system contains many other programs, not described here.

Nevertheless, if you have worked through this document (and mastered the companion document that describes the theory of CEER) you are well on the way to becoming a competent CGE modeller. You should understand the basic theory which underlies CEER – the same theory is used in every other CGE model. You can read and understand a TAB file – so now you have access to the large number of CGE models that use this notation. The tools that you have been introduced to, such as ViewHAR and TABmate, are the same tools used by other CGE model builders. Even the syntax used in RunGEM's Closure and Shocks pages is identical to the corresponding parts of the Command files (CMF files) required in GEMPACK for carrying out simulations.

The GEMPACK web page, at:

<http://www.monash.edu.au/policy/gempack.htm>

gives access to a great deal of GEMPACK related information, such as details of the GEMPACK product range and licensing arrangements, but also including much free stuff. For example, you could download the **Demonstration version of GEMPACK** which gives access to the full range of GEMPACK capabilities but is limited to very small models.

## **Appendix 1: Installing Customized RunGEM**

The Customized RunGEM for the CEER model is delivered as a single large EXE file, called CRUNGEMX.EXE, and a folder with the CEER model files. You might have downloaded this EXE file from the Internet ([www.monash.edu.au/policy/crungem.htm](http://www.monash.edu.au/policy/crungem.htm)) and saved it in your TEMP folder. CRUNGEMX.EXE is a self-extracting archive which, when you run it, launches a conventional install procedure.

The install procedure tells you how much free hard disk space you will need. You might have to clean up your hard drive before proceeding. It is best to install into a folder named C:\CRUNGEM. Avoid directory names that contain spaces, commas or Asian characters or are more than 8 letters long.

The package will typically include other models as well. To have the CEER model running properly, you should copy the CEER folder into the folder C:\CRUNGEM. If you want to launch the CEER model directly from double-clicking on the Customized RunGEM icon that will appear on your desktop after installation, you should delete all other **folders** in C:\CRUNGEM, except C:\CRUNGEM\CEER and C:\CRUNGEM\work.

Customized RunGEM assumes that the user has his own copy of the program on his own hard drive. The program cannot be installed on a network drive and used by several people at once.

**Appendix 2: Answers to questions in the text**

- Q1
- Q2
- Q3
- Q4
- Q5
- Q6
- Q7
- Q8
- Q9
- Q10
- Q11
- Q12
- Q13
- Q14
- Q15
- Q16
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- Q36
- Q37
- Q38
- Q39
- Q40

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## **Regional Effects of Port Infrastructure: A Spatial CGE Application to Brazil**

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# Regional Effects of Port Infrastructure: A Spatial CGE Application to Brazil

Eduardo A. Haddad<sup>1,2</sup>, Geoffrey J. D. Hewings<sup>3</sup>,  
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## Abstract

This article attempts to elucidate one of the mechanisms that link trade barriers, in the form of port costs, and subsequent growth and regional inequality. Prior attention has focused on inland or link costs, but port costs can be considered as a further barrier to enhancing trade liberalization and growth. In contrast to a highway link, congestion at a port may have severe impacts that are spread over space and time whereas highway link congestion may be resolved within several hours. Since a port is part of the transportation network, any congestion/disruption is likely to ripple throughout the hinterland. In this sense, it is important to model properly the role nodal components play in the context of spatial models and international trade. In this article, a spatial computable general equilibrium (CGE) model that is integrated to a transport network system is presented to simulate the impacts of increases in port efficiency in Brazil. The role of ports of entry and ports of exit are explicitly considered to grasp the holistic picture in an integrated interregional system. Measures of efficiency for different port locations are incorporated in the calibration of the model and used

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as the benchmark in our simulations. Three scenarios are evaluated: (1) an overall increase in port efficiency in Brazil to achieve international standards; (2) efficiency gains associated with decentralization in port management in Brazil; and (3) regionally differentiated increases in port efficiency to reach the boundary of the national efficiency frontier.

### Keywords

computable general equilibrium, port infrastructure, Brazil, transportation network, impact analysis

## Introduction

There is increasing recognition of the critical role of infrastructure in the promotion of national and regional economic development. The literature provides a number of alternative approaches, ranging from Martin and Rogers (1995) who adopt a model based on Helpman and Krugman (1985) and the emerging perspectives associated with the new economic geography to the work of Vickerman (1990) who collected articles addressing the role of infrastructure and regional economic development. More recently, there has been significant analysis, using some of the toolbox of spatial econometrics, to explore the role of the European Union (EU) initiatives in advancing transportation investment as a major vehicle in the reduction of disparities in regional economies (e.g., see Dall'erba and Hewings 2003).<sup>1</sup> In addition, Cohen and Monaco (2008) assess the effects of increasing port and highway infrastructure on manufacturing costs at the state level in the United States, providing interesting insights into the existence of spillovers in neighboring states. The approach in this article draws on another set of modest but expanding literature that attempts to link (regional and inter-regional) macroeconomic models with network-based transportation systems. This later literature will be reviewed more extensively in the next section.

Logistics costs are a key factor in helping or hindering the competitiveness of many economic sectors, both domestically and with respect to foreign markets; they remain the largest component of doing business in Brazil—the so-called *Custo Brasil*—and are estimated to be about 20 percent of gross domestic product (GDP), well above the levels in Organisation for Economic Co-operation and Development (OECD) countries, which are closer to 10 percent of GDP.<sup>2</sup>

Problems associated with the port activity in Brazil have been tackled recently with a set of changes in the regulation of the sector, aiming at decentralizing management, stimulating new investments (including from private investors), promoting competition, and adapting labor needs to new technological standards. If this program is successful, that is, if it helps to increase port efficiency in the country, it will be important to assess both its macro and regional impacts.

Thus, the objective of the article is to assess the main economic impacts of changes in relative costs in the port sector in Brazil.

The major contribution of this article is to explore explicitly the role of nodes, in this case, ports, in the Brazilian transportation system and their impacts on macro-economic variables and regional growth. While a great deal of attention has been directed to efficiency, congestion, and expansion of links in the transportation networks, little attention until recently has been devoted to an examination of the inefficiencies surrounding the transshipment of commodities at ports. The analysis will depart from an interregional computable general equilibrium (CGE) model developed for the Brazilian economy integrated with a transport network, the Brazilian Multisectoral And Regional/Interregional Analysis (B-MARIA) model, described in detail elsewhere (Haddad and Hewings 2005). The model will be further developed to introduce a set of nodal functions to look closely at this issue. However, this article will not address the issues of choice of ports for improvement but rather with assess, in an *ex ante* fashion, the impacts of improvement in a sample of ports that account for a large percentage of Brazilian trade.

The remainder of the article is organized as follows. After the review of the literature in the next section, the section on Modeling of Port Costs will present the general features of the basic CGE model and discuss some modeling issues, more specifically those associated with the treatment of port costs included in the basic model as well as its calibration. In the section on Port Efficiency Scenarios, the simulation experiments are designed and implemented, and the main results are discussed. Final remarks follow in an attempt to evaluate our findings and put them into perspective, considering further their extensions and limitations.

## **Integration of CGE Models and Transportation Networks**

The initial research that provided the opportunity to develop links between CGE models and transportation networks was the development of spatial CGE models, first by Roson (1994) and then subsequently by Bröcker (1998) and Bröcker and Schneider (2002). Earlier work by Buckley (1992) considered the impacts of transportation systems on the spatial economy, but the transportation systems were not represented as a network. An alternative approach by Kim and Hewings (2003) and Kim, Hewings, and Hong (2004) explored ways in which a multiregion CGE model could be linked with a transportation network model to examine the welfare implications of a massive highway construction program in South Korea. Of particular importance were the synergetic effects of simultaneous development of key network links, generating greater impacts than the sum of the impacts arising from sequential development. Sohn et al. (2003) provided a conceptually similar linkage, but in this case a multiregion econometric input–output model was linked with an interregional commodity flow model in which the network structure comprised not only links but also detail about bridges on the links. The objective of this integration was to consider the impacts of a massive earthquake centered in the Midwest of the United States on commodity flows, production, and income and thus to promote some sense of priorities in the retrofitting of existing infrastructure.

Earlier analysis with one version of the model used in this article, by Haddad and Hewings (2005), provided the methodology for integrating an interregional CGE model with a transportation network in such a way that the role of both Marshallian scale economies and transportation costs could be explored in terms of their impacts on both national and regional welfare. The results revealed that the welfare impacts were much more sensitive to changes in transportation costs than scale economies for example. The results provided motivation for this article, attempting to explore the degree to which the nodal components of these costs (especially the ports) played a key role in setting overall transportation costs. Even though interstate transportation costs are a much smaller component of total production costs in the United States than in Brazil, for instance, there are still some major issues at transfer nodes—both internally and at the interface of interstate and international trade. It would appear that serious congestion occurs still at these transfer points, as the analysis presented in Clark, Dollar, and Micco (2004) confirms for seaports.

Hence, one of the major challenges to be faced is the modeling of a nodal congestion function that also considers issues of regulation and spatial competition (e.g., the problem of competing destinations/origins/transfer for the shipment of goods, especially those either sourced outside the country or those produced within the country for export). A second issue that is not addressed in this article concerns the distinction between shippers and carriers with the former serving as essentially coordinating agents who handle the transfer from location  $r$  to  $s$  and use one or more carriers to actually move the commodity. This distinction has been handled with bi-level programming techniques (see e.g., Kim and Suh 1988; Suh and Kim 1989). The choice of carriers (and thus routes) may be significantly affected by the efficiencies of the transfer nodes.

As Clark, Dollar, and Micco (2004) noted from their analysis, the impacts of port inefficiencies are not trivial; improving port efficiency from the 25th to the 75th percentile would reduce shipping costs by 12 percent in Latin American countries. Inefficient ports also serve to deter bilateral trade with consequent welfare losses. In essence, they noted that “as liberalization continues to reduce artificial barriers, the effective rate of protection by transport costs is now in many cases higher than the one provided by tariffs” (Clark, Dollar, and Micco 2004, 418). Inefficient ports thus may place a country or region further away from sources of cheaper inputs or markets for goods produced. Drawing on a variety of sources, they revealed that on a scale of 1 (*worst*) to 7 (*best*) for port efficiency, Latin American ports scored 2.9 in contrast to scores of 6.35 for the United States and 5.3 for Europe.<sup>3</sup> These problems were further compounded by delays in customs clearance that were among the highest in the world.

The problem with port inefficiency in Latin America is the appropriate policy response; in Brazil, there are many competing ports, many of which would require significant investments in infrastructure to raise their efficiency. Should ports specialize and on what basis should investment decisions be made? Can port efficiency be detached from the problem of improving access to the port's hinterland, often a

major contributing factor to not only the port's inefficiency but in terms of driving up the total transportation cost?

It would be impossible to address all these questions in one article; as a result, the focus will be directed to an assessment of the impacts of changes in ports efficiency in Brazil on selected macroeconomic and regional variables. In the section on Modeling of Port Costs, the adapted methodology for separating out the port transactions costs from the total transportation costs will be presented.

### *Handling Port Costs*

Transfer costs at a node (e.g., moving a container from road or rail to a ship, including the documentation and export charges) are considered as a self-loop in the transportation network. The "transportation costs" on this self-loop would be relatively small (per unit of cargo moved) in the United States or Europe but significantly larger in Latin America. As capacity is reached, the transfer costs can be assumed to increase as delays create real losses (not only in an opportunity costs sense but goods stored in warehouses may be subject to theft, deterioration, or destruction).

A further issue relates to the fact that it would be unrealistic to assume that ports are perfect competitors. For a start, they are likely to have different hinterlands, limited both by the nature of the supporting transportation infrastructure (roads, rail, and waterways) as well as link costs from internal markets that are too far removed. Thus, trade areas are likely to overlap only to some degree and the market may be one characterized more by spatial monopolistic competition or imperfect competition rather than perfect competition. In addition, the ports will have different capacities.

If all these considerations were to be taken into account, modeling the system using iceberg transportation costs would be very difficult (see McCann, 2005 for an excellent review of the debate over appropriate transfer costs). As a result, the article adopts a transportation margins approach in which the link costs are separated from the nodal costs.

## **Modeling of Port Costs**

### *The Interregional CGE Model B-MARIA*

To evaluate the short-run and the long-run effects of increases in port efficiency in Brazil, under different scenarios, we departed from the B-MARIA-27 model, described in detail elsewhere (Haddad and Hewings 2005). Its structure represents a further development of the (B-MARIA), the first fully operational interregional CGE model for Brazil.<sup>4</sup> Its theoretical structure departs from the MONASH-MRF Model (Peter et al. 1996) that represents one interregional framework in the ORANI suite of CGE models of the Australian economy. The interstate version of B-MARIA, used in this research, contains over 600,000 equations, and it is designed for policy analysis in a comparative-static framework. Agents' behavior is modeled

at the regional level, accommodating variations in the structure of regional economies. The model recognizes the economies of 27 Brazilian states. Results are based on a bottom-up approach—national results are obtained from the aggregation of regional results. The model identifies eight sectors in each state producing eight commodities, one representative household in each state, regional governments and one Federal government, and a single foreign consumer who trades with each state. Special groups of equations define government finances, accumulation relations, and regional labor markets. The mathematical structure of B-MARIA is based on the MONASH-MRF Model for the Australian economy. It qualifies as a Johansen-type model in that the solutions are obtained by solving the system of linearized equations of the model. A typical result shows the percentage change in the set of endogenous variables, after a policy is carried out, compared to their values in the absence of such policy, in a given environment. The schematic presentation of Johansen solutions for such models is standard in the literature. More details can be found in Dixon et al. (1992).

*CGE core module.* The basic structure of the CGE core module is very standard and comprises three main blocks of equations determining demand and supply relations and market clearing conditions. In addition, various regional and national aggregates, such as aggregate employment, aggregate price level, and balance of trade, are defined here. Nested production functions and household demand functions are used; for production, firms are assumed to use fixed proportion combinations of intermediate inputs and primary factors in the first level while, in the second level, substitution is possible between domestically produced and imported intermediate inputs, on one hand, and between capital, labor, and land, on the other. At the third level, bundles of domestically produced inputs are formed as combinations of inputs from different regional sources. The modeling procedure adopted in B-MARIA uses a constant elasticity of substitution (CES) specification in the lower levels to combine goods from different sources. Given the property of standard CES functions, nonconstant returns are ruled out. One can modify assumptions on the parameter values to introduce external scale economies of the Marshallian type. Changes in the production functions of the manufacturing sector<sup>5</sup> in each one of the twenty-seven Brazilian states were implemented to incorporate nonconstant returns to scale, a fundamental assumption for the analysis of integrated interregional systems. We kept the hierarchy of the nested CES structure of production, which is very convenient for the purpose of calibration (Bröcker 1998), but we modified the hypotheses on parameters values, leading to a more general form. Nonconstant returns to scale were introduced in the group of equations associated with primary factor demands within the nested structure of production. The sectoral demand for the primary factor composite (in region  $r$ ),  $y$ , relates to the total output,  $z$ , in the following way:  $y = az^\rho$ , with the technical coefficient  $a$ , and the parameter  $\rho$  specific to sector  $j$  in region  $r$ . This modeling procedure allows for the introduction of Marshallian agglomeration (external) economies, by exploring local properties of the CES function.

The treatment of the household demand structure is based on a nested CES/linear expenditure system (LES) preference function. Demand equations are derived from a utility maximization problem, whose solution follows hierarchical steps. The structure of household demand follows a nesting pattern that enables different elasticities of substitution to be used. At the bottom level, substitution occurs across different domestic sources of supply. Utility derived from the consumption of domestic composite goods is maximized. In the subsequent upper level, substitution occurs between domestic composite and imported goods.

Equations for other final demand for commodities include the specification of export demand and government demand. Exports face downward sloping demand curves, indicating a negative relationship with their prices in the world market. One feature presented in B-MARIA refers to the government demand for public goods. The nature of the input–output data enables the isolation of the consumption of public goods by both the federal and regional governments. However, productive activities carried out by the public sector cannot be isolated from those by the private sector. Thus, government entrepreneurial behavior is dictated by the same cost minimization assumptions adopted by the private sector.

A unique feature of B-MARIA is the explicit modeling of the transportation services and the costs of moving products based on origin–destination pairs. The model is calibrated taking into account the specific transportation structure cost of each commodity flow, providing spatial price differentiation, which indirectly addresses the issue related to regional transportation infrastructure efficiency. Such structure is physically constrained by the available transportation network, modeled in a geocoded transportation module.<sup>6</sup> Other definitions in the CGE core module include tax rates, basic and purchase prices of commodities, tax revenues, margins, components of real and nominal gross regional product (GRP)/GDP, regional and national price indices, money wage settings, factor prices, and employment aggregates.

*Structural database.* The CGE core database requires detailed sectoral and regional information about the Brazilian economy. National data (such as input–output tables, foreign trade, taxes, margins, and tariffs) are available from the Brazilian Statistics Bureau (IBGE). At the regional level, a full set of state-level accounts were developed at Fundação Instituto de Pesquisas Econômicas–University of Sao Paulo (FIPE-USP). These two sets of information were put together in a balanced interstate social accounting matrix, updated to 2002. Previous work in this task has been successfully implemented in interregional CGE models for Brazil (e.g., Haddad 1999; Haddad and Hewings 2005).

*Behavioral parameters.* Experience with the B-MARIA framework has suggested that interregional substitution is the key mechanism that drives model's spatial results. In general, interregional linkages play an important role in the functioning of interregional CGE models. These linkages are driven by trade relations (commodity flows) and factor mobility (capital and labor migration). In the first case, of direct

**Table 1.** Trade Elasticities in the Brazilian Multisectoral And Regional/Interregional Analysis (B-MARIA) Model

	International	Regional
Agriculture	0.343	1.570
Manufacturing	1.278	2.079
Utilities	0.011	1.159
Construction	0.002	0.002
Trade	0.694	0.001
Financial institutions	0.137	1.385
Public administration	0.070	0.001
Transportation and other services	1.465	0.001

interest in our exercise, interregional trade flows should be incorporated in the model. Interregional input–output databases are required to calibrate the model, and regional trade elasticities play a crucial role in the adjustment process.

One data-related problem that modelers frequently face is the lack of such trade elasticities at the regional level. The pocket rule is to use international trade elasticities as benchmarks for “best guess” procedures. However, a recent study by Bilgic et al. (2002) tends to refute the hypothesis that international trade elasticities are lower bound for regional trade elasticities for comparable goods, an assumption widely accepted by CGE modelers. Their estimates of regional trade elasticities for the U.S. economy challenged the prevailing view and called the attention of modelers for proper estimation of key parameters. In this sense, an extra effort was undertaken to estimate model-consistent regional trade elasticities for Brazil, to be used in the B-MARIA model. Estimates are presented in table 1.

Other key behavioral parameters were properly estimated; these include econometric estimates for scale economies; econometric estimates for export demand elasticities; and the econometric estimates for regional trade elasticities. Another key set of parameters, related to international trade elasticities, was borrowed from a recent study developed at IPEA ([www.ipea.gov.br](http://www.ipea.gov.br)), for manufacturing goods, and from model-consistent estimates in the EFES model (Haddad and Domingues, 2001) for agricultural and services goods.

### *The Development of B-MARIA-PORT*

The set of equations that specify purchasers’ prices in the B-MARIA-PORT model<sup>7</sup> imposes zero pure profits in the *distribution* of commodities to different users. Prices paid for commodity  $i$  from source  $s$  in region  $q$  by each user equate to the sum of its basic value and the costs of the relevant taxes and margin commodities. This formulation, standard in the preparation in national income and product accounts, is not featured in most of the new economic geography models.

The role of margin commodities is to facilitate flows of commodities from points of production or points of entry to either domestic users or ports of exit. Margin commodities, or, simply, margins, include transportation and trade services, which take account of transfer costs in a broad sense.<sup>8</sup> The margin demand equations in the model show that the demands for margins are proportional to the commodity flows with which the margins are associated; moreover, a technical change component is also included in the specification to allow for changes in the implicit transportation rate. In the case of imported goods, the implicit transportation margin refers to the costs at the port of entry, while for exports it refers to costs at the port of exit. In this article, we adopt a special treatment in the calibration of the margins demand equations related to port services to properly address issues of port efficiency in Brazil.

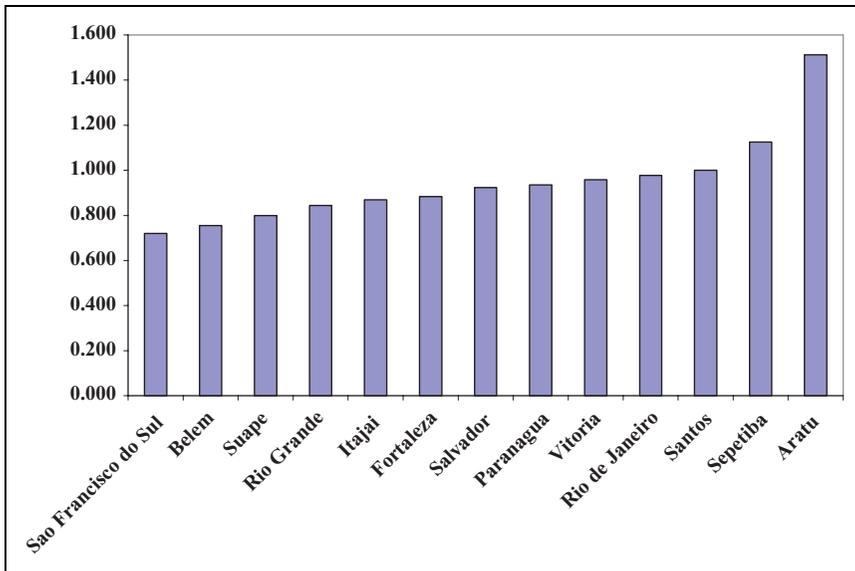
B-MARIA-PORT uses a general functional form used for the equations of margin demand on imported goods, for different users.<sup>9</sup> It can be interpreted as the demand for port services related to import activity.<sup>10</sup> In a similar fashion, the model considers a general functional form for the equations of margin demand on exported goods, to be interpreted as the demand for port services related to export activity.

Let  $x$  be a flow of some good  $i$  from some region  $s$  to the rest of the world and  $m$  the quantity of the required margin (port services).<sup>11</sup> Assuming  $m = A\eta x$ , with parameter  $\eta$  specific to  $i$  and  $s$ , and  $A$ , specific to  $i$  and  $s$ , being a shift variable used to rescale the reference estimates of  $\eta$ . Thus, an efficiency scenario raising port efficiency for region  $s$  by say 20 percent is modeled by reducing  $A$  by 20 percent for all goods  $i$ .

To calibrate the model, we need estimates of cost differentials among Brazilian ports. We relied on estimates of port efficiency measures presented in World Bank (2007). The estimates provide an index of relative efficiency across thirteen Brazilian ports. The so-called port efficiency index (PEI) for the Port of Santos was set equal to one, by construction. The indices for the remaining ports provide a measure of the extent to which port costs differ from those in Santos, in percentage terms. Ports that present an index smaller than one are considered more efficient than Santos, while those that present values greater than one are less efficient.

Figure 1 presents the estimates. Sepetiba and Aratu were the only two ports in the sample found to be less efficient than Santos; all the remaining ports were found to be more efficient than Santos. The Port of São Francisco do Sul could be considered most efficient port in our sample.

Calibration of the demand for port services requires information on the transport margins related to each commodity flow. Aggregated information for margins on imported flows associated with intersectoral transactions, capital creation, and household consumption, and margins on exports are available at the national level. The problem remains to disaggregate such information considering previous spatial disaggregation of commodity flows in the generation of the interstate social accounting matrix. Thus, given the available information—international trade commodity flows by states, PEI by ports, mapping of international transactions for each state



**Figure 1.** Port efficiency index (Santos = 1). Source: World Bank (2007).

by port of entry (imports) and port of exit (exports), and national aggregates for specific margins—the strategy adopted was as follows.

In the calibration of  $m = A\eta x$ ,  $A$  was set equal to PEI calculated for each state  $q$ ,  $PEI_q$ , invariable across commodities. To do that, we first mapped state exports (imports) by port of exit (entry).<sup>12</sup> With the estimates of  $PEI_i$  for every port  $i$ , we built the  $PEI_q$  as weighted averages of the  $PEI_i$ s considering the share of each port in the exports (imports) of a given state, as the weights.<sup>13</sup> The results are shown in table 2 (*benchmark*), for both import and export activities. The estimates for Brazil as a whole suggest that the port mix of the country's international trade, in the case of imports, is 1.3 percent less costly had all the imports entered the country through the Port of Santos. Similarly, in the case of exports, the national port mix is also more efficient than a hypothetical concentration in Santos, about 4 percent less costly.<sup>14</sup>

Changes in port efficiency can be calculated either through changes in the weights matrix or in the PEI's estimates for a given set of ports. These estimates can then be incorporated in the interstate CGE model, through changes in the shift variable,  $A$ .

### Model Closures

The full model contains 608,313 equations and 632,256 unknowns. Thus, to close the model, 23,943 variables have to be set exogenously. The nominal exchange rate was set as the *numéraire*. To capture the effects of increases in port efficiency, the

**Table 2.** Port Efficiency Index, by State, for Different Scenarios (Santos = 1)

State	Benchmark		Scenario 1		Scenario 2		Scenario 3	
	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports
AC	0.953	0.886	0.800	0.728	0.932	0.885	0.734	0.704
AP	0.977	0.983	0.806	0.821	0.816	0.832	0.713	0.728
AM	1.000	0.999	0.895	0.928	0.904	0.934	0.828	0.882
PA	0.851	0.948	0.692	0.813	0.678	0.815	0.691	0.761
RO	1.008	0.930	0.823	0.756	0.841	0.900	0.700	0.692
RR	1.000	0.997	0.957	0.987	0.961	0.996	0.930	0.983
TO	1.000	0.997	0.834	0.798	0.847	0.822	0.728	0.673
AL	0.975	0.993	0.863	0.795	0.870	0.814	0.808	0.673
BA	1.116	1.074	0.912	0.871	0.951	0.903	0.704	0.692
CE	0.885	0.896	0.719	0.738	0.714	0.734	0.690	0.706
MA	0.987	0.993	0.792	0.795	0.806	0.811	0.676	0.673
PB	0.944	0.888	0.774	0.737	0.823	0.794	0.703	0.716
PE	0.860	0.912	0.704	0.765	0.818	0.820	0.698	0.729
PI	0.924	0.909	0.776	0.744	0.775	0.741	0.733	0.699
RN	0.941	0.907	0.774	0.742	0.809	0.776	0.707	0.699
SE	0.948	0.971	0.799	0.786	0.822	0.800	0.739	0.688
ES	0.966	0.959	0.807	0.775	0.814	0.783	0.728	0.685
MG	0.984	0.987	0.826	0.806	0.838	0.822	0.734	0.699
RJ	1.031	1.032	0.874	0.847	0.893	0.869	0.753	0.708
SP	0.999	0.995	0.878	0.862	0.890	0.879	0.802	0.780
PR	0.926	0.915	0.788	0.747	0.915	0.904	0.749	0.696
SC	0.877	0.815	0.767	0.671	0.869	0.810	0.779	0.704
RS	0.935	0.866	0.797	0.725	0.867	0.857	0.752	0.726
DF	0.992	0.967	0.939	0.811	0.948	0.818	0.910	0.734
GO	0.979	0.971	0.823	0.808	0.860	0.841	0.738	0.723
MT	0.942	0.941	0.810	0.762	0.909	0.827	0.765	0.687
MS	0.998	0.906	0.939	0.756	0.949	0.859	0.903	0.723
Total	0.987	0.960	0.852	0.807	0.881	0.858	0.774	0.735

simulations were carried out under two standard closures, referring to the short run and the long run. There is no dynamics in the model. The simulations with the B-MARIA-PORT model capture the effects associated with the static impact-effect question, that is, given the structure of the economy, what-if questions can be addressed in a comparative-static framework. Short-run and long-run considerations differ in the way the equilibrating mechanisms are set through the closures specified. Structural changes are captured *only* through the evaluation of a reallocation of resources. A main distinction between the short-run and long-run closures relates to the treatment of capital stocks encountered in the standard microeconomic approach to policy adjustments.

In the short-run closure, capital stocks are held fixed, while, in the long-run, policy changes are allowed to affect capital stocks. In addition to the assumption of

interindustry and interregional immobility of capital, the short-run closure includes fixed regional population and labor supply, fixed regional wage differentials, and fixed national real wage. Regional employment is driven by the assumptions on wage rates, which indirectly determine regional unemployment rates. Labor is, thus, mobile only across sectors within the same region. On the demand-side, investment expenditures are fixed exogenously—firms cannot reevaluate their investment decisions in the short run. Household consumption follows household disposable income, and real government consumption, at both regional and central levels, is fixed. Balance of payments has to adjust to changes in government deficit. Finally, preferences and technology variables are exogenous.

In the long run, the assumptions on interregional mobility of capital and labor are relaxed and a steady state-type of solution is achieved, in which regional natural unemployment rates and regional aggregate rates of return are reestablished. Moreover, balance of payment equilibrium is reflected in the hypothesis of fixed share of trade balance in GDP. From a spatial perspective, in the long run the “relocation” effect becomes relevant; as factors are free to move between regions, new investment decisions define marginal relocation of activities, in the sense that the spatial distribution of capital stocks and the population changes.

The main differences from the short run are encountered in the labor market and the capital formation settings. In the first case, aggregate employment is determined by population change, labor force participation rates, and the natural rate of unemployment. The distribution of the labor force across regions and sectors is fully determined endogenously. Labor is attracted to more competitive industries in more favored geographical areas, keeping regional wage differentials constant. While in the same way, capital is oriented toward more attractive industries, equalizing rates of return across space. In the long run, the government deficit is set exogenously, allowing government expenditures to change.

## Port Efficiency Scenarios

The effects of three different scenarios related to port efficiency changes in Brazil are discussed in this section. The design of the shocks in the efficiency index attempts to mimic direct effects associated with improving port infrastructure in Brazil.<sup>15</sup> The B-MARIA-PORT model was applied to analyze the short-run and long-run macroeconomic and spatial effects on the Brazilian economy of such scenarios.

### Scenario 1

Both the business community’s perception and empirical studies suggest that Brazil lags behind in terms of port efficiency standards. The score achieved by the country in the component “quality of port infrastructure” of the Global Competitiveness Index, 2006, was 2.6 (88th in the rank), far away from those achieved by Singapore (1st) and the Netherlands (2nd), 6.9 and 6.7, respectively. In another survey-based

study, by the Confederação Nacional dos Transportes (CNT; 2006), the quality of port operators—which reflects not only operational efficiency but also costs and provision of infrastructure and services—was poorly rated by roughly one-third of the respondents, major users of port services. The empirical study by Blonigen and Wilson (2006) estimated a cost differential between Rotterdam and Santos of around 21.3 percent. These stylized facts suggest that Brazilian port activity still can improve to achieve best practices, given prevailing international standards. In this sense, we simulate in this first scenario an overall increase in port efficiency of 20 percent.

## *Scenario 2*

Even though the “Law of Modernization of Ports” (Law 8.630/93) was promulgated in 1993, port reforms are moving at a very slow pace. One of its pillars, namely that of port management decentralization, has not been properly implemented. Most Brazilian ports remain under Federal control. The few ports under regional control (either state or municipality administrations) seem to perform better, as the World Bank estimates of port efficiency suggest. A simple average of the PEI for the sets of federal- and regional-managed ports reveal that regional-managed ports are, on average, approximately 18 percent less costly than those ports controlled by the Union. Thus, in our second scenario, we assume that this gap is eliminated (possibly through management decentralization).<sup>16</sup>

## *Scenario 3*

As seen in figure 1, the Port of São Francisco do Sul was the most efficient port, and, therefore, can be considered as lying on the efficiency frontier of our sample. In this third scenario, we simulate regionally differentiated increases in port efficiency to reach the boundary of the national efficiency frontier. All other twelve ports are assumed to achieve the same port efficiency index as the one estimated for São Francisco do Sul.

To implement these simulations, we calculated the state PEI values, under these three scenarios (see table 2).

## *Functioning Mechanism*

How are the increases in port efficiency entered into the model? There are three major channels through which the shocks operate: import effects, export effects, and effects on the use of port services. In the first case, the increase in port efficiency related to import activity decreases the price of composite commodities, with positive implications for real regional income. In this cost-competitiveness approach, firms become more competitive—as production costs go down (inputs are less costly); investors foresee potential higher returns—as the cost of producing capital

also declines; and households increase their real income, envisaging higher consumption possibilities. Higher incomes generate higher domestic demand, while increases in the competitiveness of national products stimulate external demand. This creates room for increasing firms' output—directed for both domestic and international markets—that will require more inputs and primary factors. Increasing demand puts pressure on the factor markets for price increases, with a concomitant expectation that the prices of domestic goods would increase. In the second case (export effects), as international competitiveness increases, higher international demand put extra pressure on prices through the increase in export activity. Finally, in the third case, as transborder activities become less resource-intensive, reducing the activity level in the port services-producing transportation sector, labor and capital are freed, generating excess supply of primary factors in the economic system. This creates a downward pressure on wages and capital rentals, which are passed on in the form of lower prices.

Second-order price changes go in both directions—decrease and increase—in a loop that operates until convergence to a new equilibrium is reached. The net effect is determined by the relative strength of such countervailing forces. Figure 2 summarizes the transmission mechanisms associated with major first-order and second-order effects in the adjustment process underlying the model's aggregate results.

As for the differential spatial effects, the net results will heavily depend on the structure of the integrated interstate system. Specifically, in the long run, one mechanism becomes relevant: the “relocation” effect. As factors are free to move between regions, new investment decisions define marginal relocation of activities, in the sense that the spatial distribution of capital stocks and population changes. The main mechanism affecting regional performance is associated with capital creation. As port efficiency increases, better access to foreign capital goods increases the rate of returns in the regions. At the same time, this potentially benefits capital importing regions, and it has a negative impact on the capital good sectors in the producing regions (substitution effect).

Finally, regions might be adversely affected through reorientation of trade flows (trade diversion), as relative accessibility changes in the system. Thus, gains in efficiency in port activities are not necessarily accompanied by overall gains in regional performance.

## **Results**

Table 3 presents simulation results for the three scenarios. Gains in efficiency (real GDP growth) and welfare (equivalent variation) are positive. In all scenarios, positive impacts on real GDP growth are verified. The largest impacts occur in scenario 3.<sup>17</sup> Note that in the long run, the effects on GDP are magnified. In terms of employment, in the short run we verify negative results (reduction in employment), led by the weak performance of the transportation and construction sectors; the latter,

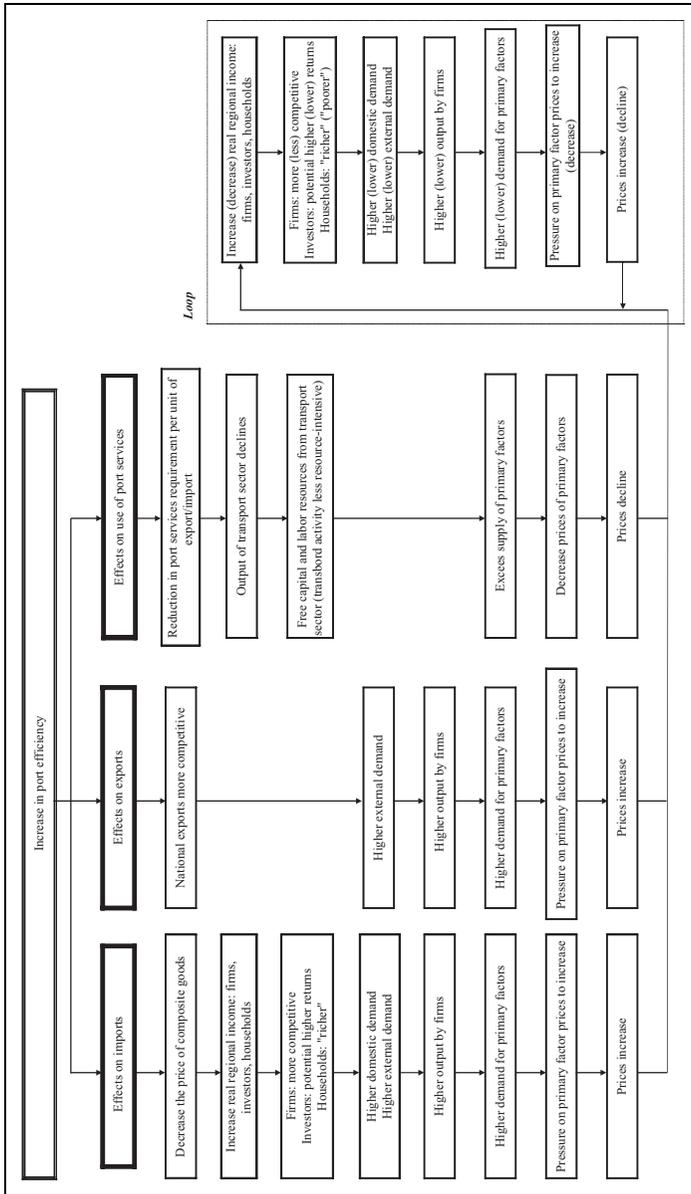


Figure 2. Functioning mechanism of the model under simulations of increases in port efficiency.

**Table 3. Aggregate Results: Selected Variables (in Percentage Change)**

	Scenario 1		Scenario 2		Scenario 3	
	Short Run	Long Run	Short Run	Long Run	Short Run	Long Run
Aggregates						
Real GDP	0.036 (0.016)	0.092 0.033	0.026 (0.011)	0.061 0.026	0.053 (0.024)	0.130 0.047
Aggregate employment, wage bill weights						
Equivalent variation – total (change in \$ 1,000,000)	693.9 (0.266)	623.5 (0.304)	460.9 (0.193)	428.6 (0.216)	1,010.2 (0.399)	1,005.4 (0.447)
Economy-wide terms of trade	0.012	0.017	(0.016)	0.006	0.001	0.003
GDP price index, expenditure side						
GDP components						
Real household consumption	0.025	0.056	0.017	0.039	0.036	0.082
Real aggregate investment	–	0.119	–	0.066	–	0.152
Real aggregate regional government demand	–	0.075	–	0.051	–	0.103
Real aggregate federal government demand	–	0.056	–	0.039	–	0.082
International export volume	0.550	0.672	0.396	0.458	0.825	0.981
International import volume	0.229	0.309	0.159	0.201	0.339	0.445
Activity level						
Agriculture	0.022	0.098	0.015	0.056	0.033	0.133
Manufacturing	0.034	0.125	0.025	0.086	0.052	0.179
Utilities	0.009	0.051	0.006	0.036	0.013	0.073
Construction	(0.001)	0.064	(0.001)	0.045	(0.002)	0.089
Trade	0.011	0.059	0.007	0.036	0.016	0.081
Financial institutions	0.041	0.098	0.029	0.059	0.061	0.136
Public administration	0.005	0.062	0.004	0.043	0.008	0.089
Transportation and other services	(0.077)	(0.064)	(0.053)	(0.047)	(0.114)	(0.099)

Note: GDP = gross domestic product.

specifically, has a strong employment coefficient. In terms of welfare gains, the results suggest that the magnitude of the changes are equivalent in both closures, for a given scenario, ranging from U.S. \$ billion 0.4 (scenario 2) to U.S. \$ billion 1.0 (scenario 3).

Changes in terms of trade tend to benefit Brazilian exports in the three scenarios, as the results point to increasing competitiveness of Brazilian products. This conclusion is reinforced by the performance of the trade balance: export volumes increase faster than import volumes. When compared to other GDP components, international trade appears to increase its share in national GDP, revealing a more open Brazilian economy after port efficiency increases. In the long run, real investments also grow faster than real GDP, led by the reduction in the capital costs.

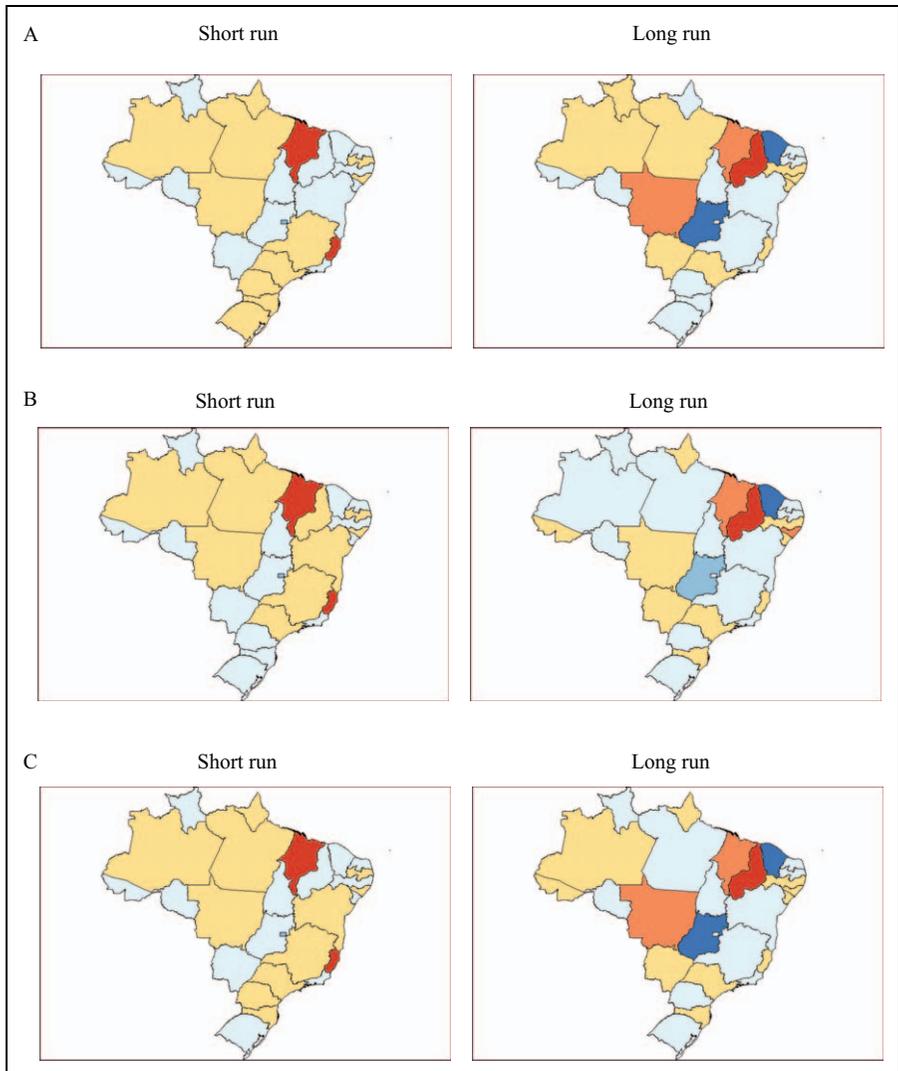
At the sectoral level, there is a shift against the production of transportation services, as expected. As resources are scarce, the reduction in the production of port services (transborder activities become less resource intensive) facilitates gains in other sectoral output, especially from sectors producing tradable goods.

In summary, in aggregate terms, the simulation results suggest that increases in port efficiency lead to a faster growing, more competitive, and more open Brazilian economy.

*Spatial impacts.* The spatial effects are presented in figure 3.<sup>18</sup> In the three scenarios, the real GDP is shown to increase in all the macro regions, except for the Center-West—a landlocked region—in the long run. In addition, in the long run, note the relative weak performance in the three scenarios of two areas (groups of states) of the country: first, the landlocked states of Minas Gerais, Goiás, and Tocantins; second, the states of Ceará, Rio Grande do Norte, and Paraíba, in the Northeast.

Regarding the spatial results for the first scenario, in terms of GDP growth, in the short run, there appear clearly three spatial regimes in the Brazilian economy. First, a space associated with “primary exporters,” in which the transportation infrastructure is sparse and the main links and nodes are easily associated with specific and scattered export activities. This area—which encompasses the states of Amazonas, Pará, and Mato Grosso—benefits from lower costs associated with its export activities. In the case of Amazonas, a relevant indirect effect also occurs through the improvement of efficiency in import transshipments, as the interstate exports from the “Zona Franca de Manaus” become more competitive. Second, there appears an “intermediate space,” which assumes a role of transition in the context of the interface of the Brazilian interregional system with the world economy and is more articulated with the domestic markets. Third, there appears a denser economic space, more integrated with the world economy, where port efficiency plays a crucial role in affecting its overall competitiveness; this third group includes Brazilian “global traders” located in the more developed regions of the southeast and south. Short-run results for scenario 3 also reveal similar spatial regimes.

In scenario 2, the results for the short run reveal the nature of the shocks. Decentralization, as designed, would have a clear north–south pattern. Regional controlled



**Figure 3.** A. Spatial results: Real gross state product, scenario 1. B. Spatial results: Real gross state product, scenario 2. C. Spatial results: Real gross state product, scenario 3.

more efficient ports are concentrated in the South of the country (Rio Grande do Sul, Santa Catarina, and Paraná). Thus, as decentralization benefits ports located elsewhere, the relative efficiency increases for those ports whose hinterland are in the other part of the country. In other words, the effects on imports and exports are mainly sensitive outside the South region.

*Systematic sensitivity analysis.* How sensitive are the results to parameter specification? In this section, sensitivity analysis for key parameters is performed, providing a more reliable range of model results. Given the nature of the simulations (see figure 2), key parameters are represented by the export demand elasticities and the international trade elasticities (Armington elasticities). Moreover, from a spatial perspective, the role of scale parameters in the manufacturing sectors should also be assessed.

The scenarios related to the gains in port efficiency experiments (scenarios 1–3) discussed above were employed using the Gaussian quadrature<sup>19</sup> approach to establish confidence intervals for the main results. The range for the parameters in the first group of sensitivity analyses was set to  $\pm 25$  percent around the default values, with independent, symmetric, triangular distributions for two sets of parameters, namely the set of export demand elasticities for the various products and the set of Armington elasticities of substitution between imported and domestic goods. The second group of sensitivity analyses was carried out in the scale economies parameters in the regional manufacturing sectors, using a similar range around the default values ( $\pm 25$  percent).

The sensitivity of GDP results in each Brazilian state, as well as for the country as a whole, for the ranges in the two sets of parameters, was analyzed in the three scenarios.<sup>20</sup> The lower bound and the upper bound columns represent the 90 percent confidence intervals for the estimates, constructed using Chebyshev's inequality. We observe that, in general, aggregate GDP results are relatively more robust to international trade elasticities rather than to scale economy parameters in the short run, while in the long run, this situation changes. Overall, the states results can be considered more robust to both sets of parameters in the short run closure.<sup>21</sup>

## Final Remarks

The results of this analysis suggest that formal consideration of nodes in a transportation network is required if the full implications of transportation costs are to be considered in spatial CGE models. While the insights gained from integrating a transport network with the interregion CGE model are substantial, in cases where nodal inefficiencies play a key role as is in the case in Brazil and much of Latin America, it becomes important to separate out link and node costs. This separation is even more important from a policy perspective, as Brazil faces daunting challenge of identifying the most critical elements of its infrastructure to upgrade. The choice of ports for government investment will have significant implications on the hinterlands serving those ports as well as on other areas that may be able to access them once the investments have been completed. Hence, there are very strong regional development policy implications. If Brazil focuses attention on upgrading ports in the more developed southeast, the result may be a further erosion of the prospects for the less developed northeast to grow fast enough to reduce disparities in welfare levels. Furthermore, improvements in port efficiency in the southeast may generate

greater bilateral trade with countries whose goods destined for Brazil may further displace those currently produced in the northeast. In a context where the public administrations experience a stronger and stronger demand on social policy, and where infrastructure budgets tend to be tightened or even scaled back, as is the case in most Latin American countries, the economic evaluation—and optimization—of port investment actions and/or policy becomes a recurrent requirement.

In other words, the interrelated character of regional economies remain a concern, since improving the port efficiency of one region may divert investment and commerce from neighboring regions. Improving the more heavily trafficked ports in more developed southern states appears to yield the higher immediate return, but diverting trade from the northern regions could increase regional inequalities.

However, the issue of allocation of scarce funds targeting subsets of ports for strategic improvements in their efficiency would require some significant modifications within the B-MARIA-PORT model. In addition, if funding involved both private and public sources, then changes to the closure rules would have to be made to account for potential state budget deficits. Hence, some future next steps might be to consider an optimal port development/modernization strategy that posits an investment fund that is fixed in size and allocated over time. The additional complication in Brazil to the application of a pure, efficiency-only set of criteria is the possibility of exacerbating existing welfare differences between the regions. Since the ports are imperfectly competitive, changes in port modernization unaccompanied by improvements in access will have a very different spatial impact than investment programs in which both node and link (accessibility) improvements are considered. A further issue to consider is the degree to which port modernization priorities reflect existing levels of demand as opposed to consideration of some potentially important synergetic effects between port modernization and the nature and structure of production in the hinterland.

As Levinson (2006) has noted, the container and the associated logistics' revolution has generated new competitive challenges for the efficient movement of goods; break-bulk movement of goods is being rapidly replaced by container movement and this transformation has changed not only the way in which goods are shipped but the spatial routing. Port transfer costs are being squeezed to maximize the use of increasingly larger container vessels. The intranational competition among ports in an individual country (as described in this article for Brazil) will need to be complemented by an international perspective in which shippers increasingly view the choice of port from the perspective of its ability to serve multiple countries. Thus, the challenge for spatial CGE modeling will be the need to consider movements of goods at multiple spatial scales in which the nodal transfers will come to play an ever more important role.

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The author(s) declared no conflicts of interest with respect to the authorship and/or publication of this article.

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## Notes

1. From a national perspective, the link between infrastructure and growth is well explored, especially in cross-country studies (see, for instance, Esfahani and Ramírez 2003).
2. Figures from the World Bank. The so-called *Custo Brasil*, or the cost of doing business in Brazil, includes a variety of added costs linked to the regulatory framework and red tape but also the overall logistics and transportations costs, including ports (and customs) that are part of the present study.
3. Figures from the *The Global Competitiveness Report*, various years (1996–2000), *apud* (cited in) Clark, Dollar, and Micco (2004).
4. The complete specification of the model is available in Haddad (1999).
5. Only the manufacturing activities were contemplated with this change due to data availability for estimation of the relevant parameters.
6. See Haddad and Hewing (2005), for more details.
7. The departure point is the B-MARIA-27 model, described in Haddad and Hewings (2005).
8. Hereafter, transportation services and margins will be used interchangeably.
9. Intermediate consumption, investment consumption, and household consumption.
10. Port services are produced within a regional resource-demanding optimizing transportation sector. A fully specified production possibility frontier (PPF) has to be introduced for the transportation sector, which produces not only services consumed directly by users but also services consumed to facilitate trade, such as port services.
11. Similarly, one can think about a flow of imports.
12. State names, abbreviations, location as well as the location of the ports are presented at the end of the Appendix (Figure A1). (Table A1).
13.  $PEI_i$  for  $i$  = other ports and other modes, was set equal to one.
14.  $PEI_q$  for  $q$  = total, equals 0.987 and 0.960 for imports and exports, respectively.
15. We did not consider the costs of such changes in our simulations.
16. The process behind decentralization in Brazil may be inextricably tied to productivity factors, providing a source of potential endogeneity: as the first ports whose management was decentralized/privatized were the relatively more efficient ones, the World Bank estimates should reflect this feature, as observed. We take that as given in our scenarios. We thank an anonymous referee for calling the attention for this fact.
17. In aggregate terms, the three scenarios point to the same direction. Relative magnitudes are different though, with a consistent hierarchy going from scenario 3 (best results) to scenario 2 (worst results); scenario 1 achieves an intermediary performance.
18. In the reading of the maps, hereafter, warm colors (orange and green) represent values above the average, in terms of standard deviations; cold colors (blue) represent values below the average, also in terms of standard deviations; warmer/colder colors represent outliers.

19. The Gaussian Quadrature (GQ) approach (Arndt 1996; DeVuyst and Preckel 1997), used in this exercise, was proposed to evaluate computable general equilibrium (CGE) model results' sensitivity to parameters and exogenous shocks. This approach views key exogenous variables (shocks or parameters) as random variables with associated distributions. Due to the randomness in the exogenous variables, the endogenous results are also random; the GQ approach produces estimates of the mean and standard deviations of the endogenous model results, thus providing an approximation of the true distribution associated with the results.
20. Results are available under request.
21. In the long run, there appear (a few) cases with qualitative changes (changes in sign) within the confidence interval.

## Appendix



**Figure A1.** Selected Brazilian ports.

**Table A1.** Brazilian States

AC	Acre
AP	Amapá
AM	Amazonas
PA	Pará
RO	Rondônia
RR	Roraima
TO	Tocantins
AL	Alagoas
BA	Bahia
CE	Ceará
MA	Maranhão

(continued)

**Table A1 (continued)**

PB	Paraíba
PE	Pernambuco
PI	Piauí
RN	Rio Grande do Norte
SE	Sergipe
ES	Espírito Santo
MG	Minas Gerais
RJ	Rio de Janeiro
SP	São Paulo
PR	Paraná
SC	Santa Catarina
RS	Rio Grande do Sul
DF	Distrito Federal
GO	Goiás
MT	Mato Grosso
MS	Mato Grosso do Sul

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## Assessing the ex ante economic impacts of transportation infrastructure policies in Brazil

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This paper uses a fully operational inter-regional computable general equilibrium (CGE) model implemented for the Brazilian economy, based on previous work by Haddad and Hewings, in order to assess the likely economic effects of road transportation policy changes in Brazil. Among the features embedded in this framework, modelling of external scale economies and transportation costs provides an innovative way of dealing explicitly with theoretical issues related to integrated regional systems. The model is calibrated for 109 regions. The explicit modelling of transportation costs built into the inter-regional CGE model, based on origin–destination flows, which takes into account the spatial structure of the Brazilian economy, creates the capability of integrating the inter-regional CGE model with a geo-coded transportation network model enhancing the potential of the framework in understanding the role of infrastructure on regional development. The transportation model used is the so-called Highway Development and Management, developed by the World Bank, implemented using the software TransCAD. Further extensions of the current model specification for integrating other features of transport planning in a continental industrialising country like Brazil are discussed, with the goal of building a bridge between conventional transport planning practices and the innovative use of CGE models. In order to illustrate the analytical power of the integrated system, the authors present a set of simulations, which evaluate the ex ante economic impacts of physical/qualitative changes in the Brazilian road network (for example, a highway improvement), in accordance with recent policy developments in Brazil. Rather than providing a critical evaluation of this debate, they intend to emphasise the likely structural impacts of such policies. They expect that the results will reinforce the need to better specifying spatial interactions in inter-regional CGE models.

**Keywords:** ex ante impact analysis; transportation; infrastructure; regional analysis; general equilibrium

### 1. Introduction

One of the main obstacles to economic development in Brazil is the so-called *Custo Brasil*, the extra costs of doing business in the country. Enterprises are faced with a heavy burden that competing firms in other countries do not confront, hampering competitiveness. It

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includes different components that represent distortions in the relation between the public and the private sectors, reflecting inadequate legislation and deficient provision of public goods. Ongoing debate centres on the contribution of different sectors to the *Custo Brasil*: labour costs; transportation infrastructure; the tax system; and the regulatory system.

A study by the World Bank (1996) in the mid-1990s provided a comprehensive examination of the diverse components of the *Custo Brasil* and an exploration of their implications for total firm costs. Regarding land transport costs, which are often viewed as a significant component of the *Custo Brasil*, the available evidence collected for the report suggested that the costs of providing rail and trucking services were high in Brazil. Nevertheless, because of overcapacity and significant competition in trucking, these costs are not passed on to shippers; transport rates per ton-kilometre are low by international standards. The principal problem with land transportation, from the point of view of shippers, is not the unit costs of different modes of transportation, but rather excessive reliance on trucking. Railroad and barge transport over long distances are far cheaper than trucking, particularly for bulk commodities. Inefficiencies and low productivity in the railroad sector have meant that the percentage of total cargo carried by trucks in Brazil is approximately twice as large as the share in Australia and the United States.

More than 10 years after the aforementioned World Bank study, the situation in the transportation sector did not change. Brazilian transport infrastructure is deteriorating fast from lack of investment and maintenance, showing an increased number of critical points, or bottlenecks, in most of the corridors. Decay in the transportation system curtails economic growth, hampering competitiveness both in the internal and external markets. Deterioration of Brazil's transportation network in the past years contributed to high operational costs, obstructing the competitive integration of the country.

The federal government has signalled its intention in reviving long-term planning in transportation in the country. The design of an ambitious *Plano Nacional de Logística e Transportes* (National Plan of Logistics and Transportation) has been initiated, involving different stakeholders. It aims at supporting decision-makers in attaining economic objectives through policy initiatives related to both public and private infrastructure and organisation of the transportation sector.<sup>1</sup>

At the state level, few initiatives have taken place in the realm of transport planning. States such as Bahia, Rio Grande do Sul, Minas Gerais and Pará have all developed thorough diagnosis of the sector, including forward-looking exercises with a long-term view on the available possibilities for policy intervention within the respective state borders.<sup>2</sup>

As a recent report by the World Road Association (2003, p. 7) points out, there is a growing need for economic and socio-economic models for helping improving road management. This paper provides an attempt to meet this requirement. We use a fully operational inter-regional computable general equilibrium (CGE) model implemented for the Brazilian economy, based on previous work by Haddad and Hewings (2005), in order to assess the likely economic effects of recent road transportation policy changes in Brazil. Among the features embedded in this framework, modelling of external scale economies and transportation costs provides an innovative way of dealing explicitly with theoretical issues related to integrated regional systems. The explicit modelling of transportation costs built into the inter-regional CGE model, based on origin–destination flows, which takes into account the spatial structure of the Brazilian economy, creates the capability of integrating the inter-regional CGE model with a geo-coded transportation network model enhancing the potential of the framework in understanding the role of infrastructure on regional development. The transportation model used is the so-called Highway

Development and Management Model, developed by the World Bank, implemented using the software TransCAD.

It is important to notice that the existing, commonly-used policy tools to address issues related to the economic impacts of transportation infrastructure policies do not come anywhere close to capturing some of the most important channels through which exogenous and transportation policy shocks are transmitted to the various dimensions of regional economic structures. Models are issue-specific; trying to ‘force’ a model to answer questions that it is not designed to address hampers our ability to address relevant policy questions (see Agénor *et al.* 2007). Thus, this paper provides quantitative and qualitative insights (general equilibrium effects) into trade-offs commonly faced by policy-makers when dealing with infrastructure projects in a spatial context. It shows that, given different policy options, decision-makers face non-trivial choices, as different projects perform differently in different dimensions, usually presenting outcomes with different hierarchies related to multi-dimensional policy goals.

The remainder of the paper is organised as follows. After the discussion of relevant modelling issues – focusing on the treatment of transportation costs in CGE models – in the next section, Section 3 will present an overview of the CGE model to be used in the simulations, focusing on its general features. After that, the simulation experiments are designed and implemented, and the main results are discussed in Section 4. Final remarks follow in an attempt to evaluate our findings and put them into perspective, considering their extensions and limitations.

## 2. Modelling issues

The development of regional and inter-regional CGE modelling has experienced, in the past 15 years, an upsurge in interest. Different models have been built for different regions of the world. Research groups, located especially in Australia, Brazil, Canada, Germany, Scotland, and the United States, as well as individual researchers, contributed to these developments through the specification and implementation of a variety of alternative models. Recent theoretical developments in the new economic geography bring new challenges to regional scientists, in general, and inter-regional CGE modellers, in particular.<sup>3</sup>

Among the potential uses of inter-regional CGE models, we can mention the analysis of transport planning policies with ranging effects on regional and national economies. National and/or state-wide transport planning is a widely institutionalised process in several countries. The use of model-based analytical procedures is in the state of practice, including the application of conventional input–output methods for forecasting freight movements. Nevertheless, the feedback impact of transport actions on the regional and/or national economies is not fully accounted for in these procedures. In recent years, the development of improved techniques was the focus of several efforts joining the transport and economics research fields in the USA (for example, Friez *et al.* 1998) and the European Union (for example, Bröcker 2002), without forgetting efforts of Asian countries (for example, Miyagi 2001) and Brazil (for example, Pietrantonio 1999).

Investments in highways and other forms of improvements in the transportation system represent an important way of achieving regional and national economic growth. Expansion and improvements of transportation facilities can be used as a means to reduce firms’ transaction costs and to expand the economic opportunities in a region/country, as it potentially helps to increase income and improve the standard of living of the resident population.

However, investments in transportation, in addition to its impact on systemic productivity, have potential differential impacts across economic spaces. Spatially localised interventions may increase regional competitiveness. External scale economies and accessibility effects would produce the expansion or contraction of the local firms' market areas and generate opportunities to access broader input markets. One of the fundamental elements to be taken into account is the spatial interaction among regions: changes in a given location may result in changes in other regions through the various types of relations (complementary and competitive) associated with the regional agents in the relevant economic spaces.

In this context, the modelling procedure developed in this paper represents an attempt to address some of these issues in the context of a unified approach, which enables the proper treatment of the role of transportation infrastructure in the allocation of resources in a given economy. The explicit modelling of transportation costs, in an inter-regional CGE model integrated into a geo-coded transportation network infrastructure model, will allow us to assess, under a macro spatial perspective, the economic effects of specific transportation projects and programmes.

### 2.1. Treatment of transportation costs

It has been noticed elsewhere (Haddad 2004) that current CGE models are not without their limitations to represent spatial phenomena. Isard's vision of integrated modelling, which anticipated the proposals reported in Isard and Anselin (1982), provided a road map for the development of more sophisticated analysis of spatial economic systems (Hewings 1986, Hewings *et al.* 2003). Given their many virtues, however, if adequately coped, inter-regional CGE models are the main candidates for the core subsystem in a fully integrated system.

The embedding of spatial trade flows into economic modelling, especially those related to inter-regional trade linkages, usually should go along with the specification of transportation services. Given existing inter-regional CGE models, one can identify at least three approaches for introducing the representation of transportation, all of them considering the fact that transportation is a resource-demanding activity.<sup>4</sup> This basic assumption is essential if one intends to properly model an inter-regional CGE framework, invalidating the model's results if not considered (see Isard *et al.* 1998).

## 3. The inter-regional CGE model

Our departure point is the B-MARIA model, developed by Haddad (1999). The B-MARIA model – and its extensions – has been widely used for assessing regional impacts of economic policies in Brazil. Since the publication of the reference text, various studies have been undertaken using, as the basic analytical tool, variations of the original model.<sup>5</sup> Moreover, critical reviews of the model can be found in the *Journal of Regional Science* (Polenske 2002), *Economic Systems Research* (Siriwardana 2001) and in *Papers in Regional Science* (Azzoni 2001).

The theoretical structure of the B-MARIA model is well documented.<sup>6</sup> In this paper, we develop a version of the B-MARIA model specified to deal with transportation policies in the state of Minas Gerais. We use a similar approach to Haddad (2004), and Haddad and Hewings (2005) to integrate the inter-regional CGE model with a geo-coded transportation network infrastructure model. However, instead of using a simpler transportation network



represent one of the functioning mechanisms of a spatial economy. The modelling procedure adopted in B-MARIA-MG uses constant elasticity of substitution (CES) nests to specify the production technology. Given the property of standard CES functions, non-constant returns are ruled out. However, one can modify assumptions on the parameters values in order to introduce non-constant returns to scale. Changes in the production functions of the manufacturing sector<sup>9</sup> in each one of the 109 regions were implemented in order to incorporate non-constant returns to scale, a fundamental assumption for the analysis of integrated inter-regional systems. We kept the hierarchy of the nested CES structure of production, which is very convenient for the purpose of calibration (Bröcker 1998), but we modified the hypotheses on parameters' values, leading to a more general form. This modelling trick allows for the introduction of parametric external scale economies (rationalised as agglomeration economies), by exploring local properties of the CES function.

The second main modification, which addresses some of the modelling issues discussed in the previous section, refers to the introduction of links between the inter-regional CGE core and a geo-coded transportation network model, allowing for a more adequate characterisation of the spatial structure of the economy, in which the role of the transportation infrastructure and the friction of distance is explicitly considered.

### 3.1. Modelling of transportation costs

The set of equations that specify purchasers' prices in the B-MARIA model imposes zero pure profits in the *distribution* of commodities to different users. Prices paid for commodity  $i$  supplied from region  $s$  and consumed in region  $q$  by each user equate to the sum of its basic value and the costs of the relevant taxes and margin-commodities.

The role of margin-commodities is to facilitate flows of commodities from points of production or points of entry to either domestic users or ports of exit. Margin-commodities, or, simply, margins, include transportation and trade services, which take account of transfer costs in a broad sense.<sup>10</sup> Margins on commodities used by industry, investors, and households are assumed to be produced at the point of consumption. Margins on exports are assumed to be produced at the point of production.

In B-MARIA, transportation services (and trade services) are produced by a regional resource-demanding optimising transportation (trade) sector. A fully specified production possibility frontier has to be introduced for the transportation sector, which produces goods consumed directly by users and consumed to facilitate trade; that is, transportation services are used to ship commodities from the point of production to the point of consumption. The explicit modelling of transportation costs, based on origin–destination flows, which takes into account the spatial structure of the Brazilian economy, creates the capability of integrating the inter-regional CGE model with a geo-coded transportation network model, enhancing the potential of the framework in understanding the role of infrastructure on regional development.

### 3.2. Structural database

The CGE core database requires detailed sectoral and regional information about the Brazilian economy. National data (such as input–output tables, foreign trade, taxes, margins and tariffs) are available from the Brazilian Statistics Bureau (IBGE). At the regional level, a full set of accounts was developed by FIPE (2007). These two sets of information were put together in a balanced inter-regional social accounting matrix. Previous work in

this task has been successfully implemented in inter-regional CGE models for Brazil (for example, Haddad 1999, Domingues 2002, Perobelli 2004, Porsse 2005).

### 3.3. *Behavioural parameters*

Experience with the B-MARIA framework has suggested that inter-regional substitution is the key mechanism that drives model's spatial results. In general, inter-regional linkages play an important role in the functioning of inter-regional CGE models. These linkages are driven by trade relations (commodity flows), and by factor mobility (capital and labour migration). In the first case, of direct interest to our exercise, inter-regional trade flows should be incorporated into the model. Thus, inter-regional input–output databases are required to calibrate the model, and regional trade elasticities play a crucial role in the adjustment process.

One data-related problem that modellers frequently face is the lack of such trade elasticities at the regional level. An extra effort was undertaken to estimate model-consistent regional trade elasticities for Brazil (see Haddad and Hewings 2005).

Other key behavioural parameters were properly estimated; these include econometric estimates for scale economies (Haddad 2004); econometric estimates for export demand elasticities (Perobelli 2004); as well as the econometric estimates for regional trade elasticities. Another key set of parameters, related to international trade elasticities, was borrowed from a recent study developed at IPEA (Instituto de Pesquisa Econômica Aplicada) (Tourinho *et al.* 2002), for manufacturing goods, and from model-consistent estimates in the EFES (Economic Forecasting Equilibrium System) model (Haddad and Domingues 2001) for agricultural and services goods.

### 3.4. *Closures*

In order to capture the effects of improvements in the transportation network, the simulations were carried out under two standard closures, referring to the short run and the long run. A distinction between the short-run and long-run closures relates to the treatment of capital stocks encountered in the standard microeconomic approach to policy adjustments. In the short-run closure, capital stocks are held fixed; while, in the long-run, policy changes are allowed to affect capital stocks. In addition to the assumption of inter-industry and inter-regional immobility of capital, the short-run closure would include fixed regional population and labour supply, fixed regional wage differentials, and fixed national real wage. Regional employment is driven by the assumptions on wage rates, which indirectly determine regional unemployment rates. On the demand side, investment expenditures are fixed exogenously – firms cannot re-evaluate their investment decisions in the short run. Household consumption follows household disposable income, and real government consumption, at both regional and federal levels, is fixed (alternatively, the government deficit can be set exogenously, allowing government expenditures to change). Finally, preferences and technology variables are exogenous.

A long-run (steady-state) equilibrium closure is used in which capital is mobile across regions and industries. Capital and investment are generally assumed to grow at the same rate. The main differences from the short-run are encountered in the labour market and the capital formation settings. In the first case, aggregate employment is determined by population growth, labour force participation rates, and the natural rate of unemployment. The distribution of the labour force across regions and sectors is fully determined endogenously. Labour is attracted to more competitive industries in more favoured geographical

areas, keeping regional wage differentials constant. While in the same way, capital is oriented towards more attractive industries. This movement keeps rates of return at their initial levels.

#### 4. Transportation infrastructure projects

In this section, we illustrate the analytical capability of the unified framework in the evaluation of specific transportation projects contemplated in the *Plano Estadual de Logística e Transportes* (PELT Minas). The case study under consideration refers to two projects of improvement of federal highways – BR-262 and BR-381 – in the State of Minas Gerais (Figure 2). The following analysis suggests a strategy of application of the framework developed here for the ex ante impact assessment of a project in a systemic context, in its operational phase. The impacts of the investment phase are not considered in these illustrative exercises. The goal is to explore the characteristics of the integrated model in the simulation phase and not to proceed with a systematic evaluation of the project, which is outside the scope of this paper. In what follows, we will assess the impacts on national variables, and on a broader set of socio-economic state variables.

The characteristics of the projects are detailed in a document prepared by FIPE (2007) for the Secretaria de Transportes e Obras Públicas. The guidelines that have been used to justify the choice of these specific tracks of the BR-262 and BR-381 highways to be improved are based upon the grounds of the strategic location of this network links in the national transportation system, which constitute two of the main corridors related to the more dynamic regions of the country. Moreover, it is hoped that such improvements will foster regional development in the State of Minas Gerais, one of the leading economies of the country.

With a total length of 441 km, between Betim and Uberaba, the BR-262 project consists of the duplication of the existing road link between Betim and Nova Serrana, and the construction of climbing and passing lanes between Nova Serrana and Araxá. Total costs of the project are estimated in BRL 554 million.<sup>11</sup>

The BR-381 project considers the duplication of the track between Belo Horizonte and Governador Valadares, in a total length of 304 km. Total costs of the implementation are estimated in BRL 1395 million.

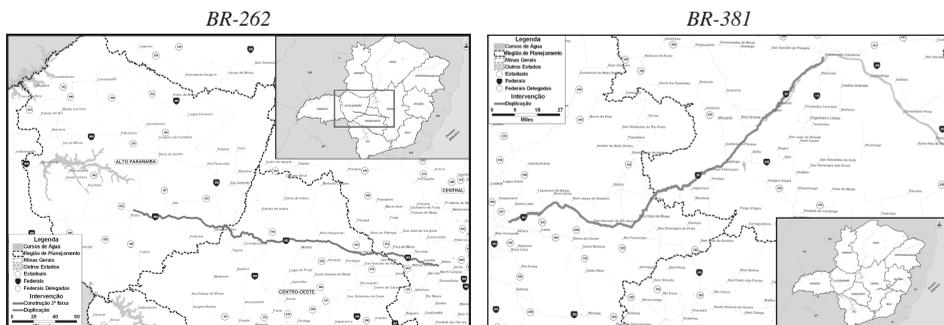


Figure 2. Location of road improvement projects.

Source: Elaborated by the authors based on the Secretaria de Transportes e Obras Públicas, Minas Gerais.

The distinction between the two projects lies on the role they play in the integration of Brazilian regions. While the BR-262 project constitutes a major improvement on the east–west integration of the country, linking the coast of the Southeast to the more agricultural areas of the Midwest, the BR-381 has a strategic role in the integration of the Northeast with the Southeast and South of the country. These distinct axes of integration play different roles in the inter-regional Brazilian system, as spatial competition occurs in a lower degree in the case of the BR-262 than in the case of the BR-381 link. In the latter case, denser economic spaces are directly involved in the spatial process, while in the former case, more specialised spaces have more prominent roles.

#### *4.1. Functioning mechanism*

The simulation exercise considers the implementation of two projects related to road improvements in the State of Minas Gerais. According to the model structure, this may represent a margin-saving change; that is, the use of transportation services per unit of output is reduced, implying a direct reduction in the output of the transportation sector. The reduction in transport cost decreases the price of composite commodities, with positive implications for real regional income: in this cost-competitiveness approach, firms become more competitive – as production costs go down (inputs are less costly); investors foresee potential higher returns – as the cost of producing capital also declines; and households increase their real income, envisaging higher consumption possibilities. Higher income generates higher domestic demand, while increases in the competitiveness of national products stimulate external demand. This creates room for increasing firms' output – directed for both domestic and international markets – which requires more inputs and primary factors. Increasing demand puts pressure on the factor markets for price increases, with a concomitant expectation that the prices of domestic goods would increase.

Second-order prices changes go in both directions – decrease and increase. The net effect is determined by the relative strength of the countervailing forces. Figure 3 summarises the transmission mechanisms associated with major first-order and second-order effects in the adjustment process underlying the model's aggregate results.

#### *4.2. Results*

The B-MARIA-MG model was used to estimate the short-run and long-run impacts of both projects, during their operational phases. The main results are discussed below.<sup>12</sup>

*4.2.1. National impacts.* Table 1 presents simulation results for national aggregates. Two distinct pictures emerge, embedding the specific structural differences between the two projects. In the case of the BR-262 project, more standard outcomes associated with commonsense expectation on infrastructure project arise.

Gains in efficiency (real Gross Domestic Product [GDP] growth) are positive in both the short run and the long run, while welfare gains (equivalent variation) are revealed only in the long run. Noteworthy is that, in the long run, the effects on GDP are magnified.

Changes in terms of trade tend to benefit Brazilian exports only in the short run, as the results point to increasing competitiveness of Brazilian products. This conclusion is reinforced by the performance of the international trade sector: exports volumes increase, leading GDP growth in the short run. When compared with other GDP components, international trade is the only component that presents a positive performance in the short run.

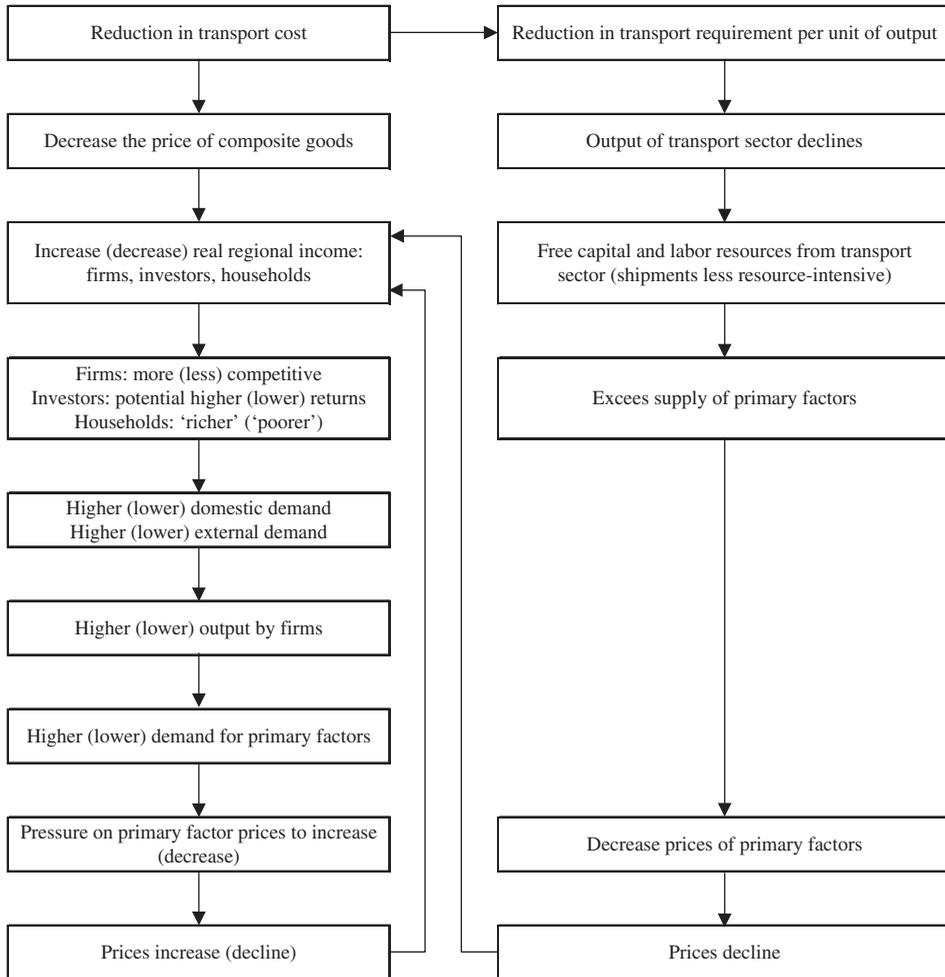


Figure 3. Causal relationships in the simulation.  
Source: Elaborated by the authors.

In the long run, however, this situation is reversed. While stronger penetration of imported products is verified, due to the reversal of the terms of trade result, domestic absorption becomes the component in chief, leading GDP growth. The rationale behind this result is as follows. In the short run, components of domestic absorption are less prone to change; while in the long run, primary factors (both labour and capital) are more flexible. Pressures on primary factor prices to increase are, thus, less sensitive, allowing stronger fall in domestic costs of production. However, in this specific simulation, prices of exports tend to increase in relation to domestic prices, hampering the international trade balance.<sup>13</sup> This fact is intrinsically related to the location of the project, which situates in a position linking agricultural markets (in the west and central parts of the country) to important domestic centres of consumption, in the east. As this east–west link is not substantially associated with export corridors of the agricultural production, the positive impacts are heavily associated with benefits to domestic markets. Moreover, the very distinct nature of the respective

Table 1. National results: selected variables (percentage change).

	BR-262		BR-381	
	Short run	Long run	Short run	Long run
<b>Aggregates</b>				
Real GDP	0.00022	0.00105	0.00018	(0.00293)
Equivalent variation – total (change in \$1,000,000)	(12.3)	58.6	(48.3)	6.4
Economy-wide terms of trade	(0.00180)	0.00040	(0.00674)	0.00299
GDP price index, expenditure side	(0.00240)	(0.01598)	(0.00818)	0.00242
<b>GDP components</b>				
Real household consumption	(0.00047)	0.00139	(0.00132)	(0.00344)
Real aggregate investment		0.00001		(0.00002)
Real aggregate regional government demand	(0.00217)	0.00129	(0.01301)	(0.00156)
Real aggregate federal government demand	(0.00047)	0.00139	(0.00132)	(0.00344)
International export volume	0.00385	(0.00017)	0.01456	(0.00683)
International import volume	(0.00239)	0.00019	(0.00823)	(0.00397)

Source: Elaborated by the authors.

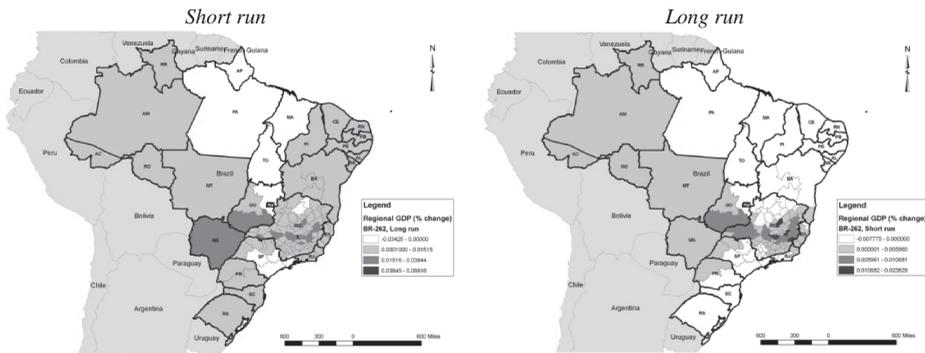


Figure 4. Spatial results: real GDP (percentage change): BR-262 project.

Source: Elaborated by the authors.

economic structures of the linked spaces imposes very weak spatial competition among regions in the area of influence of the BR-262.

In this sense, the spatial effects on GDP (Figure 4) reveal, both in the short run and in the long run, positive impacts in regions directly influenced by the BR-262. Noteworthy is that these positive impacts spread over space in the long run. Moreover, re-location effects tend to be directed to the agriculture-producing regions in the West as well as to the areas directly linked to the project itself within the borders of Minas Gerais.

Regarding the BR-381 project, macroeconomic short-run results are qualitatively equivalent to those presented by the BR-262 project: GDP growth led by the international sector and improvement in the terms of trade, as well as increasing overall competitiveness.

However, a seemingly surprising (to commonsense) result occurs: real GDP in the long run is projected to decrease, after the duplication project starts to operate. It should be

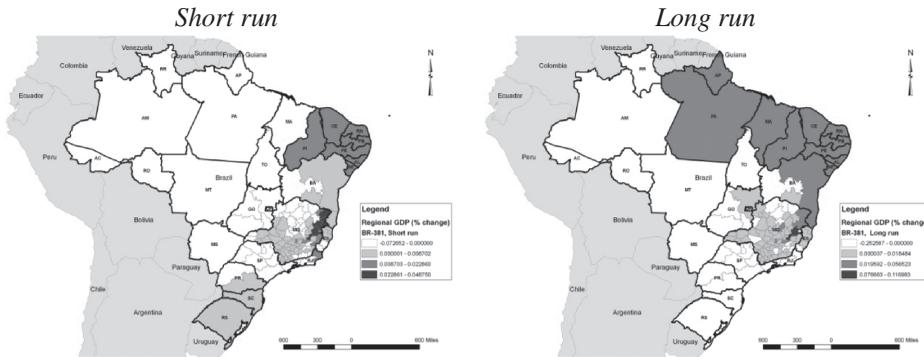


Figure 5. Spatial results: real GDP (percentage change): BR-381 project.  
Source: Elaborated by the authors.

emphasised that BR-381 has a relevant role in the integration of the country – it is part of one of the major routes linking the Northeast to the South of the country.

Figure 5 helps us clarify this issue. It presents both short-run and long-run results on GDP, from a spatial perspective. Looking more closely at such results for the long run, an ‘accounting’ explanation for the negative real GDP result emerges. Regional contributions for national GDP show that regions with positive performance (74 of them) represent a total impact of 0.00388, while regions with negative performance (35) represent a total impact of  $-0.00682$ . Thus, the negative impact, in absolute terms, is 75 per cent greater than the positive one. The map indicates that negative impacts are concentrated in the whole South region, all regions in the states of São Paulo and Rio de Janeiro. Fifty-eight per cent of the total negative impact comes from the São Paulo regions, and 12 per cent from Rio de Janeiro. In the regions that present a positive performance, major contributions come from the Northeast, especially Salvador, Aracaju, and Fortaleza, representing 68 per cent of the total positive impact on GDP growth.

Short-run results represent a counterfactual situation characterised by less flexible mechanisms of inter-regional transmission, as the possibility of inter-regional factor mobility is precluded. In the case of the South (including São Paulo), there seems to be stronger competitive interdependence with Minas Gerais and the eastern economies of the Northeast, mainly the more industrialised ones. The results for real GDP, in percentage terms, make this feature more evident, as economic growth of Minas Gerais and the Northeast is verified at the expense of growth in those economies south of Minas Gerais, even though the western economies of the Northeast, Tocantins and Mato Grosso present negative performance.

In the long run, the behavioural parameters have an even more prominent role in the functioning of the model. Re-location effects of capital and labour operate defining a new geography of winners and losers. The state of Minas Gerais and the Northeast place themselves as the main attractors of economic activity, competing directly with the centre-South of the country. The net result is the re-location of activities towards those areas, providing two distinct spatial regimes of potential winners and losers.

In summary, in the case of the BR-381 spatial competition clearly plays a prominent role. Given the favourable scenario for relative costs of production in the Northeast, in a context of systemic low quality of transport infrastructure, the Northeast increases

its spatial market area while the richer Southeast suffers from the network (congestion) effects. Lower growth with decreasing regional inequality is the main long-run macro result (see localised spillover models – Baldwin and others 2003 – for a theoretical view).

Before moving to the analysis of the specific impacts in the State of Minas Gerais, it is important to emphasise the systemic nature of the problems under analysis. The issue of coordination of spatial policies should be given its proper role. As has been seen, isolated projects may promote undesirable outcomes if not considered within a context of a well-specified programme of investments. The integrated nature of transport systems may induce policy-makers to achieve mistakes when designing programmes without sound knowledge of this property. Accordingly, it would be important to consider differences between modes of transportation (that is, highways, railways and waterways) and different flows of goods. These requirements imply the need not only for a network model of multi-modal transport – as the one used in this paper – but also a more detailed specification of products in the CGE model – still to be developed.

*4.2.2. Regional impacts.* As both projects locate in the State of Minas Gerais, it is important to assess the specific state impacts. Policy-makers in Minas Gerais may have special interests in such projects, given their strategic role in the state transport network.

Common patterns appear related to aggregate effects of both projects with Minas Gerais (Table 2). In general, positive outcomes are stronger in the BR-262 project than in the BR-381 project. However, they go in the same direction for most of the indicators. Overall, gains in efficiency (real GDP growth) are positive, with bigger impacts occurring in the long run. Real tax revenue also follows the same pattern. Competitiveness indicators suggest improvements in the terms of trade with other countries, and a reduction in the *Custo Minas* – measured in terms of the state GDP deflator. Noteworthy is that in the long run the effects on terms of trade are magnified, what does not happen to *Custo Minas* in the BR-381 project. In the long run, a less favourable situation emerges, as Minas Gerais overall competitiveness seems to be hampered by production costs increases associated with increases in consumer good prices, also affecting welfare in terms of the equivalent variation. This effect is connected with direct spatial competition with similar economies in the Northeast.

Table 2. State results: selected indicators (percentage change).

	BR-262		BR-381	
	Short run	Long run	Short run	Long run
Real GDP	0.00765	0.01554	0.00532	0.00686
Equivalent variation – total (change in \$ 1,000,000)	15.4	30.1	7.7	(7.5)
Real tax revenue	0.00269	0.01381	0.00297	0.00425
Terms of trade	(0.00024)	(0.00216)	(0.00001)	(0.00274)
<i>Custo Minas</i>	(0.00379)	(0.02270)	(0.00870)	(0.00629)
Regional concentration	(0.00757)	(0.01528)	(0.00478)	(0.00640)
Poverty	(0.28963)	(1.12426)	(0.16286)	(0.28925)

Source: Elaborated by the authors.

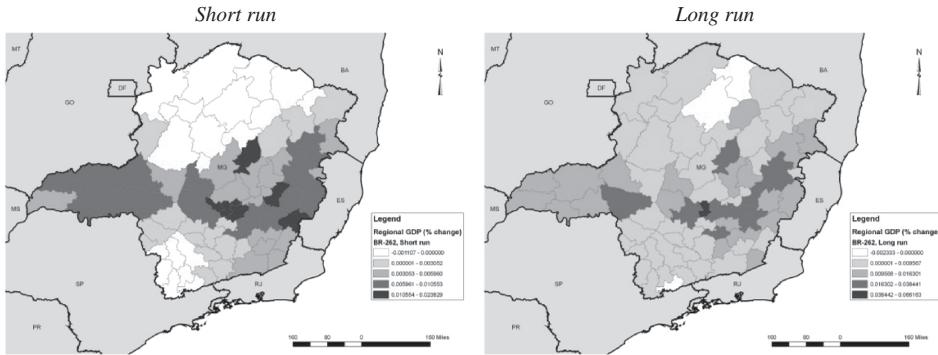


Figure 6. Spatial state results: real GDP (percentage change): BR-262 project.  
Source: Elaborated by the authors.

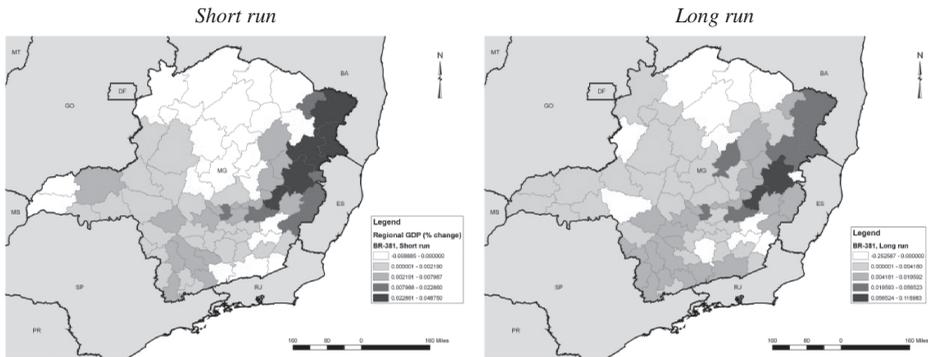


Figure 7. Spatial state results: real GDP (percentage change): BR-381 project.  
Source: Elaborated by the authors.

In terms of regional concentration, our indicator considers the relative growth of poorer regions of the State – North and Jequitinhonha/Mucuri. This outcome reveals that both projects are pro-concentration, but it happens to a lesser degree in the BR-381 project. Finally, both projects are also pro-poor, projecting reductions in the headcount poverty index for the State of Minas Gerais, both in the short (weaker) and long run (stronger). In this case, however, the BR-262 project performs better.

Figures 6 and 7 depict the spatial GDP effects of both projects, focusing on the regions of Minas Gerais. Overall, the stronger effects on the areas of influence of the projects are clearly perceived. Moreover, these effects tend to spread over time, as suggested by the smaller number of regions presenting negative performance in the long run.

### 5. Final remarks

Appropriate tools are needed to assess the ex ante economic impacts of transportation infrastructure policies. This paper has attempted to tackle this issue. It has been suggested that inter-regional CGE models can potentially be used for the analysis of transport planning policies. We have illustrated a way in which this potential use can be implemented.

However, this tool is not yet a recurrent part of the transport planning process. To do so, further amendments are still needed, in order to cope with methodological advances both in economic and transport modelling.

Despite representing the effect of transport infrastructure in a consistent way, the use of current versions of inter-regional CGE models has some drawbacks when intended for replacing conventional models used in national or state-wide transport planning. Future versions of inter-regional CGE models should envisage the incorporation of some usual features of conventional models of transport planning, such as a broader multimodal view, quality and non-price attributes, congestion effects, and a finer spatial disaggregation to allow for finer intra-regional analysis. To some extent, the integrated approach proposed here directly addresses some of these issues. More importantly, however, the results provided are encouraging in the sense that the broader issues dealt in this paper, while difficult, are not insurmountable.

The policy conclusions that can be derived from the results of this study indicate the potential effects (both national and regional) road investments may play in the Brazilian economy. A detailed analysis of the shortage of infrastructure (that is, roads, railways and waterways) in Brazil was not made in the article, which goes beyond the possibilities of the methodology used. However, the results indicate that economic integration of regional markets in Brazil can amplify the benefits of transport investments with differential spatial impacts. Accordingly, given the systemic interconnectedness in the economy and in the transportation network, more appropriate transport policies in Brazil would envisage national coordination, which very often is not the case. Coordination may play an important role in optimising the multi-dimensional outcomes of transport policies.

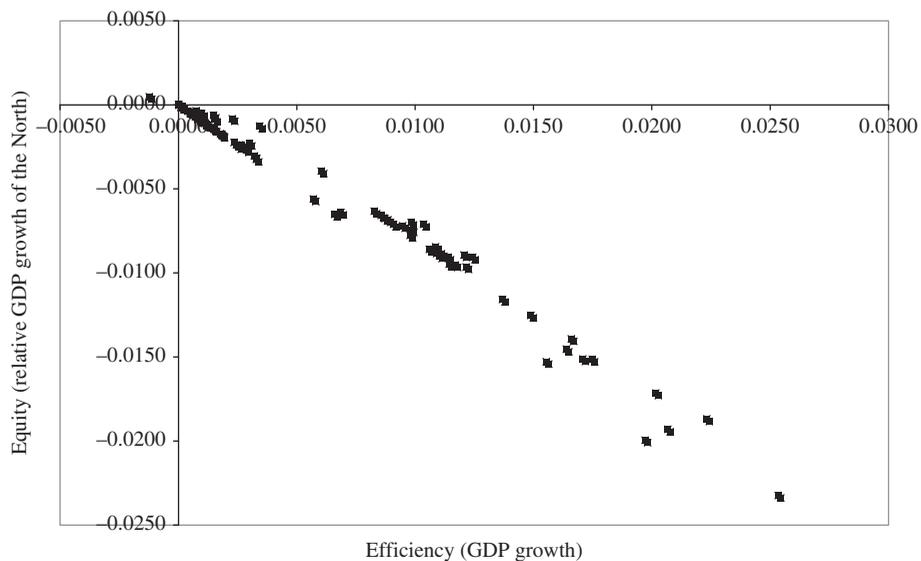


Figure 8. Regional equity-efficiency trade-off of transportation infrastructure investments in Minas Gerais, Brazil.

Source: Elaborated by the authors.

This paper makes it clear that the choice of the ‘best’ infrastructure projects depends on the policy goals to be achieved. Different trade-offs may appear when considering different investment alternatives. Time trade-offs (short run versus long run), political trade-offs (regional versus national effects), and policy outcomes trade-offs were present in the two illustrative cases drawn from the PELT Minas case.

To make this point stronger, a closer look at the complete portfolio of multimodal infrastructure projects within the PELT Minas reveals further evidence about the nature of the relationship between the provision of transport infrastructure and regional equity. Indeed, transport infrastructure is strongly region-dependent. The spatial structure of the provision of transport infrastructure matters in this question, playing a fundamental role in determining its effects on the economic system.<sup>14</sup>

Fifty-three projects (simulations) were analysed with a view to the efficiency-equity trade-off associated with investments in transportation infrastructure. Among the 53 projects, three are investments in waterways, five in railways, three in pipelines, and 42 in roads.<sup>15</sup> Figure 8 summarises the results for the effects on efficiency (measured in terms of real gross regional product growth) and regional disparity (measured in terms of the relative growth of the poor regions in the north of the state and the state as a whole; a negative value indicates that the poor region is growing at a slower pace). The results reflect a long-run environment. There is a clear trade-off between efficiency and regional equity. Projects that produce higher impacts on GDP growth also contribute more to regional concentration. Such trade-offs are commonly faced by policy-makers.

### Acknowledgements

Financial support by CNPq, Fapesp and Rede CLIMA is acknowledged.

### Notes

1. See [www.centran.eb.br](http://www.centran.eb.br) (*Programa Nacional de Logística e Transportes*).
2. In the Minas Gerais case, the *Plano Estadual de Logística e Transportes* (PELT Minas) was based in the use of state-of-the-art methodological approaches to deal explicitly with the interface between transport and economy, from diagnostics to evaluation of transport projects. A similar approach was followed in Pará.
3. See, for instance, Fujita *et al.* (1999) and Fujita and Thisse (2002).
4. First, it is possible to specify transportation technology by adopting the iceberg transportation cost hypothesis, based on Samuelson (1952). Second, one can assume transport services to be produced by a special optimising transport sector. Finally, a third approach to introduce transportation in CGE models consists of the development of a satellite module, for the transportation system.
5. Among them, five doctoral dissertations: Domingues (2002), Perobelli (2004), Porsse (2005), Ferraz (2010), and Santos (2010).
6. See Haddad (1999), and Haddad and Hewings (2005).
7. See <http://www.worldbank.org/transport/roads/tools.htm>
8. Agriculture, mining, manufacturing, construction, transportation, trade, public administration, and other services.
9. Only the manufacturing activities were contemplated with this change.
10. Hereafter, transportation services and margins will be used interchangeably.
11. Values as of December 2006.
12. Simulations results were computed using GEMPACK (Harrison *et al.* 1994).
13. Marginal trade balance is assumed to be in equilibrium in the long run.
14. See Almeida *et al.* (2010).
15. Two of them were analysed in more detail in the article.

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*THE THEORETICAL STRUCTURE OF  
MONASH-MRF*

by

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## ***ABSTRACT***

This paper presents the theoretical specification of the *MONASH-MRF* model. *MONASH-MRF* is a multiregional multisectoral model of the Australian economy. Included is a complete documentation of the model's equations, variables and coefficients. The documentation is designed to allow the reader to cross-reference the equation system presented in this paper in ordinary algebra, with the computer implementation of the model in the TABLO language presented in CoPS/IMPACT *Preliminary Working Paper* No. OP-82.

**Keywords:** multiregional, regional modelling, CGE, regional and Federal government finances.

*J.E.L.* Classification numbers: C68, D58, R10, R13.

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# The Theoretical Structure of MONASH-MRF

## 1. Acknowledgement and explanation

This document contains a draft version of chapter 2 from the forthcoming monograph, *MONASH-MRF: A Multiregional Multisectoral Model of the Australian Economy*. The *MONASH-MRF* project was initiated in mid 1992 with the sponsorship of the NSW and Victorian State government Treasuries. The authors thank P. B. Dixon, W. J. Harrison and K. R. Pearson for their helpful advice.

## 2.1. Introduction

MMRF divides the Australia economy into eight regional economies representing the six States and two Territories. There are four types of agent in the model: industries, households, governments and foreigners. In each region, there are thirteen industrial sectors. The sectors each produce a single commodity and create a single type of capital. Capital is sector and region specific. Hence, MMRF recognises 104 industrial sectors, 104 commodities and 104 types of capital. In each region there is a single household and a regional government. There is also a Federal government. Finally, there are foreigners, whose behaviour is summarised by demand curves for regional international exports and supply curves for regional international imports.

In common with the stylised multiregional model described in Chapter 1, in MMRF, regional demands and supplies of commodities are determined through optimising behaviour of agents in competitive markets. Optimising behaviour also determines demands for labour and capital. National labour supply can be determined in one of two ways. Either by demographic factors or by labour demand. National capital supply can also be determined in two ways. Either it can be specified exogenously or it can respond to rates of return. Labour and capital can cross regional borders in response to labour-market and capital-market conditions.

The specifications of supply and demand behaviour coordinated through market clearing conditions, comprise the CGE core of the model. In addition to the CGE core are blocks of equations describing: (i) regional and Federal government finances; (ii) accumulation relations between capital and investment, population and population growth, foreign debt and the foreign balance of trade, and; (iii) regional labour market settings.

### *Computing solutions for MMRF*

MMRF is in the Johansen/ORANI class of models<sup>1</sup> in that its structural equations are written in linear (percentage-change) form and results are

---

<sup>1</sup> For an introduction to the Johansen/ORANI approach to CGE modelling, see Dixon, Parmenter, Powell and Wilcoxon (DPPW, 1992) Ch. 3.

deviations from an initial solution. Underlying the linear representation of MMRF is a system of non-linear equations solved using GEMPACK. GEMPACK (see Harrison and Pearson 1994) is a suite of general purpose programs for implementing and solving general and partial equilibrium models. A percentage-change version of MMRF is specified in the TABLO syntax which is similar to ordinary algebra.<sup>2</sup> GEMPACK solves the system of nonlinear equations arising from MMRF by converting it to an Initial Value problem and then using one of the standard methods, including Euler and midpoint (see, for example, Press, Flannery, Teukolsky and Vetterling 1986), for solving such problems.

Writing down the equation system of MMRF in a linear (percentage-change) form has advantages from computational and economic standpoints. Linear systems are easy for computers to solve. This allows for the specification of detailed models, consisting of many thousands of equations, without incurring computational constraints. Further, the size of the system can be reduced by using model equations to substitute out those variables which may be of secondary importance for any given experiment. In a linear system, it is easy to rearrange the equations to obtain explicit formulae for those variables, hence the process of substitution is straightforward.

Compared to their levels counterparts, the economic intuition of the percentage-change versions of many of the model's equations is relatively transparent.<sup>3</sup> In addition, when interpreting the results of the linear system, simple share-weighted relationships between variables can be exploited to perform back-of-the-envelope calculations designed to reveal the key cause-effect relationships responsible for the results of a particular experiment.

The potential cost of using a linearised representation is the presence of linearisation error in the model's results when the perturbation from the initial solution is large. As mentioned above, GEMPACK overcomes this problem by a multistep solution procedure such as Euler or midpoint. The accuracy of a solution is a positive function of the number of steps applied. Hence, the degree of desired accuracy can be determined by the model user in the choice of the number of steps in the multistep procedure.<sup>4</sup>

#### *Notational and computational conventions*

In this Chapter we present the percentage-change equations of MMRF. Each MMRF equation is linear in the percentage-changes of the model's variables. We distinguish between the percentage change in a variable and its levels value by

<sup>2</sup> The TABLO version of MMRF is presented in the Appendix to Chapter 3.

<sup>3</sup> See Horridge, Parmenter and Pearson (1993) for an example based on input demands given CES production technology.

<sup>4</sup> See Harrison and Pearson (1994) for an introduction to the solution methods (including Euler) available in GEMPACK. For details on the Euler method, including the Richardson extrapolation, see Dixon, Parmenter, Sutton and Vincent (DPSV, 1982) Chs. 2 & 5, DPPW (1992) Chs. 3, and Horridge, Parmenter and Pearson (1993).

using lower-case script for percentage change and upper-case script for levels. Our definition of the percentage change in variable X is therefore written as

$$x = 100 \left( \frac{\Delta X}{X} \right)$$

In deriving the percentage-change equations from the nonlinear equations, we use three rules:

- the product rule,  $X = \beta YZ \Rightarrow x = y + z$ , where  $\beta$  is a constant,
- the power rule,  $X = \beta Y^\alpha \Rightarrow x = \alpha y$ , where  $\alpha$  and  $\beta$  are constants, and
- the sum rule,  $X = Y + Z \Rightarrow Xx = Yy + Zz$ .

As mentioned above, the MMRF results are reported as percentage deviations in the model's variables from an initial solution. With reference to the above equations, the percentage changes  $x$ ,  $y$  and  $z$  represent deviations from their levels values  $X$ ,  $Y$  and  $Z$ . The levels values ( $X$ ,  $Y$  and  $Z$ ) are solutions to the models underlying levels equations. Using the product-rule equation as an example, values of 100 for  $X$ , 10 for  $Y$  and 5 for  $Z$  represent an initial solution for a value of 2 for  $\beta$ . Now assume that we perturb our initial solution by increasing the values of  $Y$  and  $Z$  by 3 per cent and 2 per cent respectively, i.e., we set  $y$  and  $z$  at 3 and 2. The linear representation of the product-rule equation would give a value of  $x$  of 5, with the interpretation that the initial value of  $X$  has increased by 5 per cent for a 3 per cent increase in  $Y$  and a 2 per cent increase in  $Z$ . Values of 5 for  $x$ , 3 for  $y$  and 2 for  $z$  in the corresponding percentage change equation means that the levels value of  $X$  has been perturbed from 100 to 105,  $Y$  from 10 to 10.3 and  $Z$  from 5 to 5.1.

In the above example, the reader will notice that while satisfying the percentage-change equations, updating the levels values of  $X$ ,  $Y$  and  $Z$  by their percentage changes does not satisfy the levels form of the product-rule equation i.e.,  $105 \neq 2 \times 10.3 \times 5.1$ . Given the percentage changes to  $Y$  and  $Z$ , the solution to the nonlinear equation is  $X = 105.06$ , giving a linearisation error of 0.06 (i.e.,  $0.06 = 105.06 - 105$ ). GEMPACK eliminates the linearisation error by the application of a multistep procedure which exploits a positive relationship between the size of the perturbation from the initial solution and the size of the linearisation error. The principle of the Euler version of the multistep solution method can be illustrated using our above example. Instead of increasing the values of  $Y$  and  $Z$  by 3 per cent and 2 per cent, let us break the perturbation into two steps, first increasing  $y$  and  $z$  by half the desired amount, i.e., 1.5 per cent and 1.0 per cent respectively. Solving the linear equation gives a value for  $x$  of 2.5 per cent. Updating the value of  $X$  by 2.5 per cent gives an intermediate value of  $X$  of 102.5 [i.e.,  $100 \times (1 + 2.5/100)$ ]. Now apply the remainder of our desired perturbation to  $Y$  and  $Z$ . The percentage increase in  $y$  is 1.4778 per cent

(i.e.,  $100 \times 0.15/10.15^5$ ) and the percentage change in  $z$  is 0.9901 per cent (i.e.,  $100 \times 0.05/5.05$ ), giving a value for  $x$  (in our second step) of 2.4679 per cent. Updating our intermediate value of  $X$  by 2.4679 per cent, gives a final value of  $X$  of 105.045, which is close to the solution of the nonlinear equation of 105.06. We can further improve the accuracy of our solution by implementing more steps and by applying an extrapolation procedure.

In the percentage-change form of the power-rule equation, a constant  $\alpha$  appears as a coefficient. In the percentage-change form of the sum-rule equation, the levels values of the variables appear as coefficients. By dividing by  $X$ , this last equation can be rewritten so that  $x$  is a share-weighted average of  $y$  and  $z$ . There are two main types of coefficients in the linear equation system of MMRF: (i) price elasticities and (ii) shares of levels values of variables. Two price elasticity coefficients appear in MMRF: elasticities of substitution and own-price elasticities.<sup>6</sup> In the MMRF equation system, elasticities of substitution are identified by the Greek symbol,  $\sigma$ , and own-price elasticities are identified by the prefix ELAST. Equations with share coefficients are typically written in the form of the sum-rule equation above. Coefficients associated with shares are levels values and therefore are written in upper-case script.

The percentage-change equation system of MMRF is given in Table 2.1. The equations of Table 2.1 are presented in standard algebraic syntax. Each equation has an identifier beginning with the prefix E\_. Using the equation identifiers, the reader can cross reference the equations in Table 2.1 with the equations of the annotated TABLO file in the Appendix to Chapter 3. In Table 2.1, below the identifier in brackets, the section in which the equation appears in the annotated TABLO file is listed. The annotated TABLO file of Chapter 3 is a reproduction of the computer implementation of MMRF. The model's variables are listed in Table 2.2. Descriptions of the model's coefficients appear in Table 2.3, and Table 2.4 describes the sets used in the model.

The remainder of this Chapter is devoted to the exposition of the MMRF equation system beginning, in section 2.2, with the equations of the CGE core.

<sup>5</sup> Note that in our first step we have also updated the values of  $Y$  and  $Z$ , e.g., after the first step, our updated value of  $Y$  is  $10.15 = 10 \times 1.5/100$ .

<sup>6</sup> For example, if, in the power-rule equation,  $X$  is quantity demanded and  $Y$  is the price of  $X$ ,  $\alpha$  could be interpreted as a (constant) own-price elasticity of demand.

## 2.2. The CGE core<sup>7</sup>

The CGE core is based on ORANI, a single-region model of Australia (Dixon, Parmenter, Sutton and Vincent 1982). Each regional economy in MMRF looks like an ORANI model. However, unlike the single-region ORANI model, MMRF includes interregional linkages. The transformation of ORANI into the CGE core of MMRF, in principle, follows the steps by which the stylised single-region model of Chapter 1 was transformed into the stylised multiregional model.

### *A schematic representation of the CGE core*

Figure 2.1 is a schematic representation of the CGE core's input-output database. It reveals the basic structure of the CGE core. The columns identify the following agents:

- (1) domestic producers divided into J industries in Q regions;
- (2) investors divided into J industries in Q regions;
- (3) a single representative household for each of the Q regions;
- (4) an aggregate foreign purchaser of exports;
- (5) an other demand category corresponding to Q regional governments; and
- (6) an other demand category corresponding to Federal government demands in the Q regions.

The rows show the structure of the purchases made by each of the agents identified in the columns. Each of the I commodity types identified in the model can be obtained within the region, from other regions or imported from overseas. The source-specific commodities are used by industries as inputs to current production and capital formation, are consumed by households and governments and are exported. Only domestically produced goods appear in the export column. R of the domestically produced goods are used as margin services (domestic trade and transport & communication) which are required to transfer commodities from their sources to their users. Commodity taxes are payable on the purchases. As well as intermediate inputs, current production requires inputs of three categories of primary factors: labour (divided into M occupations), fixed capital and agricultural land. The other costs category covers various miscellaneous industry expenses. Each cell in the input-output table contains the name of the corresponding matrix of the values (in some base year) of flows of commodities, indirect taxes or primary factors to a group of users. For example, MAR2 is a 5-dimensional array showing the cost of the R margins services on the flows of I goods, both domestically and imported (S), to I investors in Q regions.

Figure 2.1 is suggestive of the theoretical structure required of the CGE core. The theoretical structure includes: demand equations are required for our

---

<sup>7</sup> Section 2.2. draws on Horridge, Parmenter and Pearson (1993).

		ABSORPTION MATRIX					
		1	2	3	4	5	6
		Producers	Investors	Household	Export	Regional Govt.	Federal Govt.
Size		$\leftarrow J \times Q \rightarrow$	$\leftarrow J \times Q \rightarrow$	$\leftarrow Q \rightarrow$	$\leftarrow 1 \rightarrow$	$\leftarrow Q \rightarrow$	$\leftarrow Q \rightarrow$
Basic Flows	$\uparrow$ $I \times S$ $\downarrow$	BAS1	BAS2	BAS3	BAS4	BAS5	BAS6
Margins	$\uparrow$ $I \times S \times R$ $\downarrow$	MAR1	MAR2	MAR3	MAR4	MAR5	MAR6
Taxes	$\uparrow$ $I \times S$ $\downarrow$	TAX1	TAX2	TAX3	TAX4	TAX5	TAX6
Labour	$\uparrow$ M $\downarrow$	LABR	I = Number of Commodities J = Number of Industries M = Number of Occupation Types Q = Number of Domestic Regions R = Number of Commodities used as Margins S = 9: 8 × Domestic Regions plus 1 × Foreign Import				
Capital	$\uparrow$ 1 $\downarrow$	CPTL					
Land	$\uparrow$ 1 $\downarrow$	LAND					
Other Costs	$\uparrow$ 1 $\downarrow$	OCTS					

Figure 2.1. The CGE core input-output database

six users; equations determining commodity and factor prices; market clearing equations; definitions of commodity tax rates. In common with ORANI, the equations of MMRF's CGE core can be grouped according to the following classification:

- *producer's demands for produced inputs and primary factors;*
- *demands for inputs to capital creation;*
- *household demands;*
- *export demands;*

- *government demands;*
- *demands for margins;*
- *zero pure profits in production and distribution;*
- *market-clearing conditions for commodities and primary factors; and*
- *indirect taxes;*
- *Regional and national macroeconomic variables and price indices.*

*Naming system for variables of the CGE core*

In addition to the notational conventions described above in section 2.1, the following conventions are followed (as far as possible) in naming variables of the CGE core. Names consist of a prefix, a main user number and a source dimension. The prefixes are:

- a  $\Leftrightarrow$  technological change/change in preferences;
- del  $\Leftrightarrow$  ordinary (rather than percentage) change;
- f  $\Leftrightarrow$  shift variable;
- nat  $\Leftrightarrow$  a national aggregate of the corresponding regional variable;
- p  $\Leftrightarrow$  prices;
- x  $\Leftrightarrow$  quantity demanded;
- xi  $\Leftrightarrow$  price deflator;
- y  $\Leftrightarrow$  investment;
- z  $\Leftrightarrow$  quantity supplied.

The main user numbers are:

- 1  $\Leftrightarrow$  firms, current production;
- 2  $\Leftrightarrow$  firms, capital creation;
- 3  $\Leftrightarrow$  households;
- 4  $\Leftrightarrow$  foreign exports;
- 5  $\Leftrightarrow$  regional government;
- 6  $\Leftrightarrow$  Federal government

The number 0 is also used to denote basic prices and values. The source dimensions are:

- a  $\Leftrightarrow$  all sources, i.e., 8 regional sources and foreign;
- r  $\Leftrightarrow$  regional sources only;
- t  $\Leftrightarrow$  two sources, i.e., a domestic composite source and foreign;
- c  $\Leftrightarrow$  domestic composite source only;
- o  $\Leftrightarrow$  domestic/foreign composite source only.

The following are examples of the above notational conventions:

- p1a  $\Leftrightarrow$  price of commodities (p), from all nine sources (a) to be used by firms in current production (1);
- x2c  $\Leftrightarrow$  demand for domestic composite (c) commodities (x) to be used by firms for capital creation.

Variable names may also include an (optional) suffix descriptor. These are:

- cap  $\Leftrightarrow$  capital;

imp  $\Leftrightarrow$  imports;  
 lab  $\Leftrightarrow$  labour;  
 land  $\Leftrightarrow$  agricultural land;  
 lux  $\Leftrightarrow$  linear expenditure system (supernumerary part);  
 marg  $\Leftrightarrow$  margins;  
 oct  $\Leftrightarrow$  other cost tickets;  
 prim  $\Leftrightarrow$  all primary factors (land, labour or capital);  
 sub  $\Leftrightarrow$  linear expenditure system (subsistence part);

Sections 2.2.1 to 2.2.14 outline the structure of the CGE core.

### 2.2.1. Production: demand for inputs to the production process

MMRF recognises two broad categories of inputs: intermediate inputs and primary factors. Firms in each regional sector are assumed to choose the mix of inputs which minimises the costs of production for their level of output. They are constrained in their choice of inputs by a three-level nested production technology (Figure 2.2). At the first level, the intermediate-input bundles and the primary-factor bundles are used in fixed proportions to output. These bundles are formed at the second level. Intermediate input bundles are constant-elasticity-of-substitution (CES) combinations of international imported goods and domestic goods. The primary-factor bundle is a CES combination of labour, capital and land. At the third level, inputs of domestic goods are formed as CES combinations of goods from each of the eight regions, and the input of labour is formed as a CES combination of inputs of labour from eight different occupational categories. We describe the derivation of the input demand functions working upwards from the bottom of the tree in Figure 2.2. We begin with the intermediate-input branch.

#### *Demands for intermediate inputs*

At the bottom of the nest, industry  $j$  in region  $q$  chooses intermediate input type  $i$  from domestic region  $s$  ( $X_{i,s,j,q}$ ) to minimise the costs

$$\sum_{s=1}^8 P_{i,s,j,q} X_{i,s,j,q}, \quad i,j=1,\dots,13 \quad q=1,\dots,8, \quad (2.1)$$

of a composite domestic bundle

$$X_{i,j,q} = \text{CES}(X_{i,1,j,q}, \dots, X_{i,8,j,q}), \quad i,j=1,\dots,13 \quad q=1,\dots,8, \quad (2.2)$$

where the composite domestic bundle ( $X_{i,j,q}$ ) is exogenous at this level of the nest. The notation  $\text{CES}(\ )$  represents a CES function defined over the set of variables enclosed in the brackets. The CES specification means that inputs of the same commodity type produced in different regions are not perfect substitutes for one another. This is an application of the so-called Armington

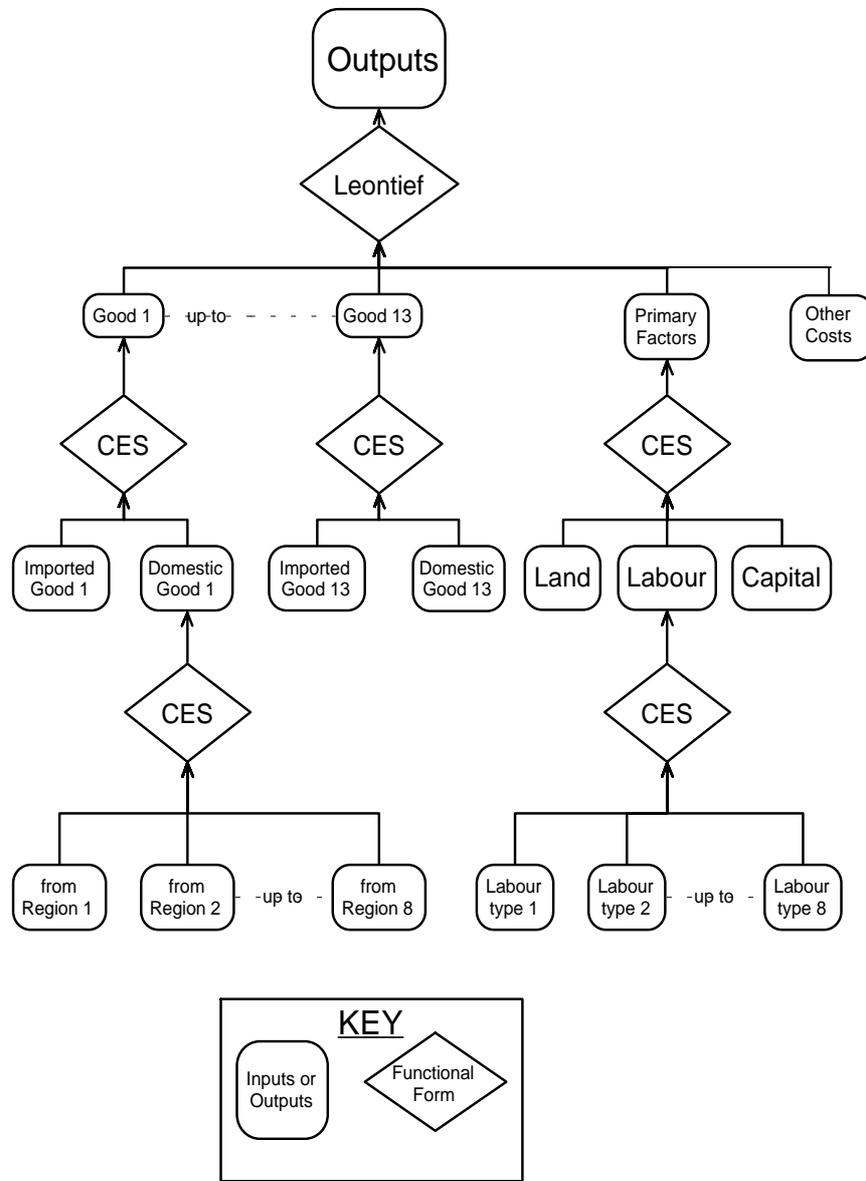


Figure 2.2. Production technology for a regional sector in MRF

(1969 1970) specification typically imposed on the use of domestically produced commodities and foreign-imported commodities in national CGE models such as ORANI.

By solving the above problem, we generate the industries' demand equations for domestically produced intermediate inputs to production.<sup>8</sup> The percentage-change form of these demand equations is given by equations E\_x1a1 and E\_p1c. The interpretation of equation E\_x1a1 is as follows: the commodity demand from each regional source is proportional to demand for the composite  $X1C_{i,j,q}$  and to a price term. The percentage-change form of the price term is an elasticity of substitution,  $\sigma 1C_i$ , multiplied by the percentage change in a price ratio representing the price from the regional source relative to the cost of the regional composite, i.e., an average price of the commodity across all regional sources. Lowering of a source-specific price, relative to the average, induces substitution in favour of that source. The percentage change in the average price,  $p1c_{i,j,q}$ , is given by equation E\_p1c. In E\_p1c, the coefficient  $S1A_{i,s,j,q}$  is the cost share in of the  $i$ th commodity from the  $s$ th regional source in the  $j$ th industry from region  $q$ 's total cost of the  $i$ th commodity from all regional sources. Hence,  $p1c_{i,j,q}$  is a cost-weighted Divisia index of individual prices from the regional sources.

At the next level of the production nest, firms decide on their demands for the domestic-composite commodities and the foreign imported commodities following a pattern similar to the previous nest. Here, the firm chooses a cost-minimising mix of the domestic-composite commodity and the foreign imported commodity

$$P1A_{i,foreign,j,q} X1A_{i,foreign,j,q} + P1C_{i,j,q} X1C_{i,j,q}, \quad i,j=1,\dots,13 \quad q=1,\dots,8, \quad (2.3)$$

where the subscript 'foreign' refers to the foreign import, subject to the production function

$$X1O_{i,j,q} = CES(X1A_{i,foreign,j,q}, \dots, X1C_{i,j,q}), \quad i,j=1,\dots,13 \quad q=1,\dots,8. \quad (2.4)$$

As with the problem of choosing the domestic-composite, the Armington assumption is imposed on the domestic-composite and the foreign import by the CES specification in equation 2.4.

The solution to the problem specified by equations 2.3 and 2.4 yields the input demand functions for the domestic-composite and the foreign import represented in their percentage-change form by equations E\_x1c, E\_x1a2, and E\_p1o. The first two equations show, respectively, that the demands for the domestic-composite commodity ( $X1C_{i,j,q}$ ) and for the foreign import

<sup>8</sup> For details on the solution of input demands given a CES production function, and the linearisation of the resulting levels equation, see Dixon, Bowles and Kendrick (1980), DPSV (1982), DPPW (1992) and Horridge, Parmenter and Pearson (1993).

( $X1A_{i,foreign,j,q}$ ) are proportional to demand for the domestic-composite/foreign-import aggregate ( $X1O_{i,j,q}$ ) and to a price term. The  $X1O_{i,j,q}$  are exogenous to the producer's problem at this level of the nest. Common with the previous nest, the change form of the price term is an elasticity of substitution,  $\sigma 1O_i$ , multiplied by a price ratio representing the change in the price of the domestic-composite (the  $p1c_{i,j,q}$  in equation E\_x1c) or of the foreign import (the  $p1a_{i,foreign,j,q}$  in equation E\_x1a2) relative to price of the domestic-composite/foreign-import aggregate (the  $p1o_{i,j,q}$  in equations E\_x1c and E\_x1a2). The percentage change in the price of the domestic-composite/foreign-import aggregate, defined in equation E\_p1o is again a Divisia index of the individual prices. We now turn our attention to the primary-factor branch of the input-demand tree of Figure 2.2.

#### *Demands for primary factors*

At the lowest-level nest in the primary-factor branch of the production tree in Figure 2.2, producers choose a composition of eight occupation-specific labour inputs to minimise the costs of a given composite labour aggregate input. The demand equations for labour of the various occupation types are derived from the following optimisation problem for the  $j$ th industry in the  $q$ th region.

Choose inputs of occupation-specific labour type  $m$ ,  $X1LABOI_{j,q,m}$ , to minimise total labour cost

$$\sum_{m=1}^8 P1LABOI_{j,q,m} X1LABOI_{j,q,m}, \quad j=1, \dots, 13, q=1, \dots, 8, \quad (2.5)$$

subject to,

$$EFFLAB_{j,q} = CES(X1LABOI_{j,q,m}), \quad j=1, \dots, 13 \quad q, m=1, \dots, 8, \quad (2.4)$$

regarding as exogenous to the problem the price paid by the  $j$ th regional industry for the each occupation-specific labour type ( $P1LABOI_{j,q,m}$ ) and the regional industries' demand for the effective labour input ( $EFFLAB_{j,q}$ ).

The solution to this problem, in percentage-change form, is given by equations E\_x1laboi and E\_p1lab. Equation E\_x1laboi indicates that the demand for labour type  $m$  is proportional to the demand for the effective composite labour demand and to a price term. The price term consists of an elasticity of substitution,  $\sigma 1LAB_{j,q}$ , multiplied by the percentage change in a price ratio representing the wage of occupation  $m$  ( $p1laboi_{j,q,m}$ ) relative to the average wage for labour in industry  $j$  of region  $q$  ( $p1lab_{j,q}$ ). Changes in the relative wages of the occupations induce substitution in favour of relatively cheapening occupations. The percentage change in the average wage is given by equation E\_p1lab where the coefficients  $S1LABOI_{j,q,m}$  are value shares of occupation  $m$  in the total wage bill of industry  $j$  in region  $q$ . Thus,  $p1lab_{j,q}$  is a Divisia index of the  $p1laboi_{j,q,m}$ . Summing the percentage changes in occupation-specific labour demands across occupations, using the  $S1LABOI_{j,q,m}$  shares, for

each industry gives the percentage change in industry labour demand ( $labind_{j,q}$ ) in equation  $E\_labind$ .

At the next level of the primary-factor branch of the production nest, we determine the composition of demand for primary factors. Their derivation follows the same CES pattern as the previous nests. Here, total primary factor costs

$$PILAB_{j,q}EFFLAB_{j,q} + PICAP_{j,q}CURCAP_{j,q} + PILAND_{j,q}N_{j,q} \\ j = 1, \dots, 13, \quad q = 1, \dots, 8,$$

where  $PICAP_{j,q}$  and  $PILAND_{j,q}$  are the unit costs of capital and agricultural land and  $CURCAP_{j,q}$  and  $N_{j,q}$  are industry's demands for capital and agricultural land, are minimised subject to the production function

$$X1PRIM_{j,q} = CES \left( \frac{EFFLAB_{j,q}}{A1LAB_{j,q}}, \frac{CURCAP_{j,q}}{A1CAP_{j,q}}, \frac{N_{j,q}}{A1LAND_{j,q}} \right) \\ j = 1, \dots, 13, \quad q = 1, \dots, 8,$$

where  $X1PRIM_{j,q}$  is the industry's overall demand for primary factors. The above production function allows us to impose factor-specific technological change via the variables  $A1LAB_{j,q}$ ,  $A1CAP_{j,q}$  and  $A1LAND_{j,q}$ .

The solution to the problem, in percentage-change form is given by equations  $E\_efflab$ ,  $E\_curcap$ ,  $E\_n$  and  $E\_xi\_fac$ . From these equations, we see that for a given level of technical change, industries' factor demands are proportional to overall factor demand ( $X1PRIM_{j,q}$ ) and a relative price term. In change form, the price term is an elasticity of substitution ( $\sigma1FAC_{j,q}$ ) multiplied by the percentage change in a price ratio representing the unit cost of the factor relative to the overall effective cost of primary factor inputs to the  $j$ th industry in region  $q$ . Changes in the relative prices of the primary factors induce substitution in favour of relatively cheapening factors. The percentage change in the average effective cost ( $xi\_fac_{j,q}$ ), given by equation  $E\_xi\_fac$ , is again a cost-weighted Divisia index of individual prices and technical changes.

#### *Demands for primary-factor and commodity composites*

We have now arrived at the topmost input-demand nest of Figure 2.2. Commodity composites, the primary-factor composite and 'other costs' are combined using a Leontief production function given by

$$Z_{j,q} = \frac{1}{A1_{j,q}} \times \text{MIN} \left( X1O_{i,j,q}, \frac{X1PRIM_{j,q}}{A1PRIM_{j,q}}, \frac{X1OCT_{j,q}}{A1OCT_{j,q}} \right) \\ i, j = 1, \dots, 13, \quad q = 1, \dots, 8.$$

In the above production function,  $Z_{j,q}$  is the output of the  $j$ th industry in region  $q$ , the  $A1_{j,q}$  are Hicks-neutral technical change terms,  $X1OCT_{j,q}$  are the industries'

demands for 'other cost tickets'<sup>9</sup> and  $A1OCT_{j,q}$  which are the industry-specific technological change associated with other cost tickets.

As a consequence of the Leontief specification of the production function, each of the three categories of inputs identified at the top level of the nest are demanded in direct proportion to  $Z_{j,q}$  as indicated in equations  $E\_x1o$ ,  $E\_x1prim$  and  $E\_x1oct$ .

### 2.2.2. Demands for investment goods

Capital creators for each regional sector combine inputs to form units of capital. In choosing these inputs they cost minimise subject to technologies similar to that in Figure 2.2. Figure 2.3 shows the nesting structure for the production of new units of fixed capital. Capital is assumed to be produced with inputs of domestically produced and imported commodities. No primary factors are used directly as inputs to capital formation. The use of primary factors in capital creation is recognised through inputs of the construction commodity (service).

The model's investment equations are derived from the solutions to the investor's three-part cost-minimisation problem. At the bottom level, the total cost of domestic-commodity composites of good  $i$  ( $X2C_{i,j,q}$ ) is minimised subject to the CES production function

$$X2C_{i,j,q} = CES(X2A_{i,1,j,q}, \dots, X2A_{i,8,j,q}) \quad i, j = 1, \dots, 13 \quad q = 1, \dots, 8,$$

where the  $XAC_{i,1,j,q}$  are the demands by the  $j$ th industry in the  $q$ th region for the  $i$ th commodity from the  $s$ th domestic region for use in the creation of capital.

Similarly, at the second level of the nest, the total cost of the domestic/foreign-import composite ( $X2O_{i,j,q}$ ) is minimised subject the CES production function

$$X2O_{i,j,q} = CES(X2A_{i,foreign,j,q}, \dots, X2C_{i,j,q}), \quad i, j = 1, \dots, 13 \quad q = 1, \dots, 8,$$

where the  $X2A_{i,foreign,j,q}$  are demands for the foreign imports.

The equations describing the demand for the source-specific inputs ( $E\_x2a1$ ,  $E\_x2a2$ ,  $E\_x2c$ ,  $E\_p2c$  and  $E\_p2o$ ) are similar to the corresponding equations describing the demand for intermediate inputs to current production (i.e.,  $E\_x1a1$ ,  $E\_x1c$ ,  $E\_p1c$  and  $E\_p2o$ ).

At the top level of the nest, the total cost of commodity composites is minimised subject to the Leontief function

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<sup>9</sup> Demand for other cost tickets includes demand for working capital and production taxes.

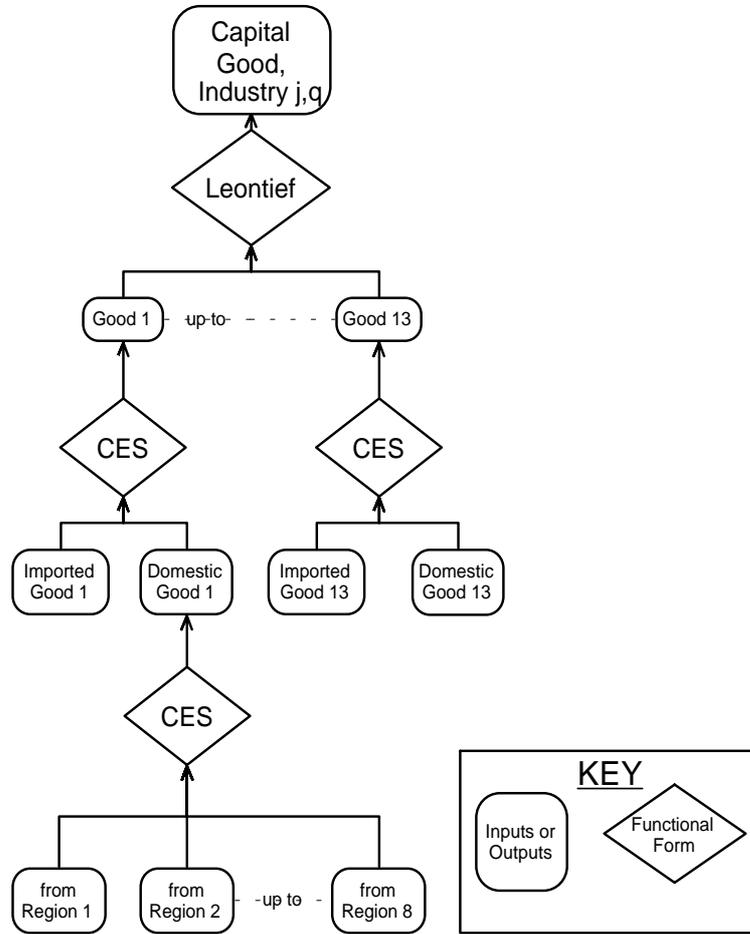


Figure 2.3. Structure of investment demand

$$Y_{j,q} = \text{MIN} \left( \frac{X2O_{i,j,q}}{A2IND_{i,j,q}} \right) \quad i,j = 1,\dots,13, \quad q = 1,\dots,8. \quad (2.5)$$

where the total amount of investment in each industry ( $Y_{j,q}$ ) is exogenous to the cost-minimisation problem and the  $A2IND_{i,j,q}$  are technological-change variables in the use of inputs in capital creation. The resulting demand equations for the composite inputs to capital creation ( $E_{x2o}$ ) correspond to the demand equations for the composite input to current production (i.e.,  $E_{x1o}$ ).

Determination of the number of units of capital to be formed for each regional industry (i.e., determination of  $Y_{j,q}$ ) depends on the nature of the experiment being undertaken. For comparative-static experiments, a distinction is drawn between the short run and long run. In short-run experiments (where the year of interest is one or two years after the shock to the economy), capital stocks in regional industries and national aggregate investment are exogenously determined. Aggregate investment is distributed between the regional industries on the basis of relative rates of return.

In long-run comparative-static experiments (where the year of interest is five or more years after the shock), it is assumed that the aggregate capital stock adjusts to preserve an exogenously determined economy-wide rate of return, and that the allocation of capital across regional industries adjusts to satisfy exogenously specified relationships between relative rates of return and relative capital growth. Industries' demands for investment goods is determined by exogenously specified investment/capital ratios.

MMRF can also be used to perform forecasting experiments. Here, regional industry demand for investment is determined by an assumption on the rate of growth of industry capital stock and an accumulation relation linking capital stock and investment between the forecast year and the year immediately following the forecast year.

Details of the determination of investment and capital are provided in section 2.x. below.

### 2.2.3. Household demands

Each regional household determines the optimal composition of its consumption bundle by choosing commodities to maximise a Stone-Geary utility function subject to a household budget constraint. A *Keynesian* consumption function determines regional household expenditure as a function of household disposable income.

Figure 2.4 reveals that the structure of household demand follows nearly the same nesting pattern as that of investment demand. The only difference is that commodity composites are aggregated by a Stone-Geary, rather than a Leontief function, leading to the linear expenditure system (LES).

The equations for the two lower nests ( $E_{x3a1}$ ,  $E_{x3a2}$ ,  $E_{x3c}$ ,  $E_{p3c}$  and  $E_{p3o}$ ) are similar to the corresponding equations for intermediate and investment demands.

The equations determining the commodity composition of household

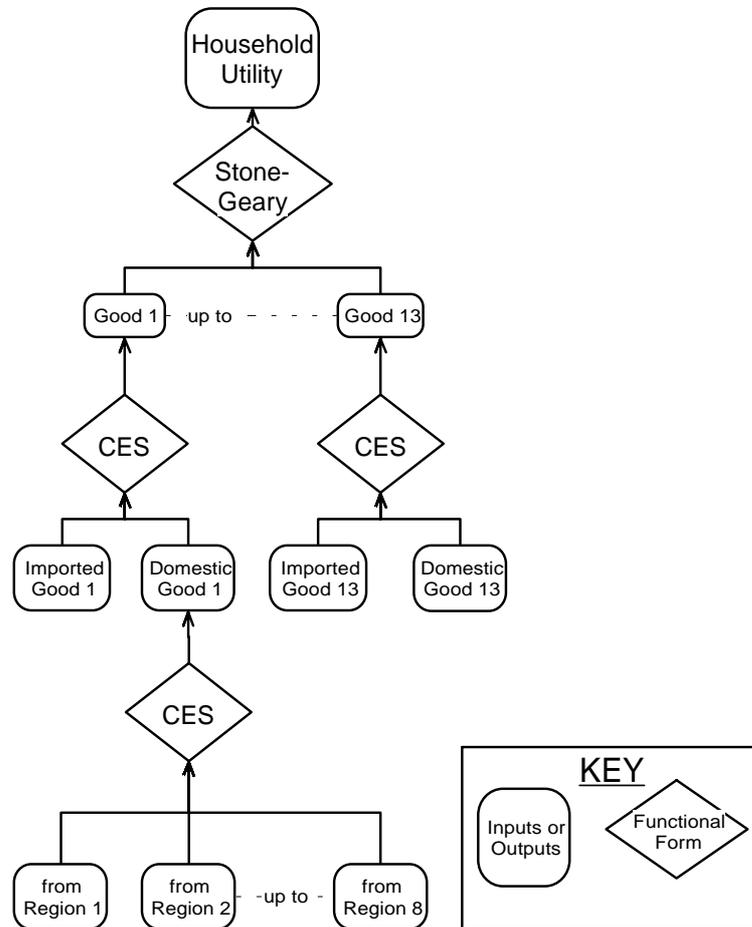


Figure 2.4. Structure of household demand

demand, which is determined by the Stone-Geary nest of the structure, differ from the CES pattern established in sections 2.2.1 and 2.2.2.<sup>10</sup> To analyse the Stone-Geary utility function, it is helpful to divide total consumption of each commodity composite ( $X3O_{i,q}$ ) into two components: a subsistence (or minimum) part ( $X3SUB_{i,q}$ ) and a luxury (or supernumerary) part ( $X3LUX_{i,q}$ )

<sup>10</sup> For details on the derivation of demands in the LES, see Dixon, Bowles and Kendrick (1980) and Horridge, Parmenter and Pearson (1993).

$$X3O_{i,q} = X3SUB_{i,q} + X3LUX_{i,q}, \quad i = 1, \dots, 13, \quad q = 1, \dots, 8. \quad (2.6)$$

A feature of the Stone-Geary function is that only the luxury components effect per-household utility (UTILITY), which has the Cobb-Douglas form

$$UTILITY_q = \frac{1}{QHOUS_q} \sum_{i=1}^{13} X3LUX_{i,q}^{A3LUX_{i,q}} \quad q = 1, \dots, 8, \quad (2.7)$$

where

$$\sum_{i=1}^{13} A3LUX_{i,q} = 1 \quad q = 1, \dots, 8.$$

Because the Cobb-Douglas form gives rise to exogenous budget shares for spending on luxuries

$$P3O_{i,q} X3LUX_{i,q} = A3LUX_{i,q} LUXEXP_q \quad i = 1, \dots, 13 \quad q = 1, \dots, 8, \quad (2.8)$$

$A3LUX_{i,q}$  may be interpreted as the marginal budget share of total spending on luxuries ( $LUXEXP_q$ ). Rearranging equation (2.8), substituting into equation (2.6) and linearising gives equation  $E_{x3o}$ , where the subsistence component is proportional to the number of households and to a taste-change variable ( $a3sub_{i,q}$ ), and  $ALPHA_{i,q}$  is the share of supernumerary expenditure on commodity  $i$  in total expenditure on commodity  $i$ . Equation  $E_{utility}$  is the percentage-change form of the utility function (2.7).

Equations  $E_{a3sub}$  and  $E_{a3lux}$  provide default settings for the taste-change variables ( $a3sub_{i,q}$  and  $a3lux_{i,q}$ ), which allow for the average budget shares to be shocked, via the  $a3com_{i,q}$ , in a way that preserves the pattern of expenditure elasticities.

The equations just described determine the composition of regional household demands, but do not determine total regional consumption. As mentioned, total household consumption is determined by regional household disposable income. The determination of regional household disposable income and regional total household consumption is described in section 2.xx.

#### 2.2.4. Foreign export demands

To model export demands, commodities in MMRF are divided into two groups: the traditional exports, agriculture and mining, which comprise the bulk of exports; and the remaining, non-traditional exports. Exports account for relatively large shares in total sales of agriculture and mining, but for relatively small shares in total sales for non-traditional-export commodities.

The traditional-export commodities ( $X4R_{i,s}$ ,  $i \in \text{agricult, mining}$ ) are modelled as facing downwardly-sloping foreign-export demand functions

$$X4R_{i,s} = FEQ_i \left( \frac{P4R_{i,s}}{FEP_i NATFEP} \right)^{EXP\_ELAST_i} \quad i = 1, 2, s = 1, \dots, 13, \quad (2.9)$$

where  $EXP\_ELAST_i$  is the (constant) own-price elasticity of foreign-export demand. As  $EXP\_ELAST_i$  is negative, equation (2.9) says that traditional exports are a negative function of their prices on world markets ( $P4R_{i,s}$ ). The variables  $FEQ_i$  and  $FEP_i$  allow for horizontal (quantity) and vertical (price) shifts in the demand schedules. The variable  $NATFEP$  allows for an economy-wide vertical shift in the demand schedules. The percentage-change form of (2.9) is given by  $E\_x4r$ .

In MMRF the commodity composition of aggregate non-traditional exports is exogenised by treating non-traditional exports as a Leontief aggregate (equation  $E\_nt\_x4r$ ). Total demand is related to the average price via a constant-elasticity demand curve, similar to those for traditional exports (see equations  $E\_aggnt\_x4r$  and  $E\_aggnt\_p4r$ ).

#### 2.2.5. Government consumption demands

Equations  $E\_x5a$  and  $E\_x6a$  determine State government and Federal government demands (respectively) for commodities for current consumption. State government consumption can be modelled to preserve a constant ratio with State private consumption expenditure by exogenising the 'f5' variables in equation  $E\_x5a$ . Likewise, Federal government consumption expenditure can be set to preserve a constant ratio with national private consumption expenditure by exogenising the 'f6' variables in equation  $E\_x6a$ .

#### 2.2.6. Demands for margins

Equations  $E\_x1marg$ ,  $E\_x2marg$ ,  $E\_x3marg$ ,  $E\_x4marg$ ,  $E\_x5marg$  and  $E\_x6marg$  give the demands, of our six users, for margins. Two margin commodities are recognised in MMRF: transport & communication and finance. These commodities, in addition to being consumed directly by the users (e.g., consumption of transport when taking holidays or commuting to work), are also consumed to facilitate trade (e.g., the use of transport to ship commodities from point of production to point of consumption). The latter type of demand for transport & communication and finance are the so-called demands for margins. The margin demand equations in MMRF indicate that the demands for margins are proportional to with the commodity flows with which the margins are associated.

#### 2.2.7. Prices

As is typical of ORANI-style models, the price system underlying MMRF is based on two assumptions: (i) that there are no pure profits in the production or distribution of commodities, and (ii) that the price received by the producer is uniform across all customers.

Also in the tradition of ORANI is presence of two types of price equations: (i) zero pure profits in current production, capital creation and importing and (ii) zero pure profits in the distribution of commodities to users. Zero pure profits in current production, capital creation and importing is imposed by setting unit prices received by producers of commodities (i.e., the commodities' basic values) equal to unit costs. Zero pure profits in the distribution of commodities is imposed by setting the prices paid by users equal to the commodities' basic value plus commodity taxes and the cost of margins.

*Zero pure profits in production, capital creation and importing*

Equations  $E_{p0a}$  and  $E_a$  impose the zero pure profits condition in current production. Given the constant returns to scale which characterise the model's production technology, equation  $E_{p0a}$  defines the percentage change in the price received per unit of output by industry  $j$  of region  $q$  ( $p0a_{j,q}$ ) as a cost-weighted average of the percentage changes in effective input prices. The percentage changes in the effective input prices represent (i) the percentage change in the cost per unit of input and (ii) the percentage change in the use of the input per unit of output (i.e., the percentage change in the technology variable). These cost-share-weighted averages define percentage changes in average costs. Setting output prices equal to average costs imposes the competitive zero pure profits condition.

Equation  $E_{pi}$  imposes zero pure profits in capital creation.  $E_{pi}$  determines the percentage change in the price of new units of capital ( $pi_{j,q}$ ) as the percentage change in the effective average cost of producing the unit.

Zero pure profits in imports of foreign-produced commodities is imposed by Equation  $E_{p0ab}$ . The price received by the importer for the  $i$ th commodity ( $POA_{i,foreign}$ ) is given as product of the foreign price of the import ( $PM_i$ ), the exchange rate ( $NATPHI$ ) and one plus the rate of tariff (the so-called power of the tariff:  $POWTAXM_i$ )<sup>11</sup>.

*Zero pure profits in distribution*

The remaining zero-pure-profits equations relate the price paid by purchasers to the producer's price, the cost of margins and commodity taxes. Six users are recognised in MMRF and zero pure profits in the distribution of commodities to the users is imposed by the equations  $E_{p1a}$ ,  $E_{p2a}$ ,  $E_{p3a}$ ,  $E_{p4r}$ ,  $E_{p5a}$  and  $E_{p6a}$ .

*2.2.8. Market-clearing equations for commodities*

Equations  $E_{mkt\_clear\_margins}$ ,  $E_{mkt\_clear\_nonmarg}$  and  $E_{x0impa}$  impose the condition that demand equals supply for domestically-produced margin and nonmargin commodities and imported commodities respectively. The

<sup>11</sup> If the tariff rate is 20 percent, the power of tariff is 1.20. If the tariff rate is increased from 20 percent to 25 percent, the percentage change in the power of the tariff is 4, i.e.,  $100 \cdot (1.25 - 1.20) / 1.20 = 4$ .

output of regional industries producing margin commodities, must equal the direct demands by the model's six users and their demands for the commodity as a margin. Note that the specification of equation  $E\_mkt\_clear\_margins$  imposes the assumption that margins are produced in the destination region, with the exception that margins on exports and commodities sold to the Federal government are produced in the source region.

The outputs of the nonmargin regional industries are equal to the direct demands of the model's six users. Import supplies are equal to the demands of the users excluding foreigners, i.e., all exports involve some domestic value added.

### 2.2.9. Indirect taxes

Equations  $E\_deltax1$  to  $E\_deltax6$  contain the default rules for setting sales-tax rates for producers ( $E\_deltax1$ ), investors ( $E\_deltax2$ ), households ( $E\_deltax3$ ), exports ( $E\_deltax4$ ), and government ( $E\_deltax5$  and  $E\_deltax6$ ). Sales taxes are treated as ad valorem on the price received by the producer, with the sales-tax variables ( $deltax(i)$ ,  $i=1,\dots,6$ ) being the ordinary change in the percentage tax rate, i.e., the percentage-point change in the tax rate. Thus a value of  $deltax1$  of 20 means the percentage tax rate on commodities used as inputs to current production increased from, say, 20 percent to 40 percent, or from, say, 24 to 44 percent.

For each user, the sales-tax equations allow for variations in tax rates across commodities, their sources and their destinations.

Equations  $E\_taxrev1$  to  $E\_taxrev6$  compute the percentage changes in regional aggregate revenue raised from indirect taxes. The bases for the regional sales taxes are the regional basic values of the corresponding commodity flows. Hence, for any component of sales tax, we can express revenue (TAXREV), in levels, as the product of the base (BAS) and the tax rate (T), i.e.,

$$TAXREV = BAS \times T.$$

Hence,

$$\Delta TAXREV = T \Delta BAS + BAS \Delta T \quad (2.10)$$

The basic value of the commodity can be written as the product the producer's price ( $P0$ ) and the output ( $XA$ )

$$BAS = P0 \times XA. \quad (2.11)$$

Using equation (2.11), we can derive the form of equations  $E\_taxrev1$  to  $E\_taxrev6$  by taking the percentage change of the first two terms in (2.10) and the ordinary change in the last term of (2.10) multiplied by 100

$$\text{TAXREV} \times \text{taxrev} = \text{TAX} \times (\text{p0} + \text{xa}) + \text{BAS} \times \text{deltax}$$

where

$$\text{taxrev} = 100 \left( \frac{\Delta \text{TAXREV}}{\text{TAXREV}} \right)$$

$$\text{TAX} = \text{BAS} \times \text{T}$$

$$\text{p0} = 100 \left( \frac{\Delta \text{P0}}{\text{P0}} \right)$$

$$\text{xa} = 100 \left( \frac{\Delta \text{XA}}{\text{XA}} \right)$$

and

$$\text{deltax} = 100 \times \Delta \text{T}$$

#### 2.2.10. Regional incomes and expenditures

In this section, we outline the derivation of the income and expenditure components of regional gross product. We begin with the nominal income components.

##### *Income-side aggregates of regional gross product*

The income-side components of regional gross product include regional totals of factor payments, other costs and the total yield from commodity taxes. Nominal regional factor income payments are given in equations E\_caprev, E\_labrev and E\_lndrev for payments to capital, labour and agricultural land, respectively. The regional nominal payments to other costs are given in equation E\_octrev.

The derivation of the factor income and other cost regional aggregates are straightforward. Equation E\_caprev, for example is derived as follows. The total value of payments to capital in region q (AGGCAP<sub>q</sub>) is the sum of the payments of the j industries in region q (CAPITAL<sub>j,q</sub>), where the industry payments are a product of the unit rental value of capital (PICAP<sub>j,q</sub>) and the number of units of capital employed (CURCAP<sub>j,q</sub>)

$$\text{AGGCAP}_q = \sum_{j=1}^{13} \text{PICAP}_{j,q} \text{CURCAP}_{j,q}, \quad q = 1, \dots, 8. \quad (2.12)$$

Equation (2.12) can be written in percentage changes as

$$\text{caprev}_q = (1.0/\text{AGGCAP}_q) \sum_{j=1}^{13} \text{CAPITAL}_{j,q} (\text{p1cap}_{j,q} + \text{curcap}_{j,q}),$$

$$q = 1, \dots, 8,$$

giving equation E\_caprev, where the variable caprev<sub>q</sub> is the percentage change in rentals to capital in region q and has the definition,

$$\text{caprev}_q = 100 \left( \frac{\Delta \text{AGGCAP}_q}{\text{AGGCAP}_q} \right) \quad q = 1, \dots, 8.$$

The regional tax-revenue aggregates are given by equations E\_taxind, E\_taxrev6 and E\_taxrevm. E\_taxrev6 has been discussed in section 2.2.9. E\_taxind determines the variable taxind<sub>q</sub>, which is the weighted average of the percentage change in the commodity-tax revenue raised from the purchases of producers, investors, households, foreign exports and the regional government. Equation E\_taxrevm determines tariff revenue on imports absorbed in region q (taxrem<sub>q</sub>). Equation E\_taxrevm is similar in form to equations E\_taxrev1 to E\_taxrev6 discussed in section 2.2.9. However, the tax-rate term in equation E\_taxrevm, powtaxm<sub>q</sub>, refers to the percentage change in the power of the tariff (see footnote 2) rather than the percentage-point change in the tax rate (as is the tax-rate term in the commodity-tax equations of section 2.2.9).

#### *Expenditure-side aggregates of regional gross product*

For each region, MMRF contains equations determining aggregate expenditure by households, investors, regional government, the Federal government and the interregional and foreign trade balances. For each expenditure component (with the exception of the interregional trade flows), we define a quantity index and a price index and a nominal value of the aggregate. For interregional exports and imports, we define an aggregate price index and quantity index only.

As with the income-side components, each expenditure-side component is a definition. As with all definitions within the model, the defined variable and its associated equation could be deleted without affecting the rest of the model. The exception is regional household consumption expenditure (see equations E\_c\_a, E\_cr and E\_xi3). It may seem that the variable c<sub>q</sub> is determined by the equation E\_c\_a. This is not the case. Nominal household consumption is determined either by a consumption function (see equation E\_c\_b in section xxx) or, say, by a constraint on the regional trade balance. Equation E\_c\_a therefore plays the role of a budget constraint on household expenditure.

The equations defining the remaining aggregate regional real expenditures, nominal expenditures and related price indices are listed below in the order: investment, regional government, Federal government, interregional

exports, interregional imports, international exports and international imports. The equations defining quantities are  $E_{ir}$ ,  $E_{othreal5}$ ,  $E_{othreal6}$ ,  $E_{int\_exp}$ ,  $E_{int\_imp}$ ,  $E_{expvol}$  and  $E_{impvol}$ . The equations describing price indices are  $E_{xi2}$ ,  $E_{xi5}$ ,  $E_{xi6}$ ,  $E_{psexp}$ ,  $E_{psimp}$ ,  $E_{xi4}$  and  $E_{xim}$ . The definitions of nominal values are given by equations  $E_{in}$ ,  $E_{othnom5}$ ,  $E_{othnom6}$ ,  $E_{export}$  and  $E_{imp}$  (remembering that the model does not include explicit equations or variables defining aggregate nominal interregional trade flows).

The derivation of the quantity and price aggregates for the interregional trade flows involves an intermediate step represented by equations  $E_{trd}$  and  $E_{psflo}$ . These equations determine inter- and intra- regional nominal trade flows in basic values.<sup>12</sup> To determine the interregional trade flows, say for interregional exports in  $E_{int\_exp}$ , the intraregional trade flow (the second term on the RHS of  $E_{int\_exp}$ ) is deducted from the total of inter- and intra- regional trade flows (the first term on the RHS of  $E_{int\_exp}$ ).

### 2.2.11. Regional wages

The equations in this section have been designed to provide flexibility in the setting of regional wages. Equation  $E_{pllaboi}$  separates the percentage change in the wage paid by industry ( $p1laboi_{j,q,m}$ ) into the percentage change in the wage received by the worker ( $pwagei_{j,q}$ ) and the percentage change in the power of the payroll tax ( $arpi_{j,q}$ ). Equation  $E_{pwagei}$  allows for the indexing of the workers' wages to the national consumer price index ( $natxi3$ , see section xxx). The 'fwage' variables in  $E_{pwagei}$  allow for deviations in the growth of wages relative to the growth of the national consumer price index.

Equation  $E_{wage\_diff}$  allows flexibility in setting movements in regional wage differentials. The percentage change in the wage differential in region  $q$  ( $wag\_diff_q$ ) is defined as the difference the aggregate regional real wage received by workers ( $pwage_q - natxi3$ ) and the aggregate real wage received by workers across all regions ( $natrealwage$ ). Equation  $E_{pwage}$  defines the percentage change in the aggregate regional nominal wage ( $pwage_q$ ) as the average (weighted across industries) of the  $pwagei_{j,q}$  and equation  $E_{natrealw}$  defines the percentage change in the variable  $natrealwage$ .

### 2.2.12. Other regional factor-market definitions

The equations in this section define aggregate regional quantities and prices in the labour and capital markets.

Equations  $E_l$ ,  $E_{kt}$  and  $E_{z\_tot}$  define aggregate regional employment, capital use and value added respectively.  $E_{lambda}$  defines regional employment of each of the eight occupational skill groups.

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<sup>12</sup> The determination in basic values reflects the convention in MMRF that all margins and commodity taxes are paid in the region which absorbs the commodity.

The remaining equations of this section define aggregate regional prices of labour and capital.

#### 2.2.13. Other miscellaneous regional equations

Equation  $E_{p1oct}$  allows for the indexation of the unit price of other costs to be indexed to the national consumer price index. The variable  $f1oct_{j,q}$  can be interpreted as the percentage change in the real price of other costs to industry  $j$  in region  $q$ .

Equation  $E_{cr\_shr}$  allows for the indexing of regional real household consumption with national real household consumption in the case where the percentage change in the regional-to-national consumption variable,  $cr\_shr_q$  is exogenous and set to zero. Otherwise,  $cr\_shr_q$  is endogenous and regional consumption is determined elsewhere in the model (say, by the regional consumption function).

Equation  $E_{ximp0}$  defines the regional duty-paid imports price index. Equation  $E_{totdom}$  and  $E_{totfor}$  define, for each region, the interregional and international terms of trade respectively.

#### 2.2.14. National aggregates

The final set of equations in the CGE core of MMRF define economy-wide variables as aggregates of regional variables. As MMRF is a bottom-up regional model, all behavioural relationships are specified at the regional level. Hence, national variables are simply add-ups of their regional counterparts.

### 2.3. Government finances

In this block of equations, we determine the budget deficit of regional and federal governments, aggregate regional household consumption and Gross State Products (GSP). To compute the government deficits, we prepare a summary of financial transactions (SOFT) which contain government income from various sources and expenditure on different accounts. To determine each region's aggregate household consumption, we compute regional household disposable income and define a regional consumption function. The value added in each region is determined within the CGE core of the model. Within the government finance block, are equations which split the regions' value added between private and public income. In this disaggregation process, the GSPs are also computed from the income and expenditure sides. The government finance equations are presented in five groups:

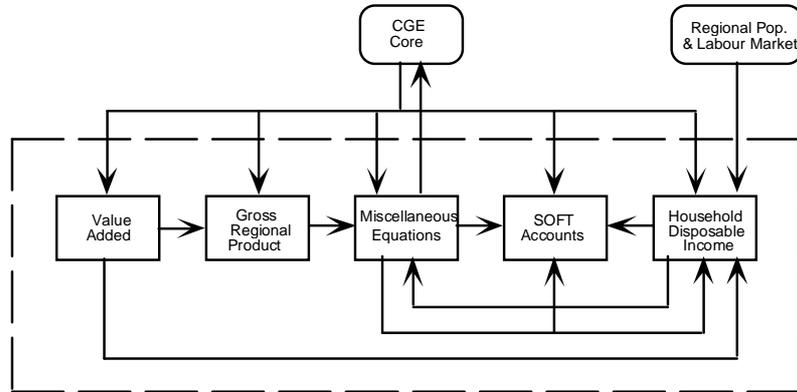
- (i) value added disaggregation;
- (ii) gross regional product;
- (iii) miscellaneous equations.
- (iv) summary of financial transactions;
- (v) household income.

Figure 2.5 illustrates the interlinkages between the five government finance equation blocks and their links with the CGE core and regional population and labour market equation block of MMRF. The activity variables and commodity taxes are determined in the CGE core.

From Figure 2.5, we see that all the equation blocks of government finances have backward links to the CGE core. The disaggregation-of-value-added block takes expenditures by firms on factors of production from the CGE core and disaggregates them into gross returns to factors and production taxes. Regional value added is used in the determination of the income side of gross regional product, hence the link from the value-added block to the gross-regional-product block in Figure 2.5. Production tax revenue also appears as a source of government income in the SOFT accounts block, which explains the link between value-added and SOFT in Figure 2.5. Factor incomes help explain household disposable income and this is recognised by the link between the value-added block and the household-disposable-income block in Figure 2.5.

The miscellaneous block in Figure 2.5 contains intermediary equations between the gross-regional-product block and the SOFT accounts, and between the household-disposable-income block and the CGE core. There are two types of equations in the miscellaneous block: (i) aggregating equations that form national macroeconomic aggregates of the expenditure and income sides of GDP by summing the corresponding regional macroeconomic variables determined in the gross-regional-product block and; (ii) mapping equations that rename variables computed in the gross-regional-product block and the CGE core for use in the SOFT accounts.

The SOFT accounts compute the regional and Federal governments' budgets. On the income side are government tax revenues, grants from the Federal government to the regional governments, interest payments and other miscellaneous revenues. Direct taxes and commodity taxes come from the gross-regional-product block via the miscellaneous block as described above. Production taxes come from the value-added block. On the expenditure side of the government budgets are purchases of goods and services, transfer payments, interest payments on debt, and for the Federal government, payments of grants to the regional governments. The purchases of goods and services come from the CGE core via the miscellaneous block. Transfer payments come from the household-disposable-income block.



## KEY

--- Government finance block of equations.

□ The five equation groupings within the government finance block.

○ Other equation blocks that link with government finances.

→ Direction of link between equation groupings, and other equation blocks.

Figure 2.5. Government finance block of equations

Finally, we come to the household-disposable-income block. Within this block, household disposable income is determined as the difference between the sum of factor incomes and transfer payments, and income taxes. Figure 2.5 shows that factor incomes come from the value-added block and that unemployment benefits are determined using information from the regional population and labour market block. Household disposable income feeds back to the miscellaneous block, which contains an equation specifying the level of regional household consumption as a function of regional household disposable income. The value of regional household consumption, in turn, feeds back to the CGE core. Also, the value of transfer payments, determined in the household-disposable-income block, feed back to the SOFT accounts.

*A notation for the government finance block*

Following the style of the CGE core, all variable names are in lower case. However, the coefficient naming system is different. A variable name in upper case with a prefix of "C\_" defines the coefficient associated with the variable. For example, the variable 'hhldy000' represents the percentage change in household disposable income. Its associated coefficient is 'C\_HHLDY00' which represents the level of household disposable income.

We have given specific notation to variables of each of the blocks which form the government finance set of equations. The following are the major array names for variables and coefficients:

- (i)  $z_{**r}$  (a value-added component in gross regional production).
- (ii)  $domy^{***}$  (domestic regional production, an income component);
- (iii)  $dompq^{***}$  (domestic regional production, an expenditure component);
- (iv)  $softy^{***}$  (summary of financial transaction, an income component);
- (v)  $softq^{***}$  (summary of financial transaction, an expenditure component) and;
- (vi)  $hhldy^{***}$  (a household income component).

In each array name '\*\*\*' represents three or two digits component numbers.

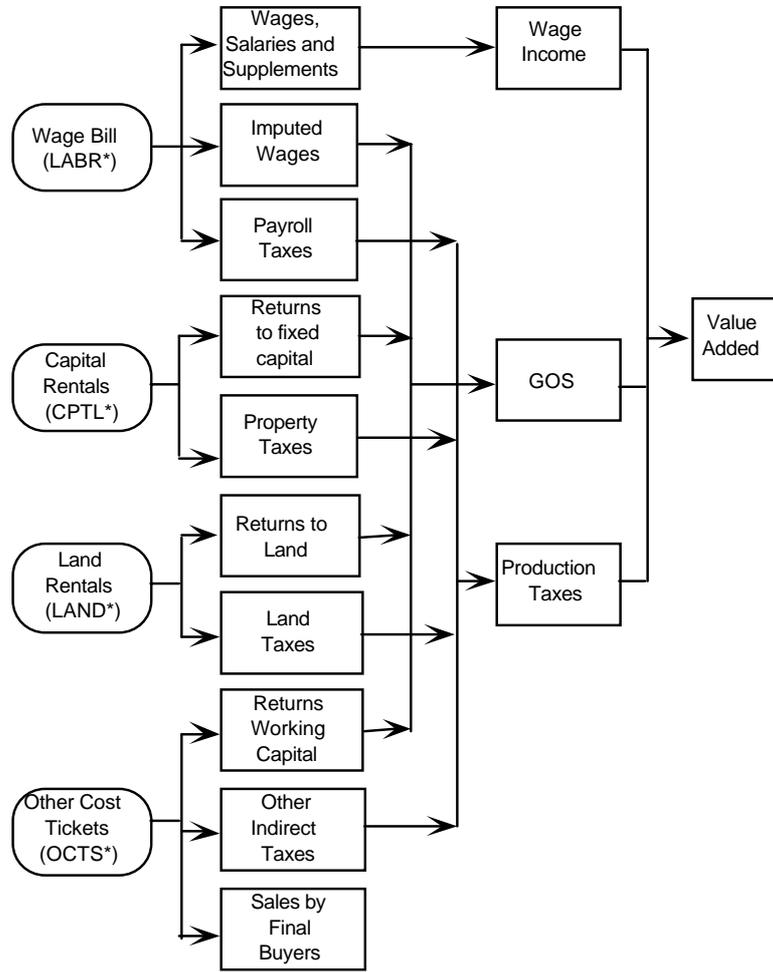
In the following sections we discuss the various blocks which constitute the government finance equations of MRF beginning with the disaggregation of value added.

### 2.3.1. Disaggregation of value added

Figure 2.6 shows that the essential purpose of the disaggregation-of-value-added block is to disaggregate the four elements of value added determined in CGE core (i.e., the wage bill, the rental cost of capital and land, and other costs) into ten components in order to separate production taxes from payments to factors. In addition, the block prepares national values as aggregates of regional values. We now turn to the details of the value-added equation block as presented in section 2.3 of Table 2.1.

In equations  $E_{z01_r}$  and  $E_{z02_r}$ , we assume that the wages, salaries and supplements and the imputed wage bill vary in direction proportion to the pre-tax wage bill, which is determined in the CGE core. Equation  $E_{z03_r}$  shows that payroll taxes are determined by the pre-tax wage bill and the payroll tax rate. Equations  $E_{z04_r}$  and  $E_{z05_r}$  show that the return to fixed capital and property taxes are assumed to vary in proportion to the rental cost of capital, which is determined in the CGE core. Returns to agricultural land and land taxes are determined by equations  $E_{z06_r}$  and  $E_{z07_r}$  respectively and vary in proportion to the total rental cost of land. Returns to working capital, other indirect taxes and sales by final buyers are all assumed to vary in proportion to other costs. The relevant equations are  $E_{z08_r}$ ,  $E_{z09_r}$  and  $E_{z010_r}$  respectively.

The values of the ten national components of value added are the sums of the corresponding regional components. The national values are calculated in the ' $E_{z0**}$ ' equations from which the ' $_r$ ' suffix has been omitted.



KEY

\* The name in parenthesis indicates the corresponding array name in Figure 2.1.

○ Elements from the CGE Core.

□ Elements in the disaggregation-of-value-added block.

Figure 2.6. Components of regional value added

Equation E\_zg\_r defines regional gross operating surplus (GOS) as the sum of imputed wages and returns to fixed capital, working capital and agricultural land. Equation E\_zt\_r calculates total regional production tax revenues.

Equation E\_rpr sets the payroll tax rates by industry and region which are determined by the payroll tax rate for all industries in a region and a shift in the industry and region specific payroll tax rate. A change in the payroll tax rate drives a wedge between the wage rate received by the workers and the cost to the producer of employing labour. The change in the cost of employing labour for a given change in the payroll tax rate depends on the share of the payroll taxes in total wages. Equation E\_rpri adjusts the payroll tax rate to compute the wedge between the wage rate and labour employment costs. The wedge is used to define the after-tax wage rate in the CGE core.

The last equation in the value-added block, E\_xisfb2, defines a regional price index for sales by final buyers.

### 2.3.2. Gross regional domestic product and its components

This block of equations defines the regional gross products from the income and expenditure sides using variables from the CGE core and the value-added block.

Figure 2.7 reveals that gross regional product at market prices from the income side is sum of wage income, non-wage income and indirect tax revenues.

In section 2.3 of Table 2.1, equations E\_dompy100, E\_dompy200 and E\_dompy330 show, respectively, that wage income, non-wage income and production taxes are mapped from the value-added block. In addition to production taxes, there are two other categories of indirect tax: tariffs and other commodity taxes less subsidies. Equations E\_dompy330 and E\_dompy320 show that these taxes are mapped from the CGE core. Total indirect taxes are defined by E\_dompy300 as the sum of the three categories of indirect taxes.

Summing wage and non-wage income, and indirect taxes gives gross regional product from the income side (equation E\_dompy000).

In addition to the defining the income-side of gross regional product, we also disaggregate factor incomes into disposable income and income tax. Disposable income is used in the household-disposable-income block and income taxes are a source of government revenue in the SOFT accounts. In equation E\_dompy110, disposable wage income is defined as wage income net of PAYE taxes. In equation E\_dompy120, PAYE taxes are assumed to be proportional to wage income and the PAYE tax rate. Likewise, equation E\_dompy210 defines disposable non-wage income as the difference between non-wage income and income taxes. Equation E\_dompy220 sets non-wage income tax proportional to non-wage income and the non-wage income tax rate.

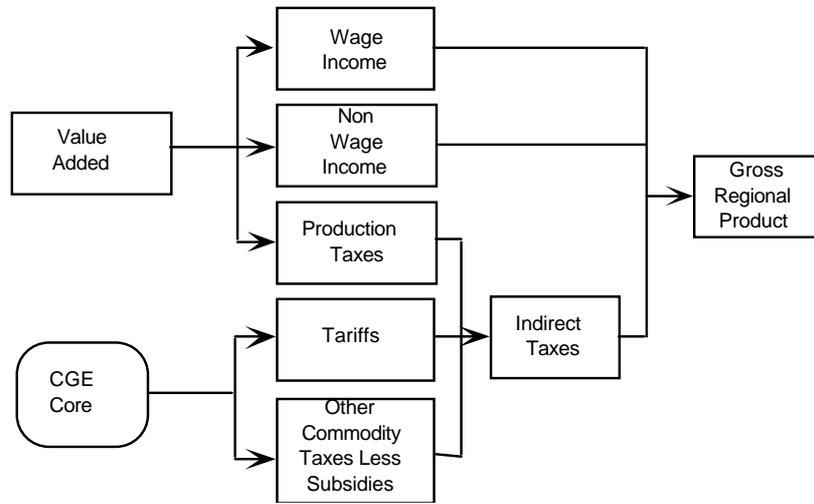


Figure 2.7. Income-side components of gross regional product

Figure 2.8 shows that gross regional product from the expenditure side is defined as the sum of domestic absorption and the interregional and international trade balances. This definition is reflected in equation  $E\_dompq000$ . Domestic absorption is defined in equation  $E\_dompq100$  as the sum of private and public consumption and investment expenditures. Equations  $E\_dompq110$  to  $E\_dompq150$  reveal that the components of domestic absorption are mapped from the CGE core. Within the components of domestic absorption, the assumption is made, in equations  $E\_dompq120$  and  $E\_dompq150$ , that the shares of private and government investment in total investment are fixed. Equations  $E\_dompq210$  and  $E\_dompq220$  show that regional exports and imports are also taken from the CGE core. The difference between regional exports and imports forms the regional trade balance and is calculated in equation  $E\_dompq200$ . Similarly the international trade variables for each region are taken from the CGE core ( $E\_dompq310$  and  $E\_dompq320$  for international exports and imports respectively) and are used to define the international trade balance for each region in equation  $E\_dompq300$ .

### 2.3.3. Miscellaneous equations

The miscellaneous equation block appears in section 2.3.3 of Table 2.1. In equation  $E\_tir$ , commodity taxes are mapped from the gross-regional-product block. The regional values are then summed in equation  $E\_ti$  to form the national aggregate of commodity taxes. Similarly, gross regional products are mapped from the gross-regional-product block in equation  $E\_yn_r$  and

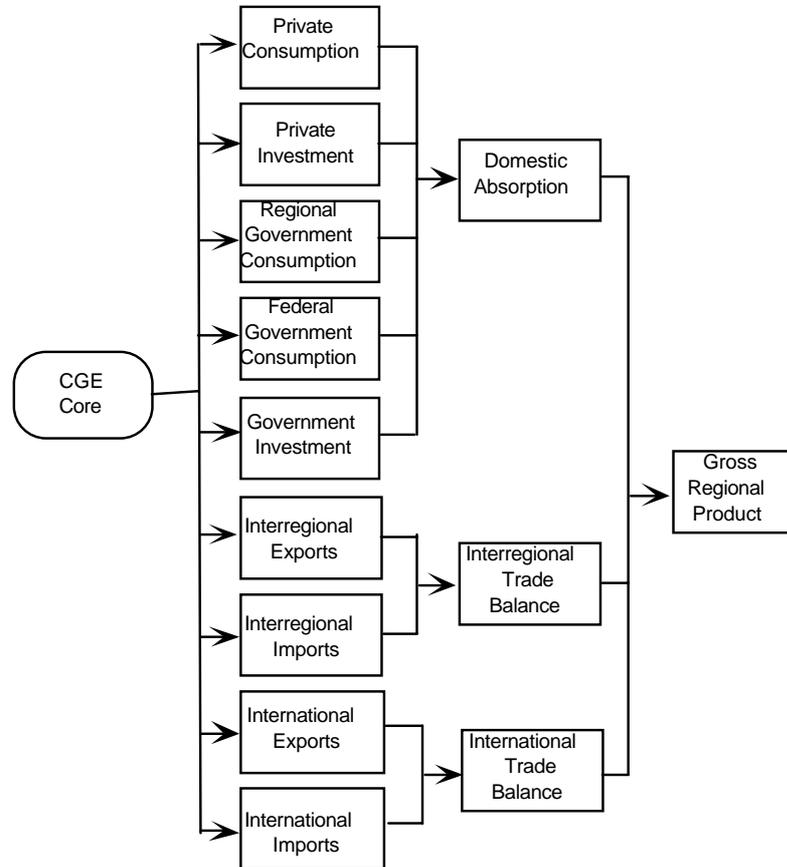


Figure 2.8 Expenditure-side components of gross regional product

then summed, in equation  $E_{yn}$ , to form national nominal GDP. In equation  $E_{xiy_r}$ , a gross-regional-product price deflator from the expenditure side, is formed using price indices taken from the CGE core. The resulting price deflator is used to define real gross regional product in equation  $E_{yr_r}$ .

Taking a weighted average of the gross regional product price deflators gives the price deflator for national GDP in equation  $E_{xiy}$ . This deflator is used to define real national GDP in equation  $E_{yr}$ .

National GDP at factor cost is defined in equation  $E_{yf}$  as the sum of the regional wage and non-wage incomes. Equation  $E_{bstar}$  defines the percentage-point change in the national balance of trade surplus to national GDP

ratio. Note that  $E\_bstar$  defines a percentage-point change in a ratio, rather than a percentage change. The underlying levels equation of  $E\_bstar$  is

$$BSTAR = \frac{\sum_{q=1}^8 DOMPQ300_q}{YN},$$

where the upper-case represents the levels values of the corresponding percentage-point change and percentage change variables. Taking the first difference of  $BSTAR$  and multiplying by 100 gives the percentage-point change in  $BSTAR$  (i.e., the variable  $bstar$  on the LHS of  $E\_bstar$ )

$$100 \times \Delta BSTAR = bstar = \frac{\sum_{q=1}^8 DOMPQ300_q \text{dompq300}_q}{YN} - \frac{NATB}{YN} \text{yn},$$

where

$$NATB = \sum_{q=1}^8 DOMPQ300_q.$$

Aggregate national income taxes are calculated in equation  $E\_ty$ . They are the sum of regional  $PAYE$  taxes and regional taxes on non-wage income. Pre-tax national wage income is calculated in equation  $E\_yl$  by summing pre-tax regional wage incomes. Equation  $E\_wn$  defines the nominal pre-tax national wage rate as the ratio of the pre-tax wage income to national employment. The nominal post-tax national wage income is calculated in equation  $E\_ylstar$  by summing the nominal post-tax regional wage incomes. The nominal post-tax national wage rate is defined in equation  $E\_wnstar$  as the ratio of the nominal post-tax wage income to national employment. The real post-tax national wage rate is defined in  $E\_wrstar$  by deflating the nominal post-tax national wage rate by the national CPI.

Equations  $E\_g\_rA$  and  $E\_g\_rB$  define the regional government and Federal government consumption expenditures respectively. The vector variable determined in these equations,  $g\_r$ , drives government consumption expenditures in the *SOFT* accounts (see section 2.3.4 below).

Equations  $E\_ip$  to  $E\_ig\_r\_fed$  disaggregate investment expenditure into private investment expenditure and public investment expenditure. The resulting values for public investment expenditure are used to drive government capital expenditures in the *SOFT* accounts (see section 2.3.4 below). Equation  $E\_ip$  imposes the assumption that aggregate private investment expenditure moves proportionally with a weighted average of total (private and public) regional investment. Aggregate public investment expenditure is then determined as a

residual in equation  $E_{ig}$ , as the difference between total aggregate total investment and aggregate private investment. Equation  $E_{ig\_reg}$  imposes the assumption that investment expenditure of regional governments moves in proportion to total regional investment. Equation  $E_{ig\_r\_fed}$  determines investment expenditure of the Federal government as the difference between total public investment and the sum of regional governments' investment.

The miscellaneous equation block is completed with equation  $E_{c\_b}$  defining the regional household consumption function and equation  $E_{rl}$  relating the PAYE tax rate to the tax rate on non-wage income.

#### 2.3.4. Summary Of Financial Transactions of the regional and Federal governments: the SOFT accounts.

In this block of equations, we prepare a statement of financial transactions containing various sources of government income and expenditure. A separate statement is prepared for each regional government and the Federal government. Our accounting system is based on the *State Finance Statistics* (cat. no. 5512.0) of the Australian Bureau of Statistics (ABS).

The SOFT accounts contain equations explaining movements in the income and expenditure sides of the governments' budgets. Our exposition of this equation block starts with the income side of the accounts. Figure 2.9 depicts the income side of the SOFT accounts. There are two major categories of government income: (i) revenues and (ii) financing transactions. Government revenues are further divided into direct and indirect tax revenues, interest payments, Commonwealth grants (for regional governments) and other revenues. The categories of direct taxes are income taxes (for the Federal government), and other direct taxes. Indirect taxes consist of tariffs (for the Federal government), other commodity taxes and production taxes. Commonwealth grants are divided into grants to finance consumption expenditure and grants used to finance capital expenditure. Financing transactions capture the change in the governments' net liabilities and represent the difference between government revenue and government expenditure. If government expenditure exceeds/is less than government revenue (i.e., the government budget is in deficit/surplus), then financing transactions increase/decrease as either the governments' net borrowings increase and/or other financing transactions increase. Variations in the latter item principally consist of changes in cash and bank balances.<sup>13</sup> We now turn our attention to the specification of movements in the income-side

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<sup>13</sup> The reader will note that financing transactions includes a third item, increase in provisions. This is a very small item in the governments' SOFT accounts and in model simulations we hold its value fixed at zero change.

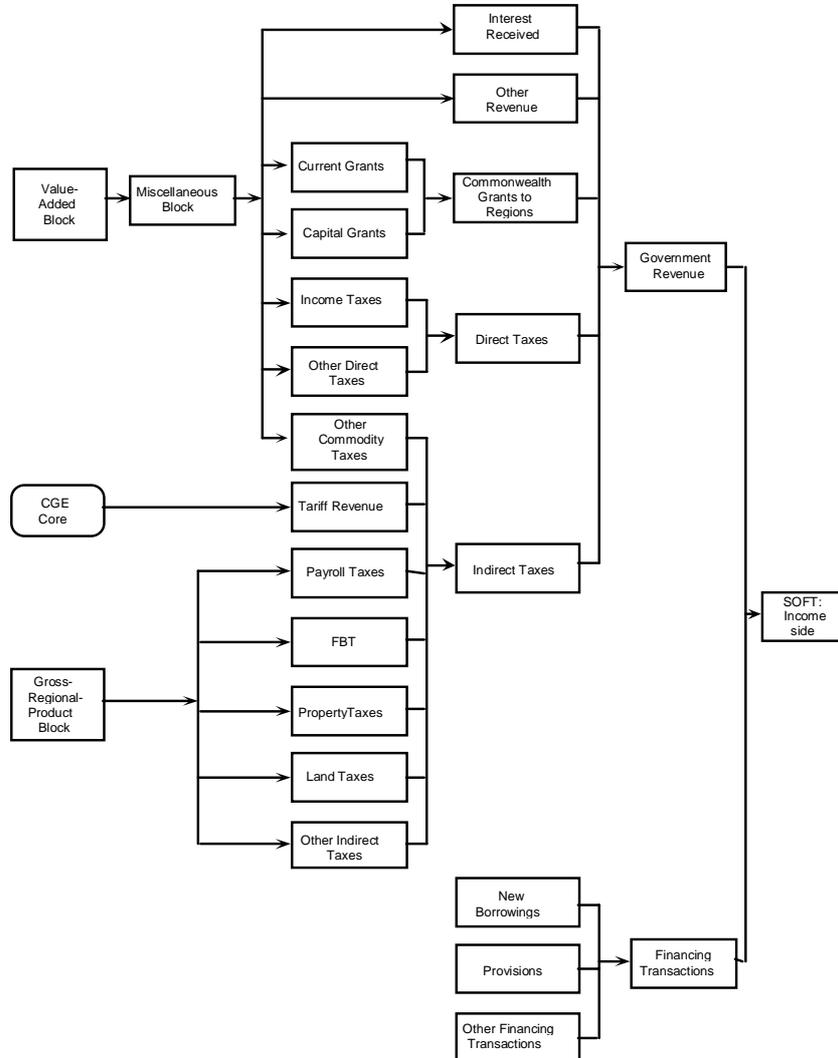


Figure 2.9. Summary of Financial Transaction (SOFT): income side

components of the SOFT accounts as presented in section 2.3.4 of Table 2.1.

Equation E\_softy111 shows that Federal government income tax collections are mapped from the miscellaneous block based on the corresponding variable in the gross-regional-product block. Equations E\_softy112A and E\_softy112B impose the assumption that regional government and Federal government collections of 'other direct taxes' move in proportion to nominal gross regional product and nominal national GDP respectively. The sum of the two above categories of direct taxes for each government is given in equation E\_softy110.

Federal government tariff revenue is mapped from the CGE core to equation E\_softy121. Equation E\_softy122A shows that regional government collections of 'other commodity taxes' are mapped from the miscellaneous block based on the corresponding variable in the gross-regional-product block. Federal government collections of 'other commodity taxes' are calculated in equation E\_softy122B as the difference between total national collection of 'other commodity taxes' and the sum of the regional governments' collections of 'other commodity taxes'. The value of the total national collection of 'other commodity taxes' is mapped from the miscellaneous block based on the corresponding variable in the gross-regional-product block.

Equation E\_softy123a shows that the regional governments' collections of payroll taxes are mapped from the value-added block. In equation E\_softy123b, the assumption is imposed that the Federal government's collection of fringe benefits moves in proportion with the value-added-block variable 'other indirect taxes'. Equations E\_124, E\_125 and E\_126A show that regional governments' collections of, respectively, property taxes, land taxes and other indirect taxes, are mapped from their corresponding values in the value-added block. Equation E\_softy126B ties movements in Federal government 'other indirect taxes' to the weighted average of movements in regional governments' 'other indirect taxes'.

Equation E\_softy120 calculates movements in the collection of aggregate indirect taxes in each region as the weighted average of movements in the regional collection of tariffs, other commodity taxes and the production taxes.

Interest received by governments<sup>14</sup> is determined in equation E\_softy130. We assume that interest received and interest paid by the government move in proportion with the size of the economy as measured by

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<sup>14</sup> This item includes gross interest received on bank balances, investment and advances of the government (see ABS cat. no. 1217.0)

nominal gross regional product for regional governments, and nominal national GDP for the Federal government.<sup>15</sup>

The next item of government revenue applies only to regional governments and is Commonwealth grants. Equations E\_softy141 and softy142 recognise Commonwealth grants for current expenditure purposes and capital expenditure purposes respectively. For each type of grant, our default assumption is that their nominal values are proportional to the nominal value of the region's gross product. Equations E\_softy141 and E\_softy142 include shift variables which allow the default option to be overridden.

The final item of government revenue, 'other revenue', is described in equation E\_softy150 (for regional governments) and equation E\_softy150B (for the Federal government). As with Commonwealth grants, the default option is that 'other revenue' of regional governments is proportional to nominal gross regional product and for the Federal government it is proportional to national nominal GDP. Also in common with the 'grants' equations is the presence of shifters which allow the default option to be overridden.

Equation E\_softy100 sums the various components of government revenue to determine total government revenue.

Equation E\_softy300 identifies the budget deficit or surplus as the difference between government expenditure and government revenue. As mentioned above, financing transactions consists of three components. Equation E\_softy320 allows a default option which sets the 'increase in provisions' component of financing transactions proportional to government expenditure on goods and services. A shift variable in equation E\_softy320 allows the default option to be overridden. The second component of financing transactions, 'other financing transactions', is determined by equation E\_softy300. The default setting is that 'other financing transactions' move in proportion with 'financing transactions'. The presence of a shift variable allows the default setting to be overridden. Government's net borrowing is determined by equation E\_softy300 as the difference between 'financing transactions' and the sum of the two components, 'increase in provisions' and 'other financing transactions'.

Figure 2.10 depicts the expenditure-side of the SOFT accounts. Figure 2.10 shows that regional government expenditure consists of five broad categories: goods and services, personal benefits, subsidies, interest payments and other outlays. Figure 2.10 also shows that expenditure by the Federal government includes the same five categories, in common with the regional

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<sup>15</sup> We would prefer to relate the change in government interest receipts and payments to changes in the level and composition of government debt. At this stage of the model's development, we lack a specification of the mechanism by which the governments may target and achieve a particular debt outcome. Our current specification of interest payments is consequently *ad hoc*.

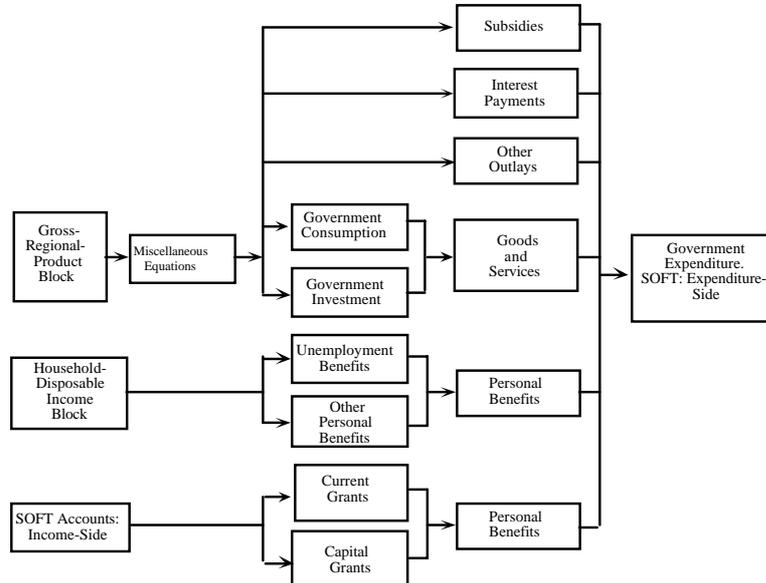


Figure 2.10. Summary of Financial Transaction (SOFT): expenditure side

governments, plus grants to the regional governments. The composition of the expenditure side of the SOFT accounts is reflected in equation E\_softq000 which gives the total, for each governments' expenditures.

Government expenditure on goods and services consists of government consumption expenditure and investment expenditure (equation E\_softq100). Government consumption expenditure (equation E\_softq110) is mapped from the miscellaneous block based on the corresponding nominal government consumption expenditure variable in the CGE core. Likewise, government investment expenditure (equation E\_softq120) is mapped from the miscellaneous block based on the corresponding nominal government investment expenditure variable in the CGE core.

Governments' expenditures on personal benefits (equation E\_softq200) are mapped from the household-disposable-income block (see section 2.3.5 below). Personal benefit payments are divided into 'unemployment benefits' and 'other personal benefit payments'. Unemployment benefits (equation E\_softq210) are mapped from the household-disposable-income block. This leaves 'other personal benefit payments' (equation E\_softq220) to be determined residually as the difference between personal benefit payments and unemployment benefits.

Equations  $E\_softq300A$  and  $E\_softq300B$  determine payments of subsidies by regional governments and the Federal government respectively. These equations impose the assumption that the ratio of the government payment of subsidies to commodity tax revenues is constant.

Equations  $E\_softq400A$  and  $E\_softq400B$  define nominal interest payments by regional governments and the Federal government respectively. As described above, we assume that interest paid by the government moves in proportion with nominal gross regional product for regional governments, and nominal national GDP for the Federal government.

Expenditure by the Federal government on grants to the regions (equation  $E\_softq500$ ) consists of grants for the purposes of consumption expenditure (equation  $E\_softq510$ ) and capital expenditure (equation  $E\_softq520$ ).

The final item in the governments' expenditure-side of the SOFT accounts is 'other outlays' (equation  $E\_softq600$ ). The default setting is that 'other outlays' is proportional to total government expenditure.

There are four remaining equations in the SOFT accounts block. Three of these define various measures of the budget deficit. The remaining equation is a mapping equation for a variable used in the household-disposable-income block.

Equation  $E\_realdefr$  defines the percentage change in the real budget deficit of regional governments. It is defined as the difference in the percentage change in financing transactions (a measure of the percentage change in the nominal budget deficit) and the percentage change in the regional CPI. Equation  $E\_realdeff$  defines the corresponding variable for the Federal government. This equation is analogous to the regional version, where the regional variables are replaced by Federal and national variables. Equation  $E\_dgstar$  calculates the percentage-point change in the ratio of government net borrowing to total outlays. The final equation,  $E\_tod\_r$  maps the 'other indirect tax' variable ( $softy112$ ) to the variable name 'tod\_r'.

### 2.3.5. Household disposable income

This block of equations computes the various components of regional household disposable income. Figure 2.11 outlines the composition of household disposable income. Regional household disposable income consists of four broad components: primary factor income, personal benefit payments from the governments, 'other income', and direct taxes. Equation  $E\_hhldy000$  defines regional household disposable income based on these four components.

Figure 2.11 also shows the disaggregation and sources of the components of household disposable income. Primary factor income is disaggregated into wage income and non-wage income (equation  $E\_hhldy100$ ). Movements in wage income and non-wage income are determined in the value-added block (equation  $E\_hhldy110$  and  $E\_hhldy120$  respectively). Personal

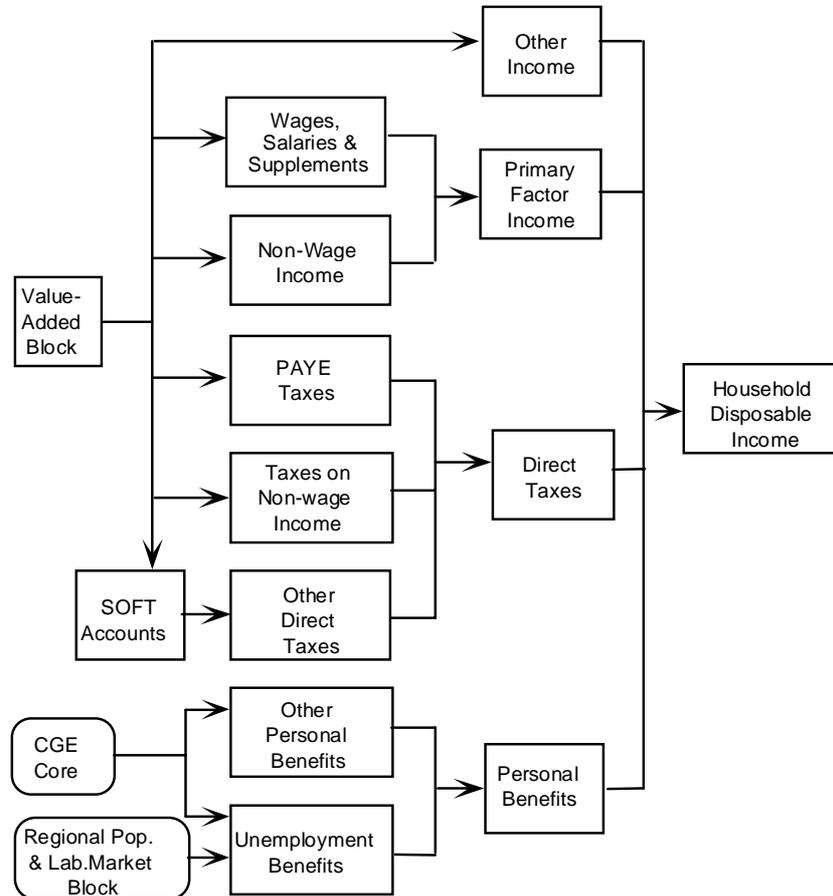


Figure 2.11. Household disposable income

benefit payments are consist of unemployment benefits and other benefit payments (equation  $E_{hhldy200}$ ). Equation  $E_{hhldy210}$  shows that unemployment benefits are indexed to the national CPI and that changes in the numbers unemployed are taken from variables determined in the regional population and labour market equation block. Other personal benefit payments are determined in equation  $E_{hhldy220}$ . They are indexed to the national CPI and proportional to the regional population. Equation  $E_{hhldy300}$  imposes the assumption that regional household 'other net income' moves in proportion with the region's nominal gross product.

In Figure 2.11, three components of direct taxes are identified: PAYE taxes, taxes on non-wage income and other direct taxes (equation E\_hhldy400). Equations E\_hhldy410 and E\_hhldy420 show that PAYE taxes and non-wage taxes are assumed to move in proportion to wage income and non-wage income respectively. Equation E\_hhldy430 shows that other direct taxes move in line with the corresponding variable taken from the SOFT accounts.

There are five remaining equations in this block. The first is a mapping equation, E\_ydr, that maps regional household disposable income to a variable to be used in the consumption-function equation described above in the miscellaneous-equation block (see section 2.3.3). The next equation, E\_upb, aggregates regional unemployment benefits to form total unemployment benefits. This variable drives Federal government expenditure on unemployment benefits in the SOFT accounts in section 2.3.4 above. The third equation, E\_pbp\_r is a mapping equation that renames the regional ‘personal benefits payments’ for use in the SOFT accounts, where it determines movements in regional governments’ payments of personal benefits. The fourth equation, E\_pbpA, calculates aggregate personal benefit payments by summing the regional payments. The final equation, E\_pbpB, uses the value of the aggregate payments of personal benefits determined in E\_pbpA and the regional payments determined in E\_pbp\_r, to determine Federal government payments of personal benefits in the SOFT accounts.

## 2.4. Dynamics for forecasting

This block of equations facilitates medium-run and long-run forecasting experiments, and the movement between comparative-static and forecasting versions of the model. The equations link key flow variables with their associated stock variables. The dynamics of MMRF are confined to accumulation relations connecting industry capital stock with industry investment, regional population with regional natural growth in population and foreign and interregional migration, and the foreign debt with the trade balance.

Also included in this block are the comparative-static alternatives to the forecasting equations. In some cases, such as investment and capital, the comparative-static and forecasting versions of the model contain different equations. In other cases, such as the trade balance and the foreign debt, we move between comparative-static and forecasting versions by different settings of exogenous variables within a common set of equations.

*Comparative statics and forecasting*<sup>16</sup>

MMRF can produce either comparative-static or forecasting simulations. In comparative-static simulations, the model's equations and variables all refer implicitly to the economy at some future time period.

This interpretation is illustrated in Figure 2.12, which graphs the values of some variable, say employment, against time. The base period (period 0) level of employment is at A and B is the level which it would attain in T years time if some policy, say a tariff change, were *not* implemented. With the tariff change, employment would reach C, all other things being equal. In a comparative-static simulation, MMRF might generate the percentage change in employment  $100(C-B)/B$ , showing how employment *in period T* would be affected by the tariff change alone.

Employment

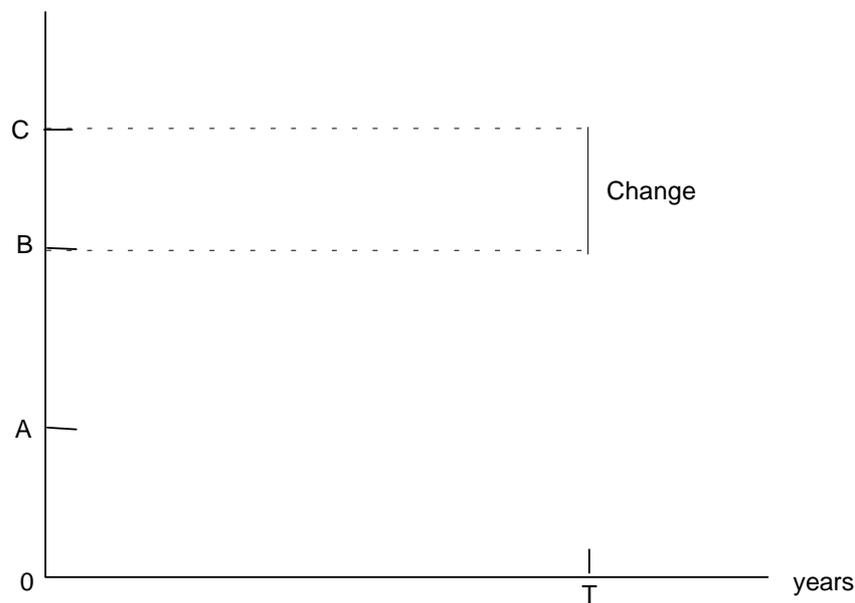


Figure 2.12. Comparative-static interpretation of results

Comparative-static simulations are usually interpreted as measuring either the short-run or long-run effects of a policy change. A distinguishing feature of short run versus long run comparative-static simulations is the treatment of industry capital. Short run simulations are characterised by the

<sup>16</sup> This section draws on Horridge, Parmenter and Pearson (1993).

assumption of fixed industry capital stocks. That is, industry capital stocks are held at their pre-shock level. Econometric evidence suggests that a short-run equilibrium will be reached in about two years, i.e.,  $T=2$  (see Cooper, McLaren and Powell, 1985). The typical long-run assumption is that industry capital stocks will have adjusted to restore (exogenous) rates of return. This might take six years, 10 years or 20 years, i.e.,  $T=6, 10$  or  $20$ . In either case, short run or long run, only the assumptions about which variables are fixed and the interpretation of the results bear on the timing of changes: the model itself is atemporal.

The comparative-static interpretation of MMRF results lends itself to policy analysis. Business and government planners, however, require forecasts of industry output, prices and other variables to inform their investment decisions. The forecasting interpretation of MMRF results is shown in Figure 2.13. As before, the model generates percentage changes in its variables but in this case they are interpreted as  $100(D-A)/A$ , comparing the values of the variables at two different time periods, period 0 and period T. In contrast to comparative-static simulations, which usually show the effect of one or a few exogenous changes, forecasting simulations normally show the effects of *all* exogenous changes assumed to occur over the simulation period 0 to T.

In the remainder of this section, we outline the forecasting equations of MMRF and, where applicable, their comparative-static alternatives. We begin with capital and investment.

#### 2.4.1. Industry capital and investment

To derive the investment-capital accumulation equations, we start with the accumulation relation

$$K_{j,q,t+1} = K_{j,q,t}DEP_j + Y_{j,q,t}, \quad j=1,\dots,13, \quad q=1,\dots,8, \quad t=0,\dots,T, \quad (2.13)$$

where  $K_{j,q,t}$  is industry  $j$ 's, in the  $q$ th region, capital stock in year  $t$ ,  $Y_{j,q,t}$  is industry  $j$ 's, in the  $q$ th region, investment in year  $t$  and  $DEP_j$  is one minus the rate of depreciation in industry  $j$ . Note that we assume that there is no region-specific rate of depreciation on capital. Equation 2.13 is therefore a standard investment-capital accumulation relation with a one year gestation lag between investment and capital.

On the basis of equation 2.13, we can write the accumulation equation for our forecast year, year T, as

$$K_{j,q,T+1} = K_{j,q,T}DEP_j + Y_{j,q,T}, \quad j=1,\dots,13, \quad q=1,\dots,8 \quad (2.14)$$

Before we derive the linearised expression of equation 2.14, we must first address the issue of an initial solution for the equation. In common with other ORANI-style models, MMRF is solved for deviations from an initial solution. In forecasting simulations, we solve the model for perturbations from

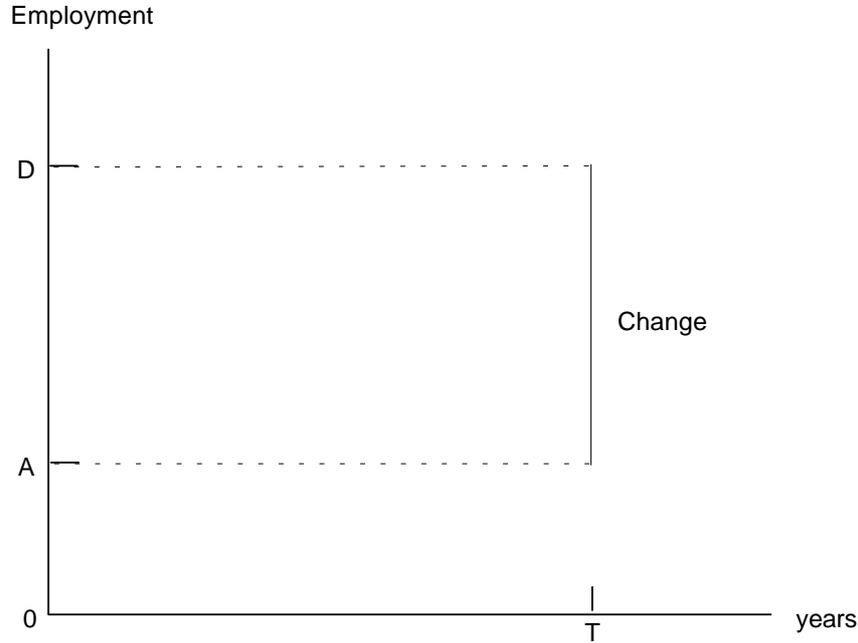


Figure 2.13. Forecasting interpretation of results

year 0 in Figure 2.13. That is, we compute the values of variables at year T, given initial values of the model's variables at year 0. For example, we solve for  $K_{j,q,T+1}$ ,  $K_{j,q,T}$  and  $Y_{j,q,T}$  for initial values,  $K_{j,q,0}$  and  $Y_{j,q,0}$ . The initial values of the model's variables must represent a solution to the model's equations. Therefore, to solve MMRF, we require a database which represents an initial solution to the model's equations. For the equations of the CGE core, the input-output data, schematically represented in Figure 2.1, provide an initial solution. Similarly, the database for the government-finance block provides an initial solution for the equations of section 2.3. A feature of the equations of sections 2.2 and 2.3 is that all their variables relate to a single time period. Hence, the database providing a solution to those equations need only contain data for a single year.

A difficulty with equation 2.14 is that it includes variables in more than one time period. This is a problem because no longer do our basecase values (which are from a single period) guarantee an initial solution. Typically, our initial solution for a variable, say  $X_T$ , is  $X_0$ . However, unless by coincidence

$$K_{j,q,0}(DEP_j - 1) + Y_{j,q,0} = 0, \quad j=1,\dots,13, q=1,\dots,8 \quad (2.15)$$

$\{K_{j,q,0}, K_{j,q,T}, Y_{j,q,0}\}$  is not a solution for  $\{K_{j,q,T+1}, K_{j,q,T}, Y_{j,q,T}\}$ . We solve this problem by the purely technical device of augmenting equation 2.14 with an additional term as follows:

$$K_{j,q,T+1} = K_{j,q,T} \text{DEP}_j + Y_{j,q,T} - F[K_{j,q,0}(1 - \text{DEP}_j) - Y_{j,q,0}],$$

$$j=1,\dots,13, q=1,\dots,8 \quad (2.16)$$

where the initial value of  $F$  is minus unity so that equation 2.14 is satisfied when  $K_{j,q,T+1}$  and  $K_{j,q,T}$  equal  $K_{j,q,0}$  and  $Y_{j,q,T}$  equals  $Y_{j,q,0}$ . In forecasting simulations, we shock  $F$  to zero ( $\Delta F=1$ ). In equation 2.16,  $\{K_{j,q,0}, K_{j,q,0}, Y_{j,q,0}, -1\}$  is now a true initial solution for  $\{K_{j,q,T+1}, K_{j,q,T}, Y_{j,q,T}, F\}$ , and the forecasting solution for equation 2.16 is  $\{K_{j,q,T+1}^*, K_{j,q,T}^*, Y_{j,q,T}^*, 0\}$ , where the ‘asterisk’ denotes a forecast solution.

Taking ordinary changes in  $F$  and percentage changes in  $K_{j,q,T+1}$ ,  $K_{j,q,T}$  and  $Y_{j,q,T}$ , equation 2.16 becomes

$$K_{j,q,T+1} k_{j,q,T+1} = K_{j,q,T} \text{DEP}_j k_{j,q,T} + Y_{j,q,T} y_{j,q,T} - 100 \Delta F [K_{j,q,0}(1 - \text{DEP}_j) - Y_{j,q,0}],$$

$$j=1,\dots,13, q=1,\dots,8, \quad (2.17)$$

where, according to our conventions, the upper case denotes levels values of coefficients, the lower case denotes percentage changes in the model’s variables and the  $\Delta$  signifies an ordinary change in a variable. Notice that the presence of the last term on the RHS of equation 2.17 means that  $k_{j,q,T+1}$  is the percentage deviation of the capital stock in industry  $j$ , region  $q$ , from the initial (base-year) value of its capital stock, i.e., all variables, including the  $T+1$  variables, are deviations from their values in the same base year.

Equation 2.17 is reported in Table 2.1 as equation E\_yTA. The coefficient and variable names that map equation 2.17 to equation E\_yTA are as follows:

$$\begin{aligned} K_{j,q,T+1} &\Leftrightarrow \text{VALK\_T1}_{j,q}; \\ K_{j,q,T} &\Leftrightarrow \text{VALK\_T}_{j,q}; \\ \text{DEP}_j &\Leftrightarrow \text{DEP}_j; \\ Y_{j,q,T} &\Leftrightarrow \text{INVEST}_{j,q}; \\ K_{j,q,0} &\Leftrightarrow \text{VALK\_0}_{j,q}; \\ Y_{j,q,0} &\Leftrightarrow \text{INVEST\_0}_{j,q}; \\ k_{j,q,T+1} &\Leftrightarrow \text{curcap\_t1}_{j,q}; \\ k_{j,q,T} &\Leftrightarrow \text{curcap}_{j,q}; \\ y_{j,q,T} &\Leftrightarrow y_{j,q} \text{ and}; \\ \Delta F &\Leftrightarrow \text{delkfudge}. \end{aligned}$$

The next equation of this section, E\_curcapT1A, sets the growth in the capital stock between the forecast year (year  $T$ ) and the year following (year

T+1) equal to the average annual growth rate over the forecast period, i.e., the average between year 0 and year T. Using the notation of equations 2.14 to 2.17,

$$K_{j,q,T+1}/K_{j,q,T} = (K_{j,q,T}/K_{j,q,0})^{\frac{1}{T}}, \quad j=1,\dots,13, \quad q=1,\dots,8. \quad (2.18)$$

Remembering that  $K_{j,q,0}$  is a constant and rearranging, the percentage change form of equation 2.18 is

$$k_{j,q,T+1} = (1 + \frac{1}{T})k_{j,q,T}, \quad j=1,\dots,13, \quad q=1,\dots,8, \quad (2.19)$$

where the mapping given above for equations 2.17 and E\_yTA also apply for equations 2.19 and E\_curcapT1A, with the addition that  $(1 + \frac{1}{T})$  in equation 2.19 is represented by the coefficient K\_TERM in equation E\_curcapT1A.

The comparative-static alternative to the above forecasting specification is given by swapping equation E\_yTA for equation E\_ytB and equation E\_curcapT1A for E\_curcapT1B. We must remember that our interpretation of the model is different in comparative-static simulations compared to forecasting simulations. As Figures 2.11 and 2.12 suggest, in comparative-static simulations, the percentage changes in the variables are interpreted as deviations from their base values at time T, whereas in forecasting, the percentage changes in variables are deviations from their base values at time 0.

Equation E\_ytB says the percentage change in an industry's capital stock in year T, is equal to the percentage change in an industry's investment in year T. Equation E\_curcapT1B says the percentage change in an industry's capital stock in year T+1, is equal to the percentage change in an industry's capital stock in year T. In short-run comparative-static simulations, the typical assumption is that the industries' capital stocks are fixed at their base values. Hence, the variable curcap<sub>j,q</sub> is exogenous and set at zero change. In short-run comparative-static simulations, the standard closure (or choice of exogenous and endogenous variables) includes curcap<sub>j,q</sub> on the exogenous list and the relationship between industries' rates of return ( $r0_{j,q}$ ) and the world interest rate (natr\_tot), that is, the variable f\_rate\_xx<sub>j,q</sub> in equation E\_f\_rate\_xx, on the endogenous list.<sup>17</sup> With industries' capital stocks set at zero change, equation E\_ytB ensures that the percentage change in industries' investment ( $y_{j,q}$ ) are also zero, when the default option, of setting the shift variable (delf\_rate<sub>j,q</sub>) exogenously and at zero, is taken. The assumption is that the short-run is a time period over which, not only are capital stocks fixed, but also the industries' investment plans are fixed. The default option can be overridden by swapping the industries' investment with the shift variable on the endogenous/exogenous list.

<sup>17</sup> For a full discussion of alternative model closures, see Chapter 4.

In long-run simulations, we assume that the industries' capital stocks are determined endogenously and the relationship between the industries rates of return and the world interest rate is exogenous, i.e.,  $\text{curcap}_{j,q}$  is endogenous and  $f\_rate\_xx_{j,q}$  is exogenous. Equation E\_curcapT1B ensures that the percentage increase in industries' capital stocks in year T+1 is the same as the percentage increase in capital stocks in year T.

The interpretation of the long-run specification is that sufficient time has elapsed such that the effects of a sustained shock to the economy no longer disturbs the *rate* of capital accumulation in our year of interest, year T. Note that the assumption is that the *rate* of capital accumulation, but not the *level* of the capital stock is assumed to be undisturbed in year T. Having made the assumption in equation E\_curcapT1B that (using the above notation)

$$k_{j,q,T+1} = k_{j,q,T}, \quad j=1,\dots,13, \quad q=1,\dots,8, \quad (2.20)$$

then the percentage change form of equation 2.14 can be written as

$$K_{j,q,T+1}k_{j,q,T} = K_{j,q,T}DEP_j k_{j,q,T} + Y_{j,q,T}y_{j,q,T}, \quad j=1,\dots,13, \quad q=1,\dots,8. \quad (2.21)$$

Rearranging equation 2.21 gives

$$(K_{j,q,T+1} - K_{j,q,T}DEP_j)k_{j,q,T} = Y_{j,q,T}y_{j,q,T}, \quad j=1,\dots,13, \quad q=1,\dots,8. \quad (2.21)$$

From equation 2.14, we note that

$$K_{j,q,T+1} - K_{j,q,T}DEP_j = Y_{j,q,T}, \quad j=1,\dots,13, \quad q=1,\dots,8, \quad (2.22)$$

hence,

$$k_{j,q,T} = y_{j,q,T}, \quad j=1,\dots,13, \quad q=1,\dots,8. \quad (2.23)$$

or equation E\_yTB in Table 2.1, section 2.4.1.

The investment and capital equations of the model are completed with the specification of industry rates of return and an equation defining aggregate economy-wide investment. These equations are common to both the forecasting and comparative-static versions of the model.

Equation E\_r0 in Table 2.1, section 2.4.1, defines the percentage change in the rate of return on capital (net of depreciation) in industry  $j$ , region  $q$ . In levels this is the ratio of the rental price of capital ( $PICAP_{j,q}$ ) to the supply price ( $PI_{j,q}$ ), minus the rate of depreciation. Hence, the coefficient  $QCOEF_{j,q}$  is the ratio of the gross to the net rate of return.

Equation E\_f\_rate\_xx makes the change in the net rate of return in an industry relative to the economy-wide rate a positive function of the change in the industry's capital stock relative to the region-wide stock. It is interpreted as a

risk-related relationship with relatively fast-/slow-growing industries requiring premia/accepting discounts on their rates of return. The parameter  $BETA_{R_{j,q}}$  specifies the strength of this relationship. The variable  $f\_rate\_xx_{j,q}$  allows exogenous shifts in the industry's rate of return and also allows us to move between long-run and short-run comparative-static simulations as described above.

The investment-capital equations conclude with equation  $E\_naty$  which defines changes in the economy-wide industry investment as the weighted average of the changes in regional industry investment.

#### 2.4.2. Accumulation of national foreign debt<sup>18</sup>

This section contains equations modelling the nation's foreign debt. They relate the debt to accumulated balance-of-trade deficits. Analogous to equation 2.13 above, we have

$$DEBT_{t+1} = DEBT_t(R\_WORLD) + B_t, \quad (2.24)$$

where  $DEBT_t$  is the debt at year  $t$ ,  $B_t$  is the trade deficit in year  $t$ , and  $R\_WORLD$  is the interest rate factor; one plus the world real interest rate, which we treat as a parameter.

In the forecast simulations, we arrive at the value of the debt in year  $T$  by accumulating, on the basis of equation 2.24 starting at year 0, leading to

$$DEBT_T = DEBT_0(R\_WORLD)^T + \sum_{t=0}^{T-1} B_t(R\_WORLD)^{T-t-1}. \quad (2.25)$$

We also assume that the trade deficit in the time span 0-T follows a straight line path

$$B_t = B_0 + \frac{t}{T} (B_T - B_0), \quad t=0, \dots, T. \quad (2.26)$$

Thus

$$DEBT_T = DEBT_0(R\_WORLD)^T + \sum_{t=0}^{T-1} [B_0 + \frac{t}{T} (B_T - B_0)](R\_WORLD)^{T-t-1}. \quad (2.27)$$

Equation 2.27 can be written as

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<sup>18</sup> This section draws on Horridge, Parmenter and Pearson (1993).

$$DEBT_T - DEBT_0 = DEBT_0(R\_WORLD^T - 1) + B_0N\_DEBT + (B_T - B_0)M\_DEBT \quad (2.28)$$

where

$$M\_DEBT = \sum_{t=0}^{T-1} (R\_WORLD)^{T-t-1} \quad (2.29)$$

and

$$N\_DEBT = \sum_{t=1}^T (R\_WORLD)^{T-t}. \quad (2.30)$$

Notice that  $DEBT_T$  is linearly related to  $B_T$ , and to predetermined values of  $DEBT_0$  and  $B_0$ . We treat  $DEBT_T$  and  $B_T$  as variables, and  $DEBT_0$ ,  $B_0$  and  $R\_WORLD$  as parameters. As explained above, our initial solution for  $\{DEBT_T, B_T\}$  is  $\{DEBT_0, B_0\}$ . Analogous to the capital accumulation relation in section 2.4.1, unless

$$DEBT_0(R\_WORLD^T - 1) + B_0N\_DEBT = 0,$$

these values for  $DEBT_T$  and  $B_T$  will not satisfy equation 2.28. The resolution of the problem is to augment equation 2.28 with an additional variable  $DFUDGE$  as follows:

$$DEBT_T - DEBT_0 = [DEBT_0(R\_WORLD^T - 1) + B_0N\_DEBT]DFUDGE + (B_T - B_0)M\_DEBT. \quad (2.31)$$

We choose the initial value of  $DFUDGE$  to be 0 so that equation 2.31 is satisfied when  $DEBT_T = DEBT_0$  and  $B_T = B_0$ . In forecasting simulations, we shock  $DFUDGE$  to 1 ( $\Delta DFUDGE=1$ ). Then equation 2.31 is equivalent to equation 2.28, and our percentage-change results are consistent with equations 2.25 to 2.28 as desired.

Taking the ordinary change in equation 2.31, and writing the ordinary change in the variables in lower case with the prefix *del*, gives

$$deldebt_T = [DEBT_0(R\_WORLD^T - 1) + B_0N\_DEBT]delfudge + M\_DEBTdelbt_T. \quad (2.32)$$

Equation 2.32 appears in Table 2.1, section 2.4.2 as equation  $E\_deldebt$ .

Since  $R\_WORLD$  is a (fixed) real foreign interest rate,  $DEBT_t$  and  $B_t$  are denominated in base-year foreign-currency units. However, they must be related to other variables, such as the values of exports and imports, which are

measured in year-t Australian dollars (\$A). We define a coefficient, P\_GLOBAL, to convert \$A values into base-year foreign dollars. It is given in percentage change form as natxim (see Table 2.1, section 2.2.14, equation E\_natxim). This means that our 'best guess' at movements in world prices and the nominal exchange rate is given by the movements in the index of national foreign imports, which is the sum of the movements of a weighted average of the foreign prices of national imports plus the movement in the nominal exchange rate.

Equation E\_delbt defines the ordinary change in the real trade deficit. The levels form of this equation is

$$BT = \frac{NATXIM \times NATIMPVOL - NATXI4 \times NATEXPVOL}{P\_GLOBAL}, \quad (2.33)$$

where BT is the national real foreign trade balance ( $B_T$  in equations 2.27 to 2.31 above), NATXIM is the price index of national imports, NATIMPVOL is the volume of national foreign imports, NATXI4 is the price index of national exports, NATEXPVOL is the volume of national foreign exports. Taking the ordinary change in BT (delbt) in equation 2.33 and the percentage changes in the remaining variables (remembering the percentage change in P\_GLOBAL is natxim) in equation 2.33 gives equation E\_delbt.

The last equation of this section defines the ordinary change in the national debt/GDP ratio. In the levels, the debt/GDP ratio (DEBT\_RATIO) is given as

$$DEBT\_RATIO = DEBT / (NATGDPEXP / P\_GLOBAL), \quad (2.44)$$

where NATGDPEXP is national nominal GDP. Taking the ordinary change in DEBT\_RATIO (deldebt\_ratio) and the percentage changes in the remaining variables gives equation E\_deldebt\_ratio.

The above national debt accumulation equations produce comparative-static results when the variable deldfudge in equation E\_deldebt is set exogenously at zero change.

The final accumulation equation is one which relates regional population to various elements of regional population growth. We hold over the discussion of the accumulation of regional population to the next section.

## 2.5. Regional population and regional labour market settings

This block of equations computes regional population from natural growth, foreign migration and interregional migration. The block also includes various regional labour market relationships. For each region, the system is designed to allow for either: (i) an exogenous determination of regional population, with an endogenous determination of at least one variable of the regional labour market, chosen from regional unemployment, regional participation rates or regional wage relativities, or; (ii) an exogenous determination of all the previously mentioned variables of the regional labour market and an endogenous determination of regional migration, and hence, of regional population.

In case (i), the user can take on board the forecasts of the three population flows (natural growth, regional migration and foreign migration) from a demographic model thereby exogenously determining regional populations. For example, the ABS (cat. no. 3222.0) makes forecasts of these flows and of regional population. The labour market & migration block of equations can then be configured to determine regional labour supply from the exogenously specified regional population and given settings of regional participation rates and movements in the ratios of population to population of working age. With labour supply determined, the labour market and regional migration block will determine either interregional wage differentials, (given regional unemployment rates) or regional unemployment rates (given regional wage differentials). With given regional unemployment rates and regional labour supply, regional employment is determined as a residual and wage differentials adjust to accommodate the labour market outcome. Fixing wage differentials determines the demand for labour so that with regional labour supply given, the model will determine regional unemployment rates as a residual.

In alternative (ii), interregional wage differentials and regional unemployment rates are exogenously specified. The labour market and regional migration block then determines regional labour supply and regional population for given settings of regional participation rates and ratios of population to population of working age.

The equations of this block have been designed with sufficient flexibility to allow variations on the two general methods described above. Importantly, the block allows for some regions to be subject to method (i) and other regions to be subject to method (ii) in the same simulation.

We begin our exposition of the equations of this section with the accumulation of regional population. In the levels, we start with the accumulation relation

$$\text{POP}_{q,t+1} = \text{POP}_{q,t} + \text{FM}_{q,t} + \text{RM}_{q,t} + \text{G}_{q,t}, \quad q=1,\dots,8, \quad t=1,\dots,T, \quad (2.45)$$

where  $POP_{q,t}$  is regional population in year  $t$ ,  $FM_{q,t}$  is the net migration of overseas residents to region  $q$  in year  $t$ ,  $RM_{q,t}$  net migration of residents from other regions to region  $q$  in year  $t$  and  $G_{q,t}$  is region  $q$ 's natural growth in population in year  $t$ .

Accumulating on the basis of equation 2.45 over the period 0-T, we can derive a value for regional population in year T ( $POP_{q,T}$ )

$$POP_{q,T} = POP_{q,0} + \sum_{t=1}^T (FM_{q,t} + RM_{q,t} + G_{q,t}), \quad q=1, \dots, 8. \quad (2.46)$$

As with the accumulation of national foreign debt, in section 2.4.2 above, we make the simplifying assumption that the flow variables in equation 2.46 grow smoothly over the period 0-T, giving

$$FM_{q,t} = FM_{q,0} + \frac{t}{T}(FM_{q,T} - FM_{q,0}), \quad q=1, \dots, 8, \quad t=0, \dots, T, \quad (2.47)$$

$$RM_{q,t} = RM_{q,0} + \frac{t}{T}(RM_{q,T} - RM_{q,0}), \quad q=1, \dots, 8, \quad t=0, \dots, T \quad (2.48)$$

and

$$G_{q,t} = G_{q,0} + \frac{t}{T}(G_{q,T} - G_{q,0}), \quad q=1, \dots, 8, \quad t=0, \dots, T. \quad (2.49)$$

Substituting equations 2.47 to 2.49 into equation 2.46 and rearranging gives

$$POP_{q,T} - POP_{q,0} = T(FM_{q,0} + RM_{q,0} + G_{q,0}) + \frac{T+1}{2} [(FM_{q,T} - FM_{q,0}) + (RM_{q,T} - RM_{q,0}) + (G_{q,T} - G_{q,0})], \quad q=1, \dots, 8. \quad (2.50)$$

As with our earlier accumulation equations, we have the problem of an initial solution to equation 2.50 in that unless by chance

$$T(FM_{q,0} + RM_{q,0} + G_{q,0}) = 0,$$

our base-year values of POP, FM, RM and G do not constitute an initial solution. To resolve the problem, we adopt the technique applied to the national-debt-accumulation equation; we multiply the first term on the RHS of equation 2.50 by the variable RPFUDGE

$$POP_{q,T} - POP_{q,0} = T(FM_{q,0} + RM_{q,0} + G_{q,0})RPFUDGE + \frac{T+1}{2} [(FM_{q,T} - FM_{q,0}) + (RM_{q,T} - RM_{q,0}) + (G_{q,T} - G_{q,0})], \quad q=1, \dots, 8. \quad (2.50)$$

Giving RPFUDGE an initial value of 0, and the remaining elements their base-year values, now provides an initial solution satisfying equation 2.50. For forecasting simulations, RPFUDGE is shocked to 1, ( $\Delta$ RPFUDGE=1).

Treating the zero subscripted elements and T in equation 2.50 as constants, and taking the percentage change in  $POP_{q,T}$  ( $pop_q$ ) and ordinary changes in  $FM_{q,T}$ ,  $RM_{q,T}$ ,  $G_{q,T}$  and RPFUDGE ( $del\_fm_q$ ,  $del\_rm_q$ ,  $del\_g_q$  and  $delrpfudge$ , respectively), gives equation  $E\_del\_rm$  in Table 2.1, section 2.5.1. The following list maps the coefficients from equation 2.50 to equation  $E\_del\_rm$ :

$$\begin{aligned} POP_{q,T} &\Leftrightarrow C\_POP_q; \\ 100T(FM_{q,0} + RM_{q,0} + G_{q,0}) &\Leftrightarrow C\_PRI_q; \\ 50(T + 1) &\Leftrightarrow C\_PA2. \end{aligned}$$

As with the accumulation of national debt, equation  $E\_del\_rm$  can be implemented in comparative-static mode by assigning a value of zero to  $delrpfudge$ .

The remaining equations of this section can be grouped into the following categories: definitions; equations imposing arbitrary assumptions; equations imposing adding-up constraints and; national aggregates based on summing regional variables.

The definitional equations are  $E\_del\_labsup$  and  $E\_wpop$ . The former equation defines the percentage-point change in the regional unemployment ( $del\_unr_q$ ) in terms of the percentage changes in regional labour supply ( $labsup_q$ ) and persons employed ( $employ_q$ ). The latter equation defines the percentage change in regional labour supply in terms of the percentage changes in the regional participation rate ( $pr_q$ ) and the regional population of working age ( $wpop_q$ ).

In equation  $E\_pop$ , the assumption that the regional population of working age is proportional to the regional (total) population is imposed. The default setting can be overridden by endogenising the shift variable ( $f\_wpop_q$ ).

Equation  $E\_rm\_0$ , allows for the imposition of either the assumption that the change in net regional migration ( $del\_rm_q$ ) is equal to a forecast change in regional migration ( $del\_rm\_0_q$ ), or that  $del\_rm_q$  is equal to  $del\_rm\_0_q$  plus a common (to all q) constant. We can interpret equation  $E\_rm\_0$  as imposing the former assumption when  $del\_rm\_0_q$  are set exogenously (equal to, say, an ABS forecast) and when the shift variable,  $delf\_rm\_0$ , is set exogenously at zero change. The latter assumption is imposed when all but one of the  $del\_rm\_0_q$  are set exogenously and  $delf\_rm\_0$  is set endogenously. The purpose of the second assumption is as follows. We may wish to believe some, *but not all*, of the ABS forecasts of net regional migration. We may wish to determine one of the region's net regional migration from economic factors within MMRF. However, we may still wish that the remaining net regional migration flows to be approximately equal to the ABS forecasts. To the extent that the region's net

regional migration determined by MMRF deviates from that forecast by the ABS means that the sum of the regional net migration will not equal zero if the remaining regional net migration flows are set equal to their ABS forecasts. To overcome this problem, we distribute the positive/negative amount of net migration evenly across the regions. If it is desired that all regional net migration flows are determined by economic factors, rather than exogenously, then all elements of  $del\_rm\_0_q$  are set endogenously and swapped with a relevant labour market variable such as regional relative wage rates ( $wage\_diff_q$ , see equation  $E\_wage\_diff$ , section 2.2.11 above and in Table 2.1).

Equation  $E\_remploy\_interf$  imposes the assumption that regional employment in wage-bill weights is proportional to regional employment in person weights by setting the percentage change in regional wage-bill weighted employment ( $l_q$ ) equal to the percentage change in regional person-weighted employment ( $employ_q$ ) when the shift variable  $f\_l_q$  is exogenous and set to zero change. The default option can be overridden by setting  $f\_l_q$  to non-zero values.

Equation  $E\_pop\_interf$  imposes the assumption that regional household formation is proportional to regional population by setting the percentage change in regional household formation ( $qhous_q$ ) equal to the percentage change in regional population ( $pop_q$ ) when the shift variable  $f\_qhous_q$  is exogenous and set to zero change. The default option can be overridden by setting  $f\_qhous_q$  to non-zero values.

An adding-up constraint is imposed in equation  $E\_rm\_addup$ . If the variable  $delf\_rm$  is exogenous (and set to zero), then at least one of the  $del\_rm_q$  must be endogenous. If all the  $del\_rm_q$  are endogenous, then  $delf\_rm$  must endogenously equal zero for the simulation to be valid.

The remaining equations of this section,  $E\_delnatfm$ ,  $E\_delnatg$ ,  $E\_natlabsup$ ,  $E\_natemploy$ , and  $E\_natunr$  determine national aggregate variables by summing the corresponding regional variables.

Table 2.1. The MMRF Equations

Identifier	Equation	Subscript Range	Number	Description
<b>2.2. The CGE Core</b>				
<i>2.2.1. Production: demand for inputs to the production process</i>				
E_x1a1 (2.8.1)	$x1a_{i,s,j,q} = x1c_{i,j,q} - \sigma1C_i(p1a_{i,s,j,q} - p1c_{i,j,q})$	i ∈ COM s ∈ RSOU j ∈ IND q ∈ RDES	13×8×13×8	Demand for goods by regional source, User 1
E_p1c (2.8.1)	$p1c_{i,j,q} = \sum_{s \in RSOU} SIA_{i,s,j,q} p1a_{i,s,j,q}$	i ∈ COM j ∈ IND q ∈ RDES	13×13×8	Price of domestic composite, User 1
E_x1c (2.8.1)	$x1c_{i,j,q} = x1o_{i,j,q} - \sigma1O_i(p1c_{i,j,q} - p1o_{i,j,q})$	i ∈ COM j ∈ IND q ∈ RDES	13×13×8	Demand for domestic composite, User 1
E_x1a2 (2.8.1)	$x1a_{i,s,j,q} = x1o_{i,j,q} - \sigma1O_i(p1a_{i,s,j,q} - p1o_{i,j,q})$	i ∈ COM s = foreign j ∈ IND q ∈ RDES	13×1×13×8	Demand for foreign imports, User 1
E_p1o (2.8.1)	$PVAL1O_{i,j,q} p1o_{i,j,q} = \sum_{s \in ASOU} PVAL1A_{i,s,j,q} p1a_{i,s,j,q}$	i ∈ COM j ∈ IND q ∈ RDES	13×13×8	Price of domestic/foreign composite, User 1
E_x1laboi (2.8.2)	$x1laboi_{j,q,m} = \text{efflab}_{j,q} - \sigma1LAB_{j,q} [p1laboi_{j,q,m} - p1lab_{j,q}]$	m ∈ OCC j ∈ IND q ∈ RDES	8×13×8	Demand for labour by industry and skill group

Identifier	Equation	Subscript Range	Number	Description
E_pllab (2.8.2)	$LABOUR_{j,q} p llab_{j,q} = \sum_{m \in OCC} LAB\_OCC\_IND_{m,j,q} p llaboi_{j,q,m}$	$j \in IND$ $q \in RDES$	13x8	Price to each industry of labour in general
E_labind (2.8.2)	$LABOUR_{j,q} labind_{j,q} = \sum_{m \in OCC} LAB\_OCC\_IND_{m,j,q} x llaboi_{j,q,m}$	$j \in IND$ $q \in RDES$	13x8	Employment by industry
E_efflab (2.8.2)	$efflab_{j,q} = x lprim_{j,q} + a llab_{j,q} - \sigma lFAC_{j,q} [p llab_{j,q} + a llab_{j,q} - xi\_fac_{j,q}]$	$j \in IND$ $q \in RDES$	13x8	Industry demands for effective labour
E_curcap (2.8.2)	$curcap_{j,q} = x lprim_{j,q} + a lcap_{j,q} - \sigma lFAC_{j,q} [p lcap_{j,q} + a lcap_{j,q} - xi\_fac_{j,q}]$	$j \in IND$ $q \in RDES$	13x8	Industry demands for capital
E_n (2.8.2)	$n_{j,q} = x lprim_{j,q} + alland_{j,q} - \sigma lFAC_{j,q} [p lland_{j,q} + alland_{j,q} - xi\_fac_{j,q}]$	$j \in IND$ $q \in RDES$	13x8	Industry demands for land
E_xi_fac (2.8.2)	$TOTFACIND_{j,q} xi\_fac_{j,q} = LABOUR_{j,q} (p llab_{j,q} + a llab_{j,q}) + CAPITAL_{j,q} (p lcap_{j,q} + a lcap_{j,q}) + LAND_{j,q} (p lland_{j,q} + alland_{j,q})$	$j \in IND$ $q \in RDES$	13x8	Effective price term for factor demand equations
E_xlo (2.8.1)	$x lo_{i,j,q} = z_{j,q} + a l_{j,q}$	$i \in COM$ $j \in IND$ $q \in RDES$	13x13x8	Demands for domestic/foreign composite inputs, User 1
E_xlprim (2.8.2)	$x lprim_{j,q} = z_{j,q} + a l_{j,q} + a lprim_{j,q}$	$j \in IND$ $q \in RDES$	13x8	Industry demands for the primary-factor composite
E_xloct (2.8.1)	$x loct_{j,q} = z_{j,q} + a l_{j,q} + a loct_{j,q}$	$j \in IND$ $q \in RDES$	13x8	Industry demands for other cost tickets
<i>2.2.2. Demands for investment goods</i>				
E_x2a1 (2.8.3)	$x 2a_{i,s,j,q} = x 2c_{i,j,q} - \sigma 2c_{i,s,j,q} - p 2c_{i,j,q}$	$i \in COM$ $s \in RSOU$ $j \in IND$ $q \in RDES$	13x8x13x8	Demand for goods by regional source, User 2

...Table 2.1. continued

Identifier	Equation	Subscript Number Range	Description
E_x2a2 (2.8.3)	$x2a_{i,s,j,q} = x2o_{i,j,q} - \sigma2o_i(p2a_{i,s,j,q} - p2o_{i,j,q})$	$i \in \text{COM}$ $s = \text{foreign}$ $j \in \text{IND}$ $q \in \text{RDES}$	Demand for foreign imports, User 2
E_x2c (2.8.3)	$x2c_{i,j,q} = x2o_{i,j,q} - \sigma2o_i(p2c_{i,j,q} - p2o_{i,j,q})$	$i \in \text{COM}$ $j \in \text{IND}$ $q \in \text{RDES}$	Demand for domestic composite, User 2
E_p2c (2.8.3)	$\text{PVAL2T}_{i,ss,j,q} p2c_{i,j,q} = \sum_{s \in \text{RSOU}} \text{PVAL2A}_{i,s,j,q} p2a_{i,s,j,q}$	$i \in \text{COM}$ $ss = \text{domesti}$ $c$ $j \in \text{IND}$ $q \in \text{RDES}$	Price of domestic composite, User 2
E_p2o (2.8.3)	$\text{PVAL2O}_{i,j,q} p2o_{i,j,q} = \sum_{s \in \text{ASOU}} \text{PVAL2A}_{i,s,j,q} p2a_{i,s,j,q}$	$i \in \text{COM}$ $j \in \text{IND}$ $q \in \text{RDES}$	Price of domestic/foreign composite, User 2
E_x2o (2.8.3)	$x2o_{i,j,q} = y_{j,q} + a2\text{ind}_{j,q}$	$i \in \text{COM}$ $j \in \text{IND}$ $q \in \text{RDES}$	Demands for domestic/foreign composite inputs, User 2
<i>2.2.3. Household demands</i>			
E_x3a1 (2.8.4)	$x3a_{i,s,q} = x3c_{i,q} - \sigma3c_i(p3a_{i,s,q} - p3c_{i,q})$	$i \in \text{COM}$ $s \in \text{RSOU}$ $q \in \text{RDES}$	Demand for goods by regional source, User 3
E_x3a2 (2.8.4)	$x3a_{i,s,q} = x3o_{i,q} - \sigma3o_i(p3a_{i,s,q} - p3o_{i,q})$	$i \in \text{COM}$ $s = \text{foreign}$ $q \in \text{RDES}$	Demand for foreign imports, User 3

Identifier	Equation	Subscript Number Range	Description
E_x3c (2.8.4)	$x3c_{i,q} = x3o_{i,q} - \sigma3O_i(p3c_{i,q} - p3o_{i,q})$	$i \in \text{COM}$ $q \in \text{RDES}$	Demand for domestic composite, User 3
E_p3c (2.8.4)	$PVAL3T_{i,\text{domestic},q} p3c_{i,q} = \sum_{s \in \text{RSOU}} PVAL3A_{i,s,q} p3a_{i,s,q}$	$i \in \text{COM}$ $q \in \text{RDES}$	Price of domestic composite, User 3
E_p3o (2.8.4)	$PVAL3O_{i,q} p3o_{i,q} = \sum_{s \in \text{ASOU}} PVAL3A_{i,s,q} p3a_{i,s,q}$	$i \in \text{COM}$ $q \in \text{RDES}$	Price of domestic/foreign composite, User 3
E_x3o (2.8.4)	$x3o_{i,q} = [1 - \text{ALPHA}_{i,q}] [q\text{hous}_q + a3\text{sub}_{i,q}] + \text{ALPHA}_{i,q} [\text{luxe}\text{xp}_q + a3\text{lux}_{i,q} - p3o_{i,q}]$	$i \in \text{COM}$ $q \in \text{RDES}$	Household demand for domestic/foreign composite commodities
E_utility (2.8.4)	$\text{utility}_q = \text{luxe}\text{xp}_q - q\text{hous}_q - \sum_{i \in \text{COM}} \text{DELTA}_{i,q} p3o_{i,q}$	$q \in \text{RDES}$	Change in utility disregarding taste change terms
E_a3sub (2.8.4)	$a3\text{sub}_{i,q} = a3\text{com}_{i,q} - \sum_{k \in \text{COM}} S3\text{COM}_{k,q} a3\text{com}_{k,q}$	$i \in \text{COM}$ $q \in \text{RDES}$	Default setting for subsistence taste shifter
E_a3lux (2.8.4)	$a3\text{lux}_{i,q} = a3\text{sub}_{i,q} - \sum_{k \in \text{COM}} \text{DELTA}_{k,q} a3\text{sub}_{k,q}$	$i \in \text{COM}$ $q \in \text{RDES}$	Default setting for luxury taste shifter
<i>2.2.4. Foreign export demands</i>			
E_x4r (2.8.8)	$x4r_{i,s} - \text{feq}_i = \text{EXP\_ELAST}_{i,p4r_{i,s}} - \text{fep}_i - \text{nattfep}$	$i \in \text{TEXP}$ $s \in \text{RSOU}$	Traditional export demand functions
E_aggnt_x4r (2.8.8)	$\text{aggnt\_x4r}_s - \text{aggnt\_feq}_s = \text{EXP\_ELAST}_{\text{manufact}[aggnt\_p4r_s - \text{aggnt\_fep}_s - \text{nattfep}]}$	$s \in \text{RSOU}$	Demand for the non-traditional export aggregate
E_nt_x4r (2.8.8)	$x4r_{i,s} = \text{aggnt\_x4r}_s + \text{faggnt\_i}_i + \text{faggnt\_s}_s + \text{faggnt\_is}_i$	$i \in \text{NTEXP}$ $s \in \text{RSOU}$	Non-traditional-export demand functions
E_aggnt_p4r (2.8.8)	$\text{AGGEXPNT}_{s,\text{aggnt\_p4r}_s} = \sum_{i \in \text{NTEXP}} PVAL4R_{i,s} p4r_{i,s} + \text{faggnt\_p4r}_s$	$i \in \text{NTEXP}$ $s \in \text{RSOU}$	Average price of non-traditional exports

Identifier	Equation	Subscript Number Range	Description
2.2.5.	<i>Government consumption demands</i>		
E_x5a (2.8.9)	$x5a_{i,s,q} = cr_q + f5a_{i,s,q} + f5gen_q + natf5gen$	$i \in \text{COM}$ $s \in \text{ASOU}$ $q \in \text{RDES}$	Regional other demands
E_x6a (2.8.10)	$x6a_{i,s,q} = natcr + f6a_{i,s,q} + f6gen_q + natf6gen$	$i \in \text{COM}$ $s \in \text{ASOU}$ $q \in \text{RDES}$	Federal other demands
2.2.6. <i>Demands for margins</i>			
E_x1marg (2.8.11)	$x1marg_{i,s,j,q,r} = x1a_{i,s,j,q}$	$i \in \text{COM}$ $j \in \text{IND}$ $q \in \text{RDES}$ $s \in \text{ASOU}$ $r \in \text{MARG}$	Margins on sales to producers
E_x2marg (2.8.11)	$x2marg_{i,s,j,q,r} = x2a_{i,s,j,q}$	$i \in \text{COM}$ $j \in \text{IND}$ $q \in \text{RDES}$ $s \in \text{ASOU}$ $r \in \text{MARG}$	Margins on sales to capital creators
E_x3marg (2.8.11)	$x3marg_{i,s,q,r} = x3a_{i,s,q}$	$i \in \text{COM}$ $s \in \text{ASOU}$ $q \in \text{RDES}$ $r \in \text{MARG}$	Margins on sales to household consumption
E_x4marg (2.8.11)	$x4marg_{i,s,r} = x4r_{i,s}$	$i \in \text{COM}$ $r \in \text{MARG}$ $s \in \text{RSOU}$	Margins on exports: factory gate to port

Identifier	Equation	Subscript Number Range	Description
E_x5marg (2.8.11)	$x5marg_{i,s,q,r} = x5a_{i,s,q}$	$i \in \text{COM}$ $s \in \text{ASOU}$ $q \in \text{RDES}$ $r \in \text{MARG}$	Margins on sales to regional other demands
E_x6marg (2.8.11)	$x6marg_{i,s,q,r} = x6a_{i,s,q}$	$i \in \text{COM}$ $r \in \text{MARG}$ $s \in \text{ASOU}$ $q \in \text{RDES}$	Margins on sales to federal other demands in each region
2.2.7. Prices			
E_p0a (2.8.13)	$\text{COSTS}_{j,q} \{ p0a_{j,q} - a_{j,q} \} = \sum_{i \in \text{COM}} \text{PVAL1A}_{i,s,j,q} p1a_{i,s,j,q}$ $+ \sum_{m \in \text{OCC}} \text{LAB\_OCC\_IND}_{m,j,q} p1laboi_{j,q,m} + \text{CAPITAL}_{j,q} p1cap_{j,q}$ $+ \text{LAND}_{j,q} p1land_{j,q} + \text{OTHCOST}_{j,q} p1oct_{j,q}$	$j \in \text{IND}$ $q \in \text{RDES}$	Zero pure profits in current production
E_a (2.8.13)	$\text{COSTS}_{j,q} [a_{j,q} - a_{j,q}] = \text{TOTFACIND}_{j,q} p1prim_{j,q} + \text{LABOUR}_{j,q} a1lab_{j,q} + \text{CAPITAL}_{j,q} a1cap_{j,q}$ $+ \text{LAND}_{j,q} a1land_{j,q} + \text{OTHCOST}_{j,q} a1oct_{j,q}$	$j \in \text{IND}$ $q \in \text{RDES}$	Technical change by industry - current production
E_pi (2.8.13)	$\text{INVEST}_{j,q} (pi_{j,q} - a2ind_{j,q}) = \sum_{i \in \text{COM}} \text{PVAL2A}_{i,s,j,q} p2a_{i,s,j,q}$	$j \in \text{IND}$ $q \in \text{RDES}$	Zero pure profits in capital creation
E_p0ab (2.8.13)	$p0a(i, \text{"foreign"}) = pm_i + natphi + powtaxm_i$	$i \in \text{COM}$	Zero pure profits in importing
E_p1a (2.8.6)	$\text{PVAL1A}_{i,s,j,q} p1a_{i,s,j,q} = [\text{BAS1}_{i,s,j,q} + \text{TAX1}_{i,s,j,q}] p0a_{i,s} + \text{BAS1}_{i,s,j,q} \text{deltax1}_{i,s,j,q}$ $+ \sum_{r \in \text{MARG}} \text{MAR1}_{i,s,j,q,r} p0a_{q,r}$	$i \in \text{COM}$ $j \in \text{IND}$ $q \in \text{RDES}$ $s \in \text{ASOU}$	Purchasers prices - User 1

Identifier	Equation	Subscript Range	Number	Description
E_p2a (2.8.6)	$PVAL2A_{i,s,j,q}p2a_{i,s,j,q} = [BAS2_{i,s,j,q} + TAX2_{i,s,j,q}]p0a_{i,s} + BAS2_{i,s,j,q}deltax2_{i,s,j,q} + \sum_{r \in MARG} MAR2_{i,s,j,q,r}p0a_{q,r}$	$i \in COM$ $j \in IND$ $q \in RDES$ $s \in ASOU$	13×13×8×9	Purchasers prices - User 2
E_p3a (2.8.6)	$PVAL3A_{i,s,q}p3a_{i,s,q} = [BAS3_{i,s,q} + TAX3_{i,s,q}]p0a_{i,s} + BAS3_{i,s,q}deltax3_{i,s,q} + \sum_{r \in MARG} MAR3_{i,s,q,r}p0a_{q,r}$	$i \in COM$ $q \in RDES$ $s \in ASOU$	13×8×9	Purchasers prices - User 3
E_p4r (2.8.6)	$PVAL4R_{i,s}(natphi + p4r_{i,s}) = [BAS4_{i,s} + TAX4_{i,s}]p0a_{i,s} + BAS4_{i,s}deltax4_{i,s} + \sum_{r \in MARG} MAR4_{i,s,r}p0a_{r,s}$	$i \in COM$ $s \in RSOU$	13×8	Purchasers prices - User 4
E_p5a (2.8.6)	$PVAL5A_{i,s,q}p5a_{i,s,q} = [BAS5_{i,s,q} + TAX5_{i,s,q}]p0a_{i,s} + BAS5_{i,s,q}deltax5_{i,s,q} + \sum_{r \in MARG} MAR5_{i,s,q,r}p0a_{s,r}$	$i \in COM$ $q \in RDES$ $s \in ASOU$	13×8×9	Purchasers prices - User 5
E_p6a (2.8.6)	$PVAL6A_{i,s,q}p6a_{i,s,q} = [BAS6_{i,s,q} + TAX6_{i,s,q}]p0a_{i,s} + BAS6_{i,s,q}deltax6_{i,s,q} + \sum_{r \in MARG} MAR6_{i,s,q,r}p0a_{r,s}$	$i \in COM$ $s \in ASOU$ $q \in RDES$	13×9×8	Purchasers prices - User 6

2.2.8. Market-clearing equations for commodities

Identifier	Equation	Subscript Number Range	Description
E_mkt_clear_margins (2.8.12)	$\begin{aligned} \text{SALES}_{r,s}^z \text{r,s} = & \sum_{j \in \text{IND}} \text{BAS1}_{r,s,j}^{x1a} \text{r,s,j,q} + \text{BAS2}_{r,s,j}^{x2a} \text{r,s,j,q} + \sum_{q \in \text{RDES}} \text{BAS3}_{r,s,q}^{x3a} \text{r,s,q} \\ & + \text{BAS4}_{r,s}^{x4r,s} + \sum_{q \in \text{RDES}} \text{BAS5}_{r,s,q}^{x5a} \text{r,s,q} + \sum_{q \in \text{RDES}} \text{BAS6}_{r,s,q}^{x6a} \text{r,s,q} \\ & + \sum_{j \in \text{IND}} \sum_{i \in \text{COM}} \text{MAR1}_{i,ss,j}^{x1a} \text{r,s,j,q} + \text{MAR2}_{i,ss,j}^{x2a} \text{r,s,j,q} + \text{MAR3}_{i,ss,s}^{x3a} \text{r,s,s,r} + \text{MAR4}_{i,s,r}^{x4a} \text{r,s,r} \\ & + \sum_{i \in \text{COM}} \sum_{s \in \text{ASOU}} \text{MAR5}_{i,ss,s}^{x5a} \text{r,s,s,r} + \sum_{i \in \text{COM}} \sum_{s \in \text{ASOU}} \text{MAR6}_{i,ss,s}^{x6a} \text{r,s,s,r} \end{aligned}$	r ∈ MARG s ∈ RSOU	Demand equals supply for margin commodities
E_mkt_clear_nomarg (2.8.12)	$\begin{aligned} \text{SALES}_{r,s}^z \text{r,s} = & \sum_{j \in \text{IND}} \text{BAS1}_{r,s,j}^{x1a} \text{r,s,j,q} + \sum_{j \in \text{IND}} \sum_{q \in \text{RDES}} \text{BAS2}_{r,s,j}^{x2a} \text{r,s,j,q} \\ & + \sum_{q \in \text{RDES}} \text{BAS3}_{r,s,q}^{x3a} \text{r,s,q} + \text{BAS4}_{r,s}^{x4r,s} + \sum_{q \in \text{RDES}} \text{BAS5}_{r,s,q}^{x5a} \text{r,s,q} + \sum_{q \in \text{RDES}} \text{BAS6}_{r,s,q}^{x6a} \text{r,s,q} \\ & + \text{IMPORTS}_{i,q}^{x0imp} = \sum_{j \in \text{IND}} \text{BAS1}_{i,foreign,j}^{x1a} \text{r,s,j,q} + \sum_{j \in \text{IND}} \sum_{q \in \text{RDES}} \text{BAS2}_{i,foreign,j}^{x2a} \text{r,s,j,q} \\ & + \sum_{q \in \text{RDES}} \text{BAS3}_{i,foreign,q}^{x3a} \text{r,s,q} + \text{BAS4}_{i,foreign}^{x4r,s} + \sum_{q \in \text{RDES}} \text{BAS5}_{i,foreign,q}^{x5a} \text{r,s,q} + \sum_{q \in \text{RDES}} \text{BAS6}_{i,foreign,q}^{x6a} \text{r,s,q} \end{aligned}$	r ∈ NONMARG G s ∈ RSOU	Demand equals supply for nonmargin commodities
E_x0impa (2.8.12)	$\text{IMPORTS}_{i,q}^{x0imp} = \sum_{j \in \text{IND}} \text{BAS1}_{i,foreign,j}^{x1a} \text{r,s,j,q} + \sum_{j \in \text{IND}} \sum_{q \in \text{RDES}} \text{BAS2}_{i,foreign,j}^{x2a} \text{r,s,j,q} + \sum_{q \in \text{RDES}} \text{BAS3}_{i,foreign,q}^{x3a} \text{r,s,q} + \text{BAS4}_{i,foreign}^{x4r,s} + \sum_{q \in \text{RDES}} \text{BAS5}_{i,foreign,q}^{x5a} \text{r,s,q} + \sum_{q \in \text{RDES}} \text{BAS6}_{i,foreign,q}^{x6a} \text{r,s,q}$	i ∈ COM q ∈ RDES	Import volumes of commodities by region
2.2.9. Indirect taxes			
E_deltax1 (2.8.5)	$\text{deltax1}_{i,s,j,q} = \text{deltax}_i + \text{deltax lall} + \text{deltax source}_s + \text{deltax dest}_q$	i ∈ COM s ∈ ASOU j ∈ IND q ∈ RDES	Tax rate on sales to User 1

Identifier	Equation	Subscript Number Range	Description
E_deltax2 (2.8.5)	$\text{deltax}2_{1,s,j,q} = \text{deltax}_i + \text{deltax}2_{\text{all}} + \text{deltaxsource}_s + \text{deltaxdest}_q$	$i \in \text{COM}$ $s \in \text{ASOU}$ $j \in \text{IND}$ $q \in \text{RDES}$	Tax rate on sales to User 2
E_deltax3 (2.8.5)	$\text{deltax}3_{1,s,q} = \text{deltax}_i + \text{deltax}3_{\text{all}} + \text{deltaxsource}_s + \text{deltaxdest}_q$	$i \in \text{COM}$ $s \in \text{ASOU}$ $q \in \text{RDES}$	Tax rate on sales to User 3
E_deltax4 (2.8.5)	$\text{deltax}4_{1,s} = \text{deltax}_i + \text{deltax}4_{\text{all}} + \text{deltaxsource}_s + \text{deltaxdest}_q$	$i \in \text{COM}$ $s \in \text{RSOU}$ $q = \text{foreign}$	Tax rate on sales to User 4
E_deltax5 (2.8.5)	$\text{deltax}5_{1,s,q} = \text{deltax}_i + \text{deltax}5_{\text{all}} + \text{deltaxsource}_s + \text{deltaxdest}_q$	$i \in \text{COM}$ $s \in \text{ASOU}$ $q \in \text{RDES}$	Tax rate on sales to User 5
E_deltax6 (2.8.5)	$\text{deltax}6_{1,s,q} = \text{deltax}_i + \text{deltax}6_{\text{all}} + \text{deltaxsource}_s + \text{deltaxdest}_k$	$i \in \text{COM}$ $s \in \text{ASOU}$ $q \in \text{RDES}$ $k = \text{federal}$	Tax rate on sales to User 6
E_taxrev1 (2.8.7)	$\text{AGGTAX}1_{\text{qtaxrev}1,q} = \sum_{i \in \text{COM}} \sum_{s \in \text{ASOU}} \sum_{j \in \text{IND}} \text{TAX}1_{1,s,j,q} \{ p0a_{1,s} + x1a_{1,s,j,q} \} + \text{BAS}1_{1,s,j,q} \text{deltax}1_{1,s,j,q}$	8	Aggregate revenue from indirect taxes levied on flows to User 1
E_taxrev2 (2.8.7)	$\text{AGGTAX}2_{\text{qtaxrev}2,q} = \sum_{i \in \text{COM}} \sum_{s \in \text{ASOU}} \sum_{j \in \text{IND}} \text{TAX}2_{1,s,j,q} \{ p0a_{1,s} + x2a_{1,s,j,q} \} + \text{BAS}2_{1,s,j,q} \text{deltax}2_{1,s,j,q}$	8	Aggregate revenue from indirect taxes levied on flows to User 2
E_taxrev3 (2.8.7)	$\text{AGGTAX}3_{\text{qtaxrev}3,q} = \sum_{i \in \text{COM}} \sum_{s \in \text{ASOU}} \text{TAX}3_{1,s,q} \{ p0a_{1,s} + x3a_{1,s,q} \} + \text{BAS}3_{1,s,q} \text{deltax}3_{1,s,q}$	8	Aggregate revenue from indirect taxes levied on flows to User 3
E_taxrev4 (2.8.7)	$\text{AGGTAX}4_{\text{qtaxrev}4,s} = \sum_{i \in \text{COM}} \text{TAX}4_{1,s} \{ p0a_{1,s} + x4a_{1,s} \} + \text{BAS}4_{1,s} \text{deltax}4_{1,s}$	8	Aggregate revenue from indirect taxes levied on flows to User 4

Identifier	Equation	Subscript Number Range	Description
E_taxrev5 (2.8.7)	$AGGTAX5_q \text{taxrev}5_q = \sum_{i \in \text{COM}} \sum_{s \in \text{ASOU}} \text{TAX5}_{i,s,q} \{ p0a_{i,s} + x5a_{i,s,q} \} + \text{BAS5}_{i,s,q} \text{deltax}5_{i,s,q}$	q ∈ RDES 8	Aggregate revenue from indirect taxes levied on flows to User 5
E_taxrev6 (2.8.7)	$AGGTAX6_q \text{taxrev}6_q = \sum_{i \in \text{COM}} \sum_{s \in \text{ASOU}} \text{TAX6}_{i,s,q} \{ p0a_{i,s} + x6a_{i,s,q} \} + \text{BAS6}_{i,s,q} \text{deltax}6_{i,s,q}$	q ∈ RDES 8	Aggregate revenue from indirect taxes levied on flows to User 6
<i>2.2.10. Regional incomes and expenditures</i>			
E_caprev (2.8.14)	$\text{caprev}_q = (1.0/\text{AGGCAP}_q) \sum_{j \in \text{IND}} \text{CAPITAL}_{j,q} \{ p1\text{cap}_{j,q} + \text{curcap}_{j,q} \}$	q ∈ RDES 8	Aggregate payments to capital
E_labrev (2.8.14)	$\text{labrev}_q = (1.0/\text{AGGLAB}_q) \sum_{j \in \text{IND}} \sum_{m \in \text{OCC}} \text{LAB\_OCC\_IND}_{m,j,q} \{ p1\text{laboi}_{j,q,m} + x1\text{laboi}_{j,q,m} \}$	q ∈ RDES 8	Aggregate payments to labour
E_Indrev (2.8.14)	$\text{Indrev}_q = (1.0/\text{AGGLND}_q) \sum_{j \in \text{IND}} \text{LAND}_{j,q} \{ p1\text{land}_{j,q} + n_{j,q} \}$	q ∈ RDES 8	Aggregate payments to land
E_octrev (2.8.14)	$\text{octrev}_q = (1.0/\text{AGGOCT}_q) \sum_{j \in \text{IND}} \text{OTH COST}_{j,q} \{ p1\text{oct}_{j,q} + x1\text{oct}_{j,q} \}$	q ∈ RDES 8	Aggregate other cost ticket payments
E_taxind (2.8.14)	$\text{taxind}_q = (1.0/\text{AGGTAX}_q) (\text{AGGTAX1}_q \text{taxrev}1_q + \text{AGGTAX2}_q \text{taxrev}2_q + \text{AGGTAX3}_q \text{taxrev}3_q + \text{AGGTAX5}_q \text{taxrev}5_q)$	q ∈ RDES 8	Aggregate value of indirect taxes
E_taxrevm (2.8.14)	$\text{AGGTAXM}_q \text{taxrevm}_q = \sum_{i \in \text{COM}} \text{TARIFF}_{i,q} \{ p m_1 + \text{natphi} + x0\text{imp}_{i,q} \} + \text{IMPORTS}_{i,q} \text{powtaxm}_i$	q ∈ RDES 8	Aggregate tariff revenue
E_c_a (2.8.14)	$\text{AGGCON}_q c_q = \sum_{i \in \text{COM}} \sum_{s \in \text{ASOU}} \text{PVAL3A}_{i,s,q} \{ x3a_{i,s,q} + p3a_{i,s,q} \}$	q ∈ RDES 8	Household budget constraint
E_cr (2.8.14)	$c_r_q = c_q - x i3_q$	q ∈ RDES 8	Real household consumption
E_xi3 (2.8.16)	$x i3_q = (1.0/\text{AGGCON}_q) \sum_{i \in \text{COM}} \sum_{s \in \text{ASOU}} \text{PVAL3A}_{i,s,q} p3a_{i,s,q}$	q ∈ RDES 8	Consumer price index

Identifier	Equation	Subscript Number Range	Description
E_ir (2.8.14)	$ir_q = (1.0/AGGINV_q) \sum_{j \in IND} INVEST_{j,q} y_{j,q}$	q ∈ RDES 8	Real investment
E_othreal5 (2.8.14)	$othreal5_q = (1.0/AGGOTH5_q) \sum_{i \in COM} \sum_{s \in ASOU} PVAL5A_{i,s,q} x^{5a}_{i,s,q}$	q ∈ RDES 8	Real regional other demands
E_othreal6 (2.8.14)	$AGGOTH6_{othreal6_q} = \sum_{i \in COM} \sum_{s \in ASOU} PVAL6A_{i,s,q} x^{6a}_{i,s,q}$	q ∈ RDES 8	Real federal other demand
E_int_exp (2.8.14)	$C\_XSEXP_s(psexp_s + xsexp_s) = \sum_{q \in RDES} C\_XSFL0_{s,q}(psflo_{s,q} + xsflo_{s,q}) - C\_XSFL0_{s,s}(psflo_{s,s} + xsflo_{s,s})$	s ∈ RSOU 8	Interregional exports
E_int_imp (2.8.14)	$C\_XSIMP_q(psimp_q + xsimp_q) = \sum_{s \in RSOU} C\_XSFL0_{s,q}(psflo_{s,q} + xsflo_{s,q}) - C\_XSFL0_{q,q}(psflo_{q,q} + xsflo_{q,q})$	q ∈ RDES 8	Interregional imports
E_expvol (2.8.14)	$expvol_q = export_q + natphi - xi4_q$	q ∈ RDES 8	Export volume index
E_impvol (2.8.14)	$impvol_q = imp_q + natphi - xim_q$	q ∈ RDES 8	Import volume index
E_xi2 (2.8.16)	$xi2_q = (1.0/AGGINV_q) \sum_{j \in IND} INVEST_{j,q} p_{j,q}$	q ∈ RDES 8	Investment price index
E_xi5 (2.8.16)	$xi5_q = (1.0/AGGOTH5_q) \sum_{i \in COM} \sum_{s \in ASOU} PVAL5A_{i,s,q} p^{5a}_{i,s,q}$	q ∈ RDES 8	Regional other demands price index
E_xi6 (2.8.16)	$xi6_q = (1.0/AGGOTH6_q) \sum_{i \in COM} \sum_{s \in ASOU} PVAL6A_{i,s,q} p^{6a}_{i,s,q}$	q ∈ RDES 8	Price index for Federal other demand
E_psexp (2.8.16)	$C\_XSEXP_s psexp_s = \sum_{q \in RDES} C\_XSFL0_{s,q} psflo_{s,q} - C\_XSFL0_{s,s} psflo_{s,s}$	s ∈ RSOU 8	Price index for interregional exports

Identifier	Equation	Subscript Range	Number	Description
E_psimp (2.8.16)	$C\_XSIMP\_q^{psimp} = \sum_{s \in RSOU} C\_XSFL0_{s,q}^{psflo} - C\_XSFL0_{q,q}^{psflo}$	q ∈ RDES	8	Price index for interregional imports
E_xi4 (2.8.16)	$xi4_q - natphi = (1.0/AGGEXP_q) \sum_{i \in COM} PVAL4R_{i,q} p^4 r_{i,q}$	q ∈ RDES	8	Foreign exports price index
E_xim (2.8.16)	$xim_q - natphi = (1.0/AGGIMP_q) \sum_{i \in COM} IMPCOST_{i,q} pm_i$	q ∈ RDES	8	Foreign imports price index
E_in (2.8.14)	$in_q = ir_q + xi2_q$	q ∈ RDES	8	Nominal investment
E_othnom5 (2.8.14)	$othnom5_q = othreal5_q + xi5_q$	q ∈ RDES	8	Nominal value of regional other demands
E_othnom6 (2.8.14)	$othnom6_q = othreal6_q + xi6_q$	q ∈ RDES	8	Nominal Federal other demand
E_export (2.8.14)	$export_q = (1.0/AGGEXP_q) \sum_{i \in COM} PVAL4R_{i,q} [p^4 r_{i,q} + x^4 r_{i,q}]$	q ∈ RDES	8	Foreign currency value of exports
E_imp (2.8.14)	$imp_q = (1.0/AGGIMP_q) \sum_{i \in COM} IMPCOST_{i,q} [pm_i + x^0 imp_{i,q}]$	q ∈ RDES	8	Foreign currency value of imports

Identifier	Equation	Subscript Number Range	Description
E_trd (2.8.14)	$C\_XSFL0_{s,q}(psflo_{s,q} + xsflo_{s,q}) = \sum_{i \in COM} \sum_{j \in IND} BAS1_{i,s,j,q}(p0a_{i,s} + x1a_{i,s,j,q})$ $+ \sum_{i \in COM} \sum_{j \in IND} BAS2_{i,s,j,q}(p0a_{i,s} + x2a_{i,s,j,q})$ $+ \sum_{i \in COM} BAS3_{i,s,q}(p0a_{i,s} + x3a_{i,s,q})$ $+ \sum_{i \in COM} BAS5_{i,s,q}(p0a_{i,s} + x5a_{i,s,q})$	s ∈ RSOU q ∈ RDES	Interregional trade flows (including diagonal term)
E_psflo (2.8.16)	$C\_XSFL0_{s,q}(psflo_{s,q}) = \sum_{i \in COM} \sum_{j \in IND} BAS1_{i,s,j,q} p0a_{i,s} + \sum_{i \in COM} \sum_{j \in IND} BAS2_{i,s,j,q} p0a_{i,s}$ $+ \sum_{i \in COM} BAS3_{i,s,q} p0a_{i,s} + \sum_{i \in COM} BAS5_{i,s,q} p0a_{i,s}$	s ∈ RSOU q ∈ RDES	Price index for interregional trade flows
<i>2.2.11. Regional wages</i>			
E_pllaboi (2.8.17)	$p \text{llaboi}_{j,q,m} = pwagei_{j,q} + arprj_{j,q}$	j ∈ IND q ∈ RDES m ∈ OCC	Payroll tax adjustment
E_pwagei (2.8.17)	$pwagei_{j,q} = natxi3 + natfwage + fwage_q + fwagej_{j,q}$	j ∈ IND q ∈ RDES	Flexible setting of money wages
E_wage_diff (2.8.17)	$wage\_diff_q = pwage_q - natxi3 - natrealwage$	q ∈ RDES	Regional real wage differential
E_pwage (2.8.17)	$AGGLAB\_q pwage_q = \sum_{j \in IND} LABOUR_{j,q} pwagej_{j,q}$	q ∈ RDES	Regional nominal wage received by workers

Identifier	Equation	Subscript Number Range	Description
E_natrealw (2.8.17)	$\text{NATAGGLAB\_natrealwage} = \sum_{j \in \text{IND}} \sum_{q \in \text{RDES}} \text{LABOUR}_{j,q} (\text{natfwage} + \text{fwage}_q + \text{fwage}_{j,q})$	1	National real wage: consumer
<i>2.2.12. Other regional factor market definitions</i>			
E_l (2.8.14)	$l_q = (1.0/\text{AGGLAB}_q) \sum_{j \in \text{IND}} \text{LABOUR}_{j,q} \text{labind}_{j,q}$	q ∈ RDES	Employment: wage bill weights
E_kt (2.8.14)	$kt_q = (1.0/\text{AGGCAP}_q) \sum_{j \in \text{IND}} \text{CAPITAL}_{j,q} \text{curcap}_{j,q}$	q ∈ RDES	Usage of capital: rental weights
E_z_tot (2.8.14)	$\text{TOTFAC}_{q^z\_tot_q} = \sum_{j \in \text{IND}} \text{TOTFACIND}_{j,q^z,j,q}$	q ∈ RDES	Output: value-added weights
E_lambda (2.8.19)	$\text{LAB\_OCC}_{m,q} \text{lambda}_{m,q} = \sum_{j \in \text{IND}} \text{LAB\_OCC\_IND}_{m,j,q} x \text{laboi}_{j,q,m}$	m ∈ OCC q ∈ RDES	Demand for labour by occupation
E_pwage_p (2.8.17)	$\text{AGGLAB}_q \text{pwage}_p = \sum_{j \in \text{IND}} \text{LABOUR}_{j,q} p \text{lab}_{j,q}$	q ∈ RDES	Nominal wage paid by producers
E_reg_plcap (2.8.18)	$\text{reg\_plcap}_q = \text{caprev}_q - kt_q$	q ∈ RDES	Rental price of capital
E_realwage_w (2.8.18)	$\text{realwage}_w = \text{pwage}_q - x \text{i}^3_q$	q ∈ RDES	Real wages for workers: deflated by CPI
E_realwage_p (2.8.18)	$\text{realwage}_p = \text{pwage}_p - x \text{iy}_q$	q ∈ RDES	Real wages for producers: deflated by GDP deflator
E_r0_tot (2.8.18)	$r0\_tot_q = (1.0/\text{AGGCAP}_q) \sum_{j \in \text{IND}} \text{CAPITAL}_{j,q} r0_{j,q}$	q ∈ RDES	Rate of return on capital
E_xiplpk_ind (2.8.18)	$x \text{iplpk\_ind}_{j,q} = p \text{lab}_{j,q} - p \text{lcap}_{j,q}$	j ∈ IND 13 × 8 q ∈ RDES	Index of relative price movements of labour & capital

Identifier	Equation	Subscript Number Range	Description
E_xiplpk (2.8.18)	$xiplpk_q = pwage\_p_q - reg\_p1cap_q$	q ∈ RDES 8	Index of relative price movements of labour & capital: regional aggregate
<i>2.2.13. Other miscellaneous regional equations</i>			
E_ploct (2.8.1)	$ploct_{j,q} = xi3_q + floct_{j,q}$	j ∈ IND 13×8 q ∈ RDES	Indexing of prices of other cost tickets
E_cr_shr (2.8.14)	$cr_q = nater + cr\_shr_q$	q ∈ RDES 8	Regional shares in national real household consumption
E_ximp0 (2.8.16)	$ximp0_q = (1.0/[AGGIMP_q + AGGTAXM_q]) \sum_{i \in COM} IMPORTS_{i,q} p0_{q,s}$	q ∈ RDES 8 s = foreign	Duty-paid imports price index
E_totdom (2.8.18)	$totdom_q = psexp_q - psimp_q$	q ∈ RDES 8	Domestic terms of trade
E_totfor (2.8.18)	$totfor_q = xi4_q - xim_q$	q ∈ RDES 8	Foreign terms of trade
<i>2.2.14. National aggregates</i>			
E_nattaxrev1 (2.8.7)	$NATAGGTAX1\_nattaxrev1 = \sum_{q \in RDES} AGGTAX1\_q taxrev1_q$	1	Revenue from indirect taxes levied on flows to User 1
E_nattaxrev2 (2.8.7)	$NATAGGTAX2\_nattaxrev2 = \sum_{q \in RDES} AGGTAX2\_q taxrev2_q$	1	Revenue from indirect taxes levied on flows to User 2
E_nattaxrev3 (2.8.7)	$NATAGGTAX3\_nattaxrev3 = \sum_{q \in RDES} AGGTAX3\_q taxrev3_q$	1	Revenue from indirect taxes levied on flows to User 3
E_nattaxrev4 (2.8.7)	$NATAGGTAX4\_nattaxrev4 = \sum_{s \in RSOU} AGGTAX4_s taxrev4_s$	1	Revenue from indirect taxes levied on flows to User 4

Identifier	Equation	Subscript Range	Number	Description
E_nattaxrev5 (2.8.7)	$\text{NATAGGTAX5} \text{ nattaxrev5} = \sum_{q \in \text{RDES}} \text{AGGTAX5}_q \text{taxrev5}_q$		1	Revenue from indirect taxes levied on flows to User 5
E_nattaxrev6 (2.8.7)	$\text{NATAGGTAX6} \text{ nattaxrev6} = \sum_{q \in \text{RDES}} \text{AGGTAX6}_q \text{taxrev6}_q$		1	Revenue from indirect taxes levied on flows to User 6
E_natx0imp (2.8.12)	$\text{NATIMPORTS}_i \text{ natx0imp}_i = \sum_{q \in \text{RDES}} \text{IMPORTS}_{i,q} \text{ x0imp}_{i,q}$	i ∈ COM	13	Import volumes
E_natlabind (2.8.14)	$\text{NATLABOUR}_j \text{ natlabind}_j = \sum_{q \in \text{RDES}} \text{LABOUR}_{j,q} \text{ labind}_{j,q}$	j ∈ IND	13	Employment: wage bill weights
E_natcaprev (2.8.15)	$\text{natcaprev} = (1.0/\text{NATAGGCAP}) \sum_{q \in \text{RDES}} \text{AGGCAP}_q \text{ caprev}_q$		1	Payments to capital
E_natlabrev (2.8.15)	$\text{natlabrev} = (1.0/\text{NATAGGLAB}) \sum_{q \in \text{RDES}} \text{AGGLAB}_q \text{ labrev}_q$		1	Payments to labour
E_natndrev (2.8.15)	$\text{natndrev} = (1.0/\text{NATAGGLND}) \sum_{q \in \text{RDES}} \text{AGGLND}_q \text{ ndrev}_q$		1	Payments to land
E_natocrev (2.8.15)	$\text{natocrev} = (1.0/\text{NATAGGOCT}) \sum_{q \in \text{RDES}} \text{AGGOCT}_q \text{ octrev}_q$		1	Other cost ticket payments
E_nattaxrevm (2.8.15)	$\text{nattaxrevm} = (1.0/\text{NATAGGTAXM}) \sum_{q \in \text{RDES}} \text{AGGTAXM}_q \text{ taxrevm}_q$		1	Tariff revenue
E_nattaxind (2.8.15)	$\text{nattaxind} = (1.0/\text{NATAGGTAX}) (\text{NATAGGTAX1} \text{ nattaxrev1} + \text{NATAGGTAX2} \text{ nattaxrev2} + \text{NATAGGTAX3} \text{ nattaxrev3} + \text{NATAGGTAX4} \text{ nattaxrev4} + \text{NATAGGTAX5} \text{ nattaxrev5} + \text{NATAGGTAX6} \text{ nattaxrev6} + \text{NATAGGTAXM} \text{ nattaxrevm})$		1	Value of indirect taxes
E_natgdpinc (2.8.15)	$\text{natgdpinc} = (1.0/\text{NATGDPIN}) (\text{NATAGGLN} \text{ Dnatndrev} + \text{NATAGGCAP} \text{ Pnatcaprev} + \text{NATAGGLAB} \text{ Bnatlabrev} + \text{NATAGGOCT} \text{ Tnatocrev} + \text{NATAGGTAX} \text{ Xnattaxind})$		1	Nominal GDP from income side

Identifier	Equation	Subscript Range	Number	Description
E_nakt (2.8.15)	$\text{natkt} = (1.0/\text{NATAGGCAP}) \sum_{q \in \text{RDES}} \text{AGGCAP}_{qt} k_t q$		1	Usage of capital: rental weights
E_natl (2.8.15)	$\text{natl} = (1.0/\text{NATAGGLAB}) \sum_{q \in \text{RDES}} \text{AGGLAB}_{qt} q$		1	Employment: wage bill weights
E_natz_tot (2.8.15)	$\text{NATTOFAC}_{\text{natz\_tot}} = \sum_{q \in \text{RDES}} \text{TOTFAC}_{qt\_tot} q$		1	Aggregate output: value-added weights
E_natz (2.8.15)	$\text{NATTOTFACIND}_{j\text{natz}} = \sum_{q \in \text{RDES}} \text{TOTFACIND}_{j,q} z_{jt} q$	$j \in \text{IND}$	13	Industry output: value-added weights
E_natc (2.8.15)	$\text{NATAGGCON}_{\text{natc}} = \sum_{q \in \text{RDES}} \text{AGGCON}_{qc} q$		1	Nominal household consumption
E_natcr (2.8.15)	$\text{NATAGGCON}_{\text{nater}} = \sum_{q \in \text{RDES}} \text{AGGCON}_{cq} q$		1	Real household consumption
E_natin (2.8.15)	$\text{natin} = \text{natir} + \text{natxi2}$		1	Nominal investment
E_natir (2.8.15)	$\text{natir} = (1.0/\text{NATAGGINV}) \sum_{j \in \text{IND}} \text{NATINVEST}_{j\text{naty}} j$		1	Real investment
E_natothnom5 (2.8.15)	$\text{natothnom5} = \text{natothreal5} + \text{natxi5}$		1	Nominal value of regional other demands
E_natothnom6 (2.8.15)	$\text{natothnom6} = \text{natothreal6} + \text{natxi6}$		1	Nominal value of Federal other demands
E_natothreal5 (2.8.15)	$\text{natothreal5} = (1.0/\text{NATAGGOTH5}) \sum_{q \in \text{RDES}} \text{AGGOTH5}_{q\text{othreal5}} q$		1	Real regional other demands

Identifier	Equation	Subscript Number Range	Description
E_natothreal6 (2.8.15)	$\text{NATAGGOTH6 natothreal6} = \sum_{i \in \text{COM}} \sum_{s \in \text{ASOU}} \sum_{q \in \text{RDES}} \text{PVAL6A}_{i,s,q} \times \delta a_{i,s,q}$	1	Real Federal other demands
E_natexport (2.8.15)	$\text{natexport} = (1.0/\text{NATAGGEXP}) \sum_{s \in \text{RSOU}} \text{AGGEXP}_s \text{export}_s$	1	Foreign currency value of exports
E_natexpvol (2.8.15)	$\text{natexpvol} = \text{natexport} + \text{natphi} - \text{natxi4}$	1	Export volume index
E_natimp (2.8.15)	$\text{natimp} = (1.0/\text{NATAGGIMP}) \sum_{i \in \text{COM}} \text{NATIMPCOST}_i [\text{pm}_i + \text{natx0imp}_i]$	1	Foreign currency value of imports
E_natimpvol (2.8.15)	$\text{natimpvol} = \text{natimp} + \text{natphi} - \text{natxim}$	1	Import volume index
E_natgdpexp (2.8.15)	$\begin{aligned} \text{natgdpexp} = & (1.0/\text{NATGDPEX})(\text{NATAGGCONnatc} + \text{NATAGGINVnatin} \\ & + \text{NATAGGOTH5natothnom5} + \text{NATAGGOTH6natothnom6} \\ & + \text{NATAGGEXP}(\text{natexport} + \text{natphi}) - \text{NATAGGIMP}(\text{natimp} + \text{natphi})) \end{aligned}$	1	Nominal GDP from expenditure side
E_natgdpreal (2.8.15)	$\text{natgdpreal} = \text{natgdpexp} - \text{natxigdp}$	1	Real GDP: expenditure side
E_natdelb (2.8.15)	$1000.0100.0 \text{ natdelb} = \text{NATAGGEXPnatexport} - \text{NATAGGIMPnatimp}$	1	Balance of trade in billions of dollars
E_natxi3 (2.8.16)	$\text{NATAGGCON natxi3} = \sum_{q \in \text{RDES}} \text{AGGCON}_q \text{xi3}_q$	1	Consumer price index
E_natxi2 (2.8.16)	$\text{NATAGGINV natxi2} = \sum_{q \in \text{RDES}} \text{AGGINV}_q \text{xi2}_q$	1	Investment price index
E_natxi4 (2.8.16)	$\text{natxi4} = (1.0/\text{NATAGGEXP}) \sum_{q \in \text{RDES}} \text{AGGEXP}_q \text{xi4}_q$	1	Exports price index

Identifier	Equation	Subscript Number Range	Description
E_natxi5 (2.8.16)	$\text{natxi5} = (1.0/\text{NATAGGOTH5}) \sum_{q \in \text{RDES}} \text{AGGOTH5}_{q, \text{xi5}} q$	1	Price index for regional other demands
E_natxi6 (2.8.16)	$\text{NATAGGOTH6}_{\text{natxi6}} = \sum_{i \in \text{COM}} \sum_{s \in \text{ASOU}} \sum_{q \in \text{RDES}} \text{PVAL6}_{i, s, q} p_{6i, s, q}$	1	Price index for Federal other demands
E_natxigdp (2.8.16)	$\begin{aligned} \text{natxigdp} = & (1.0/\text{NATGDPEX})(\text{NATAGGCON}_{\text{natxi3}} + \text{NATAGGINV}_{\text{natxi2}} \\ & + \text{NATAGGOTH5}_{\text{natxi5}} + \text{NATAGGOTH6}_{\text{natxi6}} \\ & + \text{NATAGGEXP}_{\text{natxi4}} - \text{NATAGGIMP}_{\text{natxim}}) \end{aligned}$	1	Price index for GDP: expenditure side
E_natxim (2.8.16)	$\text{natxim} = (1.0/\text{NATAGGIMP}) \sum_{q \in \text{RDES}} \text{AGGIMP}_{q, \text{xim}} q$	1	Imports price index
E_natximp (2.8.16)	$\text{natximp0} = (1.0/[\text{NATAGGIMP} + \text{NATAGGTAXM}]) \sum_{i \in \text{COM}} \text{NATIMPORTS}_{i, p0a, s}$	s=foreign 1	Duty-paid imports price index
E_nattot (2.8.16)	$\text{nattot} = \text{natxi4} - \text{natxim}$	1	Terms of trade
E_natplcap (2.8.18)	$\text{natplcap} = \text{natcaprev} - \text{natkt}$	1	Nominal capital rentals
E_natpwage (2.8.18)	$\text{NATAGGLAB}_{\text{natpwage}} = \sum_{q \in \text{RDES}} \text{AGGLAB}_{q, \text{pwage}} q$	1	Nominal wages received by workers
E_natpwage_p (2.8.18)	$\text{NATAGGLAB}_{\text{natpwage}_p} = \sum_{q \in \text{RDES}} \text{AGGLAB}_{q, \text{pwage}_p} q$	1	Nominal wages paid by producers
E_natr_wage_w (2.8.18)	$\text{natr}_w = \text{natrealwage}$	1	Real wages for workers: deflated by CPI
E_natr_wage_p (2.8.18)	$\text{natr}_w = \text{natpwage}_p - \text{natxigdp}$	1	Real wages for producers

Identifier	Equation	Subscript Number Range	Description
E_natxiplpk (2.8.18)	$\text{natxiplpk} = \text{natpwage}_p - \text{natplcap}$	1	National movement in relative prices of labour and capital
E_natlambda (2.8.19)	$\text{NATLAB\_OCC}(m)\text{natlambda}(m) = \sum_{q \in \text{RDES}} \text{LAB\_OCC}_{m,q} \lambda_{\text{bdm},q}$	$m \in \text{OCC}$	Demand for labour by occupation
<b>2.3. Government Finances</b>			
<i>2.3.1. Disaggregation of value added</i>			
E_z01_r (3.8.1)	$C\_Z01\_R_{z01\_r,q} = \sum_{j \in \text{IND}} C\_Z01\_I\_R_{j,q} (\text{labind}_{j,q} + \text{pwage}_{j,q})$	$q \in \text{RDES}$	Wages, salaries and supplements - regions
E_z02_r (3.8.1)	$C\_Z02\_R_{z02\_r,q} = \sum_{j \in \text{IND}} C\_Z02\_I\_R_{j,q} (\text{labind}_{j,q} + \text{pwage}_{j,q})$	$q \in \text{RDES}$	Imputed wages - regions
E_z03_r (3.8.1)	$C\_Z03\_R_{z03\_r,q} = \sum_{j \in \text{IND}} C\_Z03\_I\_R_{j,q} (\text{rpr}_{j,q} + \text{labind}_{j,q} + \text{pwage}_{j,q})$	$q \in \text{RDES}$	Payroll taxes - regions
E_z03 (3.8.1)	$C\_Z03\_z03 = \sum_{q \in \text{RDES}} C\_Z03\_R_{z03\_r,q}$	1	Payroll taxes - national
E_z04_r (3.8.1)	$C\_Z04\_R_{z04\_r,q} = \sum_{j \in \text{IND}} C\_Z04\_I\_R_{j,q} (\text{curcap}_{j,q} + \text{plcap}_{j,q})$	$q \in \text{RDES}$	Returns to fixed capital - regions
E_z05_r (3.8.1)	$C\_Z05\_R_{z05\_r,q} = \sum_{j \in \text{IND}} C\_Z05\_I\_R_{j,q} (\text{curcap}_{j,q} + \text{plcap}_{j,q})$	$q \in \text{RDES}$	Property taxes - regions
E_z05 (3.8.1)	$C\_Z05\_z05 = \sum_{q \in \text{RDES}} C\_Z05\_R_{z05\_r,q}$	1	Property taxes - national
E_z06_r (3.8.1)	$C\_Z06\_R_{z06\_r,q} = \sum_{j \in \text{IND}} C\_Z06\_I\_R_{j,q} (n_{j,q} + \text{plland}_{j,q})$	$q \in \text{RDES}$	Returns to agricultural land - regions

Identifier	Equation	Subscript Number Range	Description
E_z07_r (3.8.1)	$C\_Z07\_R\_qz07\_r_q = \sum_{j \in \text{IND}} C\_Z07\_I\_R\_j,q(n_j,q + p1and_j,q)$	q ∈ RDES 8	Land taxes - regions
E_z07 (3.8.1)	$C\_Z07\ z07 = \sum_{q \in \text{RDES}} C\_Z07\_R\_qz07\_r_q$	1	Land taxes - national
E_z08_r (3.8.1)	$C\_Z08\_R\_qz08\_r_q = \sum_{j \in \text{IND}} C\_Z08\_I\_R\_j,q(x1oct_j,q + p1oct_j,q)$	q ∈ RDES 8	Returns to working capital - regions
E_z09_r (3.8.1)	$C\_Z09\_R\_qz09\_r_q = \sum_{j \in \text{IND}} C\_Z09\_I\_R\_j,q(x1oct_j,q + p1oct_j,q)$	q ∈ RDES 8	Other indirect taxes - regions
E_z09 (3.8.1)	$C\_Z09\_qz09 = \sum_{q \in \text{RDES}} C\_Z09\_R\_qz09\_r_q$	1	Other indirect taxes - national
E_z10_r (3.8.1)	$C\_Z10\_R\_qz10\_r_q = \sum_{j \in \text{IND}} C\_Z10\_I\_R\_j,q(x1oct_j,q + p1oct_j,q)$	q ∈ RDES 8	Sales by final buyers - regions
E_z10 (3.8.1)	$C\_Z10\ z10 = \sum_{q \in \text{RDES}} C\_Z10\_R\_qz10\_r_q$	1	Sales by final buyers - national
E_zg_r (3.8.1)	$C\_ZG\_R\_qz06\_r_q = C\_Z02\_R\_qz02\_r_q + C\_Z04\_R\_qz04\_r_q + C\_Z06\_R\_qz06\_r_q + C\_Z08\_R\_qz08\_r_q$	q ∈ RDES 8	Gross operating surplus - regions
E_zl_r (3.8.1)	$C\_ZT\_R\_qzL\_r_q = C\_Z03\_R\_qz03\_r_q + C\_Z05\_R\_qz05\_r_q + C\_Z07\_R\_qz07\_r_q + C\_Z09\_R\_qz09\_r_q$	q ∈ RDES 8	Production taxes - regions
E_rpr (3.8.1)	$C\_Z03\_I\_R\_j,qrpr_j,q = (C\_Z01\_I\_R\_j,q + C\_Z02\_I\_R\_j,q + C\_Z03\_I\_R\_j,q)arpr_j,q$	j ∈ IND 13×8 q ∈ RDES	Payroll tax adjustment
E_rpri (3.8.1)	$rpr_j,q = rpr_q + frpr_j,q$	j ∈ IND 13×8 q ∈ RDES	Setting of payroll tax rates

Identifier	Equation	Subscript Number Range	Description
E_xisfb2 (3.8.1)	$C\_Z10\_R\_q \text{ xisfb}_q = \sum_{j \in \text{IND}} C\_Z10\_I\_R_j \cdot q^j \cdot \text{loc}_j \cdot q$	q ∈ RDES 8	Price index : sales by final buyers
<i>2.3.2. Gross regional product and its components</i>			
E_dompy100 (3.8.2)	$\text{dompy100}_q = z01\_r \cdot q$	q ∈ RDES 8	Wages, salaries and supplements
E_dompy120 (3.8.2)	$\text{dompy120}_q = \text{dompy100}_q + r_l$	q ∈ RDES 8	PAYE taxes
E_dompy110 (3.8.2)	$C\_DOMPY100\_q \cdot \text{dompy100}_q = C\_DOMPY110\_q \cdot \text{dompy110}_q + C\_DOMPY120\_q \cdot \text{dompy120}_q$	q ∈ RDES 8	Disposable wage income (residual)
E_dompy200 (3.8.2)	$\text{dompy200}_q = z_g \cdot r \cdot q$	q ∈ RDES 8	Non - wage primary factor income
E_dompy220 (3.8.2)	$\text{dompy220}_q = \text{dompy200}_q + r_k$	q ∈ RDES 8	Taxes on non - wage primary factor income
E_dompy210 (3.8.2)	$C\_DOMPY200\_q \cdot \text{dompy200}_q = C\_DOMPY210\_q \cdot \text{dompy210}_q + C\_DOMPY220\_q \cdot \text{dompy220}_q$	q ∈ RDES 8	Disposable non - wage primary factor income (residual)
E_dompy310 (3.8.2)	$\text{dompy310}_q = \text{taxrevm}_q$	q ∈ RDES 8	Tariff revenue
E_dompy320 (3.8.2)	$C\_DOMPY320\_q \cdot \text{dompy320}_q = \text{AGGTAX1}_q \cdot \text{taxrev1}_q + \text{AGGTAX2}_q \cdot \text{taxrev2}_q + \text{AGGTAX3}_q \cdot \text{taxrev3}_q + \text{AGGTAX4}_q \cdot \text{taxrev4}_q + \text{AGGTAX5}_q \cdot \text{taxrev5}_q + \text{AGGTAX6}_q \cdot \text{taxrev6}_q$	q ∈ RDES 8	Other commodity taxes less subsidies
E_dompy330 (3.8.2)	$\text{dompy330}_q = z_t \cdot r \cdot q$	q ∈ RDES 8	Production taxes
E_dompy300 (3.8.2)	$C\_DOMPY300\_q \cdot \text{dompy300}_q = C\_DOMPY310\_q \cdot \text{dompy310}_q + C\_DOMPY320\_q \cdot \text{dompy320}_q + C\_DOMPY330\_q \cdot \text{dompy330}_q$	q ∈ RDES 8	Indirect taxes less subsidies

Identifier	Equation	Subscript Range	Number	Description
E_dompy000 (3.8.2)	$C\_DOMPY000\_d\text{ompy}000_q = C\_DOMPY100_q\text{ompy}100_q + C\_DOMPY200_q\text{ompy}200_q + C\_DOMPY300_q\text{ompy}300_q$	q∈RDES	8	GDP at market prices (income side) - regions
E_dompq110 (3.8.2)	$d\text{ompq}110_q = c_q$	q∈RDES	8	Private consumption
E_dompq120 (3.8.2)	$d\text{ompq}120_q = in_q$	q∈RDES	8	Private investment
E_dompq130 (3.8.2)	$d\text{ompq}130_q = othnom5_q$	q∈RDES	8	Government consumption - regions
E_dompq140 (3.8.2)	$d\text{ompq}140_q = othnom6_q$	q∈RDES	8	Government consumption - federal
E_dompq150 (3.8.2)	$d\text{ompq}150_q = in_q$	q∈RDES	8	Government investment
E_dompq100 (3.8.2)	$C\_DOMPQ100\_d\text{ompq}100_q = C\_DOMPQ110_q\text{dompq}110_q + C\_DOMPQ120_q\text{dompq}120_q + C\_DOMPQ130_q\text{dompq}130_q + C\_DOMPQ140_q\text{dompq}140_q + C\_DOMPQ150_q\text{dompq}150_q$	q∈RDES	8	Domestic absorption
E_dompq210 (3.8.2)	$d\text{ompq}210_q = psexp_q + xsexp_q$	q∈RDES	8	Inter - regional exports
E_dompq220 (3.8.2)	$d\text{ompq}220_q = psimp_q + xsimp_q$	q∈RDES	8	Inter - regional imports
E_dompq200 (3.8.2)	$C\_DOMPQ200\_d\text{ompq}200_q = C\_DOMPQ210_q\text{dompq}210_q - C\_DOMPQ220_q\text{dompq}220_q$	q∈RDES	8	Inter - regional trade balance
E_dompq310 (3.8.2)	$d\text{ompq}310_q = export_q + natphi$	q∈RDES	8	International exports
E_dompq320 (3.8.2)	$d\text{ompq}320_q = imp_q + natphi$	q∈RDES	8	International imports

Identifier	Equation	Subscript Number Range	Description
E_dompq300 (3.8.2)	$C\_DOMPQ300\_dompq300_q = C\_DOMPQ310\_dompq310_q - C\_DOMPQ320\_dompq320_q$	q ∈ RDES 8	International trade balance
E_dompq000 (3.8.2)	$C\_DOMPQ000\_dompq000_q = C\_DOMPQ100\_dompq100_q + C\_DOMPQ200\_dompq200_q + C\_DOMPQ300\_dompq300_q$	q ∈ RDES 8	GDP at market prices (expenditure side)
<i>2.3.3. Miscellaneous equations</i>			
E_tir (3.8.3)	$ti\_r_q = dompq320_q$	q ∈ RDES 8	Commodity taxes less subsidies (excl. tariffs)
E_ti (3.8.3)	$C\_TI\ ti = \sum_{q \in RDES} C\_DOMPY320\_domy320_q$	1	Commodity taxes less subsidies (excl. tariffs)
E_yn_r (3.8.3)	$yn\_r_q = dompq000_q$	q ∈ RDES 8	Nominal regional domestic product
E_yn (3.8.3)	$C\_YN\ yn = \sum_{q \in RDES} C\_DOMPQ000\_dompq000_q$	1	Nominal GDP
E_xiy_r (3.8.3)	$C\_DOMPQ000\_xiy\_r_q = C\_DOMPQ110\_xi3_q + C\_DOMPQ120\_xi2_q + C\_DOMPQ130\_xi5_q + C\_DOMPQ140\_xi6_q + C\_DOMPQ150\_xi2_q + C\_DOMPQ210\_psimp_q - C\_DOMPQ220\_psimp_q + C\_DOMPQ310\_xi4_q - C\_DOMPQ320\_xim_q$	q ∈ RDES 8	GDP deflator
E_xiy (3.8.3)	$C\_YN\ xiy = \sum_{q \in RDES} C\_DOMPQ000\_xiy\_r_q$	1	GDP deflator
E_yr_r (3.8.3)	$yr\_r_q = yn\_r_q - xiy\_r_q$	q ∈ RDES 8	Real regional domestic product
E_yr (3.8.3)	$yr = yn - xiy$	1	Real GDP

Identifier	Equation	Subscript Number Range	Description
E_yf (3.8.3)	$C\_YF\_yf = \sum_{q \in RDES} C\_DOMPY100\_d \text{domy}100_q + \sum_{q \in RDES} C\_DOMPY200\_d \text{domy}200_q$	1	GDP at factor cost
E_bstar (3.8.3)	$C\_YN\_bstar = \sum_{q \in RDES} C\_DOMPQ300\_d \text{domp}q300_q - NATBTyn$	1	Balance of trade surplus to GDP: percentage - point change
E_ty (3.8.3)	$C\_TY\_tY = \sum_{q \in RDES} C\_DOMPY120\_d \text{domy}120_q + \sum_{q \in RDES} C\_DOMPY220\_d \text{domy}220_q$	1	Income taxes
E_yI (3.8.3)	$C\_YL\_yI = \sum_{q \in RDES} C\_DOMPY100\_d \text{domy}100_q$	1	Pre - tax wage income
E_wn (3.8.3)	$wn = yI - natI$	1	Nominal pre - tax wage rate
E_yIstar (3.8.3)	$C\_YLSTAR\_yIstar = \sum_{q \in RDES} C\_DOMPY110\_d \text{domy}110_q$	1	Post - tax wage income
E_wnstar (3.8.3)	$wnstar = yIstar - natI$	1	Nominal post - tax wage rate
E_wrstar (3.8.3)	$wrstar = wnstar - natxi3$	1	Real post - tax wage rate
E_g_rA (3.8.6)	$g\_r_q = othnom5_q$	q ∈ RDES 8	Nominal government consumption - regions
E_g_rB (3.8.6)	$g\_r_q = natothnom6$	q = federal 1	Nominal government consumption - federal
E_ip (3.8.6)	$C\_IP\_ip = \sum_{q \in RDES} C\_IP\_R_q \text{in}q$	1	Aggregate nominal private investment
E_ig_r_reg (3.8.6)	$ig\_r_q = \text{in}q$	q ∈ RDES 8	Nominal government investment - regions

Identifier	Equation	Subscript Number Range	Description
E_ig (3.8.6)	$NATAGGINV_{natin} = C_{IPip} + C_{IGig}$		Aggregate nominal government investment (residual)
E_ig_r_fed (3.8.6)	$C_{IGig} = \sum_{q \in DDES} C_{IGR}_{qig_rq}$	1	Nominal government investment - federal (residual)
E_c_b (3.8.6)	$c_q = yd_rq + miscf001_q$	q ∈ RDES 8	Consumption function
E_rl (3.8.6)	$rl = rk + miscf002$	1	Relative income tax rates
<i>2.3.4. Summary Of Financial Transactions: the SOFT accounts</i>			
E_softy111 (3.8.4)	$softy111_q = ty$	q=federal 1	Income taxes
E_softy112A (3.8.4)	$softy112_q = yn_rq + softf001_q$	q ∈ RDES 8	Other direct taxes
E_softy112B (3.8.4)	$softy112_q = yn + softf011$	q=federal 1	Other direct taxes federal
E_softy110 (3.8.4)	$C_{SOFTY110}_{softy110_q} = C_{SOFTY111}_{softy111_q} + C_{SOFTY112}_{softy112_q}$	q ∈ DDES 9	Direct taxes
E_softy121 (3.8.4)	$softy121_q = nattaxrevm$	q=federal 1	Tariff revenue
E_softy122A (3.8.4)	$softy122_q = ti_rq$	q ∈ RDES 8	Other commodity taxes - regions
E_softy122B (3.8.4)	$C_{TI} ti + C_{SUBSIDIES} ti = \sum_{q \in DDES} C_{SOFTY122}_{softy122_q}$	1	Other commodity taxes - federal (residual)
E_softy123a (3.8.4)	$softy123_q = z03_rq$	q ∈ RDES 8	Payroll taxes - regions

Identifier	Equation	Subscript Number Range	Description
E_softy123b (3.8.4)	$\text{softy123}_q = z09$	q=federal 1	Fringe benefits taxes - federal
E_softy124 (3.8.4)	$\text{softy124}_q = z05\_r\_q$	q∈RDES 8	Property taxes - regions
E_softy125 (3.8.4)	$\text{softy125}_q = z07\_r\_q$	q∈RDES 8	Land taxes - regions
E_softy126A (3.8.4)	$\text{softy126}_q = z09\_r\_q$	q∈RDES 8	Other indirect taxes - regions
E_softy126B (3.8.4)	$C\_Z09 z09 = \sum_{q \in \text{DDES}} C\_SOFTY126_q \text{softy126}_q$	1	Other indirect taxes - federal (residual)
E_softy120 (3.8.4)	$C\_SOFTY120_q \text{softy120}_q = C\_SOFTY121_q \text{softy121}_q + C\_SOFTY122_q \text{softy122}_q + C\_SOFTY123_q \text{softy123}_q + C\_SOFTY124_q \text{softy124}_q + C\_SOFTY125_q \text{softy125}_q + C\_SOFTY126_q \text{softy126}_q$	q∈DDES 9	Indirect taxes
E_softy130 (3.8.4)	$\text{softy130}_q = \text{softq400}_q$	q∈DDES 9	Interest received
E_softy141 (3.8.4)	$\text{softy141}_q = ym\_r\_q + \text{softf002}_q$	q∈RDES 8	Commonwealth grants to regions - current
E_softy142 (3.8.4)	$\text{softy142}_q = ym\_r\_q + \text{softf003}_q$	q∈RDES 8	Commonwealth grants to regions - capital
E_softy140 (3.8.4)	$C\_SOFTY140_q \text{softy140}_q = C\_SOFTY141_q \text{softy141}_q + C\_SOFTY142_q \text{softy142}_q$	q∈RDES 8	Commonwealth grants to regions
E_softy150A (3.8.4)	$\text{softy150}_q = ym\_r\_q + \text{softf004}_q$	q∈RDES 8	Other revenue - regions
E_softy150B (3.8.4)	$\text{softy150}_q = ym + \text{softf004}_q$	q=federal 1	Other revenue - federal

Identifier	Equation	Subscript Number Range	Description
E_softy100 (3.8.4)	$C\_SOFTY100\_q^{softy100}_q = C\_SOFTY110\_q^{softy110}_q + C\_SOFTY120\_q^{softy120}_q + C\_SOFTY130\_q^{softy130}_q + C\_SOFTY140\_q^{softy140}_q + C\_SOFTY150\_q^{softy150}_q$	q∈DDES 9	Government revenue
E_softy200 (3.8.4)	$softy200_q = g\_r q$	q∈DDES 9	Consumption of fixed capital - general government
E_softy300 (3.8.4)	$C\_SOFTY300\_q^{softy300}_q = C\_SOFTQ000\_q^{softy000}_q - C\_SOFTY100\_q^{softy100}_q - C\_SOFTY200\_q^{softy200}_q$	q∈DDES 9	Financing transactions
E_softy320 (3.8.4)	$softy320_q = softq100_q + softf005_q$	q∈DDES 9	Increase in provisions
E_softy330 (3.8.4)	$softy330_q = softy300_q + f\_of q$	q∈DDES 9	Other financing transactions
E_softy310 (3.8.4)	$C\_SOFTY300\_q^{softy300}_q = C\_SOFTY310\_q^{softy310}_q + C\_SOFTY320\_q^{softy320}_q + C\_SOFTY330\_q^{softy330}_q$	q∈DDES 9	Net borrowing (residual)
E_softy000 (3.8.4)	$C\_SOFTY000\_q^{softy000}_q = C\_SOFTY100\_q^{softy100}_q + C\_SOFTY200\_q^{softy200}_q + C\_SOFTY300\_q^{softy300}_q$	q∈DDES 9	Summary of financial transactions : income - side total
E_softq110 (3.8.4)	$softq110_q = g\_r q$	q∈DDES 9	Government consumption
E_softq120 (3.8.4)	$softq120_q = ig\_r q$	q∈DDES 9	Government investment
E_softq100 (3.8.4)	$C\_SOFTQ100\_q^{softq100}_q = C\_SOFTQ110\_q^{softq110}_q + C\_SOFTQ120\_q^{softq120}_q$	q∈DDES 9	Expenditure on goods and services
E_softq210 (3.8.4)	$softq210_q = upb$	q=federal 1	Unemployment benefits

Identifier	Equation	Subscript Number Range	Description
E_softq200 (3.8.4)	$softq200_q = pbp_rq$	$q \in DDES$ 9	Personal benefit payments
E_softq220 (3.8.4)	$C\_SOFTQ200_q softq200_q = C\_SOFTQ210_q softq210_q + C\_SOFTQ220_q softq220_q$	$q \in DDES$ 9	Other personal benefits (residual)
E_softq300A (3.8.4)	$softq300_q = u_rq$	$q \in RDES$ 8	Subsidies - regions
E_softq300B (3.8.4)	$C\_SUBSIDIES_{il} = \sum_{q \in DDES} C\_SOFTQ300_q softq300_q$	1	Subsidies - federal (residual)
E_softq400A (3.8.4)	$softq400_q = yn_rq + softf007_q$	$q \in RDES$ 8	Interest payments - regions
E_softq400B (3.8.4)	$softq400_k = yn + softf007_k$	k=federal 1	Interest payments - Federal
E_softq510 (3.8.4)	$C\_SOFTQ510_k softq510_k = \sum_{q \in RDES} C\_SOFTQ510_q softq510_q$	k=federal 1	Commonwealth grants to regions - current
E_softq520 (3.8.4)	$C\_SOFTQ520_k softq520_k = \sum_{q \in RDES} C\_SOFTQ520_q softq520_q$	k=federal 1	Commonwealth grants to regions - capital
E_softq500 (3.8.4)	$C\_SOFTQ500_q softq500_q = C\_SOFTQ510_q softq510_q + C\_SOFTQ520_q softq520_q$	q=federal 1	Commonwealth grants to regions
E_softq600 (3.8.4)	$softq600_q = softq000_q + softf006_q$	$q \in DDES$ 9	Other outlays
E_softq000 (3.8.4)	$C\_SOFTQ000_q softq000_q = C\_SOFTQ100_q softq100_q + C\_SOFTQ200_q softq200_q + C\_SOFTQ300_q softq300_q + C\_SOFTQ400_q softq400_q + C\_SOFTQ500_q softq500_q + C\_SOFTQ600_q softq600_q$	$q \in DDES$ 9	Summary of financial transactions : expenditure - side total

Identifier	Equation	Subscript Number Range	Description
E_realdefr (3.8.4)	$realdef_q = softy300_q - xi3_q$	q∈RDES 8	Real budget deficit for region
E_realdeff (3.8.4)	$realdef_q = softy300_q - natxi3$	q=federal 1	Real budget deficit for Fed.
E_dGstar (3.8.4)	$C\_SOFTQ000_q dgstar_q = C\_SOFTY310_q (softy310_q - softq000_q)$	q∈DDES 9	Net borrowing to total outlays: percent point change
E_tod_r (3.8.4)	$tod_r_q = softy112_q$	q∈RDES 8	Other direct taxes
<i>2.3.5. Household disposable income</i>			
E_hhldy110 (3.8.5)	$hhldy110_q = z01_r_q$	q∈RDES 8	Wages, salaries and supplements
E_hhldy120 (3.8.5)	$hhldy120_q = zg_r_q$	q∈RDES 8	Non - wage primary factor income
E_hhldy100 (3.8.5)	$C\_HHLDY100_q hhldy100_q = C\_HHLDY110_q hhldy110_q + C\_HHLDY120_q hhldy120_q$	q∈RDES 8	Primary factor income
E_hhldy210 (3.8.5)	$hhldy210_q = natxi3 + C\_HHLDD001_q labsup_q - C\_HHLDD002_q q + hhldf001_q$	q∈RDES 8	Unemployment benefit receipts
E_hhldy220 (3.8.5)	$hhldy220_q = natxi3 + pop_q + hhldf002_q$	q∈RDES 8	Other personal benefit receipts
E_hhldy200 (3.8.5)	$C\_HHLDY200_q hhldy200_q = C\_HHLDY210_q hhldy210_q + C\_HHLDY220_q hhldy220_q$	q∈RDES 8	Personal benefit receipts
E_hhldy300 (3.8.5)	$hhldy300_q = yn_r_q + hhldf003_q$	q∈RDES 8	Other Income (net)
E_hhldy410 (3.8.5)	$hhldy410_q = hhldy110_q + r_l$	q∈RDES 8	PAYE taxes

Identifier	Equation	Subscript Range	Number	Description
E_hhldy420 (3.8.5)	$hhldy420_q = hhldy120_q + rk$	q ∈ RDES	8	Taxes on non - wage primary factor income
E_hhldy430 (3.8.5)	$hhldy430_q = tod_r_q$	q ∈ RDES	8	Other direct taxes
E_hhldy400 (3.8.5)	$C\_HHLDY400\_hhldy400_q = C\_HHLDY410\_hhldy410_q + C\_HHLDY420\_hhldy420_q + C\_HHLDY430\_hhldy430_q$	q ∈ RDES	8	Direct taxes
E_hhldy000 (3.8.5)	$C\_HHLDY000\_hhldy000_q = C\_HHLDY100\_hhldy100_q + C\_HHLDY200\_hhldy200_q + C\_HHLDY300\_hhldy300_q - C\_HHLDY400\_hhldy400_q$	q ∈ RDES	8	Disposable income
E_ydr (3.8.5)	$ydr_q = hhldy000_q$	q ∈ RDES	8	Disposable income
E_upb (3.8.5)	$C\_UPB\_upb = \sum_{q \in RDES} C\_HHLDY210\_hhldy210_q$	q ∈ RDES		Aggregate unemployment benefit payments
E_pbp_r (3.8.5)	$pbp_r_q = hhldy200_q$	q ∈ RDES	8	Personal benefit payments - regions
E_pbpA (3.8.5)	$C\_PBP\_pbp = \sum_{q \in RDES} C\_HHLDY200\_hhldy200_q$	q ∈ RDES		Aggregate personal benefit payments
E_pbpB (3.8.5)	$C\_PBP\_pbp = \sum_{q \in DDES} C\_PBP\_R\_pbp_r_q$	q ∈ DDES	1	Personal benefit payments - federal (residual)
<b>2.4. Dynamics for Forecasting</b>				
<i>2.4.1. Industry capital and investment</i>				
E_yTA (4.4)	$VALK\_TI\_j,q\_curcap\_tj,q = VALKT\_j,q\_DEP\_curcap\_j,q + INVEST\_j,q\_j,q - 100(VALK\_0\_j,q(1 - DEP_j) - INVEST\_0\_j,q)delkfudge + 100delf\_rate\_j,q$	j ∈ IND q ∈ RDES	13×8	Investment in period T: forecasting

Identifier	Equation	Subscript Range	Number	Description
E_curcapT1A (4.4)	$curcap\_t1_{j,q} = K\_TERMcurcap_{j,q}$	$j \in IND$ $q \in RDES$	13x8	Capital stock in period T + 1: forecasting
E_yTB (4.4)	$curcap_{j,q} = y_{j,q} + 100del\_rate_{j,q}$	$j \in IND$ $q \in RDES$	13x8	Investment in period T: comparative statics
E_curcapT1B (4.4)	$curcap\_t1_{j,q} = curcap_{j,q}$	$j \in IND$ $q \in RDES$	13x8	Capital stock in period T + 1: comparative statics
E_r0 (4.4)	$r0_{j,q} = QCOEF_{j,q}(plcap_{j,q} - pi_{j,q})$	$j \in IND$ $q \in RDES$	13x8	Definition of rates of return to capital
E_f_rate_xx (4.4)	$r0_{j,q} - natr\_tot = BETA\_R_{j,q}[curcap_{j,q} - kt_q] + f\_rate\_xx_{j,q}$	$j \in IND$ $q \in RDES$	13x8	Capital growth rates related to rates of return
E_naty (4.4)	$NATINVEST_{j,naty} = \sum_{q \in RDES} INVEST_{j,q} y_{j,q}$	$j \in IND$	13	Total real investment
<b>2.4.2. Accumulation of national foreign debt</b>				
E_debt (5.5)	$debt = \{DEBT(R\_WORLD^{PRIOD} - 1) + B0N\_DEBT\}delfudge + M\_DEBTdelbt$		1	Ordinary change in foreign debt
E_delbt (5.5)	$100P\_GLOBALdelbt = NATAGGIMP(natimpvol) - NATAGGEXP(natexpvol + natx4 - natxim)$		1	Ordinary change in Real trade deficit
E_debt_ratio (5.5)	$debt\_ratio = (DEBT\_RATIO/DEBT)deldebt - (DEBT\_RATIO/100)(natgdpexp - natxim)$		1	Change in Debt/GDP ratio
<b>2.5. Regional Population and Labour Market Settings</b>				
E_del_rm (6.5)	$C\_POP_{popq} = C\_PRI_{q}delrpfudge + C\_PA2(del\_rm_q + del\_fm_q + del\_sq) + f\_popq$	$q \in RDES$	8	Accumulation of regional population
E_de_labsup (6.5)	$C\_de_labsup_{del\_unr_q} = C\_EMPLOY_q(labsup_q - employ_q)$	$q \in RDES$	8	Percentage-point changes in regional unemployment rates

Identifier	Equation	Subscript Number Range	Description
E_wpop (6.5)	$labsup_q = pr_q + wpop_q$	q ∈ RDES 8	Regional labour supply
E_pop (6.5)	$wpop_q = pop_q + f\_wpop_q$	q ∈ RDES 8	Regional working age population
E_rm_0 (6.5)	$del\_rm_q = del\_rm\_0_q + delf\_rm_0$	q ∈ RDES 8	ABS population forecasts can drive interregional migration
E_rempl_interfl_q (6.5)	$del\_rm_q = employ_q + f\_l_q$	q ∈ RDES 8	Interface employment in wage-bill weights and person weights.
E_pop_interf (6.5)	$qhous_q = pop_q + f\_qhous_q$	q ∈ RDES 8	Interface population and household formation.
E_rm_addup (6.5)	$delf\_rm = \sum_{q \in RDES} del\_rm_q$	1	Adding - up condition on interregional migration.
E_deInatfm (6.5)	$del\_natfm = \sum_{q \in RDES} del\_fm_q$	1	National foreign migration.
E_deInatg (6.5)	$del\_natg = \sum_{q \in RDES} del\_g_q$	1	National natural population change.
E_natlabsup (6.5)	$C\_NATLABSUP\_natlabsup = \sum_{q \in RDES} C\_LABSUP\_q\_labsup_q$	1	National labour supply
E_natemploy (6.5)	$C\_NATEMPLOY\_natemploy = \sum_{q \in RDES} C\_EMPLOY_q\_employ_q$	1	National employment
E_natunr (6.5)	$C\_NATLABSUP\_del\_natunr = C\_NATEMPLOY(natlabsup - natemploy)$	1	Percentage-point change in national unemployment rate

Table 2.2. The MMRF Variables

Variable	Subscript Range	Number	Description
<i>The CGE Core</i>			
<i>Scalar Variables</i>			
deltax1all		1	Overall percent-point change in indirect tax rates, user 1
deltax2all		1	Overall percent-point change in indirect tax rates, user 2
deltax3all		1	Overall percent-point change in indirect tax rates, user 3
deltax4all		1	Overall percent-point change in indirect tax rates, user 4
deltax5all		1	Overall percent-point change in indirect tax rates, user 5
deltax6all		1	Overall percent-point change in indirect tax rates, user 6
natc		1	Nominal total household consumption
natcaprev		1	Aggregate payments to capital
natcr		1	Real household consumption
natdelb		1	Ordinary change in balance of trade
natexport		1	Foreign-currency value of exports
natexpvol		1	Export volumes
natfep		1	Economy-wide shifter of export demand curves
natf5gen		1	Overall shift term for regional "Other" demands
natf6gen		1	Overall shift term for Federal "Other" demands
natfwage		1	Overall wage shifter
natgdpexp		1	Nominal GDP from expenditure side
natgdpinc		1	Nominal GDP from income side
natgdpreal		1	Real GDP from expenditure side
natimp		1	Foreign currency value of imports
natimpvol		1	Import volumes
natin		1	Aggregate nominal investment
natir		1	Aggregate real investment expenditure

...Table 2.2. continued

Variable	Subscript Range	Number	Description
natkt		1	Aggregate capital stock, rental weights
natl		1	Aggregate employment, wage bill weights
natlabrev		1	Aggregate payments to labour
natlndrev		1	Aggregate payments to land
natocrev		1	Aggregate other cost ticket payments
natothnom5		1	Aggregate nominal value of regional "Other" demands
natothnom6		1	Aggregate nominal value of Federal "Other" demands
natothreal5		1	Aggregate real regional "Other" demands
natothreal6		1	Aggregate real Federal "Other" demands
natplcap		1	Aggregate nominal capital rentals
natphi		1	Exchange rate
natpwage		1	Aggregate nominal wage paid to workers
natpwage_p		1	Aggregate nominal wage paid by producers
natrealwage		1	National consumer real wage
natrwage_p		1	National real wages for producers: deflated by GDP deflator
natrwage_w		1	National real wages for workers: deflated by CPI
nattaxind		1	Aggregate revenue from all indirect taxes
nattaxrev1		1	Aggregate revenue from indirect taxes on intermediate
nattaxrev2		1	Aggregate revenue from indirect taxes on investment
nattaxrev3		1	Aggregate revenue from indirect taxes on households
nattaxrev4		1	Aggregate revenue from indirect taxes on exports
nattaxrev5		1	Aggregate revenue from indirect taxes on regional "Other"
nattaxrev6		1	Aggregate revenue from indirect taxes on Federal "Other"
nattaxrevm		1	Aggregate tariff revenue
nattot		1	Economy-wide terms of trade
natxi2		1	Investment price index
natxi3		1	Consumer price index

...Table 2.2. continued

Variable	Subscript Range	Number	Description
natxi4		1	Exports price index
natxi5		1	Regional "Other" demands price index
natxi6		1	Federal "Other" demands price index
natxigdp		1	GDP price index, expenditure side
natxim		1	Imports price index
natximp0		1	Duty-paid imports price index
natxiplpk		1	Relative prices of labour and capital
natz_tot		1	Aggregate Output: Value-Added Weights
<i>Vector Variables</i>			
aggnt_fep <sub>s</sub>	s ∈ RSOU	8	Price shifter on non-traditional exports
aggnt_p4r <sub>s</sub>	s ∈ RSOU	8	Aggregate price for non-traditional exports
aggnt_x4r <sub>s</sub>	s ∈ RSOU	8	Demand for aggregate non-traditional exports
caprev <sub>q</sub>	q ∈ RDES	8	Aggregate payments to capital
c <sub>q</sub>	q ∈ RDES	8	Nominal total household consumption
cr_shr <sub>q</sub>	q ∈ RDES	8	Regional/national consumption ratio
cr <sub>q</sub>	q ∈ RDES	8	Real household consumption
delb_dom <sub>q</sub>	q ∈ RDES	8	Change in interregional trade balance
delb_for_aud <sub>q</sub>	q ∈ RDES	8	Change in AUD value of foreign trade balance
delb_tot <sub>q</sub>	q ∈ RDES	8	Sum change in of domestic and foreign trade balance
deltaxdest <sub>q</sub>	q ∈ ADES	10	Tax shifter (percentage-point change) to all destinations including foreign and Federal
deltaxsource <sub>s</sub>	s ∈ ASOU	9	Tax shifter (percentage-point change) by all sources (domestic and foreign)
exp_for_aud <sub>q</sub>	q ∈ RDES	8	AUD value of foriegn exports
export <sub>q</sub>	q ∈ RDES	8	Foreign currency value of exports
expvol <sub>q</sub>	q ∈ RDES	8	Export volumes
f5gen <sub>q</sub>	q ∈ RDES	8	Overall shift term for regional "Other" demands
f6gen <sub>q</sub>	q ∈ RDES	8	Shifter, Federal "Other" demand
faggnt_i <sub>i</sub>	i ∈ NTEXP	11	Shifter by commodity for aggregate non-traditional exports
faggnt_p4r <sub>s</sub>	s ∈ RSOU	8	Shifter on the price of aggregate non-traditional exports

....Table 2.2. continued

Variable	Subscript Range	Number	Description
faggnt_s <sub>s</sub>	s ∈ RSOU	8	Shifter by region for aggregate non-traditional exports
fep <sub>i</sub>	i ∈ COM	13	Price (upward) shift in export demands
feq <sub>i</sub>	i ∈ COM	13	Quantity (right) shift in export demands
fwage <sub>q</sub>	q ∈ RDES	8	Overall real wage shifter
imp_for_aud <sub>q</sub>	q ∈ RDES	8	AUD value of imports
imp <sub>q</sub>	q ∈ RDES	8	Foreign currency value of imports
impvol <sub>q</sub>	q ∈ RDES	8	Import volume index
in <sub>q</sub>	q ∈ RDES	8	Aggregate nominal investment
ir <sub>q</sub>	q ∈ RDES	8	Aggregate real investment expenditure
kt <sub>q</sub>	q ∈ RDES	8	Aggregate capital stock, rental weights
labrev <sub>q</sub>	q ∈ RDES	8	Aggregate payments to labour
lndrev <sub>q</sub>	q ∈ RDES	8	Aggregate payments to land
l <sub>q</sub>	q ∈ RDES	8	Aggregate employment- wage bill weights
luxexp <sub>q</sub>	q ∈ RDES	8	Total supernumerary household expenditure
natlabind <sub>j</sub>	j ∈ IND	13	Employment by Industry
natlambd <sub>a<sub>m</sub></sub>	m ∈ OCC	8	Employment in occupation M
natx0imp <sub>i</sub>	i ∈ COM	13	Import volumes
naty <sub>j</sub>	j ∈ IND	13	Capital creation by using industry
natz <sub>j</sub>	j ∈ IND	13	Activity level or value-added
octrev <sub>q</sub>	q ∈ RDES	8	Aggregate other cost ticket payments
othnom5 <sub>q</sub>	q ∈ RDES	8	Aggregate nominal regional "Other" demands
othnom6 <sub>q</sub>	q ∈ RDES	8	Aggregate nominal Federal "Other" demand
othreal5 <sub>q</sub>	q ∈ RDES	8	Aggregate real regional "Other" demands
othreal6 <sub>q</sub>	q ∈ RDES	8	Aggregate real Federal "Other" demand
pm <sub>i</sub>	i ∈ COM	13	C.I.F. foreign currency import prices
powtaxm <sub>i</sub>	i ∈ COM	13	Power of tariffs
psexp <sub>s</sub>	s ∈ RSOU	8	Price indices for interregional exports
psimp <sub>q</sub>	q ∈ RDES	8	Price indices for interregional imports
pwage <sub>q</sub>	q ∈ RDES	8	Region-wide nominal wage received by workers
pwage_p <sub>q</sub>	q ∈ RDES	8	Region-wide nominal wage paid by producers

...Table 2.2. continued

Variable	Subscript Range	Number	Description
qhous <sub>q</sub>	q∈RDES	8	Number of households
realwage_w <sub>q</sub>	q∈RDES	8	Real wages for workers: deflated by CPI
realwage_p <sub>q</sub>	q∈RDES	8	Real wages for producers: deflated by the GDP deflator
reg_p1cap <sub>q</sub>	q∈RDES	8	Regional rental price of capital
totdom <sub>q</sub>	q∈RDES	8	Domestic terms of trade
totfor <sub>q</sub>	q∈RDES	8	Foreign terms of trade
r0_tot <sub>q</sub>	q∈RDES	8	Regional aggregate rate of return
taxind <sub>q</sub>	q∈RDES	8	Aggregate revenue from all indirect taxes
taxrev1 <sub>q</sub>	q∈RDES	8	Aggregate revenue, indirect taxes on intermediate
taxrev2 <sub>q</sub>	q∈RDES	8	Aggregate revenue, indirect taxes on investment
taxrev3 <sub>q</sub>	q∈RDES	8	Aggregate revenue, indirect taxes on households
taxrev4 <sub>s</sub>	s∈RSOU	8	Aggregate revenue, indirect taxes on foreign exports
taxrev5 <sub>q</sub>	q∈RDES	8	Aggregate revenue, indirect taxes on regional "Other"
taxrev6 <sub>q</sub>	q∈RDES	8	Aggregate revenue, indirect tax on Federal "Other"
taxrevm <sub>q</sub>	q∈RDES	8	Aggregate tariff revenue
utility <sub>q</sub>	q∈RDES	8	Utility per household
wage_diff <sub>q</sub>	q∈RDES	8	Regional real wage differential
xim <sub>q</sub>	q∈RDES	8	Imports price index
ximp0 <sub>q</sub>	q∈RDES	8	Duty-paid imports price index
xiplpk <sub>q</sub>	q∈RDES	8	Index of relative price of labour and capital
xiy_r <sub>q</sub>	q∈RDES	8	Regional GDP deflator
xi2 <sub>q</sub>	q∈RDES	8	Investment price index
xi3 <sub>q</sub>	q∈RDES	8	Consumer price index
xi4 <sub>q</sub>	q∈RDES	8	Exports Price Index
xi5 <sub>q</sub>	q∈RDES	8	Regional "Other" demands price index
xi6 <sub>q</sub>	q∈RDES	8	Federal "Other" demands price index
xsexp <sub>s</sub>	s∈RSOU	8	Exports volume in interregional trade
xsimp <sub>q</sub>	q∈RDES	8	Imports volume in interregional trade
z_tot <sub>q</sub>	q∈RDES	8	Aggregate output: Value-added weights

...Table 2.2. continued

Variable	Subscript Range	Number	Description
<i>Matrix Variables</i>			
a1cap <sub>j,q</sub>	j ∈ IND q ∈ RDES	13×8	Capital augmenting technical change
a1 <sub>j,q</sub>	j ∈ IND q ∈ RDES	13×8	All input augmenting technical change
a1lab <sub>j,q</sub>	j ∈ IND q ∈ RDES	13×8	Labor augmenting technical change
a1land <sub>j,q</sub>	j ∈ IND q ∈ RDES	13×8	Land augmenting technical change
a1oct <sub>j,q</sub>	j ∈ IND q ∈ RDES	13×8	Other cost ticket technical change
a1prim <sub>j,q</sub>	j ∈ IND q ∈ RDES	13×8	All primary factor technical change
a2ind <sub>j,q</sub>	j ∈ IND q ∈ RDES	13×8	Technical change in capital creation
a3com <sub>i,q</sub>	i ∈ COM q ∈ RDES	13×8	Change in household tastes
a3lux <sub>i,q</sub>	i ∈ COM q ∈ RDES	13×8	Change in household tastes, luxury
a3sub <sub>i,q</sub>	i ∈ COM q ∈ RDES	13×8	Change in household taste, subsistence
a <sub>j,q</sub>	j ∈ IND q ∈ RDES	13×8	Average of technical change terms in production
arpri <sub>j,q</sub>	j ∈ IND q ∈ RDES	13×8	Payroll tax adjustment factor
curcap <sub>j,q</sub>	j ∈ IND q ∈ RDES	13×8	Current capital stock
deltax1 <sub>i,s,j,q</sub>	i ∈ COM s ∈ ASOU j ∈ IND q ∈ RDES	13×10×13× 8	Percentage-point change in tax rate on sales of intermediate inputs
deltax2 <sub>i,s,j,q</sub>	i ∈ COM s ∈ ASOU j ∈ IND q ∈ RDES	13×10×13× 8	Percentage-point change in tax rate on sales for capital creation

...Table 2.2. continued

Variable	Subscript Range	Number	Description
deltax <sub>3<sub>i,s,q</sub></sub>	i ∈ COM s ∈ ASOU q ∈ RDES	13×10×8	Percentage-point change in tax rate on sales to households
deltax <sub>4<sub>i,s</sub></sub>	i ∈ COM s ∈ RSOU	13×8	Percentage-point change in export tax rates
deltax <sub>5<sub>i,s,q</sub></sub>	i ∈ COM s ∈ ASOU q ∈ RDES	13×10×8	Percentage-point change in tax rate on sales to regional "Other" demand
deltax <sub>6<sub>i,s,q</sub></sub>	i ∈ COM s ∈ ASOU q ∈ RDES	13×9×8	Percent-point change in sales tax rate, Federal government demands
deltax <sub>i</sub>	i ∈ COM	13	Percentage-point change in the general sales tax rate
efflab <sub>j,q</sub>	j ∈ IND q ∈ RDES	13×8	Effective labour input
f1oct <sub>j,q</sub>	j ∈ IND q ∈ RDES	13×8	Shifters, other cost tickets
f5a <sub>i,s,q</sub>	i ∈ COM s ∈ ASOU q ∈ RDES	13×10×8	Shift in regional "Other" demands
f6a <sub>i,s,q</sub>	i ∈ COM s ∈ ASOU q ∈ RDES	13×9×8	Shift, Federal "Other" demand
faggnt <sub>is<sub>i,s</sub></sub>	i ∈ NTEXP s ∈ RSOU	11×8	Commodity and source shifter for non-traditional exports
frPR <sub>i<sub>j,q</sub></sub>	j ∈ IND q ∈ RDES	13×8	Payroll tax rate shifter
fwage <sub>i<sub>j,q</sub></sub>	j ∈ IND q ∈ RDES	13×8	Industry-specific wage shifter
labind <sub>j,q</sub>	j ∈ IND q ∈ RDES	13×8	Employment by industry
lambda <sub>m,q</sub>	m ∈ OCC q ∈ RDES	8×8	Employment by occupation
n <sub>j,q</sub>	j ∈ IND q ∈ RDES	13×8	Use of land
p0a <sub>i,s</sub>	i ∈ COM s ∈ ASOU	13×10	Basic price of good i, source s

...Table 2.2. continued

Variable	Subscript Range	Number	Description
$p1a_{i,s,j,q}$	$i \in \text{COM}$ $s \in \text{ASOU}$ $j \in \text{IND}$ $q \in \text{RDES}$	$13 \times 10 \times 13 \times 8$	Prices of inputs for current production
$p1cap_{j,q}$	$j \in \text{IND}$ $q \in \text{RDES}$	$13 \times 8$	Rental price of capital
$p1c_{i,j,q}$	$i \in \text{COM}$ $j \in \text{IND}$ $q \in \text{RDES}$	$13 \times 13 \times 8$	Prices of domestic composite inputs for current production
$p1lab_{j,q}$	$j \in \text{IND}$ $q \in \text{RDES}$	$13 \times 8$	Price of labour
$p1laboi_{j,q,m}$	$j \in \text{IND}$ $q \in \text{RDES}$ $m \in \text{OCC}$	$13 \times 8 \times 8$	Wage of occupation type m in industry j
$p1land_{j,q}$	$j \in \text{IND}$ $q \in \text{RDES}$	$13 \times 8$	Rental price of land
$p1oct_{j,q}$	$j \in \text{IND}$ $q \in \text{RDES}$	$13 \times 8$	Price of other cost tickets
$p1o_{i,j,q}$	$i \in \text{COM}$ $j \in \text{IND}$ $q \in \text{RDES}$	$13 \times 13 \times 8$	Price, domestic/foreign composite inputs for current production
$p2a_{i,s,j,q}$	$i \in \text{COM}$ $s \in \text{ASOU}$ $j \in \text{IND}$ $q \in \text{RDES}$	$13 \times 10 \times 13 \times 8$	Prices of inputs for capital creation
$p2c_{i,j,q}$	$i \in \text{COM}$ $j \in \text{IND}$ $q \in \text{RDES}$	$13 \times 13 \times 8$	Prices of domestic composite inputs for capital creation
$p2o_{i,j,q}$	$i \in \text{COM}$ $j \in \text{IND}$ $q \in \text{RDES}$	$13 \times 13 \times 8$	Price, domestic/foreign composite inputs for capital creation
$p3a_{i,s,q}$	$i \in \text{COM}$ $s \in \text{ASOU}$ $q \in \text{RDES}$	$13 \times 10 \times 8$	Purchasers prices by commodities and source for households
$p3c_{i,q}$	$i \in \text{COM}$ $q \in \text{RDES}$	$13 \times 8$	Prices of domestic composite inputs for households

...Table 2.2. continued

Variable	Subscript Range	Number	Description
$p3o_{i,q}$	$i \in \text{COM}$ $q \in \text{RDES}$	13×8	Price, domestic/foreign composite inputs for households
$p4r_{i,s}$	$i \in \text{COM}$ $s \in \text{RSOU}$	13×8	F.O.B. foreign currency export prices
$p5a_{i,s,q}$	$i \in \text{COM}$ $s \in \text{ASOU}$ $q \in \text{RDES}$	13×10×8	Purchasers' prices for commodities (by source) by regional "Other"
$p6a_{i,s,q}$	$i \in \text{COM}$ $s \in \text{ASOU}$ $q \in \text{RDES}$	13×10×8	Purchasers' prices paid for commodities by Federal "Other"
$pj_{j,q}$	$j \in \text{IND}$ $q \in \text{RDES}$	13×8	Costs of units of capital
$psflo_{s,q}$	$s \in \text{RSOU}$ $q \in \text{RDES}$	8×8	Price indices in interregional trade flows
$pwagei_{j,q}$	$j \in \text{IND}$ $q \in \text{RDES}$	13×8	Nominal wage rates
$r0_{j,q}$	$j \in \text{IND}$ $q \in \text{RDES}$	13×8	Current rates of return on capital
$rpri_{j,q}$	$j \in \text{IND}$ $q \in \text{RDES}$	13×8	Payroll tax rate (in per cent)
$x0imp_{i,q}$	$i \in \text{COM}$ $q \in \text{RDES}$	13×8	Import volumes
$x1a_{i,s,j,q}$	$i \in \text{COM}$ $s \in \text{ASOU}$ $j \in \text{IND}$ $q \in \text{RDES}$	13×10×13× 8	Demands for inputs for current production
$x1c_{i,j,q}$	$i \in \text{COM}$ $j \in \text{IND}$ $q \in \text{RDES}$	13×13×8	Demands for domestic composite inputs for current production
$x1laboi_{j,q,m}$	$j \in \text{IND}$ $q \in \text{RDES}$ $m \in \text{OCC}$	13×8×8	Employment of occupation type m in industry j
$x1marg_{i,s,j,q,r}$	$i \in \text{COM}$ $s \in \text{ASOU}$ $j \in \text{IND}$ $q \in \text{RDES}$ $r \in \text{MARG}$	13×10×13× 8×2	Margins - current production

...Table 2.2. continued

Variable	Subscript Range	Number	Description
$x1o_{j,q}$	$j \in \text{IND}$ $q \in \text{RDES}$	13×8	Demand for other cost tickets
$x1o_{i,j,q}$	$i \in \text{COM}$ $j \in \text{IND}$ $q \in \text{RDES}$	13×13×8	Demands for domestic/foriegn composite inputs for current production
$x1\text{prim}_{j,q}$	$j \in \text{IND}$ $q \in \text{RDES}$	13×8	Demand for primary factor composite
$x2a_{i,s,j,q}$	$i \in \text{COM}$ $s \in \text{ASOU}$ $j \in \text{IND}$ $q \in \text{RDES}$	13×10×13× 8	Demands for inputs for capital creation
$x2c_{i,j,q}$	$i \in \text{COM}$ $j \in \text{IND}$ $q \in \text{RDES}$	13×13×8	Demands for domestic composite inputs for capital creation
$x2\text{marg}_{i,s,j,q,r}$	$i \in \text{COM}$ $s \in \text{ASOU}$ $j \in \text{IND}$ $q \in \text{RDES}$ $r \in \text{MARG}$	13×10×13× 8×2	Margins - capital creation
$x2o_{i,j,q}$	$i \in \text{COM}$ $j \in \text{IND}$ $q \in \text{RDES}$	13×13×8	Demands for domestic/foriegn composite inputs for capital creation
$x3a_{i,s,q}$	$i \in \text{COM}$ $s \in \text{ASOU}$ $q \in \text{RDES}$	13×10×8	Household demand for goods
$x3c_{i,q}$	$i \in \text{COM}$ $q \in \text{RDES}$	13×8	Demands for domestic composite inputs for households
$x3\text{marg}_{i,s,q,r}$	$i \in \text{COM}$ $s \in \text{ASOU}$ $q \in \text{RDES}$ $r \in \text{MARG}$	13×10×8×2	Margins - on sales to households
$x3o_{i,q}$	$i \in \text{COM}$ $q \in \text{RDES}$	13×8	Demands for domestic/foriegn composite inputs for households
$x4\text{marg}_{i,s,r}$	$i \in \text{COM}$ $s \in \text{RSOU}$ $r \in \text{MARG}$	13×8×2	Margins - on exports

...Table 2.2. continued

Variable	Subscript Range	Number	Description
$x4r_{i,s}$	$i \in \text{COM}$ $s \in \text{RSOU}$	13×8	Export volumes
$x5a_{i,s,q}$	$i \in \text{COM}$ $s \in \text{ASOU}$ $q \in \text{RDES}$	13×10×8	Regional "Other" demands
$x5\text{marg}_{i,s,q,r}$	$i \in \text{COM}$ $s \in \text{ASOU}$ $q \in \text{RDES}$ $r \in \text{MARG}$	13×10×8×2	Margins - regional "Other"
$x6a_{i,s,q}$	$i \in \text{COM}$ $s \in \text{ASOU}$ $q \in \text{RDES}$	13×10×8	Federal "Other" demands in each region
$x6\text{marg}_{i,s,q,r}$	$i \in \text{COM}$ $s \in \text{ASOU}$ $q \in \text{RDES}$ $r \in \text{MARG}$	13×10×8×2	Margins - on sales to Federal "Other" demand
$xi\_fac_{j,q}$	$j \in \text{IND}$ $q \in \text{RDES}$	13×8	Index of factor costs
$xiplpk\_ind_{j,q}$	$j \in \text{IND}$ $q \in \text{RDES}$	13×8	Index of ratio of price of labour to price of capital
$xsflo_{s,q}$	$s \in \text{RSOU}$ $q \in \text{RDES}$	8×8	Volume of inter and intraregional trade flows
$y_{j,q}$	$j \in \text{IND}$ $q \in \text{RDES}$	13×8	Capital creation by using industry
$z_{j,q}$	$j \in \text{IND}$ $q \in \text{RDES}$	13×8	Activity level or value-added
<i>Government Finances</i>			
<i>Scalar Variables</i>			
bstar		1	Balance of trade surplus as percentage of GDP
ig		1	Nominal government investment
ip		1	Nominal private investment
miscf002		1	Shift variable : relative income tax rates
pbp		1	Personal benefit payments
rl		1	Tax rate - wages, salaries and supplements
rk		1	Tax rate - non-wage primary factor income

...Table 2.2. continued

Variable	Subscript Range	Number	Description
softf011		1	Shifter for Federal collection of other indirect taxes
ti		1	Commodity taxes less subsidies (excl tariffs)
ty		1	Income taxes
upb		1	Unemployment benefits
wn		1	Nominal pre-tax wage rate
wnstar		1	Nominal post-tax wage rate
wrstar		1	Real post-tax wage rate
xiy		1	GDP deflator
yf		1	GDP at factor cost
yl		1	Pre-tax wage income
ylstar		1	Post-tax wage income
yn		1	Nominal GDP
yr		1	Real GDP
z03		1	Payroll taxes
z05		1	Property taxes
z07		1	Land taxes
z09		1	Other indirect taxes
z10		1	Sales by final buyers
<i>Vector Variables</i>			
dgstar <sub>q</sub>	q∈DDES	9	Government net borrowing/total outlays
debtg <sub>q</sub>	q∈DDES	9	Government debt
g <sub>r</sub> <sub>q</sub>	q∈DDES	9	Government consumption
ig <sub>r</sub> <sub>q</sub>	q∈DDES	9	Government investment
labsup <sub>q</sub>	q∈RDES	8	Labour supply
pbp <sub>r</sub> <sub>q</sub>	q∈DDES	9	Personal benefit payments
rpr <sub>q</sub>	q∈RDES	8	payroll tax rate
ti <sub>r</sub> <sub>q</sub>	q∈RDES	8	Commodity taxes less subsidies (excl tariffs)
tod <sub>r</sub> <sub>q</sub>	q∈RDES	8	Other direct taxes
xisfb <sub>q</sub>	q∈RDES	8	price index : sales by final buyers
yn <sub>r</sub> <sub>q</sub>	q∈RDES	8	Nominal GSP - regions
yr <sub>r</sub> <sub>q</sub>	q∈RDES	8	Real GSP - regions

...Table 2.2. continued

Variable	Subscript Range	Number	Description
yd_r <sub>q</sub>	q∈RDES	8	Household disposable income
z01_r <sub>q</sub>	q∈RDES	8	Wages, salaries and supplements
z02_r <sub>q</sub>	q∈RDES	8	Imputed wages
z03_r <sub>q</sub>	q∈RDES	8	Payroll taxes
z04_r <sub>q</sub>	q∈RDES	8	Returns to fixed capital
z05_r <sub>q</sub>	q∈RDES	8	Property taxes
z06_r <sub>q</sub>	q∈RDES	8	Returns to agricultural land
z07_r <sub>q</sub>	q∈RDES	8	Land taxes
z08_r <sub>q</sub>	q∈RDES	8	Returns to working capital
z09_r <sub>q</sub>	q∈RDES	8	Other indirect taxes
z10_r <sub>q</sub>	q∈RDES	8	Sales by final buyers
zg_r <sub>q</sub>	q∈RDES	8	Gross operating surplus
zt_r <sub>q</sub>	q∈RDES	8	Production taxes
domy000 <sub>q</sub>	q∈RDES	8	GSP at market prices (income side)
domy100 <sub>q</sub>	q∈RDES	8	Wages, salaries and supplements
domy110 <sub>q</sub>	q∈RDES	8	Disposable wage income
domy120 <sub>q</sub>	q∈RDES	8	PAYE taxes
domy200 <sub>q</sub>	q∈RDES	8	GOS : non-wage primary factor income
domy210 <sub>q</sub>	q∈RDES	8	Disposable non-wage primary factor income
domy220 <sub>q</sub>	q∈RDES	8	Taxes on non-wage primary factor income
domy300 <sub>q</sub>	q∈RDES	8	Indirect taxes less subsidies
domy310 <sub>q</sub>	q∈RDES	8	Tariff revenue
domy320 <sub>q</sub>	q∈RDES	8	Other commodity taxes less subsidies
domy330 <sub>q</sub>	q∈RDES	8	Production taxes
dompq000 <sub>q</sub>	q∈RDES	8	GSP at market prices (expenditure side)
dompq100 <sub>q</sub>	q∈RDES	8	Domestic absorption
dompq110 <sub>q</sub>	q∈RDES	8	Private consumption
dompq120 <sub>q</sub>	q∈RDES	8	Private investment
dompq130 <sub>q</sub>	q∈RDES	8	Government consumption - regions
dompq140 <sub>q</sub>	q∈RDES	8	Government consumption - federal
dompq150 <sub>q</sub>	q∈RDES	8	Government investment

....Table 2.2. continued

Variable	Subscript Range	Number	Description
dompq200 <sub>q</sub>	q∈RDES	8	Interregional trade balance
dompq210 <sub>q</sub>	q∈RDES	8	Interregional exports
dompq220 <sub>q</sub>	q∈RDES	8	Interregional imports
dompq300 <sub>q</sub>	q∈RDES	8	International trade balance
dompq310 <sub>q</sub>	q∈RDES	8	International exports
dompq320 <sub>q</sub>	q∈RDES	8	International imports
softy000 <sub>q</sub>	q∈DDES	9	SOFT : income side total
softy100 <sub>q</sub>	q∈DDES	9	Government revenue
softy110 <sub>q</sub>	q∈DDES	9	Direct taxes
softy111 <sub>q</sub>	q∈DDES	9	Income taxes
softy112 <sub>q</sub>	q∈DDES	9	Other direct taxes
softy120 <sub>q</sub>	q∈DDES	9	Indirect taxes
softy121 <sub>q</sub>	q∈DDES	9	Tariff revenue
softy122 <sub>q</sub>	q∈DDES	9	Other commodity taxes
softy123 <sub>q</sub>	q∈DDES	9	Payroll taxes
softy124 <sub>q</sub>	q∈DDES	9	Property taxes
softy125 <sub>q</sub>	q∈DDES	9	Land taxes
softy126 <sub>q</sub>	q∈DDES	9	Other indirect taxes
softy130 <sub>q</sub>	q∈DDES	9	Interest received
softy140 <sub>q</sub>	q∈DDES	9	Commonwealth grants to regions
softy141 <sub>q</sub>	q∈DDES	9	Current grants
softy142 <sub>q</sub>	q∈DDES	9	Capital grants
softy150 <sub>q</sub>	q∈DDES	9	Other revenue
softy200 <sub>q</sub>	q∈DDES	9	Consumption of fixed capital - general government
softy300 <sub>q</sub>	q∈DDES	9	Financing transactions
softy310 <sub>q</sub>	q∈DDES	9	Net borrowing
softy320 <sub>q</sub>	q∈DDES	9	Increase in provisions
softy330 <sub>q</sub>	q∈DDES	9	Other financing transactions
f_oft <sub>q</sub>	q∈DDES	9	Other financing transactions shifter
realdef <sub>q</sub>	q∈DDES	9	Real government budget deficit
softq000 <sub>q</sub>	q∈DDES	9	SOFT: expenditure side total

...Table 2.2. continued

Variable	Subscript Range	Number	Description
softq100 <sub>q</sub>	q∈DDES	9	Expenditure on goods and services
softq110 <sub>q</sub>	q∈DDES	9	Government consumption
softq120 <sub>q</sub>	q∈DDES	9	Government investment
softq200 <sub>q</sub>	q∈DDES	9	Personal benefit payments
softq210 <sub>q</sub>	q∈DDES	9	Unemployment benefits
softq220 <sub>q</sub>	q∈DDES	9	Other personal benefits
softq300 <sub>q</sub>	q∈DDES	9	Subsidies
softq400 <sub>q</sub>	q∈DDES	9	Interest payments
softq500 <sub>q</sub>	q∈DDES	9	Commonwealth grants to regions
softq510 <sub>q</sub>	q∈DDES	9	Current grants
softq520 <sub>q</sub>	q∈DDES	9	Capital grants
softq600 <sub>q</sub>	q∈DDES	9	Other outlays
softf001 <sub>q</sub>	q∈RDES	8	Shift variable : other direct taxes
softf002 <sub>q</sub>	q∈RDES	8	Shift variable : current Commonwealth grants
softf003 <sub>q</sub>	q∈RDES	8	Shift variable : capital Commonwealth grants
softf004 <sub>q</sub>	q∈DDES	9	Shift variable : other revenue
softf005 <sub>q</sub>	q∈DDES	9	Shift variable : increase in provisions
softf006 <sub>q</sub>	q∈DDES	9	Shift variable : other outlays
softf007 <sub>q</sub>	q∈DDES	9	Shift variable : government debt
hhldy000 <sub>q</sub>	q∈RDES	8	Disposable income
hhldy100 <sub>q</sub>	q∈RDES	8	Primary factor income
hhldy110 <sub>q</sub>	q∈RDES	8	Wages, salaries and supplements
hhldy120 <sub>q</sub>	q∈RDES	8	Non-wage primary factor income
hhldy200 <sub>q</sub>	q∈RDES	8	Personal benefit receipts
hhldy210 <sub>q</sub>	q∈RDES	8	Unemployment benefits
hhldy220 <sub>q</sub>	q∈RDES	8	Other personal benefits
hhldy300 <sub>q</sub>	q∈RDES	8	Other income (net)
hhldy400 <sub>q</sub>	q∈RDES	8	Direct taxes
hhldy410 <sub>q</sub>	q∈RDES	8	PAYE taxes
hhldy420 <sub>q</sub>	q∈RDES	8	Taxes on non-wage primary factor income
hhldy430 <sub>q</sub>	q∈RDES	8	Other direct taxes

...Table 2.2. continued

Variable	Subscript Range	Number	Description
hhldf001 <sub>q</sub>	q∈RDES	8	Shift variable : unemployment benefits
hhldf002 <sub>q</sub>	q∈RDES	8	Shift variable : other personal benefits
hhldf003 <sub>q</sub>	q∈RDES	8	Shift variable : other income (net) - hholds
miscf001 <sub>q</sub>	q∈RDES	8	Shift variable : consumption function
<i>Investment-Capital Accumulation</i>			
<i>Scalar Variables</i>			
delkfudge		1	Dummy variable to switch on capital accumulation equation
natr_tot		1	Average rate of return
<i>Matrix Variables</i>			
delf_rate <sub>j,q</sub>	j∈IND q∈RDES	13×8	A change shifter in capital accumulation equation
f_rate_xx <sub>j,q</sub>	j∈IND q∈RDES	13×8	Shifter, rate of return equation
curcap_t1 <sub>j,q</sub>	j∈IND q∈RDES	13×8	Capital stock in period T+1
<i>National Foreign Debt</i>			
deldfudge		1	Dummy variable in equation E_delDebt
delbt		1	Ordinary change in Real trade deficit
deldebt_ratio		1	Change in Debt/GDP ratio
deldebt		1	Ordinary change in foreign debt
<i>Regional Population and Labour Markets</i>			
<i>Scalar Variables</i>			
del_natfm		1	Ordinary change in national net foreign migration.
del_natg		1	Ordinary change in national net natural population.
del_natunr		1	Percentage-point change in the national unemployment rate
delf_rm		1	Shift variable in equation E_rm_addup
delf_rm_0		1	Shift variable in equation E_rm_0
natlabsup		1	National labour supply.
natemploy			National employment.

...Table 2.2. continued

Variable	Subscript Range	Number	Description
<i>Vector Variables</i>			
del_fm <sub>q</sub>	q∈RDES	8	Ordinary change in regional net foreign migration.
del_g <sub>q</sub>	q∈RDES	8	Ordinary change in regional net natural population.
del_rm <sub>q</sub>	q∈RDES	8	Ordinary change in net interregional migration.
del_rm_0 <sub>q</sub>	q∈RDES	8	Exogenous forecast of interregional migration
delrpfudge <sub>q</sub>	q∈RDES	8	Dummy variable in equation E_del_rm.
del_unr <sub>q</sub>	q∈RDES	8	Percentage-point change in regional unemploy rate
employ <sub>q</sub>	q∈RDES	8	Regional employment: persons.
f_l <sub>q</sub>	q∈RDES	8	Shift variable in equation E_remploy_interf.
f_pop <sub>q</sub>	q∈RDES	8	Shift variable in equation E_del_rm.
f_wpop <sub>q</sub>	q∈RDES	8	Shift variable in equation E_wpop
f_qhous <sub>q</sub>	q∈RDES	8	Shift variable in equation E_pop_interf
pop <sub>q</sub>	q∈RDES	8	Regional population
pr <sub>q</sub>	q∈RDES	8	Regional workforce participation rate
wpop <sub>q</sub>	q∈RDES	8	Regional population of working age

Table 2.3. The MMRF Coefficients and Parameters

Coefficient	Description	Value
$\sigma 1C_i$	Elasticity of substitution between regional sources of good $i$ for use as an input in production.	Arbitrarily set at five times the value of the elasticity of substitution between domestic goods and foreign imported goods:
$S1A_{i,s,j,q}$	Share of purchasers-price value of good $i$ from regional source $s$ in industry $j$ in region $q$ 's total purchases of good $i$ from domestic sources for use in production	The numerator of this share, for the $isjq^{\text{th}}$ element ( $s \neq 9$ ), is the sum of the corresponding elements of the BAS1, MAR1 and TAX1 matrices. The denominator is the sum, over the 8 $s$ regional sources (i.e., for all $s; s \neq 9$ ), of the sum of the $isjq^{\text{th}}$ elements of BAS1, MAR1 and TAX1.
$\sigma 1O_i$	Elasticity of substitution between domestic composite and foreign import of good $i$ for use as an input in production.	Econometric estimate from MONASH model.
$PVAL1O_{i,j,q}$	Purchaser's value of domestic composite and foreign import of good $i$ as an input the $jq^{\text{th}}$ industry's production.	The $ijq^{\text{th}}$ value is the sum, over the 9 (all domestic plus foreign) sources, of the sum of the $isjq^{\text{th}}$ elements of BAS1, MAR1 and TAX1.
$PVAL1A_{i,s,j,q}$	Purchaser's value of good $i$ from the $s^{\text{th}}$ source ( $s = 1, \dots, 9$ ) as an input in the $jq^{\text{th}}$ industry's production.	The $isjq^{\text{th}}$ value ( $s = 1, \dots, 9$ ) is the sum of the corresponding elements of the BAS1, MAR1 and TAX1 matrices. Dividing by PVAL1O, forms the share of the $i^{\text{th}}$ good in the firm's total expenditure on the $i^{\text{th}}$ good from all $s$ sources ( $s = 1, \dots, 9$ ) for use in production.
$\sigma 1LAB_{i,\alpha}$	Elasticity of substitution for labour of $m$ occupational types used as an inputs to production by industry $j$ in region $q$	Econometric estimate from MONASH model.
$LABOUR_{j,q}$	Total wage bill of the $jq^{\text{th}}$ industry.	Sum of the $m$ elements of LABR for the $jq^{\text{th}}$ industry. Dividing by TOTFACIND gives the share of the wage bill in the value-added of the $jq^{\text{th}}$ industry.
$LAB\_OCC\_IND_{m,j,q}$	Wage bill of the $m^{\text{th}}$ occupation used by the $jq^{\text{th}}$ industry.	The $jqm^{\text{th}}$ element of LABR. Dividing by LABOUR gives the share of the wage bill of the $m^{\text{th}}$ occupational group in the total wage bill of the $jq^{\text{th}}$ industry.

...Table 2.3. continued

Coefficient	Description	Value
$\sigma 1FAC_{i,\alpha}$	Elasticity of substitution for primary factors (agricultural land, labour and capital) used as inputs to production by industry $j$ in region $q$ .	Econometric estimate from MONASH model.
TOTFACIND $_{j,q}$	Total cost of primary factors used by industry $j$ in region $q$ .	Sum of $jq^{\text{th}}$ element of coefficient LABOUR and the corresponding $jq^{\text{th}}$ elements of the CPTL and LAND matrices.
CAPITAL $_{j,q}$	Value of rentals to capital for industry $j$ in region $q$ .	The $jq^{\text{th}}$ element of the CPTL matrix.
LAND $_{j,q}$	Value of rentals to agricultural land for industry $j$ in region $q$ .	The $jq^{\text{th}}$ element of the LAND matrix.
$\sigma 2C_i$	Elasticity of substitution between regional sources of good $i$ for use as an input in the creation of capital.	Arbitrarily set at five times the value of the elasticity of substitution between domestic goods and foreign imported goods:
$\sigma 2O_i$	Elasticity of substitution between domestic composite and foreign import of good $i$ for use as an input in creation of capital.	Econometric estimate from MONASH model.
PVAL2T $_{i,ss,j,q}$	Purchaser's value of domestic composite good $i$ as an input the $jq^{\text{th}}$ industry's creation of capital.	The sum, over the 8 regional sources ( $ss = \text{domestic}$ ; i.e., for all $s$ ; $s \neq 9$ ), of the sum of the $isjq^{\text{th}}$ elements of BAS2, MAR2 and TAX2.
PVAL2A $_{i,s,j,q}$ (in E_p2c)	Purchaser's value of good $i$ from the $s^{\text{th}}$ regional source ( $s = 1, \dots, 8$ ) as an input in the $jq^{\text{th}}$ industry's creation of capital.	The $isjq^{\text{th}}$ value ( $s = 1, \dots, 8$ ) is the sum of the corresponding elements of the BAS2, MAR2 and TAX2 matrices. Dividing by PVAL2T, forms the share of the $is^{\text{th}}$ good in the firm's total expenditure on the $i^{\text{th}}$ good from all regional sources ( $s = 1, \dots, 8$ ) for the purpose of capital creation.
PVAL2A $_{i,s,j,q}$ (in E_p2o)	Purchaser's value of good $i$ from the all sources ( $s = 1, \dots, 9$ ) as an input in the $jq^{\text{th}}$ industry's creation of capital.	The $isjq^{\text{th}}$ value ( $s = 1, \dots, 9$ ) is the sum of the corresponding elements of the BAS2, MAR2 and TAX2 matrices. Dividing by PVAL2O, forms the share of the $is^{\text{th}}$ good in the firm's total expenditure on the $i^{\text{th}}$ good from all sources ( $s = 1, \dots, 9$ ) for the purpose of capital creation.
PVAL2O $_{i,j,q}$	Purchaser's value of domestic composite and foreign import of good $i$ as an input the $jq^{\text{th}}$ industry's capital creation.	The $ijq^{\text{th}}$ value is the sum over the 9 (all domestic plus foreign) sources of the sum of the $isjq^{\text{th}}$ elements of BAS2, MAR2 and TAX2.

....Table 2.3. continued

Coefficient	Description	Value
$\sigma 3C_i$	Elasticity of substitution between regional sources of good $i$ in regional household demand.	Arbitrarily set at five times the value of the elasticity of substitution between domestic goods and foreign imported goods:
$\sigma 2O_i$	Elasticity of substitution between domestic composite and foreign import of good $i$ in regional household demand.	Econometric estimate from MONASH model.
$PVAL3T_{i,domestic,q}$	Purchaser's value of domestic composite good $i$ consumed by the household in region $q$ .	The sum, over the 8 regional sources, of the sum of the $isq^{th}$ elements of BAS3, MAR3 and TAX3.
$PVAL3A_{i,s,q}$ (in E_p3c)	Purchaser's value of good $i$ from the $s^{th}$ regional source ( $s = 1, \dots, 8$ ) consumed by the household in region $q$ .	The $isq^{th}$ value ( $s = 1, \dots, 8$ ) is the sum of the corresponding elements of the BAS3, MAR3 and TAX3 matrices. Dividing by PVAL3T, forms the share of the $is^{th}$ good in the household's total expenditure on the $ith$ good from all regional sources ( $s = 1, \dots, 8$ ).
$PVAL3A_{i,s,q}$ (in E_p3o)	Purchaser's value of good $i$ from the all sources ( $s = 1, \dots, 9$ ) consumed by the household in region $q$ .	The $isq^{th}$ value ( $s = 1, \dots, 9$ ) is the sum of the corresponding elements of the BAS3, MAR3 and TAX3 matrices. Dividing by PVAL3O, forms the share of the $is^{th}$ good in the household's total expenditure on the $ith$ good from all sources ( $s = 1, \dots, 9$ ).
$PVAL3O_{i,q}$	Purchaser's value of domestic composite and foreign import of good $i$ consumed by the household in region $q$ .	The $iq^{th}$ value is the sum, over the 9 (all domestic plus foreign) sources of the sum of the $isq^{th}$ elements of BAS3, MAR3 and TAX3.
$ALPHA_{I_{i,q}}$	Supernumerary expenditure on good $i$ as a share of supernumerary and subsistence expenditure on good $i$ by the household in region $q$ .	The formula for $ALPHA_{I_{i,q}}$ is $ALPHA_{I_{i,q}} = (1/FRISCH_{i,q}) \times (DELTA_{i,q}/S3COM_{i,q})$ where $FRISCH_{i,q}$ is an econometrically estimated parameter taken from the MONASH model database, and $DELTA_{i,q}$ and $S3COM_{i,q}$ are described below.
$DELTA_{i,q}$	Marginal household budget share of good $i$ in total marginal expenditure by the household in region $q$ .	Econometric estimate from MONASH model.
$S3COM_{i,q}$	Share of good $i$ in total household expenditure by the household in region $q$ .	The formula for $S3COM_{i,q}$ is $S3COM_{i,q} = PVAL3O_{i,q}/AGGCON_{i,q}$ where $PVAL3O_{i,q}$ is described above and $AGGCON_{i,q}$ is described below.

....Table 2.3. continued

Coefficient	Description	Value
$EXP\_ELAST_i$	Foreign export demand elasticity of good $i$ .	Econometric estimate from MONASH model.
$AGGEXPNT_s$	Total regional non-traditional export earnings.	The sum, over all non-traditional export commodities ( $1 = 3, \dots, 13$ ) of $PVAL4R_{ix}$ (which is described below).
$PVAL4R_{is}$ (in $E\_agnt\_p4r$ )	Purchaser's value of non-traditional export good $i$ ( $i = 3, \dots, 13$ ) from the $s^{th}$ regional source ( $s = 1, \dots, 8$ ) consumed by foreigners.	The $is^{th}$ value ( $i = 3, \dots, 13$ , $s = 1, \dots, 8$ ) is the sum of the corresponding elements of the $BAS4$ , $MAR4$ and $TAX4$ matrices. Dividing by $AGGEXPNT$ , forms the share of the $i^{th}$ good in the foreigners expenditure on the all goods from region $s$ ( $s = 1, \dots, 8$ ).
$COSTS_{j,q}$	Total costs of production in industry $j$ in region $q$	The $jq^{th}$ value is the sum over the 9 (all domestic plus foreign) sources of the sum of the $isjq^{th}$ elements of the $BAS1$ , $MAR1$ and $TAX1$ matrices, plus the sum over $m$ occupational types of the corresponding element of the $LABR$ matrix, plus the corresponding elements of $CPTL$ and $OCTS$ matrices.
$OTHCOST_{j,q}$	Other cost tickets paid by industry $j$ in region $q$ .	The $jq^{th}$ value is the corresponding element in the $OCTS$ matrix.
$INVEST_{j,q}$	Value of total capital created for industry $j$ in region $q$ .	The $jq^{th}$ value is the sum over $i$ ( $i = 1, \dots, 13$ ) of $PVAL20$ .
$BAS1_{i,s,j,q}$	Basic value of good $i$ from source $s$ (domestic and foreign) used in production by industry $j$ in region $q$ .	The $isjq^{th}$ value is the corresponding element in the $BAS1$ matrix.
$TAX1_{i,s,j,q}$	Value of commodity taxes paid on good $i$ from source $s$ (domestic and foreign) used in production by industry $j$ in region $q$ .	The $isjq^{th}$ value is the corresponding element in the $TAX1$ matrix.
$MAR1_{i,s,j,q,r}$	Value of expenditure on margin commodity $r$ , to facilitate the transfer of good $i$ from source $s$ (domestic and foreign) to industry $j$ in region $q$ to be used in production.	The $isjqr^{th}$ value is the corresponding element in the $MAR1$ matrix.
$BAS2_{i,s,j,q}$	Basic value of good $i$ from source $s$ (domestic and foreign) used in capital creation by industry $j$ in region $q$ .	The $isjq^{th}$ value is the corresponding element in the $BAS2$ matrix.

....Table 2.3. continued

Coefficient	Description	Value
$TAX2_{i,s,j,q}$	Value of commodity taxes paid on good $i$ from source $s$ (domestic and foreign) used in capital creation by industry $j$ in region $q$ .	The $isjq^{\text{th}}$ value is the corresponding element in the TAX2 matrix.
$MAR2_{i,s,j,q,r}$	Value of expenditure on margin commodity $r$ , to facilitate the transfer of good $i$ from source $s$ (domestic and foreign) to industry $j$ in region $q$ to be used in capital creation.	The $isjqr^{\text{th}}$ value is the corresponding element in the MAR2 matrix.
$BAS3_{i,s,q}$	Basic value of good $i$ from source $s$ (domestic and foreign) consumed by the household in region $q$ .	The $isq^{\text{th}}$ value is the corresponding element in the BAS3 matrix.
$TAX3_{i,s,q}$	Value of commodity taxes paid on good $i$ from source $s$ (domestic and foreign) consumed by the household in region $q$ .	The $isq^{\text{th}}$ value is the corresponding element in the TAX3 matrix.
$MAR3_{i,s,q,r}$	Value of expenditure on margin commodity $r$ , to facilitate the transfer of good $i$ from source $s$ (domestic and foreign) to the household in region $q$ .	The $isqr^{\text{th}}$ value is the corresponding element in the MAR3 matrix.
$PVAL4R_{is}$ (in $E_{p4r}$ )	Purchaser's value of good $i$ ( $i = 1, \dots, 13$ ) from the $s^{\text{th}}$ regional source ( $s = 1, \dots, 8$ ) consumed foreigners.	The $is^{\text{th}}$ value ( $i = 1, \dots, 13$ , $s = 1, \dots, 8$ ) is the sum of the corresponding elements of the BAS4, MAR4 and TAX4 matrices.
$BAS4_{i,s}$	Basic value of good $i$ from source $s$ (domestic and foreign) sold to the foreigner.	The $is^{\text{th}}$ value is the corresponding element in the BAS4 matrix.
$TAX4_{i,s}$	Value of commodity taxes paid on good $i$ from source $s$ (domestic and foreign) sold to the foreigner.	The $is^{\text{th}}$ value is the corresponding element in the TAX4 matrix.
$MAR4_{i,s,r}$	Value of expenditure on margin commodity $r$ , to facilitate the transfer of good $i$ from source $s$ (domestic and foreign) to the Australian port of departure for shipment to the foreign consumer.	The $isr^{\text{th}}$ value is the corresponding element in the MAR4 matrix.

....Table 2.3. continued

Coefficient	Description	Value
$PVAL5A_{i,s,q}$	Purchaser's value of good $i$ ( $i = 1, \dots, 13$ ) from the $s^{\text{th}}$ source (domestic and foreign) to be used by the regional government in region $q$ .	The $isq^{\text{th}}$ value is the sum of the corresponding elements of the BAS5, MAR5 and TAX5 matrices.
$BAS5_{i,s,q}$	Basic value of good $i$ from source $s$ (domestic and foreign) consumed by the regional government in region $q$ .	The $isq^{\text{th}}$ value is the corresponding element in the BAS5 matrix.
$TAX5_{i,s,q}$	Value of commodity taxes paid on good $i$ from source $s$ (domestic and foreign) consumed by the regional government in region $q$ .	The $isq^{\text{th}}$ value is the corresponding element in the TAX5 matrix.
$MAR5_{i,s,q,r}$	Value of expenditure on margin commodity $r$ , to facilitate the transfer of good $i$ from source $s$ (domestic and foreign) to the regional government in region $q$ .	The $isqr^{\text{th}}$ value is the corresponding element in the MAR5 matrix.
$PVAL6A_{i,s,q}$	Purchaser's value of good $i$ ( $i = 1, \dots, 13$ ) from the $s^{\text{th}}$ source (domestic and foreign) to be used by the Federal government in region $q$ .	The $isq^{\text{th}}$ value is the sum of the corresponding elements of the BAS5, MAR5 and TAX6 matrices.
$BAS6_{i,s,q}$	Basic value of good $i$ from source $s$ (domestic and foreign) consumed by the Federal government in region $q$ .	The $isq^{\text{th}}$ value is the corresponding element in the BAS6 matrix.
$TAX6_{i,s,q}$	Value of commodity taxes paid on good $i$ from source $s$ (domestic and foreign) consumed by the Federal government in region $q$ .	The $isq^{\text{th}}$ value is the corresponding element in the TAX6 matrix.
$MAR6_{i,s,q,r}$	Value of expenditure on margin commodity $r$ , to facilitate the transfer of good $i$ from source $s$ (domestic and foreign) to the Federal government in region $q$ .	The $isqr^{\text{th}}$ value is the corresponding element in the MAR6 matrix.

....Table 2.3. continued

Coefficient	Description	Value
SALES <sub>r,s</sub> (in E_mkt_clear_margins)	Total value of sales received by the producer of the r <sup>th</sup> margin commodity produced in the s <sup>th</sup> region. Note that we distinguish two purposes for which margin commodities are purchased (i) for direct usage and (ii) to facilitate trade. Our convention regarding the second form of usage is that the margin commodity is produced by the corresponding margin industry in the purchasing region of the traded commodity.	The r <sup>s</sup> <sup>th</sup> value is the sum of sales for direct usage and sales for use as a margin. The direct sales are the sum of: the sum over j industries and q regions of the corresponding isjq <sup>th</sup> elements of the BAS1 and BAS2 matrices (for i = r); the sum over q regions of the corresponding isq <sup>th</sup> elements of the BAS3, BAS5 and BAS6 matrices (for i = r); and the corresponding element the BAS4 matrix (for r = i). For the margin sales component, we are adding the purchases of the r <sup>th</sup> margin commodity facilitating the transfer of all i commodities from all ss (regional and foreign) sources to be used by (i) the j industries in the q <sup>th</sup> region (MAR1 and MAR2); (ii) the household in the q <sup>th</sup> region (MAR3); (iii) the governments in the q <sup>th</sup> region (MAR5 and MAR6); and the exporter in the q <sup>th</sup> where it is assumed that the q <sup>th</sup> region is the region producing the margin (i.e., for q = s).
SALES <sub>r,s</sub> (in E_mkt_clear_nonmargins)	Total value of sales received by the producer of the r <sup>th</sup> nonmargin commodity produced in the s <sup>th</sup> region. Note that nonmargin commodities are purchased only for direct usage.	The r <sup>s</sup> <sup>th</sup> value is the sum of: the sum over j industries and q regions of the isjq <sup>th</sup> elements of the BAS1 and BAS2 matrices (for i = r); the sum over q regions of the isq <sup>th</sup> elements of the BAS3, BAS5 and BAS6 matrices (for i = r); and the corresponding element the BAS4 matrix (for r = i).
IMPORTS <sub>i,q</sub>	Total basic-value imports of good i into region q.	The iq <sup>th</sup> value is the sum of: the sum over j industries of the corresponding isjq <sup>th</sup> (s = foreign) elements of the BAS1 and BAS2 matrices; and (ii) the corresponding isq <sup>th</sup> elements of BAS3, BAS5 and BAS6.
AGGTAX1 <sub>q</sub>	Sales tax on current production collected in region q.	The q <sup>th</sup> value is the sum over i, s (s = 1,...,9) and j of the corresponding isjq <sup>th</sup> elements of the TAX1 matrix.
AGGTAX2 <sub>q</sub>	Sales tax on capital creation collected in region q.	The q <sup>th</sup> value is the sum over i, s (s = 1,...,9) and j of the corresponding isjq <sup>th</sup> elements of the TAX2 matrix.

....Table 2.3. continued

Coefficient	Description	Value
AGGTAX3 <sub>q</sub>	Sales tax on household consumption collected in region q.	The q <sup>th</sup> value is the sum over i and s (s = 1,...,9) of the corresponding isq <sup>th</sup> elements of the TAX3 matrix.
AGGTAX4 <sub>q</sub>	Sales tax on exports collected in region q.	The q <sup>th</sup> value is the sum over i, for s = q, of the corresponding iq <sup>th</sup> elements of the TAX4 matrix.
AGGTAX5 <sub>q</sub>	Sales tax on regional government consumption collected in region q.	The q <sup>th</sup> value is the sum over i and s (s = 1,...,9) of the corresponding isq <sup>th</sup> elements of the TAX5 matrix.
AGGTAX6 <sub>q</sub>	Sales tax on Federal government consumption collected in region q.	The q <sup>th</sup> value is the sum over i and s (s = 1,...,9) of the corresponding isq <sup>th</sup> elements of the TAX6 matrix.
AGGCAP <sub>q</sub>	Total payments to capital in region q.	The q <sup>th</sup> value is the sum over j of the corresponding jq <sup>th</sup> elements of CAPITAL <sub>i,α</sub> .
AGGLAB <sub>q</sub>	Total payments to labour in region q.	The q <sup>th</sup> value is the sum over j of the corresponding jq <sup>th</sup> elements of LABOUR <sub>i,α</sub> .
AGGLND <sub>q</sub>	Total payments to agricultural land in region q.	The q <sup>th</sup> value is the sum over j of the corresponding jq <sup>th</sup> elements of LAND <sub>i,α</sub> .
AGGOCT <sub>q</sub>	Total payments to other cost tickets in region q.	The q <sup>th</sup> value is the sum over j of the corresponding jq <sup>th</sup> elements of OTHCOST <sub>i,α</sub> .
AGGTAX <sub>q</sub>	Aggregate indirect tax revenue collected by region q.	The q <sup>th</sup> value is the sum of the corresponding q <sup>th</sup> elements of AGGTAX1 <sub>α</sub> , AGGTAX2 <sub>α</sub> , AGGTAX3 <sub>α</sub> and AGGTAX5 <sub>α</sub> .
TARIFF <sub>i,q</sub>	The value of tariffs collected on good i in region q.	The iq <sup>th</sup> value is the corresponding element in the MMRF database file TARF.
AGGTAXM <sub>q</sub>	The total value of tariffs collected in region q.	The q <sup>th</sup> value is the sum over i of the corresponding iq <sup>th</sup> elements of TARIFF <sub>i,α</sub> .
AGGCON <sub>q</sub>	Total value in purchaser's prices of household expenditure in region q.	The q <sup>th</sup> value is the sum over i of the corresponding iq <sup>th</sup> elements of PVAL3O <sub>i,α</sub> .
AGGINV <sub>q</sub>	Total value in purchaser's prices of capital creation in region q.	The q <sup>th</sup> value is the sum over i of the corresponding iq <sup>th</sup> elements of INVEST <sub>i,α</sub> .
AGGOTH5 <sub>q</sub>	Total value in purchaser's prices of regional government expenditure in region q.	The q <sup>th</sup> value is the sum over i and s of the corresponding isq <sup>th</sup> elements of PVAL5A <sub>i,α</sub> .
AGGOTH6 <sub>q</sub>	Total value in purchaser's prices of Federal government expenditure in region q.	The q <sup>th</sup> value is the sum over i and s of the corresponding isq <sup>th</sup> elements of PVAL6A <sub>i,α</sub> .

....Table 2.3. continued

Coefficient	Description	Value
$C\_XSFL0_{s,q}$	Basic value of inter and intra regional trade flows.	The $sq^{th}$ value is the sum of: the sum over $i$ and $j$ of the corresponding $isjq^{th}$ elements of $BAS1_{i,s;n}$ ; the sum over $i$ and $j$ of the corresponding $isjq^{th}$ elements of $BAS2_{i,s;n}$ ; and the sum over $i$ of the corresponding $isq^{th}$ elements of $BAS3_{i,s;n}$ and $BAS5_{i,s;n}$ .
$C\_XSEXP_s$	Total value of interregional exports from region $s$ .	The $s^{th}$ value is the difference between the sum over $q$ of the corresponding $sq^{th}$ elements of $C\_XSFL0$ and the corresponding $ss^{th}$ element of $C\_XSFL0$ .
$C\_XSIMP_q$	Total value of interregional imports to region $q$ .	The $q^{th}$ value is the difference between the sum over $s$ of the corresponding $sq^{th}$ elements of $C\_XSFL0$ and the corresponding $qq^{th}$ element of $C\_XSFL0$ .
$AGGEXP_q$	Total value of export earnings in region $q$ .	The $q^{th}$ value is the sum over $i$ of corresponding $iq^{th}$ elements of $PVAL4R$ .
$IMPCOST_{i,q}$	Total ex-duty value of imports of good $i$ to region $q$ .	The $iq^{th}$ value is the sum of: the sum over $j$ of the corresponding $isjq^{th}$ elements ( $s = \text{foreign}$ ) of the $BAS1$ and $BAS2$ matrices; and the corresponding $isq^{th}$ elements ( $s = \text{foreign}$ ) of the $BAS3$ , $BAS5$ and $BAS6$ matrices
$AGGIMP_q$	Total value of foreign import expenditures in region $q$ .	The $q^{th}$ value is the sum over $i$ of corresponding $iq^{th}$ elements of $IMPCOST$ .
$TOTFAC_q$	Total primary factor payments in region $q$ .	The $q^{th}$ value is the sum of the corresponding elements of $AGGLAB$ , $AGGCAP$ and $AGGLND$ .
$LAB\_OCC_{m,q}$	Total labour bill in occupation $m$ in region $q$ .	The $mq^{th}$ value is the sum over $j$ of the corresponding $mjq^{th}$ elements of $LAB\_OCC\_IND$ .
NAT coefficients	All coefficients with the NAT prefix are national add-ups formed by summing across the $q$ elements of the corresponding regional variable.	Example: $NATAGGTAX1 = \sum_{q=1} AGGTAX1_q$
NATGDPIN	National GDP from the income side.	The sum of $NATTOTFAC$ , $NATAGGOCT$ and $NATAGGTAX$ .
NATGDPEX	National GDP from the expenditure side.	The sum of $NATAGGCON$ , $NATAGGINV$ , $NATAGGOTH5$ , $NATAGGOTH6$ , $NATAGGEXP$ and $NATAGGIMP$ .

....Table 2.3. continued

Coefficient	Description	Value
C_Z01_I_R <sub>j,q</sub>	Industry by region value of wages, salaries and supplements.	The j <sup>q</sup> <sup>th</sup> value is the corresponding element in the MMRF database file FZ01.
C_Z01_R <sub>q</sub>	Regional value of wages, salaries and supplements.	The q <sup>th</sup> value is the sum, over j, of the corresponding j <sup>q</sup> <sup>th</sup> elements of C_Z01_I_R
C_Z02_I_R <sub>j,q</sub>	Industry by region value of imputed wages.	The j <sup>q</sup> <sup>th</sup> value is the corresponding element in the MMRF database file FZ02.
C_Z02_R <sub>q</sub>	Regional value of imputed wages.	The q <sup>th</sup> value is the sum, over j, of the corresponding j <sup>q</sup> <sup>th</sup> elements of C_Z02_I_R.
C_Z03_I_R <sub>j,q</sub>	Industry by region value of payroll taxes	The j <sup>q</sup> <sup>th</sup> value is the corresponding element in the MMRF database file FZ03.
C_Z03_R <sub>q</sub>	Regional value of payroll taxes.	The q <sup>th</sup> value is the sum, over j, of the corresponding j <sup>q</sup> <sup>th</sup> elements of C_Z03_I_R.
C_Z03	National value of payroll taxes.	The sum of the elements of C_Z03_R.
C_Z04_I_R <sub>j,q</sub>	Industry by region value of returns to fixed capital.	The j <sup>q</sup> <sup>th</sup> value is the corresponding element in the MMRF database file FZ04.
C_Z04_R <sub>q</sub>	Regional value of returns to fixed capital.	The q <sup>th</sup> value is the sum, over j, of the corresponding j <sup>q</sup> <sup>th</sup> elements of C_Z04_I_R.
C_Z05_I_R <sub>j,q</sub>	Industry by region value of property taxes	The j <sup>q</sup> <sup>th</sup> value is the corresponding element in the MMRF database file FZ05.
C_Z05_R <sub>q</sub>	Regional value of property taxes.	The q <sup>th</sup> value is the sum, over j, of the corresponding j <sup>q</sup> <sup>th</sup> elements of C_Z05_I_R.
C_Z05	National value of property taxes.	The sum of the elements of C_Z05_R.
C_Z06_I_R <sub>j,q</sub>	Industry by region value of returns to agricultural land.	The j <sup>q</sup> <sup>th</sup> value is the corresponding element in the MMRF database file FZ06.
C_Z06_R <sub>q</sub>	Regional value of returns to agricultural land.	The q <sup>th</sup> value is the sum, over j, of the corresponding j <sup>q</sup> <sup>th</sup> elements of C_Z06_I_R.
C_Z07_I_R <sub>j,q</sub>	Industry by region value of land taxes.	The j <sup>q</sup> <sup>th</sup> value is the corresponding element in the MMRF database file FZ07.
C_Z07_R <sub>q</sub>	Regional value of land taxes.	The q <sup>th</sup> value is the sum, over j, of the corresponding j <sup>q</sup> <sup>th</sup> elements of C_Z07_I_R.
C_Z07	National value of land taxes.	The sum of the elements of C_Z07_R.
C_Z08_I_R <sub>j,q</sub>	Industry by region value of returns to working capital.	The j <sup>q</sup> <sup>th</sup> value is the corresponding element in the MMRF database file FZ08.
C_Z08_R <sub>q</sub>	Regional value of returns working capital.	The q <sup>th</sup> value is the sum, over j, of the corresponding j <sup>q</sup> <sup>th</sup> elements of C_Z08_I_R.
C_Z09_I_R <sub>j,q</sub>	Industry by region value of other indirect taxes.	The j <sup>q</sup> <sup>th</sup> value is the corresponding element in the MMRF database file FZ09.
C_Z09_R <sub>q</sub>	Regional value of other indirect taxes.	The q <sup>th</sup> value is the sum, over j, of the corresponding j <sup>q</sup> <sup>th</sup> elements of C_Z09_I_R.

...Table 2.3. continued

Coefficient	Description	Value
C_Z09	National value of other indirect taxes.	The sum of the elements of C_Z09_R.
C_Z010_I <sub>R,j,q</sub>	Industry by region value of sales by final buyers.	The $j^{\text{th}}$ value is the corresponding element in the MMRF database file FZ010.
C_Z010_R <sub>q</sub>	Regional value of sales by final buyers.	The $q^{\text{th}}$ value is the sum, over $j$ , of the corresponding $j^{\text{th}}$ elements of C_Z010_I_R.
C_Z010	National value of sales by final buyers.	The sum of the elements of C_Z010_R.
C_ZG_R <sub>q</sub>	Regional value gross operating surplus.	The $q^{\text{th}}$ value is the sum of the corresponding elements of C_Z02_R, C_Z04_R, C_Z06_R and C_Z08_R.
C_ZT_R <sub>q</sub>	Regional value production taxes.	The $q^{\text{th}}$ value is the sum of the corresponding elements of C_Z03_R, C_Z05_R, C_Z07_R and C_Z09_R.
C_DOMPY000 <sub>q</sub>	Gross regional product: income side.	The $q^{\text{th}}$ value is the corresponding element in the MMRF database file PA01.
C_DOMPY100 <sub>q</sub>	Regional wages, salaries and supplements.	The $q^{\text{th}}$ value is the corresponding element in the MMRF database file PA02.
C_DOMPY110 <sub>q</sub>	Regional disposable wage income.	The $q^{\text{th}}$ value is the corresponding element in the MMRF database file PA03.
C_DOMPY120 <sub>q</sub>	Regional PAYE taxes.	The $q^{\text{th}}$ value is the corresponding element in the MMRF database file PA04.
C_DOMPY200 <sub>q</sub>	Regional GOS : non-wage primary factor income.	The $q^{\text{th}}$ value is the corresponding element in the MMRF database file PA05.
C_DOMPY210 <sub>q</sub>	Regional disposable non-wage income.	The $q^{\text{th}}$ value is the corresponding element in the MMRF database file PA06.
C_DOMPY220 <sub>q</sub>	Regional tax collected on non-wage income.	The $q^{\text{th}}$ value is the corresponding element in the MMRF database file PA07.
C_DOMPY300 <sub>q</sub>	Regional indirect taxes less subsidies.	The $q^{\text{th}}$ value is the corresponding element in the MMRF database file PA08.
C_DOMPY310 <sub>q</sub>	Regional collection of tariff revenue.	The $q^{\text{th}}$ value is the corresponding element in the MMRF database file PA09.
C_DOMPY320 <sub>q</sub>	Regional tax collected on other indirect taxes and subsidies.	The $q^{\text{th}}$ value is the corresponding element in the MMRF database file PA10.
C_DOMPY330 <sub>q</sub>	Regional collection of production taxes.	The $q^{\text{th}}$ value is the corresponding element in the MMRF database file PA11.
C_DOMPQ000 <sub>q</sub>	Gross regional product: expenditure side.	The $q^{\text{th}}$ value is the corresponding element in the MMRF database file PA12.
C_DOMPQ100 <sub>q</sub>	Regional domestic absorption.	The $q^{\text{th}}$ value is the corresponding element in the MMRF database file PA13.

....Table 2.3. continued

Coefficient	Description	Value
C_DOMPQ110 <sub>q</sub>	Regional private consumption.	The q <sup>th</sup> value is the corresponding element in the MMRF database file PA14.
C_DOMPQ120 <sub>q</sub>	Regional private investment.	The q <sup>th</sup> value is the corresponding element in the MMRF database file PA15.
C_DOMPQ130 <sub>q</sub>	Regional-government consumption.	The q <sup>th</sup> value is the corresponding element in the MMRF database file PA16.
C_DOMPQ140 <sub>q</sub>	Federal-government consumption.	The q <sup>th</sup> value is the corresponding element in the MMRF database file PA17.
C_DOMPQ150 <sub>q</sub>	Government investment.	The q <sup>th</sup> value is the corresponding element in the MMRF database file PA18.
C_DOMPQ200 <sub>q</sub>	Interregional trade balance.	The q <sup>th</sup> value is the corresponding element in the MMRF database file PA19.
C_DOMPQ210 <sub>q</sub>	Interregional exports.	The q <sup>th</sup> value is the corresponding element in the MMRF database file PA20.
C_DOMPQ220 <sub>q</sub>	Interregional imports.	The q <sup>th</sup> value is the corresponding element in the MMRF database file PA21.
C_DOMPQ300 <sub>q</sub>	Regional international trade balance.	The q <sup>th</sup> value is the corresponding element in the MMRF database file PA22.
C_DOMPQ310 <sub>q</sub>	Regional international exports.	The q <sup>th</sup> value is the corresponding element in the MMRF database file PA23.
C_DOMPQ320 <sub>q</sub>	Regional international imports.	The q <sup>th</sup> value is the corresponding element in the MMRF database file PA24.
C_TI	National collection of commodity taxes less subsidies (excluding tariffs).	The sum of the elements of C_DOMPY320.
C_YN	National nominal GDP.	The sum of the elements of C_DOMPY000.
C_YF	National nominal GDP at factor cost.	The sum of the elements of C_DOMPY100 and C_DOMPY200.
NATBT	National nominal trade balance	The sum of the elements of C_DOMPQ300.
C_TY	National income tax collection.	The sum of the elements of C_DOMPY120 and C_DOMPY220.
C_YL	National pre-tax wage income.	The sum of the elements of C_DOMPY100.
C_YLSTAR	National post-tax wage income.	The sum of the elements of C_DOMPY110.
C_IP_R <sub>q</sub>	Regional nominal private investment.	The q <sup>th</sup> value is the corresponding element in the MMRF database file MI02.
C_IP	National nominal private investment.	The sum of the elements of C_IP_R.

....Table 2.3. continued

Coefficient	Description	Value
$C_{IG_R}_q$	Regional nominal government investment (by regional and Federal governments).	The $q^{\text{th}}$ value is the corresponding element in the MMRF database file MI03.
$C_{IG}$	National nominal government investment.	The sum of the elements of $C_{IG_R}$ .
$C_{SOFTY000}_q$	SOFT: income-side total.	The $q^{\text{th}}$ value is the corresponding element in the MMRF database file GA01.
$C_{SOFTY100}_q$	Government revenue.	The $q^{\text{th}}$ value is the corresponding element in the MMRF database file GA02.
$C_{SOFTY110}_q$	Direct taxes.	The $q^{\text{th}}$ value is the corresponding element in the MMRF database file GA03.
$C_{SOFTY111}_q$	Income taxes.	The $q^{\text{th}}$ value is the corresponding element in the MMRF database file GA04.
$C_{SOFTY112}_q$	Other direct taxes.	The $q^{\text{th}}$ value is the corresponding element in the MMRF database file GA05.
$C_{SOFTY120}_q$	Indirect taxes.	The $q^{\text{th}}$ value is the corresponding element in the MMRF database file GA06.
$C_{SOFTY121}_q$	Tariff revenue.	The $q^{\text{th}}$ value is the corresponding element in the MMRF database file GA07.
$C_{SOFTY122}_q$	Other commodity taxes.	The $q^{\text{th}}$ value is the corresponding element in the MMRF database file GA08.
$C_{SOFTY123}_q$	Payroll taxes.	The $q^{\text{th}}$ value is the corresponding element in the MMRF database file GA09.
$C_{SOFTY124}_q$	Property taxes.	The $q^{\text{th}}$ value is the corresponding element in the MMRF database file GA10.
$C_{SOFTY125}_q$	Land taxes.	The $q^{\text{th}}$ value is the corresponding element in the MMRF database file GA11.
$C_{SOFTY126}_q$	Other indirect taxes.	The $q^{\text{th}}$ value is the corresponding element in the MMRF database file GA12.
$C_{SOFTY130}_q$	Interest received.	The $q^{\text{th}}$ value is the corresponding element in the MMRF database file GA13.
$C_{SOFTY140}_q$	Commonwealth grants to the regions.	The $q^{\text{th}}$ value is the corresponding element in the MMRF database file GA14.
$C_{SOFTY141}_q$	Current grants.	The $q^{\text{th}}$ value is the corresponding element in the MMRF database file GA15.
$C_{SOFTY142}_q$	Capital grants.	The $q^{\text{th}}$ value is the corresponding element in the MMRF database file GA16.
$C_{SOFTY150}_q$	Other revenue.	The $q^{\text{th}}$ value is the corresponding element in the MMRF database file GA17.

....Table 2.3. continued

Coefficient	Description	Value
C_SOFTY200 <sub>q</sub>	Depreciation, general government.	The q <sup>th</sup> value is the corresponding element in the MMRF database file GA18.
C_SOFTY300 <sub>q</sub>	Financing transactions.	The q <sup>th</sup> value is the corresponding element in the MMRF database file GA19.
C_SOFTY310 <sub>q</sub>	Net borrowings.	The q <sup>th</sup> value is the corresponding element in the MMRF database file GA20.
C_SOFTY320 <sub>q</sub>	Increase in provisions.	The q <sup>th</sup> value is the corresponding element in the MMRF database file GA21.
C_SOFTY330 <sub>q</sub>	Other financing transactions.	The q <sup>th</sup> value is the corresponding element in the MMRF database file GA22.
C_SOFTQ000 <sub>q</sub>	SOFT: expenditure-side total.	The q <sup>th</sup> value is the corresponding element in the MMRF database file GA23.
C_SOFTQ100 <sub>q</sub>	Expenditure on goods and services.	The q <sup>th</sup> value is the corresponding element in the MMRF database file GA24.
C_SOFTQ110 <sub>q</sub>	Government consumption.	The q <sup>th</sup> value is the corresponding element in the MMRF database file GA25.
C_SOFTQ120 <sub>q</sub>	Government investment.	The q <sup>th</sup> value is the corresponding element in the MMRF database file GA26.
C_SOFTQ200 <sub>q</sub>	Personal benefit payments.	The q <sup>th</sup> value is the corresponding element in the MMRF database file GA27.
C_SOFTQ210 <sub>q</sub>	Unemployment benefits.	The q <sup>th</sup> value is the corresponding element in the MMRF database file GA28.
C_SOFTQ220 <sub>q</sub>	Other personal benefits.	The q <sup>th</sup> value is the corresponding element in the MMRF database file GA29.
C_SOFTQ300 <sub>q</sub>	Subsidies.	The q <sup>th</sup> value is the corresponding element in the MMRF database file GA30.
C_SOFTQ400 <sub>q</sub>	Interest payments.	The q <sup>th</sup> value is the corresponding element in the MMRF database file GA31.
C_SOFTQ500 <sub>q</sub>	Commonwealth grants to regions.	The q <sup>th</sup> value is the corresponding element in the MMRF database file GA32.
C_SOFTQ510 <sub>q</sub>	Current grants.	The q <sup>th</sup> value is the corresponding element in the MMRF database file GA33.
C_SOFTQ520 <sub>q</sub>	Capital grants.	The q <sup>th</sup> value is the corresponding element in the MMRF database file GA34.
C_SOFTQ600 <sub>q</sub>	Other outlays.	The q <sup>th</sup> value is the corresponding element in the MMRF database file GA35.
C_SUBSIDIES	Subsidies.	The sum of the elements of C_SOFTQ300.
C_HHLDY000 <sub>q</sub>	Disposable income.	The q <sup>th</sup> value is the corresponding element in the MMRF database file HA01.

...Table 2.3. continued

Coefficient	Description	Value
C_HHLDY100 <sub>q</sub>	Primary factor income.	The q <sup>th</sup> value is the corresponding element in the MMRF database file HA02.
C_HHLDY110 <sub>q</sub>	Wages, salaries and supplements.	The q <sup>th</sup> value is the corresponding element in the MMRF database file HA03.
C_HHLDY120 <sub>q</sub>	Non-wage primary factor income.	The q <sup>th</sup> value is the corresponding element in the MMRF database file HA04.
C_HHLDY200 <sub>q</sub>	Personal benefit receipts.	The q <sup>th</sup> value is the corresponding element in the MMRF database file HA05.
C_HHLDY210 <sub>q</sub>	Unemployment benefits.	The q <sup>th</sup> value is the corresponding element in the MMRF database file HA06.
C_HHLDY220 <sub>q</sub>	Other personal benefits.	The q <sup>th</sup> value is the corresponding element in the MMRF database file HA07.
C_HHLDY300 <sub>q</sub>	Other income (net).	The q <sup>th</sup> value is the corresponding element in the MMRF database file HA08.
C_HHLDY400 <sub>q</sub>	Direct taxes.	The q <sup>th</sup> value is the corresponding element in the MMRF database file HA09.
C_HHLDY410 <sub>q</sub>	PAYE taxes.	The q <sup>th</sup> value is the corresponding element in the MMRF database file HA10.
C_HHLDY420 <sub>q</sub>	Taxes on non-wage primary factor income.	The q <sup>th</sup> value is the corresponding element in the MMRF database file HA11.
C_HHLDY430 <sub>q</sub>	Other direct taxes.	The q <sup>th</sup> value is the corresponding element in the MMRF database file HA12.
C_LABSUP <sub>q</sub>	Labour supply.	The q <sup>th</sup> value is the corresponding element in the MMRF database file RLBS.
C_EMPLOY <sub>q</sub>	Persons employed.	The q <sup>th</sup> value is the corresponding element in the MMRF database file REMP.
C_HHLD001 <sub>q</sub>	Reciprocal of the unemployment rate.	The q <sup>th</sup> value is given by the formula C_LABSUP/(C_LABSUP-C_EMPLOY).
C_HHLD002 <sub>q</sub>	Reciprocal of the proportion of the unemployed to the employed.	The q <sup>th</sup> value is given by the formula C_EMPLOY/(C_LABSUP-C_EMPLOY).
C_UPB	National payments of unemployment benefits.	The sum of the elements of C_HHLDY210.
C_PBP_R <sub>q</sub>	Personal benefit payments.	The q <sup>th</sup> value is the corresponding element in the MMRF database file MI04.
C_PBP	National payments of personal benefits.	The sum of the elements of C_PBP_R.
VALK_T1 <sub>j,q</sub>	Asset value of the capital stock in period T+1.	The j <sup>q</sup> th value is the corresponding element in the MMRF database file VALK.

....Table 2.3. continued

Coefficient	Description	Value
VALKT <sub>j,q</sub>	Asset value of the capital stock in period T.	The j <sup>th</sup> value is the corresponding element in the MMRF database file VALK.
VALK_0 <sub>j,q</sub>	Asset value of the capital stock in period 0.	The j <sup>th</sup> value is the corresponding element in the MMRF database file VALK.
INVEST_0 <sub>j,q</sub>	Asset value of investment in period 0.	The j <sup>th</sup> value is the corresponding element of the coefficient INVEST.
DEP <sub>j</sub>	Depreciation factor, one minus the rate of depreciation.	The j <sup>th</sup> value is the corresponding element in the MMRF database file DPRC.
K_TERM	A constant in equation E_curcapT1A.	Its value is given by the formula $1+(1/T)$ .
QCOEF <sub>i,α</sub>	Ratio of gross to net rate of return.	The j <sup>th</sup> value is the corresponding element in the MMRF database file P027.
BETA_R <sub>j,q</sub>	Parameter to distribute investment. Can be thought of as risk premia.	The j <sup>th</sup> value is the corresponding element in the MMRF database file BETR.
DEBT_RATIO	National foreign debt to GDP ratio.	Its value is stored in the MMRF database file DGDP.
R_WORLD	World real interest rate factor, one plus the real world rate of interest.	Its value is stored in the MMRF database file RWLD.
P_GLOBAL	Converts \$A into 'real' terms.	It is set equal to NATXIM.
B0	National real trade deficit in year 0.	Its value is given by the formula $(NATAGGIMP-NATAGGEXP+NATXI4-NATXIM)/P\_GLOBAL$ .
M_DEBT & N_DEBT	Constants in the foreign debt accumulation equations.	Functions of time; see section 2.4.2 for their formulas.
C_POP <sub>q</sub>	Regional population.	The q <sup>th</sup> value is the corresponding element in the MMRF database file RPOP.
C_RM <sub>q</sub>	Net interregional migration.	The q <sup>th</sup> value is the corresponding element in the MMRF database file RRGm.
C_FM <sub>q</sub>	Net regional foreign migration.	The q <sup>th</sup> value is the corresponding element in the MMRF database file RFRM.
C_G <sub>q</sub>	Net regional natural population.	The q <sup>th</sup> value is the corresponding element in the MMRF database file RGRO.
C_PRI <sub>q</sub>	Constant in the population accumulation equation.	The q <sup>th</sup> value is given by the formula $100T(C\_RM+C\_FM+C\_RM)$ .
C_PA2	Constant in the population accumulation equation.	Its value is given by the formula $50(T+1)$ .
C_NATLABSUP	National labour supply.	The sum of the elements of C_LABSUP.
C_NATEMPLOY	National employment: persons.	The sum of the elements of C_EMPLOY.

Table 2.4. Dimensions of MMRF

Set	TABLO Name	Description	Elements
COM	COM	Commodities	13: Agriculture, Mining, Manufacturing, Public Utilities, Construction, Domestic Trade, Transport & Communication, Finance, Housing, Public Services, Community Services, Personal Services, Non-competing Imports
RSOU	REGSOURCE	Regional sources	8: NSW, Victoria, Queensland, South Australia, Western Australia, Tasmania, Northern Territory, ACT
IND	IND	Industries	13: Same as for COM
RDES	REGDEST	Regional destinations	8: Same as for RSOU
OCC	OCC	Occupation types	8: ASCO categories
TEXP	TEXP	Traditional exports	2: Agriculture, Mining
NTEXP	NTEXP	Non-traditional exports	11: Manufacturing, Public Utilities, Construction, Domestic Trade, Transport & Communication, Finance, Housing, Public Services, Community Services, Personal Services, Non-competing Imports
ASOU	ALLSOURCE	Origin of goods	9: Same as RSOU plus foreign
MARG	MARCOM	Margin commodities	2: Domestic Trade, Transport & Communication
NONMARG	NONMARCOM	Non-margin commodities	11: Agriculture, Mining, Manufacturing, Public Utilities, Construction, Finance, Housing, Public Services, Community Services, Personal Services, Non-competing Imports
DDES	DOMDEST	Destination of goods	9: Same as for RSOU plus 'Federal'.

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## Spatial aspects of trade liberalization in Colombia: A general equilibrium approach\*

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**Abstract.** This paper offers some preliminary steps in the marriage of some of the theoretical foundations of new economic geography with spatial computable general equilibrium models. Modelling the spatial economy of Colombia using the traditional assumptions of computable general equilibrium (CGE) models makes little sense when one territorial unit, Bogotá, accounts for over one quarter of GDP and where transportation costs are high and accessibility low compared to European or North American standards. Hence, handling market imperfections becomes imperative as does the need to address internal spatial issues from the perspective of Colombia's increasing involvement with external markets. The paper builds on the Centro de Estudios de Economía Regional (CEER) model, a spatial CGE model of the Colombian economy; non-constant returns and non-iceberg transportation costs are introduced and some simulation exercises carried out. The results confirm the asymmetric impacts that trade liberalization has on a spatial economy in which one region, Bogotá, is able to more fully exploit scale economies *vis-à-vis* the rest of Colombia. The analysis also reveals the importance of different hypotheses on factor mobility and the role of price effects to better understand the consequences of trade opening in a developing economy.

**JEL classification:** R13, F17, D58

**Key words:** Trade liberalization, spatial general equilibrium, CGE, Latin America, New Economic Geography

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## 1 Introduction

Colombia was late in its efforts towards the integration of the country in the global network,<sup>1</sup> as was the case of most Latin American countries until the 1990s. Among the measures adopted in the trade reforms, initiated in the late 1980s, the restructuring of the tariff schedule played an important role. Even though some tariffs were reduced drastically, it has been argued that there are still areas where further structural reforms are needed in Latin America, including scaling back remaining high tariffs.<sup>2</sup> However, the modelling of changes of trade policy in Colombia has always neglected the regional dimension. To our knowledge, this is the first attempt to look at the spatial consequences of trade liberalization in Colombia, from a general equilibrium perspective.<sup>3</sup> At the national level, there have been several attempts to evaluate the impact of trade liberalization on the economy. This literature has been stimulated by the free trade agreement (FTA) that Colombia has been negotiating with the United States since 2004. According to Toro et al. (2006), these studies concluded that there will be an increase in the trade deficit after the FTA's application, while the economy growth rates, depending on the model used, range between 1% and 4%, but the fiscal cost would not be very large.<sup>4</sup>

Other authors are less optimistic about the impact of trade liberalization on the economic performance. For instance, Ocampo et al. (2004) estimated the short-run (fixed capital stocks) effects of a uniform 50% decrease in tariff rates showed a positive performance of the economy: real GDP increased by 0.27%.<sup>5</sup>

However, with the exception of Ocampo et al. (2004), who explored the effects of protectionism on the distribution of income between urban and rural households, no attention has been directed to differential regional impacts. Since Colombia exhibits huge differences in the development of its regions, it is important to evaluate the spatial impacts of trade policies. We explore in this paper a cost-competitiveness approach, based on relative changes in the sectoral and regional cost and demand structures, to isolate the likely spatial effects of further tariff reductions in Colombia.

We found considerable differences in the short-run and long-run impacts. While, in the short-run, structural constraints impose a spatial trap that leads to more concentration, in the long-run factor, mobility enables spatial re-location of production in a way that regional disparities tend to diminish. Long-run results using the spatial computable general equilibrium (CGE) approach can reconcile theoretical predictions based on recent economic geography models with empirical applications to real economies. In summary, such results show that the openness of the Colombian economy leads to a reduction of Bogotá's primacy and greater regional specialization, as suggested by Krugman and Elisondo (1996).

The paper is organized as follows: Section 2 provides a description of the regional setting in Colombia, highlighting spatial inequality in the country. Following Section 3 discusses some of the theoretical and empirical literature that attempts to address spatial aspects of trade liberalization. Section 4 presents the model used in the trade policy simulations. Section 5 presents and discusses the short-run and long-run impacts of the tariff reduction experiment. Final remarks conclude the paper, discussing limitations of the model and analysis.

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<sup>1</sup> Starting in 1985, Colombia experienced gradual trade liberalization that culminated in the drastic tariff reductions of 1990–1991. Average tariff declined 27% to about 10% from 1984 to 1998. (Attanasio et al. 2004).

<sup>2</sup> World Economic Outlook, April 2003.

<sup>3</sup> One pioneer work using a multiregional CGE model for Colombia is Iregui (2005). This paper quantifies the welfare effects of decentralization considering five geographic regions.

<sup>4</sup> Some of the papers focus on the analysis of the impacts of the FTA with the United States using CGE models are DNP (2003), Botero (2004), and Martín and Ramírez (2005). Other authors studying the effects of trade liberalization on the Colombian economy with the same methodological approach are Light and Rutherford (2003), Esguerra et al. (2004), and Vaughan (2005).

<sup>5</sup> The CGE model was calibrated for 1997.

## 2 The regional setting

The spatial distribution of economic activity in Colombia can be gauged through the analysis of the evolution of the gross departmental income.<sup>6</sup> According to Bonet and Meisel (2006), the main feature is the dominance of Bogotá. The national capital showed a growing share in the national gross income, from 30% in 1975 to 36% in 2000. Additionally, Bogotá's per capita gross income was, on average, more than double the national mean. Bogotá's supremacy became more evident during the 1990s, when there was a bi-modal distribution with Bogotá located in the upper side and the rest of the country in the lower. What can be observed is that some departments that used to be above the national average such as Antioquia, Atlántico and Valle, moved closer to the mean during the 1990s. As a result, these departments converge to those territorial entities that were below the national average. Finally, another element is the persistence in the disparities during all the 25 years studied; Bogotá is always top of the per capita gross income ranking, while the departments located in the periphery occupying the last positions (Caquetá, Cauca, Cesar, Córdoba, Chocó, Nariño, Norte de Santander, Magdalena and Sucre).

In accordance with their share in gross national income, the territorial entities may be grouped into four categories. In the first stands Bogotá, this generated more than a third of the total gross income. The second group is made up of Antioquia and Valle, which registered shares that oscillate between 10 and 15%, with a descending tendency during the period. The third group is composed of departments which maintained their shares at a level close to 5%: Atlántico, Cundinamarca and Santander. The rest of the departments registered shares at rates of less than 3%, with a number of extreme cases like Caquetá, Chocó, La Guajira and Sucre, which registered rates of less than 1%. With the exception of Bogotá and the new departments (located mainly in the Amazon region), the territorial entities showed decreasing or relatively stable trends. Bogotá of course accounted for the largest share (see Figure 1).

To provide an idea about the strength of the linkages in the Colombian economy, from a spatial perspective, Figure 2 shows the average distribution of the impacts associated with the input-output table embedded in the Centro de Estudios de Economía Regional (CEER) model. The spatial concentration is again perceived as the extended core region of the country. Its ability to internalize multiplier effects from the whole economy represents a further evidence of spatial concentration in Colombia. Given the nature of the (backward) linkages associated with the Colombian economic structure, there appear elements for a 'spatial trap' for the country, as all the regions are somehow dependent on the core.

## 3 Spatial aspects of trade liberalization

The effects of trade reforms have been extensively studied in the international trade literature. However, as noticed by Goldberg and Pavcnik (2004), the literature on the relationship between trade and growth is already vast, and has failed to reach a consensus on the effect of trade on growth. Trade liberalization processes are said to have benefits derived from gains in both the production side (there is an overall increase in the foreign exchange revenue earned in export industries, or saved in import industries, per unit of labour and capital) and the consumption side (the same basket of products can be obtained at lower cost). However, the liberalization process also involves two kinds of short-run costs to the economy: distributional costs (protected sectors tend to lose) and balance of payments pressures due to the rapid increase in imports (Bruno

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<sup>6</sup> Colombia is politically divided into nation, departments, districts, and municipalities. Nation is formed by departments which are formed by municipalities. There are also districts which are municipalities with higher territorial status.



**Fig. 1.** Departmental share of gross national income, 2000

Source: Bonet and Meisel (2006).

1987). However, the short-term growth consequences of a trade reform will depend on the structure of the reforming economy. From a spatial perspective, the short-run effects will also be heavily influenced by the respective regional structures. The first set of simulations in this paper will try to address some of these issues.

The second set of simulations is inspired by the work by Krugman and Elisondo (1996). They have shown that trade policies of developing countries and their tendency to develop huge metropolitan centres are closely linked. They developed a spatial model in the new economic geography (NEG) tradition, whose equilibrating mechanisms draw heavily on the balance of real wage differentials through labour mobility. Their Krugman-type core-periphery model, inspired by the case of Mexico, explained the existence of such giant cities as a consequence of the strong forward and backward linkages that arise when manufacturing tries to serve a small domestic market. The model implies that these linkages are much weaker when the economy is open to international trade; in other words, closed markets promote huge central agglomerations, while open markets discourage them.

As seen in Section 2, Colombia is characterized by strong spatial concentration. Bogotá, the capital city, is responsible for around 25% of total GDP (28% in manufacturing), and covers only 0.14% of total territory. Trade opening should then reduce its relative importance. From the work by Krugman (1994), Krugman and Elisondo (1996), Puga (1998), and Alonso-Villar

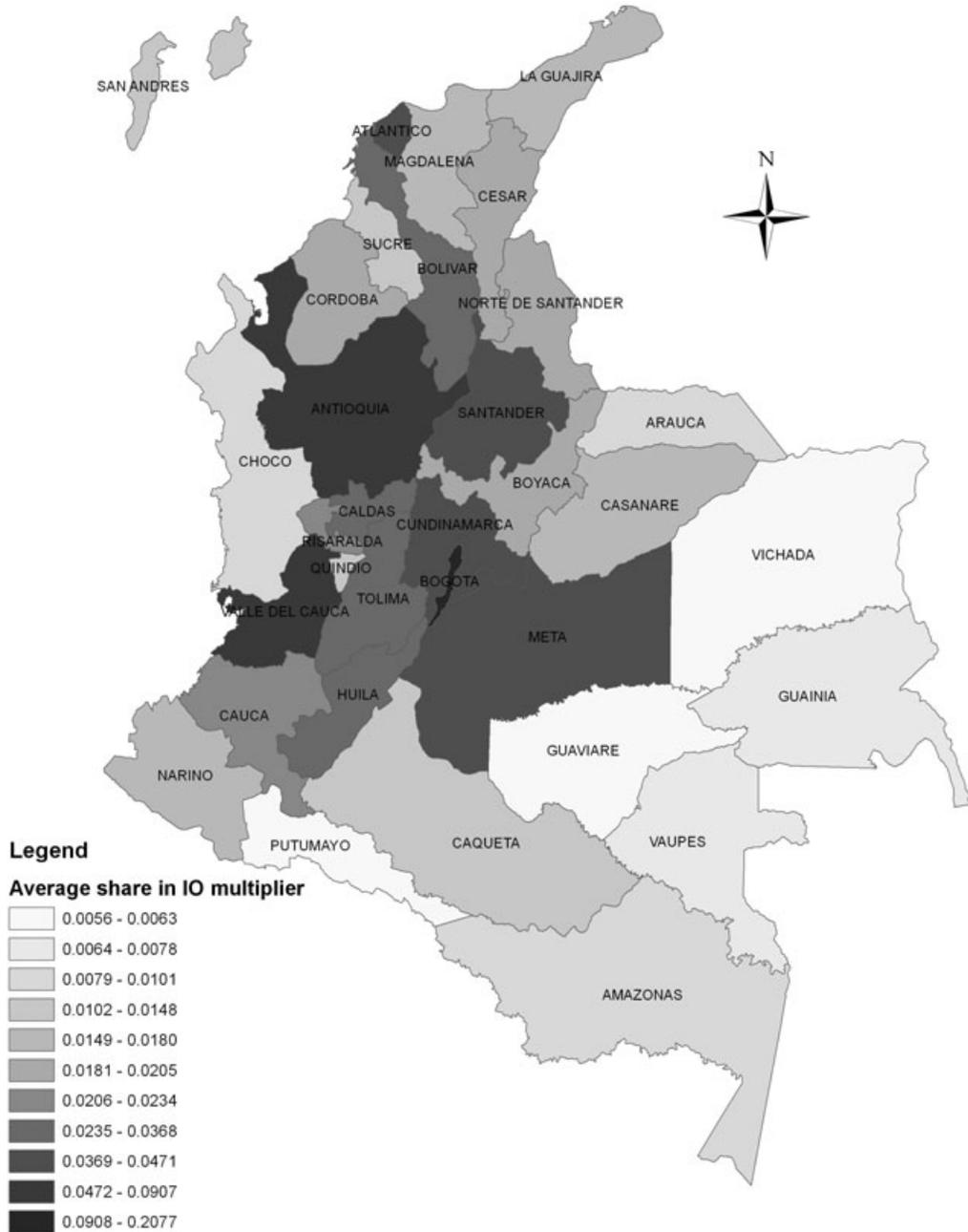


Fig. 2. Linkages in Colombia (average % share in net I-O output multipliers)

(2001), the notion is advanced that trade liberalization policies may reduce regional inequality in developing countries, especially by reducing the size of primate cities or at least reducing their relative growth. Trade liberalization would also lead to more specialized regions. Given the long-run nature of these models, a final result would be strongly related to population movements from the core region, which would ultimately increase welfare through reduction of congestion costs. However, empirical studies are not conclusive about these results.

Ades and Glaeser (1995), using cross country data, corroborated Krugman and Elisondo's predictions, showing that countries with high shares of trade in GDP or low tariff barriers (even holding trade levels constant) rarely have their population concentrated in a single city. The case of Mexico seems to reinforce the theoretical results. Hanson (1998) showed that trade reform appears to have contributed to the breakup of the Mexico City manufacturing belt and the formation of new industrial centres in northern Mexico. However, the reality of Brazil, another major Latin American country, seems to be more complex, as trade liberalization in the 1990s did not produce any relevant de-concentration from the core region (Haddad 1999; Haddad and Azzoni 2001). As Haddad and Hewings (2005) point out, one should consider some intermediate perspectives between a core-periphery model, on the one hand, and a perfectly competitive, homogeneous space model at the other extreme. In the Brazilian case, firms can exploit increasing returns to scale without serving a national market; in large part, market imperfections derive from transportation costs that essentially serve to segment markets. Further, the asymmetries in the distribution of productive activity, with the primacy of São Paulo, serve to strengthen existing competitive advantages. In a context of trade opening, peripheral regions may have then been adversely affected.

One of the first attempts to test the Krugman and Elisondo model in Colombia was made by Fernández (1998). This author concludes that, contrary to the predictions of the theory, the empirical evidence suggests a positive relationship between agglomeration and trade for most sectors, excluding food, beverages and chemicals, which showed a negative association. As Fernández pointed out, further work should make a model more suitable for the Colombian case, and also that the effects of changes in trade liberalization in agglomeration may take longer to be seen. In the second set of simulations, this paper looks at the Colombian case, from a long-run perspective. In addition, the model presents a finer spatial disaggregation, considering all 32 departments plus Bogotá, rather than just two cities, Bogotá and Barranquilla, as in Fernández's approach. A rather more realistic approach to spatial phenomena is considered, as opposed to stylized models that have been used so far.

#### 4 The CEER Model

In this paper, we present the CEER<sup>7</sup> model, the first fully operational spatial CGE model for Colombia.<sup>8</sup> The paper uses a similar approach to Haddad and Hewings (2005) to incorporate recent theoretical developments in the new economic geography. Experimentation with the introduction of scale economies, market imperfections, and transportation costs provide innovative ways of dealing explicitly with theoretical issues related to integrated regional systems. The model used in this research contains over 35,000 equations in its condensed form, and it is designed for policy analysis. Agents' behaviour is modelled at the regional level, accommodating variations in the structure of regional economies. Regarding the regional setting, the main innovation in the CEER model is the detailed treatment of interregional trade flows in the Colombian economy, in which the markets of regional flows are fully specified for each origin and destination. The model recognizes the economies of the 32 Colombian departments and the capital city, Bogotá.

Results are based on a bottom-up approach – namely, national results are obtained from the aggregation of regional results. The model identifies seven production/investment sectors in each region producing seven commodities (Table 1), one representative household in each region, regional governments and one Central government, and a single foreign area that trades

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<sup>7</sup> Centro de Estudios de Economía Regional del Banco de la República, Colombia.

<sup>8</sup> Full model description is available in the appendix.

**Table 1.** Sectors in the CEER model

1	Agriculture
2	Mining
3	Manufacturing
4	Construction
5	Transportation
6	Public administration
7	Other services

with each domestic region. Two local primary factors are used in the production process, according to regional endowments (capital and labour).

The basic structure of the CGE core module comprises three main blocks of equations determining demand and supply relations, and market clearing conditions. In addition, various regional and national aggregates, such as aggregate employment, aggregate price level, and balance of trade, are defined. Nested production functions and household demand functions are employed; for production, firms are assumed to use fixed proportion combinations of intermediate inputs and primary factors in the first level while, in the second level, substitution is possible between domestically produced and imported intermediate inputs, on the one hand, and between capital and labour, on the other. At the third level, bundles of domestically produced inputs are formed as combinations of inputs from different regional sources. The modelling procedure adopted in CEER uses a constant elasticity of substitution (CES) specification in the lower levels to combine goods from different sources.

The treatment of the household demand structure is based on a nested CES/linear expenditure system (LES) preference function. Demand equations are derived from a utility maximization problem, whose solution follows hierarchical steps. The structure of household demand follows a nesting pattern that enables different elasticities of substitution to be used. At the bottom level, substitution occurs across different domestic sources of supply. Utility derived from the consumption of domestic composite goods is maximized. In the subsequent upper-level, substitution occurs between domestic composite and imported goods.

The model is structurally calibrated for 2004; a complete data set is available for that year, which is the year of the last publication of the full national input-output tables that served as the basis for the estimation of the interregional input-output database, facilitating the choice of the base year. Additional structural data from the period 2000–2004 complemented the database.

The CEER framework includes explicitly some important elements from an interregional system, needed to better understand macro spatial phenomena, namely: interregional flows of goods and services, transportation costs based on origin-destination pairs, interregional movement of primary factors, regionalization of the transactions of the public sector, and regional labour markets segmentation.

#### 4.1 Structural database

The CGE core database requires detailed sectoral and regional information about the Colombian economy. National data (such as input-output tables, foreign trade, taxes, margins and tariffs) are available from the Colombian Statistics Bureau (DANE).<sup>9</sup> At the regional level, a full set of accounts was developed by the Colombian institute CEGA. These two sets of data were put

<sup>9</sup> Official statistics do not fully consider illegal activities in Colombia.

**Table 2.** Tariff rate and Armington elasticity, by product

Product	Tariff rate	Armington elasticity
AGR	8.8	1.05
MNE	0.9	1.28
IND	5.7	1.63
CNT	0.0	1.28
TRN	2.7	1.34
ADP	0.0	1.32
OTS	2.7	1.34

together in a balanced interregional social accounting matrix. Previous work in this task has been successfully implemented in CGE models for Brazil and Colombia (Haddad 1999; Jensen et al. 2004).

#### 4.2 Behavioral parameters

Parameter values for international trade elasticities,  $\sigma$  s in Equation (A2) in Appendix, were taken from estimates from Ocampo et al. (2004); regional trade elasticities,  $\sigma$  s in Equation (A1), were set at the same values as the corresponding international trade elasticities (Table 2). Substitution elasticity between primary factors,  $\sigma$  s in Equation (A3), was set to 0.5. Scale economies parameters,  $\mu$  s in Equation (A4), were set to one in all sectors and regions, except for the manufacturing sector in Bogotá, which was set to 0.8. The marginal budget share in regional household consumption,  $\beta$  s in Equation (A5), were calibrated from the Social Accounting Matrix (SAM) data, assuming the average budget share to be equal to the marginal budget share. We have set to  $-2.0$  the export demand elasticities,  $\eta$  s in Equation (A9). Finally, we have assumed constant returns to bulk transportation, setting the parameter of scale economies in bulk transportation to one ( $\theta$  s in Equation A12).

Further details of the model, including equation specification may be found in Haddad and Hewings (2005).

#### 4.3 Closures

In order to capture the effects of trade liberalization, the simulations are carried out under two standard closures, referring to the short-run and the long-run. A distinction between the short-run and long-run closures relates to the treatment of capital stocks encountered in the standard microeconomic approach to policy adjustments. In the short-run closure, capital stocks are held fixed, while, in the long-run, policy changes are allowed to affect capital stocks. In addition to the assumption of interindustry and interregional immobility of capital, the short-run closure would include fixed regional population and labour supply, fixed regional wage differentials, and fixed national real wage. Regional employment is driven by the assumptions on wage rates, which indirectly determine regional unemployment rates. Labour is, thus, mobile only across sectors within the same region. On the demand side, investment expenditures are fixed exogenously – firms cannot reevaluate their investment decisions in the short-run. Household consumption follows household disposable income, and real government consumption, at both regional and central levels, is fixed (alternatively, the government deficit can be set exogenously, allowing government expenditures to change). Finally, preferences and technology variables are exogenous.

A long-run (steady-state) equilibrium closure is also used in which capital is mobile across regions and industries. Capital and investment are generally assumed to grow at the same rate. The main differences from the short-run are encountered in the labour market and the capital formation settings. In the first case, aggregate employment is determined by population growth, labour force participation rates, and the natural rate of unemployment. The distribution of the labour force across regions and sectors is fully determined endogenously. Labour is attracted to more competitive industries in more favoured geographical areas, keeping regional wage differentials constant. While in the same way, capital is oriented towards more attractive industries. This movement keeps rates of return at their initial levels.

## 5 Results

Trade liberalization is an important element of the range of structural changes foreseen by the Colombian government. To explore the effects of such policies, the CEER model is used to simulate the impacts of tariff changes in the Colombian economy. The model is applied to analyze the effects of a uniform 25% decrease in all tariff rates. All exogenous variables are set equal to zero, except the changes in the power of tariffs, i.e., one plus the tariff rates, which were set such that the percentage change decrease in each tariff rate was 25%. Results of the simulation computed via a four-step Euler procedure with extrapolation, under short-run and long-run closures, are presented in Tables 3–4 and 8–9; they show the percentage deviation from the base case (which is the situation without policy changes).<sup>10</sup> The analysis is concentrated on

**Table 3.** Short-run effects on selected macro and sectoral variables

Real GDP	0.177
Real household consumption	0.483
Activity level	0.149
Employment: Persons	0.264
Unemployment rate (percentage point change)	-0.251
Nominal wage paid by producers	-0.336
GDP price index	-0.380
Consumer price index	-0.336
Export volume	0.380
Import volume	1.017
Balance of trade (percentage of GDP)	-0.174

**Table 4.** Short-run effects on sectoral activity (percentage change)

Sector	%
AGR	0.141
MNE	0.048
IND	0.050
CNT	0.019
TRN	0.282
ADP	-
OTS	0.227

<sup>10</sup> The model was implemented using the software GEMPACK ([www.monash.edu.au/policy/gempack.htm](http://www.monash.edu.au/policy/gempack.htm)).

the effects on spatial activity and welfare levels, and on some general macro variables.<sup>11</sup> Because of the nature of the data base, it should be pointed out that the model deals with changes in the real tariff rates (the ratio of import tax collected over the volume of imports), as opposed to nominal tariff rates, which are much higher. Moreover, the model does not consider non-tariff barriers. Thus, the real tariff rate in 2004 (benchmark year) was close to 5.5% as compared to the average nominal rate of over 10%. It is also important to note that the model takes into account differential sectoral tariff rates at the national level, and, given the specific regional import baskets, the overall tariff reduction produces asymmetric shocks in the regions.

### 5.1 Short-run

Table 3 summarizes the simulation short-run results on some macro variables. The real GDP of Colombia is shown to increase by 0.177% with all regions positively affected (Table 4), with real Gross Regional Product (GRP) increases ranging from 0.045% and 0.046% (Vaupés and Chocó, respectively) to 0.275% and 0.292% (Cundinamarca and Bogotá).

The results indicate that (industry) employment levels expand/contract in the same direction as activity levels. However, the expansions of these changes are more intense for employment: the value of the percentage change in employment (0.264%) is higher than the value of percentage change in activity level (0.149%). The explanation for the more intense change in the level of employment lies in the nature of the closure adopted in the simulation. It reflects the combined effects of fixed capital stocks and the general change in the price of hiring labour, which captures movements in the nominal wage paid to workers (-0.336%) relative to movements in the producers' product price (-0.380%). Thus, given the nature of the closure, which allows for producers to respond to exogenous shocks through changes in the employment level only, the employment figure reveals the short-run supply responses from the model, for a tariff decrease (0.264%).

Real household consumption increases by 0.483%, reflecting welfare gains as, with a fixed population, per capita real consumption also increases. In the CEER model, household consumption (in each region) is assumed to be a function of household disposable income. Since the national real wage is assumed fixed (nominal wages are indexed to the national CPI), this effect results directly from the increase in the activity level (employment effect). An examination of the national unemployment rates (which falls by 0.251 points) confirms this result.

Industry activity results show that, in general, nontradable sectors benefit most from the tariff cut, while import-competing sectors are the main relative losers. The manufacturing sector, which presents higher import substitution elasticities, higher import shares in their domestic markets, and higher percentage changes in their tariff rates (second after agriculture) is more likely to be harmed, in relative terms, by the policy change. Service sectors, that do not face strong competition from foreign products, tend to perform better in the short-run due to positive income effects.<sup>12</sup>

To better understand the short-run regional results of the model, a thorough analysis of the structure of the economy is needed. A close inspection on the benchmark data base is necessary,

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<sup>11</sup> The volume of information that the model produces in each simulation is overwhelming. To interpret the results, the study tries to focus the analysis on a few interesting issues associated with the respective simulations, in order to rationalize particular results in terms of the model's theoretical framework and its underlying data base. This process, apart from giving insights into a particular economic phenomenon, serves to act as an informal verification of the simulations' results.

<sup>12</sup> In the short run closure, the assumption on fixed government demand is reflected in the public administration result.

**Table 5.** Short-run effects on selected spatial variables

		GRPP	Activity level	Equivalent variation
D1	Antioquia	0.136	0.112	364,628
D2	Atlántico	0.147	0.135	112,651
D3	Bogotá D. C.	0.292	0.262	1,187,467
D4	Bolívar	0.113	0.093	86,795
D5	Boyacá	0.156	0.113	62,240
D6	Caldas	0.106	0.106	28,371
D7	Caquetá	0.052	0.053	3,184
D8	Cauca	0.064	0.053	19,940
D9	Cesar	0.115	0.110	30,169
D10	Córdoba	0.131	0.100	76,318
D11	Cundinamarca	0.275	0.258	214,639
D12	Chocó	0.046	0.042	3,805
D13	Huila	0.055	0.051	15,576
D14	La Guajira	0.110	0.100	33,038
D15	Magdalena	0.153	0.146	27,142
D16	Meta	0.121	0.115	26,222
D17	Nariño	0.119	0.090	33,091
D18	Norte Santander	0.105	0.097	24,256
D19	Quindío	0.087	0.086	8,416
D20	Risaralda	0.097	0.089	28,357
D21	Santander	0.198	0.132	286,486
D22	Sucre	0.084	0.083	7,527
D23	Tolima	0.101	0.090	33,516
D24	Valle	0.117	0.107	226,986
D25	Amazonas	0.064	0.065	533
D26	Arauca	0.274	0.139	11,584
D27	Casanare	0.060	0.061	28,015
D28	Guanía	0.054	0.053	301
D29	Guaviare	0.116	0.124	1,218
D30	Putumayo	0.092	0.092	2,811
D31	San Andrés y Providencia	0.181	0.174	4,878
D32	Vaupés	0.045	0.047	159
D33	Vichada	0.167	0.174	1,552

conducted not only on the relationships in the interregional input-output data base, but also on the other relevant structural parameters of the model. As shown in Haddad et al. (2002), structural coefficients derived from the SAM lead short-run results in less flexible environments (closures). As one precludes factor mobility to a great extent, understanding of disaggregated results may be achieved through econometric regressions on key structural coefficients.

How important is the existing economic structure in explaining the short-run spatial results associated with a trade liberalization policy in Colombia? Do backward and forward linkages matter? To answer these questions, following Dixon et al. (1982, 2007), the model results (GRP, activity level and equivalent variation) presented in Table 5 are regressed against selected structural coefficients of the model (figures available from the authors on request). The OLS regressions are shown in Tables 6 to 8, and aim only at revealing the influence of the benchmark structure on the short-run results.

According to the results for GRP and regional activity level, Tables 6 and 7, structural indicators explain 74 and 76%, respectively, of the variation across departments in the CEER model results. These results go in the same direction (correlation of 92.08%), as can be visually

**Table 6.** Structural analysis of short-run GRP results

Dependent variable: PIB_SR				
Variable	Coefficient	Std. error	t-statistic	Prob.
Constant	-0.239680	0.102458	-2.339312	0.0270
IMPSHTOT	0.361736	0.105921	3.415145	0.0020
SH_1	0.434683	0.128793	3.375053	0.0022
SH_3	0.459034	0.153107	2.998128	0.0058
SH_4	0.642070	0.124899	5.140696	0.0000
MNE	-0.314800	0.059138	-5.323118	0.0000
R-squared	0.744891			

*Notes:* PIB\_SR = percentage change in GRP; IMPSHTOT = import penetration in total consumption; SH\_1 = intermediate inputs share in total sales; SH\_3 = household share in total sales; SH\_4 = export share in total sales; MNE = share of mining in total output.

**Table 7.** Structural analysis of Short-run activity level results

Dependent variable: ACT_SR				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	-0.157437	0.083251	-1.891106	0.0698
IMPSH_3	-0.666530	0.342087	-1.948421	0.0622
IMPSHTOT	1.310548	0.430980	3.040852	0.0053
SH_1	0.390297	0.106954	3.649206	0.0012
SH_3	0.370619	0.124310	2.981411	0.0062
SH_4	0.407252	0.095772	4.252299	0.0002
KL	-0.064311	0.020033	-3.210213	0.0035
R-squared	0.758846			

*Notes:* ACT\_SR = percentage change in regional activity level; IMPSH\_3 = import penetration in household consumption; IMPSHTOT = import penetration in total consumption; SH\_1 = intermediate inputs share in total sales; SH\_3 = household share in total sales; SH\_4 = export share in total sales; KL = capital to labour ratio.

**Table 8.** Structural analysis of short-run equivalent variation results

Dependent Variable: EV_SR				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	101,092.5	29,728.72	3.400500	0.0020
IMPSH_1	-14,102,528	2,096,919.	-6.725356	0.0000
IMPSH_2	6,023,651	916,107.7	6.575266	0.0000
IMPSH_3	12,497,712	2,030,318.	6.155545	0.0000
NONCON	-311,691.1	125,681.9	-2.479999	0.0194
R-squared	0.828179			

*Notes:* EV\_SR = change in regional equivalent variation; IMPSH\_1 = import penetration in intermediate consumption; IMPSH\_2 = import penetration in capital goods consumption; IMPSH\_3 = import penetration in household consumption; NONCON = share of non-consumer goods in total output.

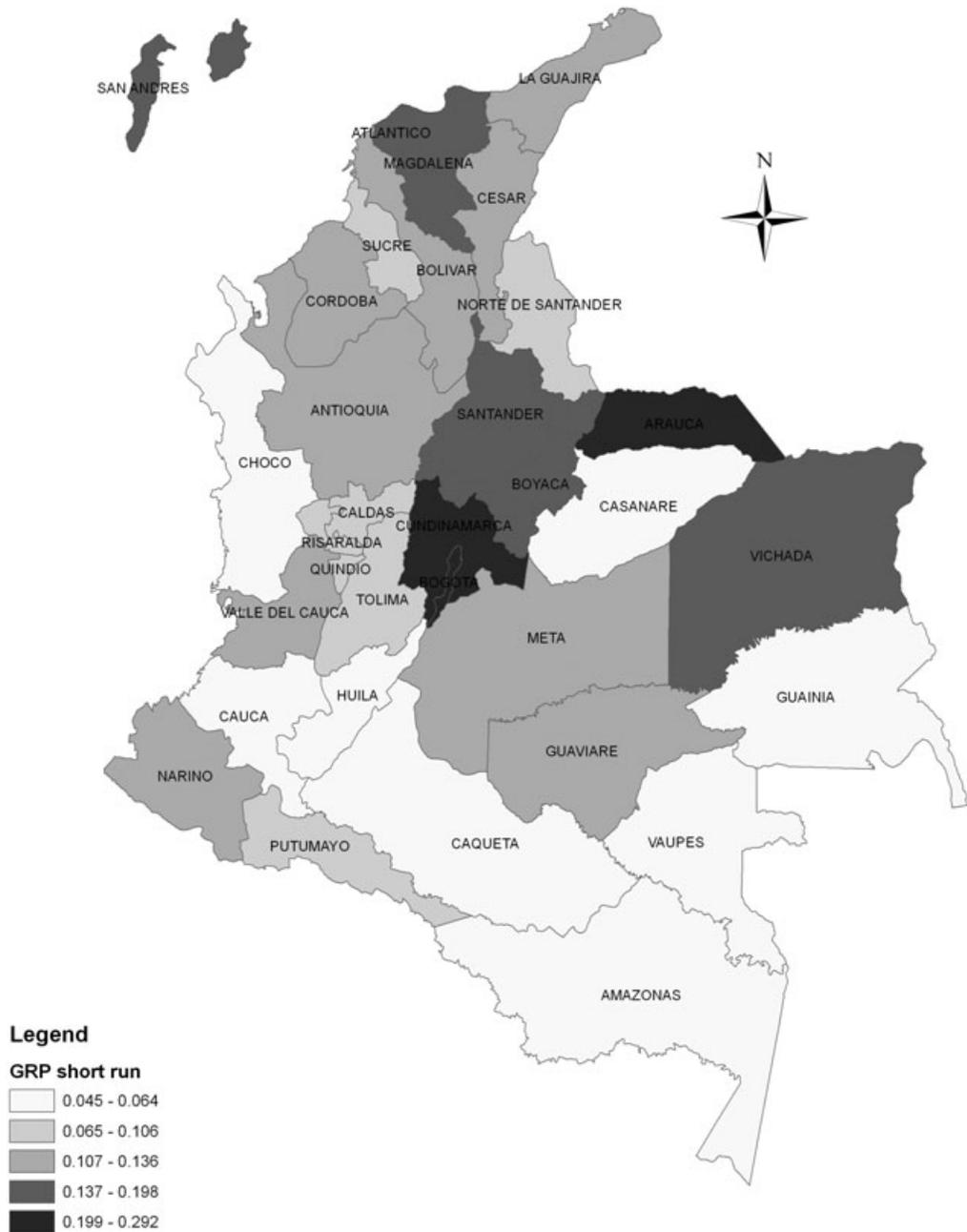


Fig. 3. Short-run effects on GRP

perceived in Figures 3 and 4. Regional GRP/activity results show that, in general, Departments in the dynamic core of the country tend to benefit most from the tariff cut, while peripheral regions are the main losers in the short-run. Explanations for specific regional results should consider structural and parametric aspects of the data base. Regions that present higher increases in their output tend to have an overall higher share of imports, benefiting from lower cost of imported inputs; however the higher the share of imports in final consumption (households), the

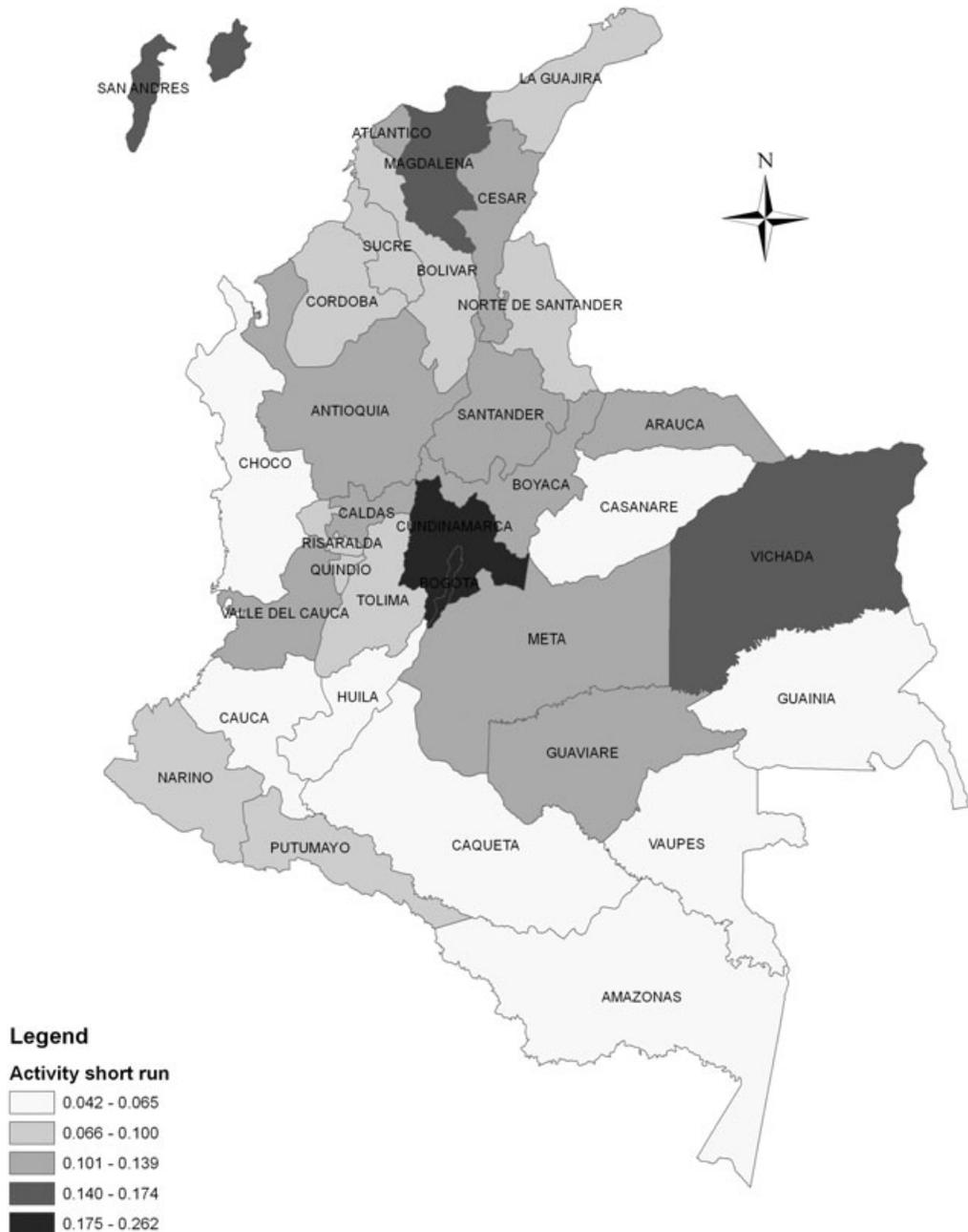


Fig. 4. Short-run effects on activity level

lower the benefit to increase output in the region, as substitution effects at this stage of the chain do not translate into cost advantages (Table 7). Also, regions that face stronger positive effects tend to concentrate their sales to other sectors (intermediate inputs), to households, or to foreign consumers. A higher capital/labour ratio seems to hamper economic performance in the short-run, as employment expansion turns out to be less feasible. Specifically in terms of GRP effects, regions with a high share of the mining sector in their output are more likely to be harmed by

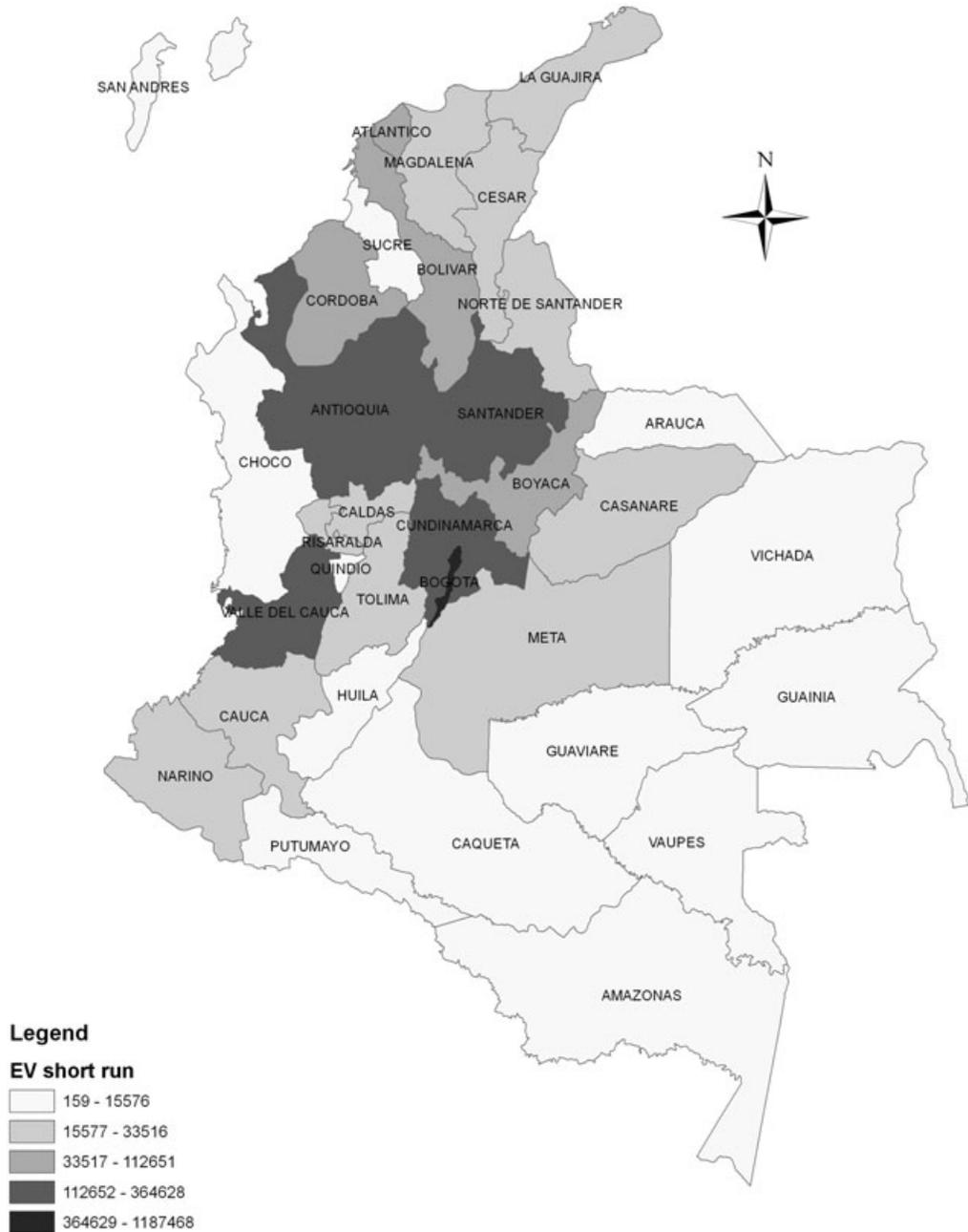
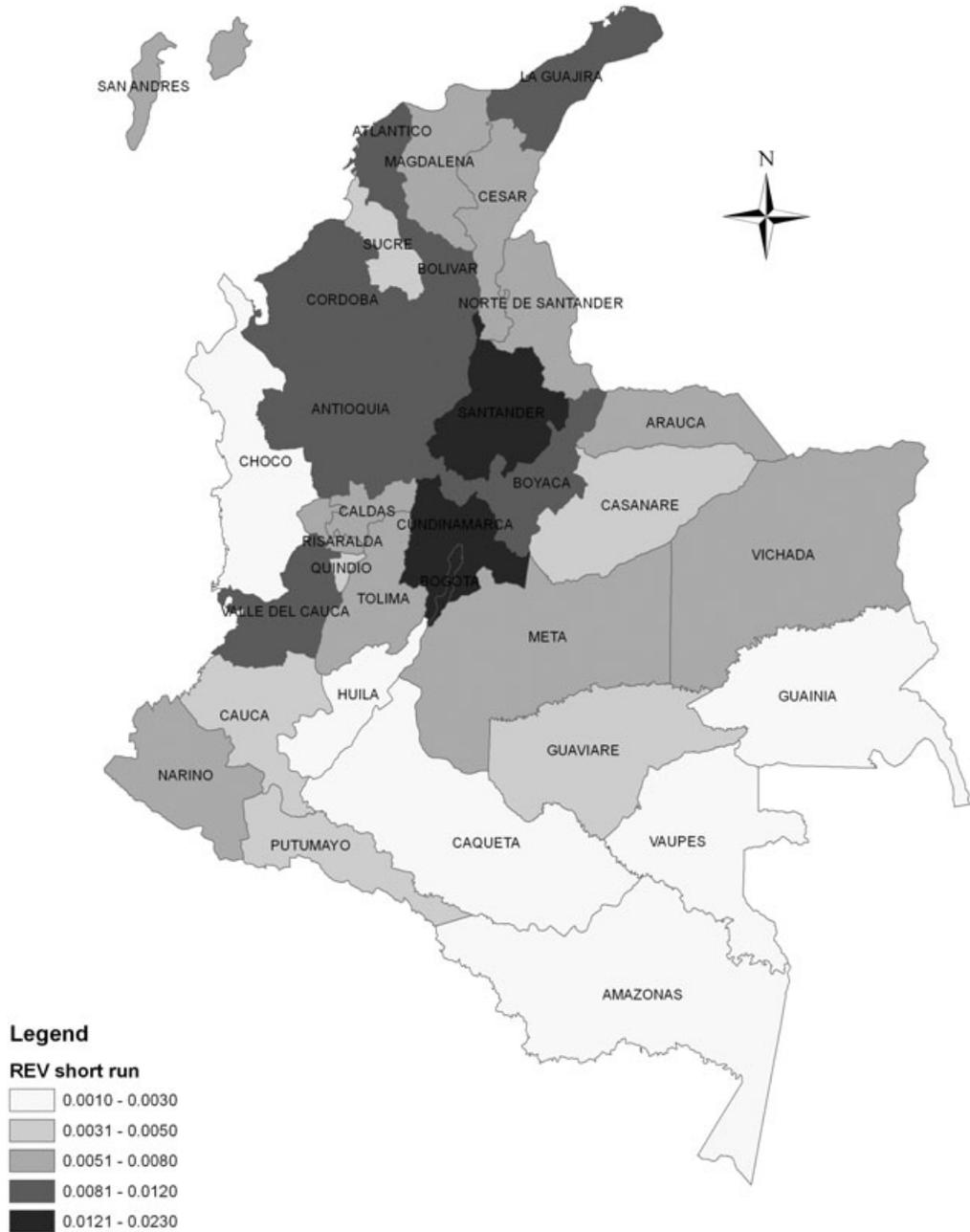


Fig. 5. Short-run effects on equivalent variation

the policy change. In the case of the model results for welfare (Figures 5 and 6), measured in terms of (relative) equivalent variation, the core region also benefits from the shock, both in absolute (EV) and relative terms (REV<sup>13</sup>).

<sup>13</sup> Relative equivalent variation is measured by the ratio of the equivalent variation to pre-shock regional household disposable income.



**Fig. 6.** Short-run effects on relative equivalent variation

The specification of the household demand system in the CEER model allows the computation of measures of welfare. More specifically, one can calculate the equivalent variation (EV) associated with a policy change. The equivalent variation is the amount of money one would need to give to an individual, if an economic change did not happen, to make him as well off as if it did (Layard and Walters 1978). The Hicksian measure of EV would consider computing the hypothetical change in income in prices of the post-shock equilibrium (Bröcker and Schneider

2002). Alternatively, it can be measured as the monetary change of benchmark income the representative household would need in order to get a post-simulation utility under benchmark prices. Another informative welfare measure refers to the relative equivalent variation (REV). It is defined as the percentage change of benchmark income the representative household would need in order to get a post-simulation utility under benchmark prices (Bröcker 1998).

Given the nature of the welfare measures, the relevant structural coefficients to explain regional performance identified in Table 8 seem plausible. In the short-run, regions with higher shares of imports in final consumption (households) would receive greater welfare gains. The intuition here is that lower tariff rates would result in a greater volume of goods being available at lower prices in the regions. Regions presenting high import shares of capital goods also tend to face welfare gains, through indirect effects in the consumption of (durable) consumer goods. On the other hand, regions that depend more on imported inputs and whose economic structures are more concentrated in the output of non-producer goods are negatively affected.

## 5.2 Long-run

The results described above refer to the short-run effects of the tariff reduction, which are important for macroeconomic management. As trade reform aims at improving the allocation of resources in the long term, a simulation was carried out adopting a long-run closure, in the realm of new economic geography models. In this exercise, the assumptions on interregional mobility of capital and labour are relaxed and a steady-state-type of solution is achieved, in which regional natural unemployment rates and regional aggregate rates of return are reestablished. Moreover, balance of payment equilibrium is reflected in the hypothesis of fixed share of trade balance in GDP. From a spatial perspective, in the long-run the 're-location' effect becomes relevant; as factors are free to move between regions, new investment decisions define marginal re-location of activities, in the sense that the spatial distribution of capital stocks and the population changes. In what follows, attention will be focused on results usually discussed in the NEG literature, presented in Section 3.

Table 9 shows the long-run results of the simulation for selected national variables. As the aggregate level of employment is now assumed exogenously determined by demographic variables, the national real wage is allowed to change to keep national employment in the base case level. Supply-side effects are restricted to the distribution of labour across sectors and regions, and to capital movements. At the national level, the increase in GDP by 0.027% above the base case level is possible through the increase in the capital stock of the economy (0.149%)

**Table 9.** Long-run effects on selected macro variables (percentage change)

Real GDP	0.027
Real household consumption	-0.269
Real investment	0.937
Capital stock	0.149
Activity level	0.043
Regional government consumption	-0.168
Central government consumption	-0.269
Consumer price index	0.326
International export volume	0.704
International import volume	0.349
Balance of trade (percentage of GDP)	-
Nominal wage	-0.416
GDP price index	0.319

**Table 10.** Long-run effects on sectoral activity  
(percentage change)

Sector	%
AGR	0.332
MNE	0.374
IND	0.140
CNT	0.849
TRN	-0.117
ADP	-0.244
OTS	-0.135

induced by the initial fall in the aggregate rental price of capital. Imported commodities are important inputs for capital creation and the fall in the prices of imports reduces the cost of producing capital. The hypothesis of fixed trade balance share in GDP together with low export elasticities are accompanied by reductions in the real wage to make exports more competitive. With lower real wages, household disposable income goes down in real terms, inducing a decrease in the real household consumption. As regional government consumption of public goods is assumed to move with regional household consumption, and central government consumption of public goods follows the national household consumption level, domestic absorption is leveraged only by real investments. As a consequence, real GDP growth is smaller than in the short-run.

From a sectoral perspective, long-run results clearly benefit the tradable-good sectors as well as investment-related activities (mainly construction). Estimates presented in Table 10 show that there is a shift in the Colombian economic structure towards agriculture, mining, manufacturing and construction, at the expense of service sectors.

Regional unemployment and wage differentials are assumed constant in the simulation. The CEER model accommodates the labour market assumptions by allowing population movements between regions so that labour supply is increased in regions experiencing employment expansion, and vice-versa. The impact of the trade liberalization policy favours activity levels outside Bogotá, especially in its vicinity, at the expense of the main economic centre, with a consequent transfer of population from the latter (Figure 7).

In the long-run, producers are able to reevaluate their investment decisions, which was not possible in the short-run. The short-run movements in the rental values of capital and cost of capital define differential rates of returns in each sector, providing indicators of more profitable investment opportunities. Current rates of return are defined by the ratio of the rental values of a unit of capital (that depends on the productivity of the current capital stock in each industry) and the cost of a unit of capital, based on its cost structure. The CEER model assumes that if the percentage change in the rate of return in a regional industry grows faster than the national average rate of return, capital stocks in that industry will increase at a higher rate than the average national stock. For industries with lower-than-average increase in their rates of return to fixed capital, capital stocks increase at a lower-than-average rate, namely, capital is attracted to higher return industries.

The role of price changes proves to be very important in understanding the net results, in real terms in the components of GRP, in the different departments (Table 11). Regions that do not face strong price changes benefit more from real growth, as they perceive gains in relative efficiency. From a spatial perspective, there appears to be a de-concentration pattern from Bogotá to its vicinity. It is noteworthy that movements within the extended core region of the Colombian economy tend to go towards the coast. This 'coastal effect' relates also to the cost structure of the regional economies. Given their location closer to external markets, the relative

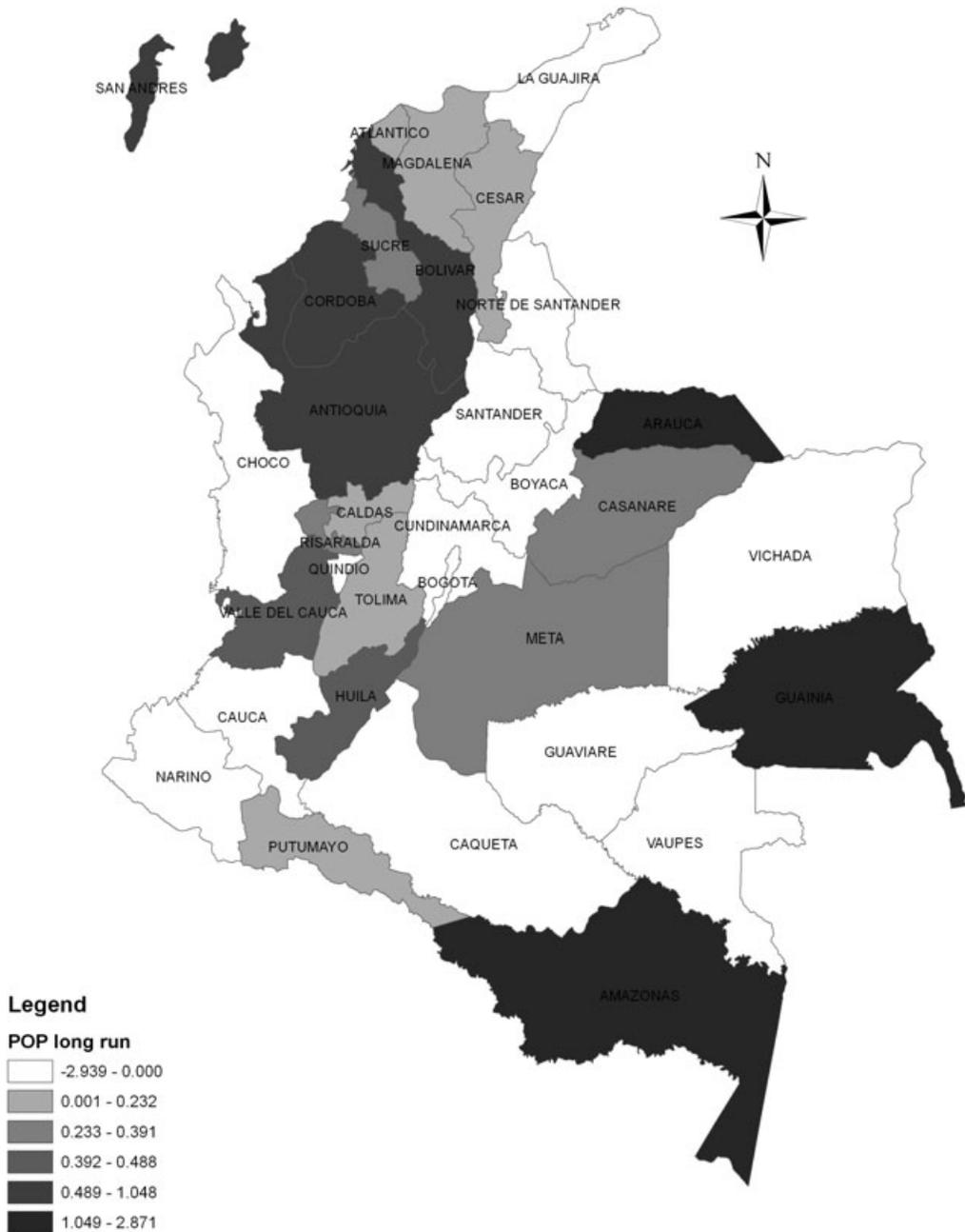


Figure 7. Long-run effects on population growth

importance of tariffs to these regions is greater, as they face lower internal transportation costs to the ports of entry/exit.<sup>14</sup> Thus, market accessibility is one of the elements that implicitly drive the spatial activity results in the long-run (Figures 8 and 9).

<sup>14</sup> Differential spatial cost structures associated with import flows are considered in the calibration of the model, as imported goods are assigned internal transportation costs from the port of entry to the place of consumption (likewise for export goods).

Table 11. Long-run effects on GRP components (% change)

	Household	Investment	Regional Govt	Central Govt	Regional		International		GRP	GRP deflator	CPI
					Exports	Imports	Exports	Imports			
D1	0.652	4.422	0.652	-0.269	-0.184	1.124	1.027	2.012	0.927	0.485	0.280
D2	-0.049	1.178	-0.049	-0.269	0.256	-0.014	1.100	1.260	0.187	0.213	0.258
D3	-0.507	-0.081	-0.507	-0.269	-0.275	-0.298	0.528	0.050	-0.551	0.604	0.458
D4	0.228	4.049	0.228	-0.269	0.539	0.411	1.284	1.711	0.637	-0.137	0.138
D5	-1.489	-4.140	-1.489	-0.269	0.163	-1.402	0.682	-0.316	-0.100	-0.209	0.458
D6	-0.181	-0.285	-0.181	-0.269	0.274	-0.163	1.386	0.590	0.100	-0.064	0.103
D7	-1.057	-6.147	-1.057	-0.269	-0.086	-1.643	0.939	-0.825	-0.768	-0.077	0.261
D8	-0.897	-3.829	-0.897	-0.269	0.355	-1.097	1.142	-0.218	-0.682	0.002	0.205
D9	-0.064	3.006	-0.064	-0.269	-0.152	0.296	0.566	1.523	0.267	0.428	0.297
D10	0.171	2.658	0.171	-0.269	0.557	0.678	1.522	0.584	0.750	-0.204	-0.034
D11	-1.233	-0.314	-1.233	-0.269	-1.205	-0.254	0.036	-0.081	-0.936	1.383	0.929
D12	-2.028	-6.091	-2.028	-0.269	-0.078	-2.912	-1.312	-0.848	-1.965	0.775	0.669
D13	0.051	1.520	0.051	-0.269	0.099	0.298	0.967	0.374	0.444	-0.210	0.035
D14	0.061	3.797	0.061	-0.270	-0.013	0.554	0.314	0.832	0.247	0.601	0.263
D15	-0.240	-1.488	-0.240	-0.269	0.097	-0.572	1.819	0.734	0.019	-0.173	0.156
D16	-0.113	1.293	-0.113	-0.269	-0.012	-0.009	0.846	-0.014	0.321	-0.203	0.053
D17	-0.262	-0.344	-0.262	-0.269	0.227	-0.339	1.064	0.871	0.046	-0.039	0.177
D18	-0.451	-2.122	-0.451	-0.269	0.407	-0.675	0.815	0.430	-0.122	-0.149	0.179
D19	-0.419	-1.840	-0.419	-0.269	0.334	-0.575	1.294	-0.054	-0.150	-0.165	0.114
D20	0.064	1.188	0.064	-0.269	0.304	0.258	1.232	1.402	0.320	0.156	0.170
D21	-1.160	-1.635	-1.160	-0.269	0.393	-0.742	0.847	-0.157	-0.440	-0.181	0.186
D22	-0.032	0.132	-0.032	-0.269	0.613	0.058	1.211	0.125	0.259	-0.138	0.148
D23	-0.498	-0.984	-0.498	-0.269	0.268	-0.501	0.637	0.724	-0.064	-0.148	0.217
D24	0.061	1.852	0.061	-0.269	0.373	0.167	1.305	0.873	0.364	-0.019	0.164
D25	0.787	-5.605	0.787	-0.269	0.119	-0.422	4.969	0.229	1.316	-3.387	-0.612
D26	1.626	9.318	1.626	-0.269	-0.229	2.181	1.628	3.277	1.440	-0.141	0.088
D27	0.030	1.939	0.030	-0.269	-0.048	0.494	0.286	1.645	0.261	0.700	0.509
D28	1.492	7.306	1.492	-0.269	0.206	1.794	5.841	0.090	2.225	-1.988	-0.489
D29	-3.107	-13.803	-3.107	-0.269	-0.564	-3.876	-2.556	-2.035	-2.759	1.270	0.841
D30	-0.417	-0.199	-0.417	-0.269	0.209	-0.405	0.609	-0.346	0.053	-0.118	0.186
D31	0.193	3.186	0.193	-0.269	0.698	0.493	1.677	0.129	0.538	-0.152	0.159
D32	-0.798	-3.835	-0.798	-0.269	0.036	-0.720	0.149	-0.417	-0.640	0.519	0.144
D33	-1.500	-8.927	-1.500	-0.269	-0.322	-1.804	-0.305	-1.401	-1.201	0.183	0.289
National	-0.269	0.937	-0.168	-0.269	0.000	0.000	0.704	0.490	0.270	0.319	0.360

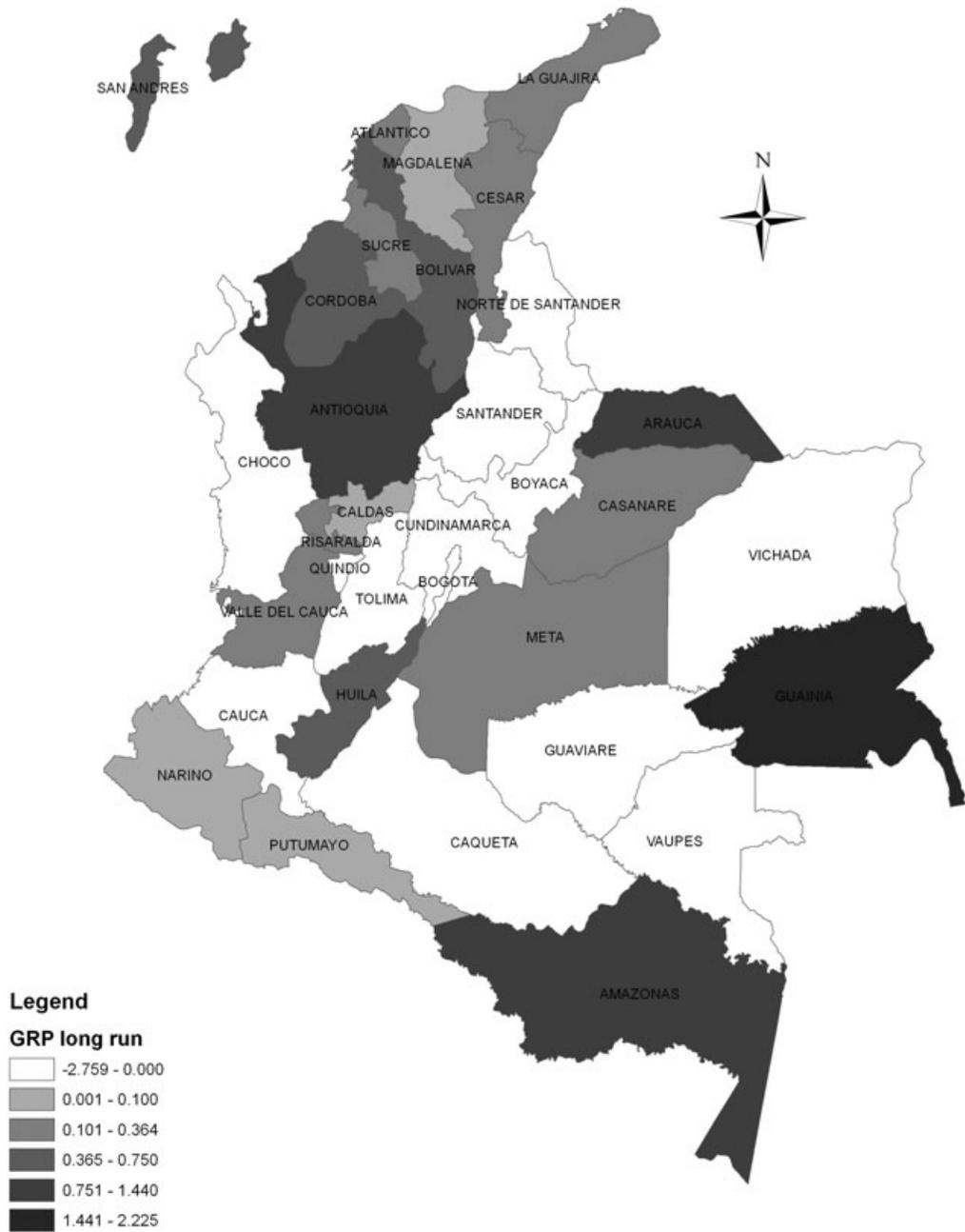
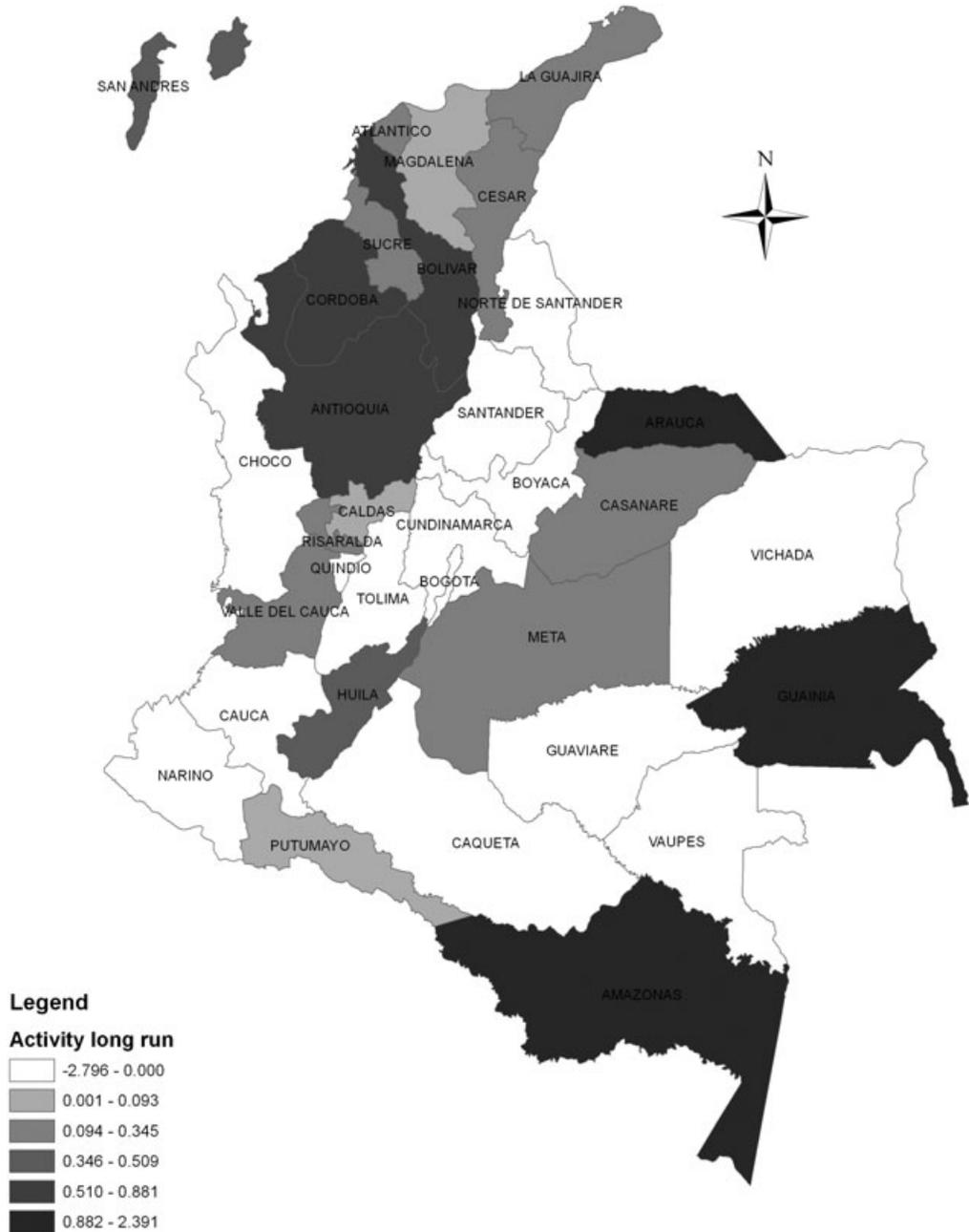


Fig. 8. Long-run effects on GRP

As for welfare (Figures 10 and 11), the measures used in the model reflect also congestion effects in the long-run, as they impose a penalty to population growth.<sup>15</sup> Regions that present better indicators for welfare, in relative terms (REV), are those regions that face reductions in

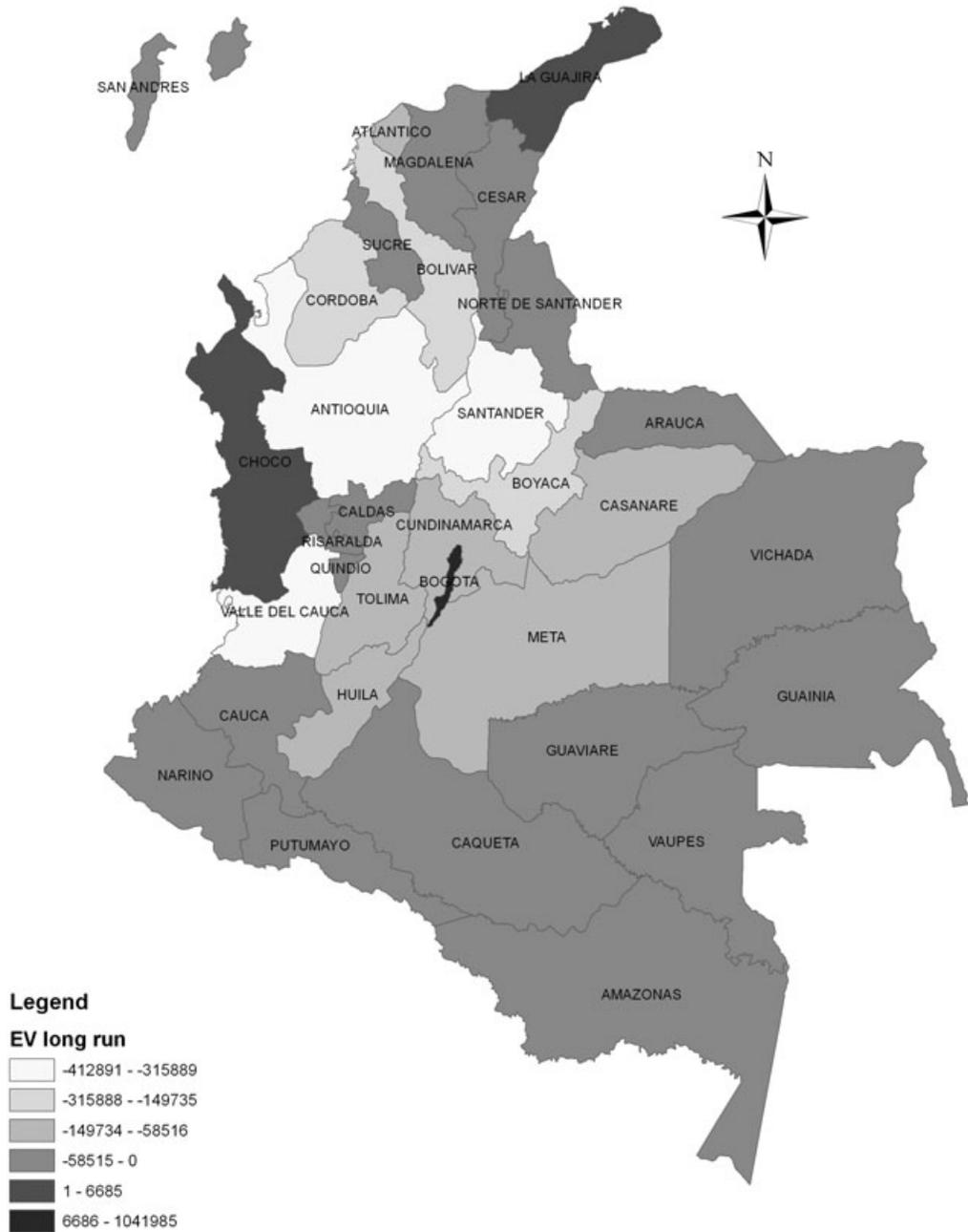
<sup>15</sup> In the equation for equivalent variation the relevant argument is the variable utility per household. As the number of households in each region follows population change, in-migrants will negatively impact on welfare, increasing congestion costs in the region.



**Fig. 9.** Long-run effects on activity level

congestion costs, measured in terms of population change.<sup>16</sup> The spatial pattern that arises reveals welfare improvement only in Bogotá and a few peripheral departments, further away from the Colombian economic core.

<sup>16</sup> Correlation of  $-97.7\%$  between the results for population change and relative equivalent variation, in the long-run.



**Fig. 10.** Long-run effects on equivalent variation

Finally, the impact on regional specialization was analysed. As has been noted, one of the main results of the NEG literature on the effects of trade liberalization is that regions become more specialized. To look at this issue, the regional coefficients of specialization (Isard 1960), was calculated using the benchmark database and the post-simulation updated database. The Departments that presented increases in their coefficients of specialization after the trade liberalization experiment (in Figure 12 those regions in dark tint) were then identified. Together,



**Fig. 11.** Long-run effects on relative equivalent variation

these departments are responsible for close to 75% of total output in Colombia. Given the nature of the coefficient – which compares two percentage distributions measuring the extent to which the distribution of output by sector in a given region deviate from such distribution for Colombia – the fact that the bigger regions become more specialized suggests that Colombian regions, in general, become more specialized. This result supports theoretical findings in the NEG literature.

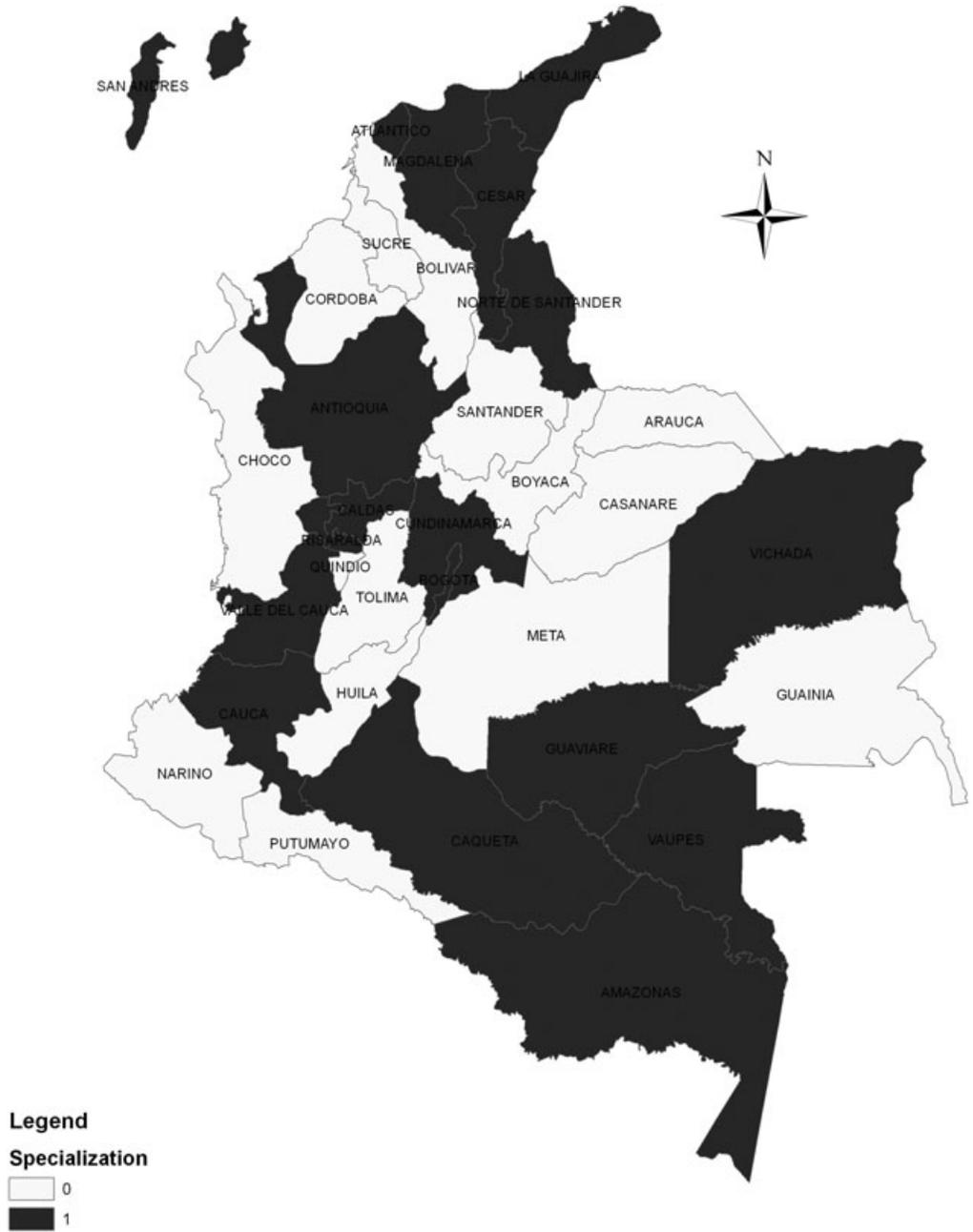


Fig. 12. Long-run effects on regional specialization (1 = more specialized)

### 5.3 Systematic sensitivity analysis

How sensitive are the results to parameter specification? In this sub-section, sensitivity analysis for key parameters is performed, providing a more reliable range of model results. Given the nature of the simulations, key parameters are represented by the export demand elasticities and the regional/international trade elasticities (Armington elasticities). Experience with spatial

CGE modelling has suggested that interregional substitution is the key mechanism that drives the model's spatial results. In general, interregional linkages play an important role in the functioning of interregional CGE models. These linkages are driven by trade relations (commodity flows), and factor mobility (capital and labour migration). In the first case, of direct interest to our exercise, interregional trade flows should be incorporated in the model. Interregional input-output databases are required to calibrate the model, and regional trade elasticities play a crucial role in the adjustment process. Moreover, from a spatial perspective, the role of scale parameters in the manufacturing sectors should also be assessed.

The scenarios related to the tariff cut experiments discussed above were employed using the Gaussian quadrature<sup>17</sup> approach to establish confidence intervals for the main results. The range for the parameters in the first group of sensitivity analyses was set to  $\pm 25\%$  around the default values, with independent, symmetric, triangular distributions for three sets of parameters, namely the export demand elasticities for the various products,  $\eta$  s in Equation (A9) in the Appendix, and Armington elasticities of substitution between goods from different domestic regions,  $\sigma$  s in Equation (A1), and between imported and domestic goods,  $\sigma$  s in Equation (A2).

The second group of sensitivity analyses was carried out in the scale economies parameters in the regional manufacturing sectors,  $\mu$  s in Equation (A4), using a similar range around the default values ( $\pm 25\%$ ).

Table 12 summarizes the sensitivity of GRP results in each Colombian territorial unit, as well as for the country as a whole, for the ranges in the two sets of parameters, both in the short-run and long-run scenarios. The lower bound and the upper bound columns represent the 90% confidence intervals for the estimates, constructed using Chebyshev's inequality. We observe that, in general, aggregate GRP results are relatively more robust to scale economy parameters than to trade elasticities both in the short-run and in the long-run. Overall, the territorial results can be considered to be more robust to both sets of parameters in the short-run closure.<sup>18</sup>

## 6 Final remarks

This paper has offered some preliminary steps in the marriage of some of the theoretical foundations of new economic geography with spatial computable general equilibrium models. Modelling the spatial economy of Colombia using the traditional assumptions of CGE models makes little sense when one territorial unit, Bogotá, accounts for over one quarter of GDP and where transportation costs are high and accessibility low compared to European or North American standards. Hence, handling market imperfections becomes imperative as does the need to address internal spatial issues from the perspective of Colombia's increasing involvement with external markets. The paper built on the CEER model, a spatial CGE model of the Colombian economy with non-constant returns and non-iceberg transportation costs.

The results of tariff cut simulations confirmed the asymmetric impacts that trade liberalization has on a spatial economy in which one region, Bogotá, is able to more fully exploit scale economies *vis-à-vis* the rest of Colombia. The analysis also revealed the importance of different

<sup>17</sup> The Gaussian quadrature (GQ) approach (Arndt 1996; DeVuyst and Preckel 1997), used in this exercise, was proposed to evaluate CGE model results' sensitivity to parameters and exogenous shocks. This approach views key exogenous variables (shocks or parameters) as random variables with associated distributions. Due to the randomness in the exogenous variables, the endogenous results are also random; the GQ approach produces estimates of the mean and standard deviations of the endogenous model results, thus providing an approximation of the true distribution associated with the results.

<sup>18</sup> In the long run there appear (a few) cases with qualitative changes (changes in sign) within the confidence interval, especially for smaller regions.

Table 12. Systematic sensitivity analysis: GRP/GDP changes (%)

	Trade elasticities						Scale economies parameters					
	Short-run			Long-run			Short-run			Long-run		
	Lower bound	Upper bound	Long-run	Lower bound	Upper bound	Long-run	Lower bound	Upper bound	Long-run	Lower bound	Upper bound	Long-run
D1	0.13106	0.14167	0.84223	1.01114	0.13437	0.13836	0.90154	0.13836	0.95183			
D2	0.14105	0.15212	0.17045	0.20303	0.14647	0.14670	0.17966	0.14670	0.19381			
D3	0.27741	0.30735	-0.57592	-0.52666	0.29072	0.29404	-0.57735	0.29404	-0.52523			
D4	0.10766	0.11905	0.56298	0.71104	0.11315	0.11355	0.62688	0.11355	0.64713			
D5	0.14578	0.16566	-0.69320	-0.52807	0.15310	0.15834	-0.67065	0.15834	-0.55061			
D6	0.09895	0.11313	0.07267	0.12802	0.10589	0.10619	0.08606	0.10619	0.11463			
D7	0.03958	0.06512	-0.86085	-0.67442	0.05115	0.05354	-0.78556	0.05354	-0.74971			
D8	0.05733	0.07111	-1.61065	0.24679	0.06420	0.06424	-0.87050	0.06424	-0.49336			
D9	0.11146	0.11908	0.22671	0.30767	0.11359	0.11694	0.24758	0.11694	0.28680			
D10	0.12454	0.13707	0.68171	0.81830	0.12883	0.13279	0.71318	0.13279	0.78683			
D11	0.25878	0.29208	-1.18673	-0.68512	0.25609	0.29476	-1.10418	0.29476	-0.76767			
D12	0.04031	0.05150	-6.00005	2.06926	0.04501	0.04680	-2.61918	0.04680	-1.31161			
D13	0.04998	0.05944	0.17573	0.71194	0.05346	0.05596	0.38752	0.05596	0.50015			
D14	0.10622	0.11351	0.19313	0.30085	0.10878	0.11095	0.22695	0.11095	0.26703			
D15	0.14572	0.16117	-0.00466	0.04203	0.15193	0.15496	0.00193	0.15496	0.03544			
D16	0.11400	0.12711	0.28130	0.36048	0.11892	0.12219	0.31226	0.12219	0.32952			
D17	0.11181	0.12708	-0.05509	0.14726	0.11424	0.12464	0.00651	0.12464	0.08566			
D18	0.09992	0.10949	-0.15220	-0.09168	0.10378	0.10563	-0.13748	0.10563	-0.10640			
D19	0.08089	0.09335	-0.19703	-0.10284	0.08606	0.08818	-0.18234	0.08818	-0.11753			
D20	0.09273	0.10176	-0.13238	0.77173	0.09707	0.09743	0.20565	0.09743	0.43371			
D21	0.18896	0.20755	-0.54192	-0.33773	0.19712	0.19939	-0.51375	0.19939	-0.36591			
D22	0.07751	0.09137	0.20091	0.31687	0.08304	0.08584	0.19209	0.08584	0.32568			
D23	0.09252	0.10932	-0.67090	0.54223	0.09921	0.10264	-0.07549	0.10264	-0.05318			
D24	0.11063	0.12433	0.31131	0.41675	0.11678	0.11818	0.33682	0.11818	0.39124			
D25	0.05964	0.06933	1.00127	1.63128	0.06380	0.06517	1.26571	0.06517	1.36684			
D26	0.21969	0.32812	1.26506	1.61526	0.26288	0.28493	1.39586	0.28493	1.48445			
D27	0.05409	0.06590	0.23381	0.28761	0.05865	0.06134	0.25952	0.06134	0.26189			
D28	0.04981	0.05777	-11.80199	16.25231	0.05312	0.05446	1.83696	0.05446	2.61336			
D29	0.10619	0.12582	-3.12476	-2.39250	0.11438	0.11764	-2.76846	0.11764	-2.74880			
D30	0.08807	0.09549	-0.02026	0.12526	0.09045	0.09311	0.04432	0.09311	0.06068			
D31	0.17729	0.18469	0.46830	0.60757	0.17999	0.18199	0.52974	0.18199	0.54613			
D32	0.03808	0.05204	-0.77122	-0.50942	0.04377	0.04634	-0.71516	0.04634	-0.56548			
D33	0.15074	0.18322	-1.31811	-1.08386	0.16499	0.16897	-1.20236	0.16897	-1.19960			
National	0.17054	0.18302	0.01558	0.03743	0.17411	0.17944	0.01925	0.17944	0.03376			

hypotheses on factor mobility and the role of price effects to better understand the consequences of trade opening in a developing economy. We found considerable differences from short-run and long-run impacts. While in the short-run structural constraints impose a spatial trap that leads to more concentration, in the long-run factor mobility enables spatial re-location of production in a way that regional disparities tend to diminish. In summary, long-run results using the spatial CGE approach has shown to be able to reconcile theoretical predictions based on recent economic geography models with empirical applications to real economies. However, this model (as with all CGE models) does not account for inertia factors that may preclude the spatial reallocations that the price signals indicate. As noted earlier, in Brazil, significant trade liberalization over a decade has not been accompanied by any significant spatial re-allocation of economic activity.

However, the model used and the analysis are not without their limitations. Although it is recognized that accurate parameters values are very important, it is not easy to find empirical estimates of key parameters, such as substitution elasticities in the literature. In the CEER model, calibration of some of the key parameters was based on limited information. Even though systematic sensitivity analysis was performed, other aspects of the model could be further tested, such as the degree of factor mobility, explored only partially in the two closures adopted, different sets of tariff reductions by sectors, and aspects involving alternative calibration. Moreover, CGE models provide results emanating from a given shock, from where one usually compares the changes in the variables of interest, but do not provide any insight on the dynamics to achieve these post-shock levels. One always wonders if transition was monotonic or if it has overshoot before setting in the final level. Perhaps a gradual relaxation of labour and capital mobility could shed some light on this.<sup>19</sup>

In this sense, directions for future research on this topic would include, among others, (i) accounting for the relative proportions of the quality of the labour force for better understanding the differential effects of trade liberalization; (ii) obtaining model-consistent econometric estimates for the key parameters; (iii) carrying out more realistic simulations considering differentiated sectoral specific tariff reductions in the realm of recent developments of Colombian trade policy (e.g. FTA with the USA); and (iv) examining different closure rules.

## Appendix: The CGE core equations

The functional forms of the main groups of equations of the spatial CGE core are presented in this Appendix together with the definition of the main groups of variables, parameters and coefficients.

The notational convention uses uppercase letters to represent the levels of the variables and lowercase for their percentage-change representation. Superscripts ( $u$ ),  $u = 0, 1j, 2j, 3, 4, 5, 6$ , refer, respectively, to output (0) and to the six different regional-specific users of the products identified in the model: producers in sector  $j$  ( $1j$ ), investors in sector  $j$  ( $2j$ ), households (3), purchasers of exports (4), regional governments (5) and the Central government (6); the second superscript identifies the domestic region where the user is located. Inputs are identified by two subscripts: the first takes the values  $1, \dots, g$ , for commodities,  $g + 1$ , for primary factors, and  $g + 2$ , for 'other costs' (basically, taxes and subsidies on production); the second subscript identifies the source of the input, be it from domestic region  $b$  ( $1b$ ) or imported (2), or coming from labour (1), capital (2) or land (3). The symbol ( $\bullet$ ) is employed to indicate a sum over an index.

<sup>19</sup> We are indebted to an anonymous referee for this point.

## Equations

(A1) Substitution between products from different regional domestic sources

$$x_{(i(1b))}^{(u)r} = x_{(i(1\bullet))}^{(u)r} - \sigma_{(i)}^{(u)r} (p_{(i(1b))}^{(u)r} - \sum_{l \in S^*} (V(i, 1l, (u), r) / V(i, 1\bullet, (u), r)) (p_{(i(1l))}^{(u)r}))$$

 $i = 1, \dots, g, b = 1, \dots, q, (u) = 3$  and  $(kj)$  for  $k = 1$  and  $2$  and  $j = 1, \dots, h, r = 1, \dots, R$ 

(A2) Substitution between domestic and imported products

$$x_{(is)}^{(u)r} = x_{(i\bullet)}^{(u)r} - \sigma_{(i)}^{(u)r} (p_{(is)}^{(u)r} - \sum_{l=1\bullet,2} (V(i, l, (u), r) / V(i, \bullet, (u), r)) (p_{(il)}^{(u)r}))$$

 $i = 1, \dots, g, s = 1 \bullet$  and  $2; (u) = 3$  and  $(kj)$  for  $k = 1$  e  $2$  and  $j = 1, \dots, h, r = 1, \dots, R$ 

(A3) Substitution between labour, capital and land

$$x_{(g+1,s)}^{(1j)r} - a_{(g+1,s)}^{(1j)r} = \alpha_{(g+1,s)}^{(1j)r} x_{(g+1\bullet)}^{(1j)r} - \sigma_{(g+1)}^{(1j)r} \left\{ p_{(g+1,s)}^{(1j)r} + a_{(g+1,s)}^{(1j)r} \right. \\ \left. - \sum_{l=1,2,3} (V(g+1, l, (1j), r) / V(g+1, \bullet, (1j), r)) (p_{(g+1,l)}^{(1j)r} + a_{(g+1,l)}^{(1j)r}) \right\}$$

 $j = 1, \dots, h, s = 1, 2$  and  $3, r = 1, \dots, R$ 

(A4) Intermediate and investment demands for composites commodities and primary factors

$$x_{(i\bullet)}^{(u)r} = \mu_{(i\bullet)}^{(u)r} z^{(u)r} + a_{(i)}^{(u)r} \quad \begin{array}{l} u = (kj) \text{ for } k = 1, 2 \text{ and } j = 1, \dots, h \\ \text{if } u = (1j) \text{ then } i = 1, \dots, g+2 \\ \text{if } u = (2j) \text{ then } i = 1, \dots, g; \\ r = 1, \dots, R \end{array}$$

(A5) Household demands for composite commodities

$$V(i, \bullet, (3), r) (p_{(i\bullet)}^{(3)r} + x_{(i\bullet)}^{(3)r}) = \gamma_{(i)}^r P_{(i\bullet)}^{(3)r} Q^r (p_{(i\bullet)}^{(3)r} + x_{(i\bullet)}^{(3)r}) + \beta_{(i)}^r \left( C^r - \sum_{j \in G} \gamma_{(j)}^r P_{(i\bullet)}^{(3)r} Q^r (p_{(i\bullet)}^{(3)r} + x_{(i\bullet)}^{(3)r}) \right)$$

 $i = 1, \dots, g, r = 1, \dots, R$ 

(A6) Composition of output by industries

$$x_{(i1)}^{(0j)r} = z^{(1j)r} + \sigma^{(0j)r} \left( p_{(i1)}^{(0)r} - \sum_{t \in G} (Y(t, j, r) / Y(\bullet, j, r)) p_{(t1)}^{(0)r} \right)$$

 $j = 1, \dots, h, i = 1, \dots, g, r = 1, \dots, R$ 

(A7) Indirect tax rates

$$t(\tau, i, s, (u)r) = f_{(\tau)} + f_{(\tau i)} + f_{(\tau i)}^{(u)} + f_{(\tau i)}^{(u)r}, \quad \begin{array}{l} i = 1, \dots, g; \quad s = 1b, 2 \text{ for } b = 1, \dots, q; \quad \tau = 1, \dots, t \\ (u) = (3), (4), (5), (6) \text{ and } (kj) \text{ for } k = 1, 2; \quad j = 1, \dots, h \\ r = 1, \dots, R \end{array}$$

(A8) Purchasers' prices related to basic prices, margins (transportation costs) and taxes

$$\begin{aligned}
 V(i, s, (u), r) p_{(is)}^{(u)r} &= \left( B(i, s, (u), r) + \sum_{\tau \in T} T(\tau, i, s, (u), r) \right) \left( p_{(is)}^{(0)} + t(\tau, i, s, u, r) \right) \\
 &+ \sum_{m \in G} M(m, i, s, (u), r) p_{(m1)}^{(0)r}, \\
 i &= 1, \dots, g; (u) = (3), (4), (5), (6) \\
 \text{and } (kj) &\text{ for } k = 1, 2 \text{ and } j = 1, \dots, h; s = 1b, 2 \text{ for } b = 1, \dots, q \\
 r &= 1, \dots, R
 \end{aligned}$$

(A9) Foreign demands (exports) for domestic goods

$$(x_{(is)}^{(4)r} - fq_{(is)}^{(4)r}) = \eta_{(is)}^r (p_{(is)}^{(4)r} - e - fp_{(is)}^{(4)r}), \quad i = 1, \dots, g; s = 1b, 2 \text{ for } b = 1, \dots, q; r = 1, \dots, R$$

(A10) Regional government demands

$$x_{(is)}^{(5)r} = x_{(\bullet\bullet)}^{(3)r} + f_{(is)}^{(5)r} + f^{(5)r} + f^{(5)} \quad i = 1, \dots, g; s = 1b, 2 \text{ for } b = 1, \dots, q; r = 1, \dots, R$$

(A11) Regional government demands

$$x_{(is)}^{(6)r} = x_{(\bullet\bullet)}^{(3)r} + f_{(is)}^{(6)r} + f^{(6)r} + f^{(6)} \quad i = 1, \dots, g; s = 1b, 2 \text{ for } b = 1, \dots, q; r = 1, \dots, R$$

(A12) Margins demands for domestic goods

$$\begin{aligned}
 x_{(m1)}^{(is)(u)r} &= \theta_{(is)}^{(u)r} x_{(is)}^{(u)r} + a_{(m1)}^{(is)(u)r} \\
 m, i &= 1, \dots, g; \\
 (u) &= (3), (4b) \text{ for } b = 1, \dots, r, (5) \text{ and } (kj) \text{ for } k = 1, 2; \\
 j &= 1, \dots, h; s = 1b, 2 \text{ for } b = 1, \dots, r; \\
 r &= 1, \dots, R
 \end{aligned}$$

(A13) Demand equals supply for regional domestic commodities

$$\begin{aligned}
 \sum_{j \in H} Y(l, j, r) x_{(l1)}^{(0j)r} &= \sum_{u \in U} B(l, 1, (u), r) x_{(l1)}^{(u)r} \\
 &+ \sum_{i \in G} \sum_{s \in S} \sum_{u \in U} M(l, i, s, (u), r) x_{(l1)}^{(is)(u)r} \quad l = 1, \dots, g; r = 1, \dots, R
 \end{aligned}$$

(A14) Regional industry revenue equals industry costs

$$\sum_{l \in G} Y(l, j, r) (p_{(l1)}^{(0)r} + a_{(l1)}^{(0)r}) = \sum_{l \in G^*} \sum_{s \in S} V(l, s, (1j), r) (p_{(ls)}^{(1j)r}), \quad j = 1, \dots, h; r = 1, \dots, R$$

(A15) Basic price of imported commodities

$$p_{(i(2))}^{(0)} = p_{(i(2))}^{(w)} - e + t_{(i(2))}^{(0)}, \quad i = 1, \dots, g$$

(A16) Cost of constructing units of capital for regional industries

$$V(\bullet, \bullet, (2j), r) (p_{(k)}^{(1j)r} - a_{(k)}^{(1j)r}) = \sum_{i \in G} \sum_{s \in S} V(i, s, (2j), r) (p_{(is)}^{(2j)r} + a_{(is)}^{(2j)r}), \quad j = 1, \dots, h; r = 1, \dots, R$$

(A17) Investment behaviour

$$z^{(2j)r} = x_{(g+1,2)}^{(1j)r} + 100f_{(k)}^{(2j)r}, \quad j = 1, \dots, h; r = 1, \dots, R$$

(A18) Capital stock in period T + 1 – comparative statics

$$x_{(g+1,2)}^{(1j)r}(1) = x_{(g+1,2)}^{(1j)r} \quad j = 1, \dots, h; r = 1, \dots, R$$

(A19) Definition of rates of return to capital

$$r_{(j)}^r = Q_{(j)}^r (P_{(g+1,2)}^{(1j)r} - p_{(k)}^{(1j)r}), \quad j = 1, \dots, h; r = 1, \dots, R$$

(A20) Relation between capital growth and rates of return

$$r_{(j)}^r - \omega = \epsilon_{(j)}^r (x_{(g+1,2)}^{(1j)r} - x_{(g+1,2)}^{(*)r}) + f_{(k)}^r, \quad j = 1, \dots, h; r = 1, \dots, R$$

Other definitions in the CGE core include: revenue from indirect taxes, import volume of commodities, components of regional/national GDP, regional/national price indices, wage settings, definitions of factor prices, and employment aggregates.

### Variables

Variable	Index ranges	Description
$x_{(is)}^{(u)r}$	( $u$ ) = (3), (4), (5), (6) and ( $kj$ ) for $k = 1, 2$ and $j = 1, \dots, h$ ; if ( $u$ ) = (1 $j$ ) then $i = 1, \dots, g + 2$ ; if ( $u$ ) $\neq$ (1 $j$ ) then $i = 1, \dots, g$ ; $s = 1b, 2$ for $b = 1, \dots, q$ ; and $i = 1, \dots, g$ and $s = 1, 2, 3$ for $i = g + 1$ $r = 1, \dots, R$	Demand by user ( $u$ ) in region $r$ for good or primary factor ( $is$ )
$p_{(is)}^{(u)r}$	( $u$ ) = (3), (4), (5), (6) and ( $kj$ ) for $k = 1, 2$ and $j = 1, \dots, h$ ; if ( $u$ ) = (1 $j$ ) then $i = 1, \dots, g + 2$ ; if ( $u$ ) $\neq$ (1 $j$ ) then $i = 1, \dots, g$ ; $s = 1b, 2$ for $b = 1, \dots, q$ ; and $i = 1, \dots, g$ and $s = 1, 2, 3$ for $i = g + 1$ $r = 1, \dots, R$	Price paid by user ( $u$ ) in region $r$ for good or primary factor ( $is$ )
$x_{(is)}^{(u)r}$	( $u$ ) = (3) and ( $kj$ ) for $k = 1, 2$ and $j = 1, \dots, h$ ; if ( $u$ ) = (1 $j$ ) then $i = 1, \dots, g + 1$ ; if ( $u$ ) $\neq$ (1 $j$ ) then $i = 1, \dots, g$ $r = 1, \dots, R$	Demand for composite good or primary factor $i$ by user ( $u$ ) in region $r$
$a_{(g+1,s)}^{(1j)r}$	$j = 1, \dots, h$ and $s = 1, 2, 3$ $r = 1, \dots, R$	Primary factor saving technological change in region $r$
$a_{(i)}^{(u)r}$	$i = 1, \dots, g$ , ( $u$ ) = (3) and ( $kj$ ) for $k = 1, 2$ and $j = 1, \dots, h$ $r = 1, \dots, R$	Technical change related to the use of good $i$ by user ( $u$ ) in region $r$
$C^r$		Total expenditure by regional household in region $r$
$Q^r$		Number of households
$z^{(u)r}$	( $u$ ) = ( $kj$ ) for $k = 1, 2$ and $j = 1, \dots, h$ $r = 1, \dots, R$	Activity levels: current production and investment by industry in region $r$
$fq_{(is)}^{(4)r}$	$i = 1, \dots, g$ ; $s = 1b, 2$ for $b = 1, \dots, q$ $r = 1, \dots, R$	Shift (quantity) in foreign demand curves for regional exports
$fp_{(is)}^{(4)r}$	$i = 1, \dots, g$ ; $s = 1b, 2$ for $b = 1, \dots, q$ $r = 1, \dots, R$	Shift (price) in foreign demand curves for regional exports

## Variables Continued

Variable	Index ranges	Description
$e$		Exchange rate
$x_{(m1)}^{(is)(u)r}$	$m, i = 1, \dots, g; s = 1b, 2 \text{ for } b = 1, \dots, q$ $(u) = (3), (4), (5), (6) \text{ and } (kj) \text{ for } k = 1, 2$ $\text{and } j = 1, \dots, h$ $r = 1, \dots, R$	Demand for commodity $(m1)$ to be used as a margin to facilitate the flow of $(is)$ to $(u)$ in region $r$
$\alpha_{(m1)}^{(is)(u)r}$	$m, i = 1, \dots, g; s = 1b, 2 \text{ for } b = 1, \dots, q$ $(u) = (3), (4), (5), (6) \text{ and } (kj) \text{ for } k = 1, 2$ $\text{and } j = 1, \dots, h$ $r = 1, \dots, R$	Technical change related to the demand for commodity $(m1)$ to be used as a margin to facilitate the flow of $(is)$ to $(u)$ in region $r$
$x_{(i1)}^{(0j)r}$	$i = 1, \dots, g; j = 1, \dots, h$ $r = 1, \dots, R$	Output of domestic good $i$ by industry $j$
$P_{(is)}^{(0)r}$	$i = 1, \dots, g; s = 1b, 2 \text{ for } b = 1, \dots, q$ $r = 1, \dots, R$	Basic price of good $i$ in region $r$ from source $s$
$P_{(i(2))}^{(u)}$	$i = 1, \dots, g$	USD c.i.f. price of imported commodity $i$
$t_{(i(2))}^{(0)}$	$i = 1, \dots, g$	Power of the tariff on imports of $i$
$t(\tau, i, s, (u)r)$	$i = 1, \dots, g;$ $\tau = 1, \dots, t;$ $s = 1b, 2 \text{ for } b = 1, \dots, q$ $(u) = (3), (4), (5), (6) \text{ and } (kj) \text{ for } k = 1, 2$ $\text{and } j = 1, \dots, h$ $r = 1, \dots, R$	Power of the tax $\tau$ on sales of commodity $(is)$ to user $(u)$ in region $r$
$f_{(k)}^{(2j)r}$	$j = 1, \dots, h$ $r = 1, \dots, R$	Regional-industry-specific capital shift terms
$f_{(k)}^r$	$r = 1, \dots, R$	Capital shift term in region $r$
$X_{(s+1,2)}^{(1j)r}(1)$	$j = 1, \dots, h$ $r = 1, \dots, R$	Capital stock in industry $j$ in region $r$ at the end of the year, i.e., capital stock available for use in the next year
$P_{(k)}^{(1j)r}$	$j = 1, \dots, h$ $r = 1, \dots, R$	Cost of constructing a unit of capital for industry $j$ in region $r$
$f_{(\tau)}$	$\tau = 1, \dots, t$	Shift term allowing uniform percentage changes in the power of tax $\tau$
$f_{(\tau)}$	$\tau = 1, \dots, t;$ $i = 1, \dots, g$	Shift term allowing uniform percentage changes in the power of tax $\tau$ on commodity $i$
$f_{(\tau)}^{(u)}$	$\tau = 1, \dots, t;$ $(u) = (3), (4), (5), (6) \text{ and } (kj) \text{ for } k = 1, 2$ $\text{and } j = 1, \dots, h$	Shift term allowing uniform percentage changes in the power of tax $\tau$ of commodity $i$ on user $(u)$
$f_{(\tau)}^{(u)r}$	$\tau = 1, \dots, t;$ $(u) = (3), (4), (5), (6) \text{ and } (kj) \text{ for } k = 1, 2$ $\text{and } j = 1, \dots, h$ $r = 1, \dots, R$	Shift term allowing uniform percentage changes in the power of tax $\tau$ of commodity $i$ on user $(u)$ in region $r$
$f_{(is)}^{(5)r}$	$i = 1, \dots, g; s = 1b, 2 \text{ for } b = 1, \dots, q$ $r = 1, \dots, R$	Commodity and source-specific shift term for regional government expenditures in region $r$
$f^{(5)r}$	$r = 1, \dots, R$	Shift term for regional government expenditures in region $r$
$f^{(5)}$		Shift term for regional government expenditures
$f_{(is)}^{(6)r}$	$i = 1, \dots, g; s = 1b, 2 \text{ for } b = 1, \dots, q$ $r = 1, \dots, R$	Commodity and source-specific shift term for Central government expenditures in region $r$
$f^{(6)r}$	$r = 1, \dots, R$	Shift term for Central government expenditures in region $r$
$f^{(6)}$		Shift term for Central government expenditures
$\omega$		Overall rate of return on capital (short-run)
$r_{(j)}^r$	$j = 1, \dots, h$ $r = 1, \dots, R$	Regional-industry-specific rate of return

## Parameters, Coefficients and Sets

Symbol	Description
$\sigma_{(i)}^{(u)r}$	Parameter: elasticity of substitution between alternative sources of commodity or factor $i$ for user $(u)$ in region $r$
$\sigma^{(0)jr}$	Parameter: elasticity of transformation between outputs of different commodities in industry $j$ in region $r$
$\alpha_{(g+1,s)}^{(1)jr}$	Parameter: returns to scale to individual primary factors in industry $j$ in region $r$
$\beta_{(i)}^r$	Parameter: marginal budget shares in linear expenditure system for commodity $i$ in region $r$
$\gamma_{(i)}^r$	Parameter: subsistence parameter in linear expenditure system for commodity $i$ in region $r$
$\epsilon_{(j)}^r$	Parameter: sensitivity of capital growth to rates of return of industry $j$ in region $r$
$\eta_{(is)}^r$	Parameter: foreign elasticity of demand for commodity $i$ from region $r$
$\theta_{(is)}^{(u)r}$	Parameter: scale economies to transportation of commodity $(i)$ produced in region $r$ shipped to user $(u)$ in region $r$
$\mu_{(i^*)}^{(u)r}$	Parameter: returns to scale to primary factors ( $i = g + 1$ and $u = 1j$ ); otherwise, $\mu_{(i^*)}^{(u)r} = 1$
$B(i, s, (u), r)$	Input-output flow: basic value of $(is)$ used by $(u)$ in region $r$
$M(m, i, s, (u), r)$	Input-output flow: basic value of domestic good $m$ used as a margin to facilitate the flow of $(is)$ to $(u)$ in region $r$
$T(\tau, i, s, (u), r)$	Input-output flow: collection of tax $\tau$ on the sale of $(is)$ to $(u)$ in region $r$
$V(i, s, (u), r)$	Input-output flow: purchasers' value of good or factor $i$ from source $s$ used by user $(u)$ in region $r$
$Y(i, j, r)$	Input-output flow: basic value of output of domestic good $i$ by industry $j$ from region $r$
$Q_{(j)}^r$	Coefficient: ratio, gross to net rate of return
G	Set: $\{1, 2, \dots, g\}$ , $g$ is the number of composite goods
G*	Set: $\{1, 2, \dots, g + 1\}$ , $g + 1$ is the number of composite goods and primary factors
H	Set: $\{1, 2, \dots, h\}$ , $h$ is the number of industries
U	Set: $\{(3), (4), (5), (6), (kj)$ for $k = 1, 2$ and $j = 1, \dots, h\}$
U*	Set: $\{(3), (kj)$ for $k = 1, 2$ and $j = 1, \dots, h\}$
S	Set: $\{1, 2, \dots, r + 1\}$ , $r + 1$ is the number of regions (including foreign)
S*	Set: $\{1, 2, \dots, r\}$ , $r$ is the number of domestic regions
T	Set: $\{1, \dots, t\}$ , $t$ is the number of indirect taxes

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## Market imperfections in a spatial economy: some experimental results

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### Abstract

This paper offers some preliminary steps in the marriage of some of the theoretical foundations of the new economic geography with spatial computable general equilibrium models. Modeling the spatial economy of Brazil using the usual assumptions of CGE models makes little sense when one state, São Paulo, accounts for 40% of GDP and where transportation costs are high and accessibility low compared to European or North American standards. Hence, handling market imperfections becomes imperative as does the need to address internal spatial issues from the perspective of Brazil's increasing involvement with external markets such as MERCOSUL, EU, NAFTA. The paper builds on the B-MARIA-27, a multiregional CGE model of the Brazilian economy; non-constant returns and non-iceberg transportation costs are introduced and some simulation exercises carried out. The results, limited in this paper to short-run considerations, confirm the asymmetric impacts that transportation investment has on a spatial economy in which one state (São Paulo) is able to more fully exploit scale economies vis a vis the rest of Brazil. The analysis also reveals the importance of parameter estimation in handling imperfectly competitive markets.

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*Keywords:* Economic geography; CGE model; Efficiency gains

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## **1. Introduction**

This paper reports on some experimental results derived from a multiregional computable general equilibrium model for the Brazilian economy. While it address some of the theoretical developments derived from the New Economic Geography, it provides some intermediate perspectives between a core-periphery model on the one hand and a perfectly competitive, homogeneous space model at the other extreme. In the Brazilian case, firms can exploit increasing returns to scale without serving a national market; in large part, market imperfections derive from transportation costs that essentially serve to segment markets. Further, the asymmetries in the distribution of productive activity, with the primacy of São Paulo, serve to strengthen existing competitive advantages.

This paper adds two new features to standard spatial CGE models; first, the system is integrated with a transportation network over which interregional commodities move. Secondly, firms in some regions are assumed to exploit increasing returns to scale. The impact of improvement in transportation costs thus has the impact of increasing the variety of goods and services shipped between regions, thus changing the spatial market structure and allowing some firms to enjoy even greater scale economies. The impacts on short-run welfare by region are examined.

The Brazilian case has been further complicated by a transportation infrastructure that until recently was regulated and biased towards investment in highways to the exclusion of water and railroad modes. Efficiency gains from investments appear not to have been considered from a broader perspective – such as enhancing interregional cohesion – but appear to have been oriented towards supporting increased exports. How are these investments to be estimated and can some method be found to simulate the effects of deregulation, through a process of increased competition that reduces spatial transfer costs?

The remainder of the paper is organized in four sections. First, after this introduction, an overview of the CGE model to be used in the simulations (B-MARIA-27) is presented, focusing on its general features. In section three, modeling issues associated with the treatment of non-constant returns and transportation costs are presented. As already mentioned, recent theoretical developments in the New Economic Geography bring new challenges to regional scientists, in general, and interregional CGE modelers, in particular. Experimentation with the introduction of scale economies, market imperfections and transportation costs should provide innovative ways of dealing explicitly with theoretical issues related to integrated regional systems. An attempt to address these issues is then discussed in details. After that, the short-run simulation experiments are designed and implemented, and the main results are discussed in the following section. Final remarks follow in an attempt to evaluate our findings and put them into perspective, considering their extension and limitations.

## **2. The B-MARIA-27 model**

In order to evaluate the short-run and long-run effects of reductions in transportation costs, an interstate CGE model was developed and implemented (B-MARIA-27). The structure of the model represents a further development of the Brazilian Multisectoral and Regional/Interregional Analysis Model (B-MARIA), the first fully operational interregional

CGE model for Brazil; full details of the model may be found in Haddad and Hewings (1997) and Haddad (1999) and will not be presented here. The interstate version of B-MARIA, used in this research, contains over 600,000 equations, and it is designed for forecasting and policy analysis. Agents' behavior is modeled at the regional level, accommodating variations in the structure of regional economies. The model recognizes the economies of 27 Brazilian states. Results are based on a bottom-up approach—national results are obtained from the aggregation of regional results. The model identifies eight sectors in each state producing eight commodities, one representative household in each state, regional governments and one Federal government, and a single foreign consumer who trades with each state. Special groups of equations define government finances, accumulation relations, and regional labor markets. The model is calibrated for 1996 since a rather complete data set is available and it is also the year of the last publication of the full national input–output tables that served as the basis for the estimation of the interstate input–output database (Haddad, Hewings, & Peter, 2002), facilitating the choice of the base year.

Previous analysis with the B-MARIA framework has suggested that interregional substitution is the key mechanism that drives the model's spatial results. In general, interregional linkages play an important role in the functioning of interregional CGE models. These linkages are driven by trade relations (commodity flows), and factor mobility (capital and labor migration). In the first case, of direct interest in our exercise, interregional trade flows should be incorporated in the model. Interregional input–output databases are required to calibrate the model, and regional trade elasticities play a crucial role in the adjustment process. Drawing on Bilgic, King, Lusby, and Schreiner (2002) findings about the importance of regional trade elasticities, a concerted effort was made to estimate these for Brazil rather than relying on other published (usually internationally based) trade elasticities.

As is usual with CGE models, the number of unknowns exceeded the number of equations; short- and long-run closure rules were adopted. In addition to the assumption of interindustry and interregional immobility of capital, the short-run closure would include fixed regional population and labor supply, fixed regional wage differentials, and fixed national real wages. Regional employment is driven by the assumptions on wage rates, which indirectly determine regional unemployment rates. On the demand side, investment expenditures are fixed exogenously—firms cannot reevaluate their investment decisions in the short-run. Household consumption follows household disposable income, and government consumption, at both regional and federal levels, is fixed (alternatively, the government deficit can be set exogenously, allowing government expenditures to change). Further, technology variables are exogenous. While the model can be run with either short-run or long-run closures, only the results from the former simulations will be presented.<sup>1</sup>

<sup>1</sup> In the long-run (steady-state) equilibrium closure, capital is mobile across regions and industries. Capital and investment are generally assumed to grow at the same rate. The main differences from the short-run are encountered in the labor market and the capital formation settings. In the first case, aggregate employment is determined by population growth, labor force participation rates, and the natural rate of unemployment. The distribution of the labor force across regions and sectors is fully determined endogenously. Labor is attracted to more competitive industries in more favored geographical areas. While in the same way, capital is oriented towards more attractive industries. This movement keeps rates of return at their initial levels.

### 3. Modeling issues: non-constant returns to scale and transportation networks

Two important changes were made to the B-MARIA model. The first attempted to develop a more flexible functional form for the manufacturing sector production function in each one of the 27 Brazilian states to incorporate non-constant returns to scale, a fundamental assumption for the analysis of integrated interregional systems. The hierarchy of a nested CES structure of production is retained, since it turn out to be very convenient for the purpose of calibration (Bröcker, 1998), the hypotheses on the parameters values are modified, leading to a more general form. This modeling trick allows for the introduction of non-constant returns to scale, by exploring local properties of the CES function. Care should be taken in order to retain local convexity properties of the functional forms to guarantee, from the theoretical point of view, the existence of the equilibrium. The experimentation on scale effects undertaken in this paper, inspired by Whalley and Trela (1986), considers parameters that enable increasing returns to scale to be incorporated in an industry production function in any region through parametric scale economy effects. Changes in the production system are introduced only in the manufacturing sector, as data are available for the estimation of the relevant parameters. The proper estimation of such parameters provides point estimates for improved calibration, and standard errors to be further used in exercises of systematic sensitivity analysis (SSA).

The results, shown in Table 1, reveal evidence of increasing returns in the following states: Minas Gerais, São Paulo, Paraná, Rio Grande do Sul, and Santa Catarina, all located in the more developed Center-South of the country. Also, Rondônia (North), Piauí (Northeast), and Mato Grosso (Center-West) presented evidence of increasing returns. The poor, relatively isolated states of Amapá, Maranhão and Sergipe showed evidence of decreasing returns to scale. Other states did not show evidence of non-constant returns in the manufacturing sector.

The second major change in the structure of B-MARIA was the formal inclusion of transportation margins to account for the real costs of moving goods from one region to another.

Fig. 1 highlights the production technology of a typical regional transport sector in B-MARIA in the broader regional technology. Regional transportation sectors are assumed to operate under constant returns to scale (nested Leontief/CES function), using as inputs composite intermediate goods—a bundle including similar inputs from different sources.<sup>2</sup> Locally supplied labor and capital are the primary factors used in the production process. Finally, the regional sector pays net taxes to Regional and Federal governments. The sectoral production serves both domestic and international markets.

As already mentioned, the supply of the transportation sector meets margin and non-margin demands. In the former case, Fig. 2 illustrates the role of transportation services in the process of facilitating commodity flows. In a given consuming region, regionally produced transportation services provide the main mechanism to physically bring products (intermediate inputs, and capital and consumption goods) from different sources (local, other regions, other countries) to within the regional border. Also, foreign exporters use transportation services to take exports from the production site to the respective port of exit.

However, rather than modeling the interstate flows over a topological network, the flows were mapped onto a geo-coded transportation network model, enhancing the po-

<sup>2</sup> The Armington assumption is used here.

Table 1  
Estimates of scale parameters

	$\beta$	Sample size
Acre	0.983 (0.074)	30
Amapá	1.110 (0.053)	36
Amazonas	0.952 (0.054)	120
Pará	0.987 (0.025)	114
Rondônia	0.780 (0.071)	66
Roraima	0.890 (0.142)	36
Tocantins	0.919 (0.055)	72
Alagoas	1.029 (0.042)	108
Bahia	0.979 (0.024)	132
Ceará	0.993 (0.037)	114
Maranhão	1.135 (0.058)	96
Paraíba	1.007 (0.031)	108
Pernambuco	0.060 (0.799)	120
Piauí	0.890 (0.043)	84
Rio Grande do Norte	1.049 (0.041)	90
Sergipe	1.091 (0.030)	96
Espírito Santo	0.974 (0.031)	108
Minas Gerais	0.892 (0.023)	534
Rio de Janeiro	1.032 (0.022)	498
São Paulo	0.951 (0.008)	588
Paraná	0.956 (0.014)	528
Santa Catarina	0.965 (0.015)	402
Rio Grande do Sul	0.961 (0.013)	522
Distrito Federal	0.887 (0.060)	96
Goiás	0.942 (0.036)	114
Mato Grosso	0.818 (0.065)	114
Mato Grosso do Sul	0.930 (0.039)	108
Brazil	0.907 (0.012)	618

tential of the framework in understanding the role of infrastructure on regional development. Hence, it would be possible now to simulate changes in the system, which might affect relative accessibility (e.g. road improvements, investments in new highways). A minimum distance matrix can be calculated *ex ante* and *ex post*, and mapped into the interregional CGE model. This mapping includes two stages, one associated with the calibration phase, and another with the simulation phase; both of them are discussed below.

In the interstate CGE model, it is assumed that the *locus* of production and consumption in each state is located in the state capital. Thus, the relevant distances associated with the flows of commodities from points of production to points of consumption are limited to a matrix of distances between state capitals; it is assumed that trade within the state takes place on an abstract route between the capital and a point located at a distance equal to half the implicit radius related to the state area.<sup>3</sup> The transport model calculates the minimum interstate distances, considering the existing road network in 1997.

<sup>3</sup> Given the state area, we assume the state is a circle and calculate the implicit radius.

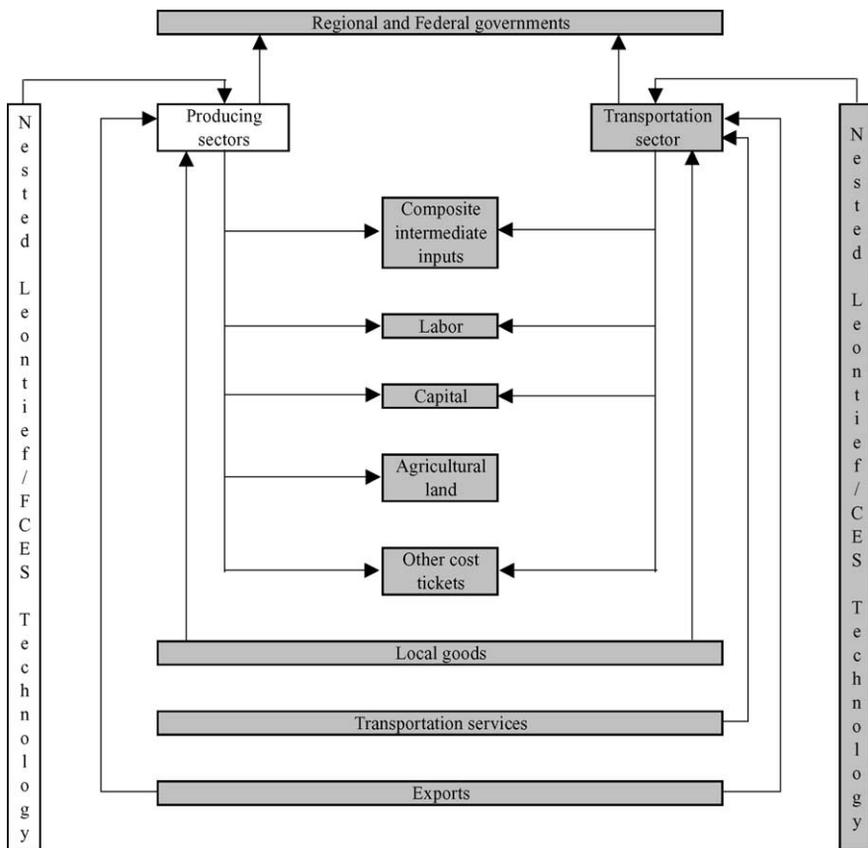


Fig. 1. Flowchart with regional production technology in B-MARIA: highlighting the transportation sector.

The process of calibration of the B-MARIA model requires information on the transport and trade margins related to each commodity flow. Aggregated information for margins on intersectoral transactions, capital creation, household consumption, and exports are available at the national level. The problem remains to disaggregate this information considering previous spatial disaggregation of commodity flows in the generation of the interstate input–output accounts. The calibration strategy adopted here takes into account explicitly, for each origin–destination pair, key elements of the Brazilian integrated interstate economic system, namely: (a) the type of trade involved (margins vary according to specific commodity flows); (b) the transportation network (distance matters); and (c) scale effects in transportation, in the form of long-haul economies. Moreover, the possibility of dealing explicitly with increasing returns to transportation is also introduced in the simulation phase.

The specification of the household demand system in the B-MARIA model allows the computation of measures of welfare. More specifically, one can calculate the equivalent variation (EV) associated with a policy change. The equivalent variation is the amount of

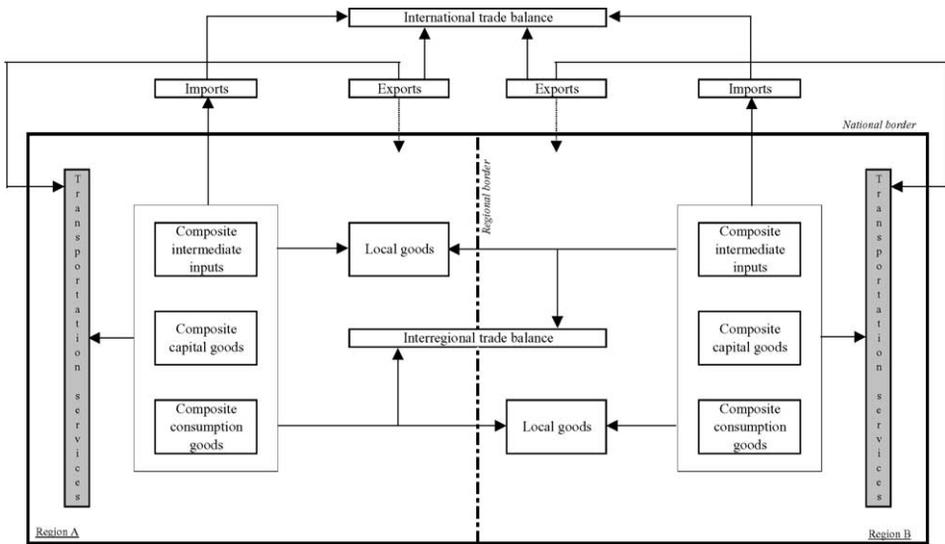


Fig. 2. The role of transportation services in B-MARIA: illustrative flowchart in a two-region integrated framework.

money one would need to give to an individual, if an economic change did not happen, to make him as well off as if it did (Layard & Walters, 1978). The Hicksian measure of EV would consider computing the hypothetical change in income in prices of the post-shock equilibrium (Bröcker & Schneider, 2002). Alternatively, it can be measured as the *monetary change* of benchmark income the representative household would need in order to get a post-simulation utility under benchmark prices. More precisely, for homogenous linear utility functions, it can be written as in Almeida (2003):

$$EV^r = \left( \frac{U^r(1) - U^r}{U^r} \right) I^r \tag{1}$$

where  $U^r(1)$  is the post-shock utility;  $U^r$  is the benchmark utility; and  $I^r$  is the benchmark household disposable income. Note that the EV has the same sign as the direction of the change in welfare, i.e., for a welfare gain (loss) it is positive (negative). Aggregate (national) welfare can be assessed by simply summing up the regional  $EV^r$  over  $r$ . Another informative welfare measure refers to the relative equivalent variation (REV). It is defined as the *percentage change* of benchmark income the representative household would need in order to get a post-simulation utility under benchmark prices (Bröcker, 1998). That is:

$$REV^r = \frac{EV^r}{I^r} \tag{2}$$

Calibration of the household demand system in B-MARIA requires benchmark values for each regional household's income and expenditure flows, which are derived from the SAM database, and estimates for the regional budget shares,  $\beta_{(i)}^r$  (see Dixon, Parmenter, Sutton, & Vincent, 1982).

#### 4. The simulation phase

To capture the impacts of investments that involve any change in the structure of the transportation system, the model accommodates the changes through changes in the matrix of minimum interregional distances. Basically, improvements in transportation result in the “shrinking” of distance; the impacts can thus be traced, through changes in transportation margins on the production function by commodity and region. On this issue, Cukrowski and Fischer (2000) and Mansori (2003) have shown that these spatial implications are considered in the context of international trade, and therefore, increasing returns to transportation should be carefully considered *within* a national economy.

In the next section, the main results from the simulations are presented. The basic experiment consisted of the evaluation of an overall 1% reduction in transportation cost within the country. In other words, for every domestic origin–destination pairs, the usage of transportation margins is reduced by 1%. Only the short-run simulations will be presented as a first step in the more extensive analysis that would be needed to assess potential efficiency gains in the transportation network associated with regulation issues, as discussed in the introduction.

How are the decreases in transportation costs entered into the model? As shipments become less resource-intensive, labor and capital are freed, generating excess supply of primary factors in the economic system. This creates a downward pressure on wages and capital rentals, which are passed on in the form of lower prices. A more comprehensive attempt would need to link this system with a model of the transportation shippers’ market to explore the degree to which de-regulation would effect downward pressure of transportation costs and the extent to which these changes would or would not be uniform across commodities and interstate routes.<sup>4</sup>

The reduction in transport cost decreases the price of composite commodities, with positive implications for real regional income: in this cost-competitiveness approach, firms become more competitive – as production costs go down (inputs are less costly); investors foresee potential higher returns – as the cost of producing capital also declines; and households increase their real income, envisaging higher consumption possibilities. Higher incomes generate higher domestic demand, while increases in the competitiveness of national products stimulates external demand. This creates room for increasing firms’ output – directed for both domestic and international markets – that will require more inputs and primary factors. Increasing demand puts pressure on the factor markets for price increases, with a concomitant expectation that the prices of domestic goods would increase.

Second-order prices changes go in both directions—decrease and increase. The net effect is determined by the relative strength of the countervailing forces. Fig. 3 summarizes the transmission mechanisms associated with major first-order and second-order effects in the adjustment process underlying the model’s aggregate results.

As for the differential spatial effects, three major forces operate in the short-run – two price effects and one income effect – and the net result will heavily depend on the structure of

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<sup>4</sup> Further extensions would include the specification of a distinction between shippers and carriers, with the latter choosing not only the routes between regions but also the mode of transportation used. For an example, see Sohn, Kim, Hewings, Lee, and Jang, (2003, 2004).

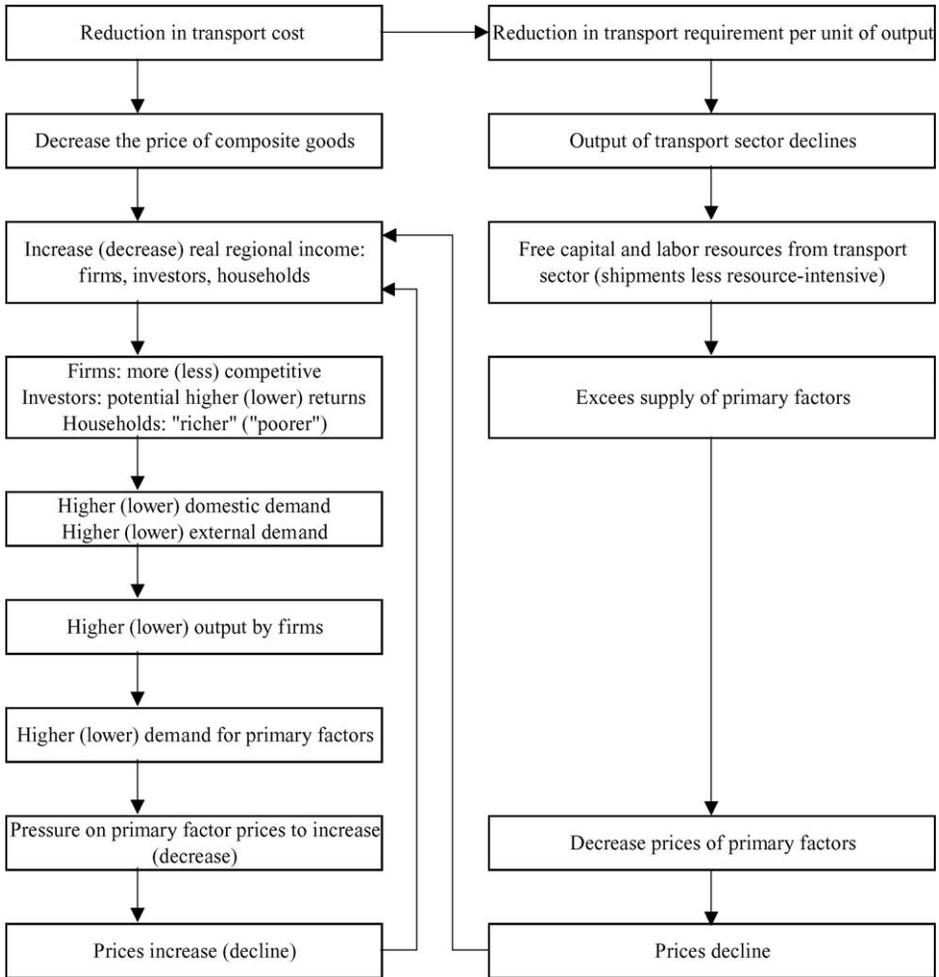


Fig. 3. Causal relationships in the simulation.

the integrated interstate system. Regarding regional performance, two substitution mechanisms through price effects are relevant to understand the adjustment process. First, there is a direct substitution effect. Consider two trading regions, one exporting ( $r$ ) and another importing ( $s$ ), respectively. As transportation costs between the two regions go down,  $r$  will increase its penetration into  $s$ , producing more for  $s$ , as it will now be cheaper for agents in  $s$  to buy from  $r$ . A substitution effect operates in the sense that  $s$  will directly substitute output from  $r$  for either its own regional output, or other regions' output (including foreign products).

Moreover, another substitution effect operates. In order to produce for  $s$ ,  $r$  will buy inputs from other regions. As these inputs are now cheaper, due to reductions in transportation costs, region  $r$ , with better access to input sources, becomes more competitive, expanding its output. This is the indirect substitution effect.

However, a third countervailing force appears in the form of an income effect. With better accessibility, the demand for products from region  $r$  increases. The sources of higher demand for the region's output come from a substitution effect – prices of  $r$ 's output are now lower – and an income effect – real income increases. This put pressures on prices, and the net effect will depend on whether the direct and indirect substitution effects will prevail over the income effect.<sup>5</sup>

Finally, regions might be adversely affected through re-orientation of trade flows (trade diversion), as relative accessibility changes in the system. Thus, overall gains in efficiency in the transportation sector are not necessarily accompanied by overall gains in welfare. This issue of trade diversion versus trade creation has been an important one in the international trade literature and would likely feature prominently for trade between regions within a nation.

## 5. Results

The presentation of the simulation results will focus on the short-run effects; the impacts on the longer-run changes (when, for example, capital and labor are free to move between regions) may be found. Attention will be directed to the relevant aggregate variables that help us understand the functioning mechanism of the model. Spatial effects considering changes in welfare and real GDP are also presented. Secondly, we check the robustness of the results for the key parameters related to the simulation exercises, namely, regional trade elasticities, and parameters to scale economies. To reach this goal, systematic sensitivity analysis is carried out.

Finally, in an attempt to better understand the role of increasing returns in the spatial allocation of activities in an integrated interregional system, we adjust the parameter of scale economies in the São Paulo manufacturing sector with the idea to check whether, in the Brazilian case, with improvements in transportation, the São Paulo firms have a competitive advantage to further exploit scale economies with reductions in transportation costs, thereby exacerbating the welfare differentials between regions.

### 5.1. Basic results

Table 2 summarizes the results; gains in efficiency (real GDP growth) and welfare (equivalent variation) are positive. Table 3 presents the efficiency and welfare spatial effects. While in terms of efficiency, states in the Center-South seem to have a better performance, in terms of welfare, households in the less developed regions with better access to producing regions appear to be better-off. The intuition here is that lower transport costs will result in a greater

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<sup>5</sup> In the long-run, a fourth mechanism becomes relevant: the “re-location” effect. As factors are free to move between regions, new investment decisions define marginal re-location of activities, in the sense that the spatial distribution of capital stocks and the population changes. The main mechanism affecting regional performance is associated with capital creation. As transportation costs decreases, better access to non-local capital goods increases the rate of returns in the regions. At the same time this potentially benefits capital importing regions, it has a positive impact on the capital-good sectors in the producing regions. However, in this paper, only short-run (essentially fixing capital) considerations are taken into account.

Table 2  
Short-run aggregate results (in percentage-change)

Activity level	% Change
Agriculture	0.0016
Manufacturing	0.0030
Utilities	0.0003
Construction	−0.0002
Trade	0.0002
Financial institutions	0.0021
Public administration	0.0004
Transportation and other services	−0.0098
Total	−0.0015
<i>Prices</i>	
Investment price index	−0.0172
Consumer price index	−0.0239
Exports price index	−0.0132
Regional government demand price index	−0.0240
Federal government demand price index	−0.0250
GDP price index, expenditure side	−0.0236
<i>Primary factors</i>	
Aggregate payments to capital	−0.0256
Aggregate payments to labor	−0.0279
Aggregate capital stock, rental weights	−
Aggregate employment, wage bill weights	−0.0040
<i>Aggregate demand</i>	
Real household consumption	0.0006
Aggregate real investment expenditure	−
Aggregate real regional government demand	−
Aggregate real Federal government demand	−
Export volume	0.0273
<i>Aggregate indicators</i>	
Equivalent variation—total (change in \$)	8.97
Real GDP	0.0031

volume of goods being available at lower prices in the less developed regions; regional welfare would also be enhanced by the expectation that a greater variety of goods and services will now be made available in those regions.

Consider the findings for the Southeast and South states; Minas Gerais, Espírito Santo, Paraná, and Rio Grande do Sul gain while São Paulo, Rio de Janeiro and Santa Catarina lose. Since the impacts feature short-run solutions, the intuition here is that for São Paulo, supply is relatively inelastic. Consumer in this state now face more competition from consumers in other states since the effects of decreases in transportation costs serve to expand the geographical scope of the market that could potentially be served by São Paulo. This increase in demand is met by higher prices in São Paulo, leading to a negative equivalent variation. Minas Gerais, on the other hand, is a primary producer of intermediate rather than final products and thus expansion of consumer demand will lead to increases in demand for intermediates, yielding, on balance a positive short run outcome.

Table 3  
Spatial results

		Short-run		
		EV	REV (%)	GDP
North	Acre	0.46	0.062	0.0059
	Amapá	0.41	0.043	0.0101
	Amazonas	2.64	0.015	0.0039
	Pará	2.71	0.028	0.0037
	Rondônia	0.64	0.025	0.0034
	Roraima	0.26	0.075	0.0110
	Tocantins	0.24	0.024	0.0102
Northeast	Alagoas	2.06	0.058	0.0062
	Bahia	5.56	0.020	0.0043
	Ceará	3.09	0.028	0.0052
	Maranhão	2.55	0.054	0.0082
	Paraíba	1.76	0.033	0.0049
	Pernambuco	5.54	0.033	0.0055
	Piauí	0.71	0.029	0.0079
	Rio Grande do Norte	1.77	0.041	0.0045
Southeast	Sergipe	0.75	0.023	0.0025
	Espírito Santo	−0.35	−0.003	0.0030
	Minas Gerais	5.33	0.009	0.0054
	Rio de Janeiro	−1.86	−0.002	0.0019
South	São Paulo	−21.51	−0.008	0.0026
	Paraná	1.93	0.005	0.0020
	Santa Catarina	−0.99	−0.004	0.0023
	Rio Grande do Sul	0.69	0.001	0.0032
	Distrito Federal	−3.79	−0.012	0.0015
Center-West	Goiás	0.29	0.003	0.0030
	Mato Grosso	−1.11	−0.015	0.0035
	Mato Grosso do Sul	−0.80	−0.010	0.0018
	Brazil	8.97	0.001	0.0031

EV measured in 1996 R\$ millions; REV measured in percentage of benchmark disposable income; GDP measured as a percentage-change in real terms.

## 5.2. Systematic sensitivity analysis

How sensitive are the results to parameter specification? CGE models have been frequently criticized for resting on weak empirical foundations.<sup>6</sup> While Hansen and Heckman (1996) argue that the flexibility of the general equilibrium paradigm is a virtue hard to reject and provides a rich apparatus for interpreting and processing data, it can be considered as being empirically irrelevant because it imposes no testable restrictions on market data. McKittrick (1998) has also criticized the parameter selection criteria used in most

<sup>6</sup> The discussion below draws on Domingues et al. (2003).

CGE models, arguing that the calibration approach leads to an over-reliance on non-flexible functional forms.

Although most CGE modelers recognize that accurate parameters values are very important, it is not easy to find empirical estimates of key parameters, such as substitution elasticities, in the literature. Most of the models take up estimates “found in the literature” or even “best guesstimates” (Deardorff & Stern, 1986). Thus, if there is considerable uncertainty surrounding the “right” parameters, and these are key elements in the CGE results, a consistent procedure in their evaluation is imperative. The problem in CGE models is compounded by the presence of a variety of parameters, some estimated with known probability distributions, others with no known distributions combined with input–output/SAM data that are provided as point estimates (see Haddad et al., 2002).

If a consistent econometric estimation for key parameters in a CGE model study is not possible, the effort should be directed to tests of the uncertainty surrounding these parameters in terms of their impact on the model. Robustness tests are an important step in enhancing the acceptance of the model results in applied economics. The assumptions embodied in CGE models come from general equilibrium theory. However, one set of assumptions, the values of model parameters are natural candidates for sensitivity analysis. Wigle (1991) has discussed alternative approaches for evaluating model sensitivity to parameter values, while DeVuyst and Preckel (1997) have proposed a quadrature-based approach to evaluate robustness of CGE models results, and demonstrated how it could be used for an applied policy model.

The Gaussian quadrature (GQ) approach (Arndt, 1996; DeVuyst & Preckel, 1997; Domingues, Haddad, & Hewings, 2003) was proposed to evaluate CGE model results’ sensitivity to parameters and exogenous shocks. This approach views key exogenous variables (shocks or parameters) as random variables with associated distributions. Due to the randomness in the exogenous variables, the endogenous results are also random; the GQ approach produces estimates of the mean and standard deviations of the endogenous model results, thus providing an approximation of the true distribution associated with the results. The accuracy of the procedure depends on the model, the aggregation and the simulations employed. Simulations and tests with the Global Trade Analysis Project (GTAP) model, a large-scale model, have shown that the estimates of mean and standard deviations are quite accurate.

In the B-MARIA-27 model, one set of regional trade elasticities in the Armington demand structure determines the substitution possibilities between goods from different domestic sources. Smaller trade elasticities imply less substitution among regional sources in the model. The change in the results will depend on the interaction of the transportation cost cuts, price responses and these elasticities. Table 4 shows the default values in the aggregation used in this paper. Data from the balanced interstate SAM were extracted to estimate implicit regional trade elasticities, to be used in the calibration of the model. This procedure guarantees data consistency between the SAM database and the estimated parameters. Moreover, it is now possible to provide point and standard error estimates for such key parameters. However, the model-consistent information is not free from the structural constraints imposed during the process of building the SAM; on the other hand, without this information, proper estimation would not be possible. The second group of sensitivity analyses was carried out in the scale economies parameters,  $\mu$ .

Table 4  
Trade elasticities in the B-MARIA-27 model

	International	Regional
Agriculture	0.343	1.570
Manufacturing	1.278	2.079
Utilities	0.011	1.159
Construction	0.002	0.002
Trade	0.694	0.001
Financial institutions	0.137	1.385
Public administration	0.070	0.001
Transportation and other services	1.465	0.001

The transportation cost reduction experiments discussed above are employed using the Gaussian quadrature approach to establish confidence intervals for the main results. The range for the elasticities was set to  $\pm$  one standard error estimate around the default value, with independent, symmetric, triangular distributions for the two parameters.

Table 5 summarize the sensitivity of GDP and welfare results in each Brazilian state for the ranges in the two individual sets of parameters. The lower bound and the upper bound columns represent the 90% confidence intervals for the estimates, constructed using Chebyshev's inequality. We observe that, in general, state results are relatively more robust to scale economies parameters rather than to regional trade elasticities. Overall, the state simulation results can be considered robust to both sets of parameters.

### 5.3. Analytically important transportation links

It has been argued that, given the intrinsic uncertainty in the shock magnitudes and parameter values, sensitivity tests are an important next step in the more formal evaluation of the robustness of (interregional) CGE analysis and the fight against the “black-box syndrome.” However, some important points should be addressed in order to have a better understanding of the sensitivity of the models' results. In similar fashion to the fields of influence approach for input–output models developed by Sonis and Hewings (1989), attention needs to be directed to the most important synergetic interactions in a CGE model. It is important to try to assemble information on the parameters, shocks and database flows, for example, that are the *analytically* most important in generating the model outcomes, in order to direct efforts to a more detailed investigation.<sup>7</sup>

To accomplish this task, the role played by each transportation link –  $27 \times 27$  in total – in generating the model's results were evaluated.<sup>8</sup> For each transportation link, we calculated its contribution to the total outcome, considering different dimensions of regional policy. Impacts on regional efficiency and welfare were considered. We looked at the effects on regional efficiency, through the differential impacts on GDP growth for the five Brazilian macro regions (North, Northeast, Southeast, South and Center-West), and for the coun-

<sup>7</sup> See Domingues et al. (2003).

<sup>8</sup> We were able to consider the two-way dimension of a transportation link between to regions, i.e. the way “in” and the way “out”.

Table 5  
Systematic sensitivity analysis

	Trade elasticities				Scale economies parameter	
	Welfare changes (R\$ million)		GDP changes (%)		GDP changes (%)	
	Lower bound	Upper bound	Lower bound	Upper bound	Lower bound	Upper bound
Acre	0.46	0.46	0.0058	0.0059	0.0059	0.0059
Amapá	0.41	0.41	0.0101	0.0101	0.0101	0.0101
Amazonas	2.62	2.65	0.0039	0.0039	0.0039	0.0039
Pará	2.69	2.73	0.0037	0.0038	0.0037	0.0037
Rondônia	0.63	0.65	0.0033	0.0034	0.0033	0.0034
Roraima	0.26	0.26	0.0110	0.0110	0.0110	0.0110
Tocantins	0.24	0.25	0.0099	0.0105	0.0102	0.0102
Alagoas	2.05	2.06	0.0062	0.0062	0.0062	0.0062
Bahia	5.53	5.58	0.0043	0.0043	0.0043	0.0043
Ceará	3.08	3.11	0.0052	0.0052	0.0052	0.0052
Maranhão	2.54	2.56	0.0081	0.0082	0.0081	0.0083
Paraíba	1.75	1.76	0.0049	0.0049	0.0049	0.0049
Pernambuco	5.53	5.55	0.0055	0.0055	0.0055	0.0055
Piauí	0.71	0.71	0.0078	0.0079	0.0078	0.0079
Rio Grande do Norte	1.77	1.79	0.0044	0.0045	0.0045	0.0045
Sergipe	0.74	0.75	0.0025	0.0025	0.0025	0.0025
Espírito Santo	-0.37	-0.33	0.0029	0.0030	0.0030	0.0030
Minas Gerais	5.28	5.38	0.0054	0.0055	0.0054	0.0055
Rio de Janeiro	-1.97	-1.76	0.0019	0.0019	0.0019	0.0019
São Paulo	-21.59	-21.44	0.0026	0.0026	0.0026	0.0026
Paraná	1.91	1.95	0.0020	0.0020	0.0020	0.0020
Santa Catarina	-1.00	-0.98	0.0023	0.0023	0.0023	0.0023
Rio Grande do Sul	0.65	0.72	0.0031	0.0032	0.0031	0.0032
Distrito Federal	-3.82	-3.75	0.0014	0.0016	0.0015	0.0015
Goiás	0.27	0.31	0.0029	0.0030	0.0030	0.0030
Mato Grosso	-1.11	-1.10	0.0035	0.0036	0.0035	0.0036
Mato Grosso do Sul	-0.81	-0.79	0.0018	0.0018	0.0018	0.0018
Brazil	8.81	9.14	0.0031	0.0031	0.0031	0.0031

try as a whole (systemic efficiency). Moreover, we considered the differential impacts on regional welfare, looking at the specific macro regional results, and also at total national welfare.

Table 6 presents the results for the welfare effects. Transportation links between and within macro regions are explicitly considered, and the estimates of their contributions to the specific policy outcome are presented. Focus attention, first on the entries in Table 6 that reveal the welfare effects. The overall national impact shown in Table 2 (R\$ 8.97 million) is now decomposed into region-to-region links. For the North region, there is a positive intra-regional impact (2.92) from a transportation cost reduction in this region. Essentially, the transportation cost decrease lowers delivered prices to consumers who respond by purchasing more of the goods and services produced in the North region states. Further, consumers in this region are now able to purchase a greater number of goods and services produced in the Southeast, yielding to an increase of 6.50. A simi-

Table 6

Short-run regional and total welfare effects: decomposition of equivalent variation (EV) according to origin–destination pairs of transportation cost reductions (–1%)

<u>North</u>								<u>South</u>							
		<i>Destination</i>								<i>Destination</i>					
		N	NE	SE	S	CO	Total			N	NE	SE	S	CW	Total
<i>Origin</i>	N	2.92	-0.03	-0.12	-0.01	0.00	2.75	<i>Origin</i>	N	-0.33	-0.08	-0.25	0.27	0.00	-0.39
	NE	0.72	-0.40	-0.16	-0.02	-0.01	0.13		NE	-0.08	-1.20	-0.35	0.49	-0.03	-1.17
	SE	6.50	-0.61	-1.65	-0.29	-0.26	3.68		SE	-0.72	-1.85	-3.98	5.93	-0.64	-1.26
	S	1.55	-0.16	-0.29	-0.36	-0.07	0.66		S	-0.15	-0.49	-0.70	6.35	-0.12	4.88
	CW	0.37	-0.02	-0.11	-0.01	-0.10	0.14		CW	-0.04	-0.05	-0.28	0.16	-0.23	-0.43
Total	12.06	-1.21	-2.34	-0.70	-0.45	7.36	Total	-1.32	-3.66	-5.58	13.21	-1.02	1.63		
<u>Northeast</u>								<u>Center-west</u>							
		<i>Destination</i>								<i>Destination</i>					
		N	NE	SE	S	CW	Total			N	NE	SE	S	CW	Total
<i>Origin</i>	N	-0.48	0.77	-0.59	-0.06	-0.02	-0.37	<i>Origin</i>	N	-0.23	-0.05	-0.26	-0.03	0.04	-0.54
	NE	-0.12	13.55	-0.75	-0.10	-0.06	12.52		NE	-0.06	-0.83	-0.32	-0.05	0.10	-1.16
	SE	-0.99	20.78	-7.53	-1.22	-1.18	9.86		SE	-0.49	-1.28	-3.21	-0.60	2.13	-3.45
	S	-0.20	5.55	-1.35	-1.38	-0.33	2.28		S	-0.10	-0.34	-0.56	-0.48	0.66	-0.83
	CW	-0.05	0.53	-0.51	-0.03	-0.44	-0.50		CW	-0.02	-0.03	-0.20	-0.02	0.85	0.58
Total	-1.84	41.18	-10.74	-2.79	-2.02	23.79	Total	-0.90	-2.54	-4.57	-1.18	3.79	-5.40		
<u>Southeast</u>								<u>Brazil</u>							
		<i>Destination</i>								<i>Destination</i>					
		N	NE	SE	S	CW	Total			N	NE	SE	S	CW	Total
<i>Origin</i>	N	-1.42	-0.29	0.44	-0.16	-0.04	-1.46	<i>Origin</i>	N	0.46	0.32	-0.79	0.02	-0.02	-0.01
	NE	-0.34	-4.44	0.66	-0.28	-0.14	-4.53		NE	0.13	6.68	-0.93	0.03	-0.13	5.78
	SE	-2.91	-6.80	10.37	-3.39	-2.88	-5.62		SE	1.39	10.24	-6.01	0.42	-2.83	3.21
	S	-0.57	-1.82	1.40	-3.99	-0.80	-5.78		S	0.53	2.73	-1.52	0.14	-0.67	1.21
	CW	-0.13	-0.17	0.49	-0.09	-1.09	-1.01		CW	0.13	0.26	-0.62	0.01	-1.00	-1.22
Total	-5.37	-13.52	13.35	-7.91	-4.95	-18.40	Total	2.63	20.24	-9.87	0.63	-4.65	8.97		

lar pattern may be found for the Northeast; here the intra-regional effect (13.55) and the Southeast–Northeast trade flow (20.78) are larger than comparable linkages for the North region. The gains in the South region for similar linkages lie between these two while those for the Center–West are smaller. For the Southeast region, the largest effect is the intra-regional gain—the impacts for those states within that region that gain offset the losses in other states.

#### 5.4. *The role of increasing returns*

In interregional CGE modeling, another possible way to overcome the scarcity of estimates of regional key parameters is to estimate policy results based on different qualitative sets of values for the behavioral parameters and structural coefficients (Haddad et al., 2002). Through the judgment of the modeler, a range of alternative combinations reflecting differential structural hypotheses for the regional economies can be used to achieve a range of results for a policy simulation. This method, called *qualitative* or *structural sensitivity analysis*,<sup>9</sup> provides a “confidence interval” to policy makers, and incorporates an extra component to the model’s results, which contributes to increased robustness through the use of possible structural scenarios. As data deficiency has always been a big concern in regional modeling, one that will not be overcome in the near future, this method tries to adjust the model for possible parameter misspecification. If the modeler knows enough about the functioning of the particular national and regional economies, the model achieves a greater degree of accuracy when such procedure is adopted. Qualitative and systematic sensitivity analysis should be used on a regular basis in interregional CGE modeling in order to avoid, paradoxically, speculative conclusions over policy outcomes.

Qualitative sensitivity analysis is carried out in this sub-section in order to grasp a better understanding on the role played by the introduction of non-constant returns to scale in the modeling framework. More specifically, the goal here is to assess the role played by increasing returns in the manufacturing sector in the state of São Paulo, the richest, most industrialized state in Brazil and for which there is evidence that it is the focal point of agglomeration economies in the country. For instance, a crude indicator using the PIA data set mentioned above shows that, while São Paulo’s share in manufacturing value added in the period 1996–2001 was 47.3%, the state’s share in total manufacturing labor was 39.9%.

Theoretical results from the new economic geography literature suggest that there is a fundamental trade-off between transportation costs and increasing returns. If this is the case, in a core-periphery interregional system, the core region, which hosts the increasing-returns sector, can potentially further benefit from improvements in the transportation sector by exploiting scale economies. We check this result using the B-MARIA model with a special set of values for the scale economies parameters; we assume constant returns in

<sup>9</sup> The term “qualitative sensitivity analysis” is used as opposed to “quantitative sensitivity analysis”, which is the practice adopted by modelers to define confidence intervals for the simulations’ results. Usually, the parameters are allowed to deviate over a range centered in the initial assigned values, or to present small increases/decrease in one direction, which does not address the likely cases of structural misspecifications.

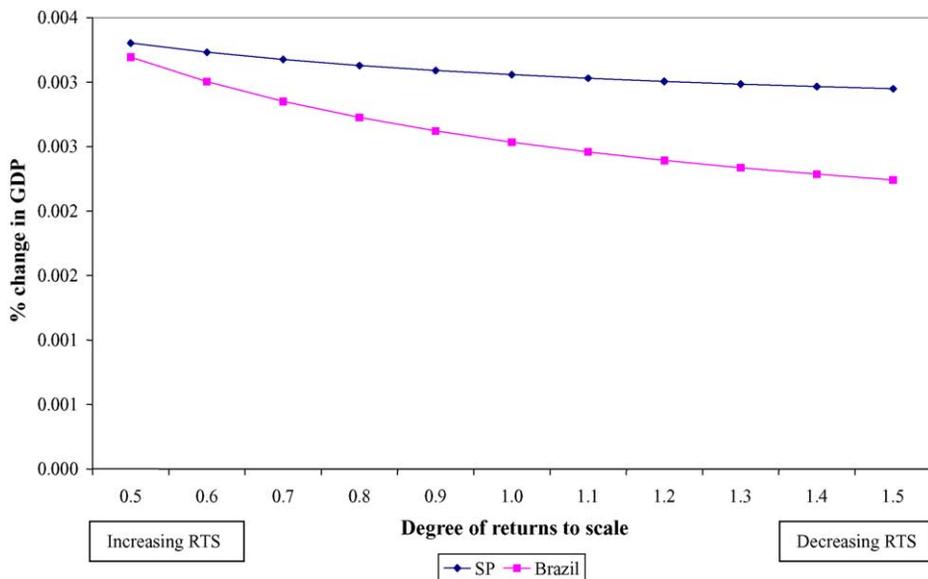


Fig. 4. Short-run effects on national and state GDP [efficiency gains].

every sector in every state. The only exception is the manufacturing sector in the state of São Paulo, for which we consider an interval in the IRTS curve, ranging from high increasing returns ( $\mu = 0.5$ ) to decreasing returns to scale ( $\mu = 1.5$ ), i.e.,  $\mu \in [0.5, 1.5]$  in the manufacturing sector. A series of simulations is run for various values of  $\mu$  in the assumed interval. Results are presented in the Figs. 4 and 5. Theoretical results are confirmed in the empirical experimentation with B-MARIA-27. As it becomes clear from the results for both São Paulo’s GDP and welfare, the further down the IRTS curve, the better the state’s performance in terms of GDP growth and welfare.

The results reveal that, in general, the Rest of Brazil has more to gain from increasing returns to scale than São Paulo; further, the variation in welfare effects are smaller (Fig. 5) than for efficiency effects (Fig. 4). While it would be premature to draw general conclusions from this single case study, it may turn out that transportation costs variations generate more impact on the spatial economy than scale economies in the short run, when supply constraints are stronger. However, it should be noted that transportation costs are often a relatively smaller component of total costs, so while percentage changes might be large, they need to be considered in the context of total input costs. Secondly, while the underlying input–output table assumes no scale economies, the production structure implicit in the Leontief system obviously includes a density function of production technologies that are in some sense averaged. For some sectors, the realization of scale economies may be more modest in that these sectors may contain a greater proportion of establishments that use more modern techniques and thus produce more efficiently. Unfortunately, these are empirical questions that cannot be answered without information on establishment level production functions.

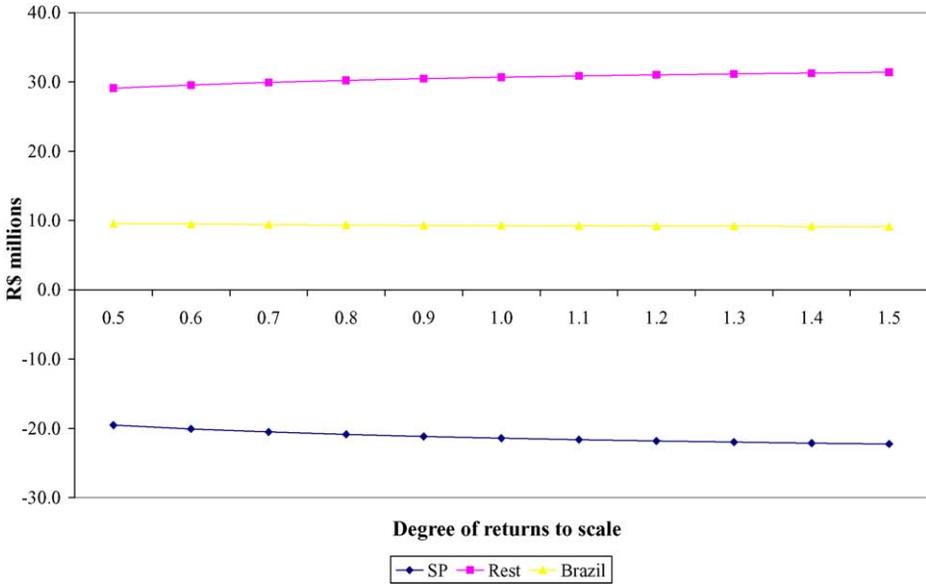


Fig. 5. Short-run effects on national and state welfare [welfare gains].

### 6. Final remarks

This paper begins an exploration of the Brazilian economy using a multiregional computable general equilibrium model that is in the process of being unfettered from the reins of the perfectly competitive modeling paradigm. The process is ongoing and difficult; attempts to handle non-constant returns to scale, agglomeration and core-periphery phenomena, imperfect competition, transportation costs present enormous challenges. Put together, the analysis becomes even more intractable. Further, there is the issue of parameter estimation and sensitivity; some of the analysis in this paper suggests that this area remains contentious. However, these steps will be necessary if CGE models are to achieve credibility in their ability to mimic changes in regulation and to provide policy makers with some reasonable degree of confidence in the measurement of outcomes generated by strategic, spatially targeted investment strategies, especially those focused on transportation networks.

However, the results provided are encouraging in the sense that the issues, while difficult, are not insurmountable. The challenges to competitive equilibrium in the spatial economy presented by the new economic geography remain largely untested. The present paper offers one approach to a goal of narrowing the gap between theory and empirical application. The Brazilian economy, sharing features of both developed and developing countries, presents a further challenge; the non-uniformity of the spatial distribution of resources and population, the glaring disparities in welfare across states and the presence of a hegemonic economy, in São Paulo, that renders traditional CGE modeling of limited value.

The results reveal that it is possible to handle increasing returns to scale, to address issues of asymmetric impacts of transportation investment and to approach the problems of

more flexible functional forms, uncertainties about data and parameter estimates in ways that are tractable and theoretically defensible. The paper offers the perspective that there is a need, perhaps, to pause and take stock of the current state of the art in CGE modeling for multiregional (spatial) economies and to pursue further some of the lines of inquiry initiated by this work.

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