The Skill Dimension of Labour Market Impacts of External Price Shocks: Numerical Calculations From a Canadian Regional Trade Model*

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Abstract

Because Canada's economy is so open, import and export price shocks can significantly reverberate through its labour market. This paper evaluates the impacts of two such shocks, namely, a fuel price shock (increased world prices of crude oil and refined petroleum products) and a manufactures price shock (drops in world price of selected manufactured goods). We use a CGE regional trade model of Canada to estimate these impacts on the provincial economies, notably in terms of the skill profile of wages. The results show that the fuel price shock tends to increase the national welfare and GDP somewhat, although the provincial effects are quite varied (ranging from -0.6% and 2.0%). It also reduces real labour incomes, particularly those of the less skilled. On the other hand, the manufactures price shock generates larger welfare and GDP gains (about 1%) and the interprovincial variation is in terms of size (up to 3.6% for GDP) but not sign. This shock also reduces real wages overall, but it tends to increase those of the less skilled. In other words, the simulation results seem to suggest that a fuel price shock is likely to have a more marked negative impact on real wages and the skill-distribution of real wages (i.e., low-skilled wages decline relative to high skilled). By contrast, even though the manufactured goods price shock reduces real earnings, its distributional impacts favour the less skilled. The policy implication is that *rising energy prices may represent a greater threat to unskilled workers than cheap imports of manufactured goods* from emerging economies like China. Our findings suggest that the skill dimension may be more important to Canada than previously thought and its regional impacts warrant further investigation.

Keywords: labour skills, external shock, regional trade, cge models
JEL Classifications: C68, F14, J24, R13

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1 Introduction

Canada is a very open economy, with exports accounting for roughly 40% of GDP. As a result, the Canadian economy is particularly vulnerable to various shocks originating in world markets. This paper undertakes a provincial analysis of two such shocks using a computable general equilibrium (CGE) approach. Static CGE models are well suited to addressing issues of long-term resource reallocation such as impacts from changes in the international economic environment. We consider two external price shocks, namely, a fuel price shock (i.e., increase in world prices of crude oil and refined petroleum products) followed by a manufactures price shock (i.e., drop in the world price of selected manufactured goods).

One of the novel features of our data and findings is that we are able to identify separate effects on different levels of skill intensity of employment by sector by province. There are up to 26 occupational categories which can be aggregated into a range of skill levels in the labour market (in contrast with the usual skilled-unskilled dichotomy in the literature [4] [5]). The model is then extended to represent separate markets for workers of different skill levels (say, low, medium and high skilled workers).

Both of the shocks considered in this paper have positive and negative dimensions for Canada. In the case of higher fuel prices, the good side is that Canada exports a significant quantity of crude oil and natural gas, so its export earnings would be expected to rise. At the same time, such changes in the terms of trade could cause a so-called 'Dutch Disease' effect.[1] Our results show that the fuel price shock tends to increase the national welfare and GDP somewhat, although the provincial effects are quite varied (ranging from -0.6% and 2.0%). It also reduces real labour incomes, particularly those of the less skilled.

For the case of declining prices of manufactured goods, the positive dimension is that cheaper imports of manufactured goods benefit consumers and firms buying intermediate inputs. On the other hand, exporters of manufactured goods face a competitive challenge when their export prices fall along with the prices of competing imports. This manufactured price shock generates larger welfare and GDP gains (about 1%) and the interprovincial variation is in terms of size (up to 3.6% for GDP) but not sign. However, no province experiences a welfare loss. Although the manufactures price shock also tends to reduce total labour earnings in Canada, real wages tend to rise among the less skilled, in contrast to the fuel price increase.

Finally, in both cases, there is widespread concern about how such shocks are likely to affect unskilled relative to skilled workers.

[1] This term refers to a decline in manufacturing caused by an increased value of the domestic currency (or by higher fuel prices in our case).

The plan of the remaining of the paper is as follows. Section 2 briefly describes the features of the model and data to be used, including a discussion of the skill intensity of various sectors. Sections 3 and 4 discuss the two experiments considered, namely, a fuel price increase and a manufactures price drop. Section 5 concludes the paper with a summary of the main findings and discussion of possible extensions. Appendix A describes the theoretical structure of the basic model for the interested readers.

2 Basic Framework

This section provides an overview of the basic modelling framework used for the two price shock experiments in this paper. Detailed descriptions can be found in the documentations [6] [7] available from the web site http://creap.wlu.ca

2.1 Model Overview

The underlying Basic Model of Regional Trade (BMRT) is a static CGE model of Canada with the usual features of constant returns to scale technology and perfectly competitive market structure. In the model, Canada is represented by a number of provinces or regions (e.g., 11 regions in this paper). Trade is engaged at both interprovincial and international levels.

2.1.1 Production

On the production side, each sector has a multi-output technology taking an input aggregation and processing it through an output transformation. As the model is implemented in GAMS/MPSGE [2] [8], in most cases, switching between Leontief, Cobb Douglas and CES substitution on the input side is trivially easy

An input bundle of intermediate inputs and primary factors is used to produce a 'generic' output. Different intermediate inputs are combined in fixed proportions to produce an intermediate composite. In other words, a fixed ratio of agricultural goods to machinery is required to satisfy the intermediate input requirements. The primary input composite is a CES composite of primary factor inputs (e.g., labour of different classes and capital inputs). Finally, the intermediate inputs composite and the primary factors composite (value added) are combined in fixed proportions to produce the 'generic' output

The transformation of this 'generic' output into goods for domestic and foreign consumption is handled in two stages. Firstly, the generic output is transformed among different output goods according to a CET transformation function. Secondly, there is an added level of transformation among goods destined for the own province market, and goods destined for export (i.e., other province or the rest of the world)

2.1.2 Trade

Each province of Canada is modelled as a small open economy relative to a single rest of the world. On the supply (export) side, this means that provinces are price takers in world markets for their goods. On the import (demand) side, the goods demanded (both final and intermediate) in a given region are Armington [1] aggregates of own production, those produced in other provinces and those produced in the rest of the world. Initial trade imbalances are accommodated by giving each province's representative consumer an offsetting endowment of foreign exchange.

2.1.3 Final Demand

Final demand is composed of a representative consumer, provincial government and (optionally) a local government in each region, plus one federal government.

On the private final demand side, each region has one representative consumer which is endowed with all the primary factors in the region. The consumer demands a CES composite of consumption goods and investment goods. Each of these two goods is in turn a Cobb-Douglas composite of the individual final goods

On the government side, each level of government receives tax revenues earmarked for that level of government and spend the remainder on either government expenditures or investment. Once again, each of these two good is a Cobb-Douglas composite of the individual goods. The governments' initial surpluses or deficits are accommodated by offsetting endowments of foreign exchange.

2.2 Data Overview

The Canadian Regional Economic Analysis Project (CREAP) data set is based on the 2001 S-level provincial input-output (IO) table compiled by the Input-Output Division of Statistics Canada [9]. To be used in modelling work, the raw data first needs to be balanced to produce a micro-consistent benchmark data set satisfying the usual zero profit and market equilibrium conditions.

It is noteworthy that the Canadian IO table is in a rectangular format which means that each sector can produce a vector of outputs (multi-product). This data structure makes our model different from the usual single-product case as in most CGE models with squared data. Since goods and sectors in our framework are not uniquely linked to one another, there is significant scope for a given sector to differ across provinces. For example, it is possible that the Mining sector in Alberta produces a different range of outputs and uses a different input pattern than the Mining sector in neighbouring Saskatchewan.

2.2.1 Data Aggregation

The full-blown version of the CREAP data set provides a numerical snapshot of Canada as a small open regional economy with 10 provinces, 3 territories, 25 production sectors, and 56 aggregated commodities. In addition, there are sufficient details on emission, energy, taxes, and trade to allow explorations in various policy issues on the environment, public finance, agriculture, and trade. In this paper, in order to introduce the additional feature of skill level by sector and by provinces without getting in too much details, we opted for a smaller data set with 11 regions (10 provinces plus territories), 12 production sectors, and 21 aggregated commodities (see Tables 2.1, 2.2, 2.3). This level of data aggregation provides a proper balance between model complexity and interesting policy analysis.

Table 2.1: Region Listing

	Code	Description
1	NF	Newfoundland
2	PEI	Prince Edward Island
3	NS	Nova Scotia
4	NB	New Brunswick
5	QC	Québec
6	ON	Ontario
7	MB	Manitoba
8	SK	Saskatchewan
9	AB	Alberta
10	BC	British Columbia
11	TR	Territories (Yukon, Northwest Territories, Nunavut)
	CD	Canada

2.2.2 Skill Intensity

The labour-related classes of inputs (wages and salaries plus supplementary labour income) used in each sector were allocated among three skill classes (low, medium and high) based on information relating sectoral employment income among the National Occupational Classification (NOC) database by province and source [3]. The NOC classifications are aggregated into our three general skill classes as follows: low (NOC levels C, D), medium (NOC level A), and high (NOC levels O, A).

To summarize the skill-intensity of various sectors, we calculated a skill intensity index I_S based on their employment of low, medium and high skilled workers as follows:

$$I_S = 3\alpha^H + 2\alpha^M + \alpha^L$$

where α^i is the proportion of workers in skill class $i = H, M, L$. We ranked the sectors accordingly. Based on the index, the 12 sectors can be split into three average skill groups (low, medium, high) each of which contains four sectors as follows:

- low average skill: proportion of high skill 10% or less and proportion of low skill at least 45%,
- medium average skill: proportion of high skill 13–18% and proportion of low skill 29–51%,

Table 2.2: Sector Listing

	Code	Abbreviation	Description
1	UTL	Utilities	Utilities
2	AGR	Agriculture	Agriculture
3	MIN	Mining	Mining
4	CON	Construction	Construction
5	FFT	Forestry	Forestry, fishing, trapping
6	SGS	Social services	Social, health and government services
7	M1	Food	Food, textiles and publishing
8	M2	Chemicals	Chemicals, rubber, plastic and metals
9	M3	Machinery	Machinery, equipment, vehicles and furniture
10	WRF	Wholesale	Wholesale, retail, financial, commercial services
11	TRN	Transportation	Transportation
12	ACE	Accommodation	Arts, entertainment, accommodation, travel

- high average skill: proportion of high skill at least 20% and proportion of low skill less than 50%.

Table 2.4 presents the share of employment income attributable to each sector for Canada as a whole. To look at it differently, we can look at the sectors based on which skill group has the highest share of employment. The only sector which is predominantly high-skill intensive is the Social, Health and Government Services sector (SGS) while Mining, Agriculture, Construction and Utilities are predominantly medium-skill intensive. The remaining seven sectors are low-skill intensive.

2.2.3 Sectoral and Regional Characteristics

We briefly describe some sectoral and regional characteristics which have some bearings to the external price shock experiments in the next two sections. We consider three manufacturing sectors ranked in terms of their level of processing and factor intensity. At one extreme, the Food, Textiles, and Publishing (M1) sector (including clothing) is relatively labour intensive. At the other extreme, the Chemicals, Rubber, Plastic and Metals (M2) sector is both highly energy and capital intensive. Within these two extremes, the Machinery, Equipment, Vehicles and Furniture (M3) sector is not energy-intensive and has a capital-labour share between the other two.

From a regional perspective, the relative importance of a sector varies significantly across provinces. For example, the Forestry, Fishing and Trapping (FFT) sector is significantly more important to the four Atlantic provinces (NF, PEI, NS, NB) and British Columbia than to the rest of the country. On the other hand, almost 63% of Canada's mining industry is located in Alberta, composed largely of oil and gas extraction. Finally, manufacturing is crucial to Ontario, and to a lesser extent Québec and British Columbia. In particular, Ontario's dominance is mainly in the Machinery, Equipment Vehicles and

Table 2.3: Commodity Listing

	Code	Abbreviation	Description
1	AGR	Agriculture	Agricultural goods
2	FFT	Forestry	Forestry, fishing, trapping
3	MIN	Mining	Mining
4	FBT	Food	Food, beverages, tobacco
5	TCL	Textiles	Textiles, clothing, and apparel
6	LWP	Lumber	Lumber and wood products
7	MMP	Metal	Metal and metal products
8	MEV	Machinery	Machinery, equipment, vehicles
9	OMP	Other manufactures	Other manufactured products
10	CON	Construction	Construction
11	TRS	Transportation	Transportation and storage
12	UTL	Utilities	Utilities,
13	CFS	Commercial	Commercial, financial services
14	AFB	Accommodation	Accommodation, food, beverage services
15	SGS	Social services	Social, health, and government services
16	ELY	Electricity	Electricity generation plus transmission
17	COL	Coal	Coal
18	CRU	Crude oil	Crude oil
19	GAS	Natural gas	Natural gas
20	RPP	Refined petroleum	Refined petroleum products
21	ORP	Other petroleum	Other petroleum and coal products

Furniture (M3) sector which accounts for over 70% of the total production in the country.

Another point worth stressing is that the markets for fuels and manufactures tend to be among those regions which are more integrated into world markets. To pick a few numbers, 80% of Canadian natural gas is exported. Crude oil is exported in Western Canada and imported in the East. Ontario and Québec are significant net importers of crude, but have limited net trade in refined petroleum. Alberta is a large net exporter of both crude oil and refined petroleum products. The net trade in crude oil and refined petroleum products by province is summarized in Table 2.5.

The most internationally open market in Canada is that for the Machinery, Equipment and Vehicles (MEV) commodity. In that case, over 85% of the domestic demand is supplied from foreign markets. Similarly, almost 80% of Canadian production is exported. This openness is due in no small part to the huge bilateral trade in motor vehicles and parts between Canada and the United States. Table 2.6 presents the provincial and sectoral composition of production in Canada and Table 2.7 presents the role played by trade in the supply and demand for various goods in Canada.

Table 2.4: Skill Intensity by Employment (%)

Code	Sector	Skill Shares Low	Med	High	Predominant Skill Intensity
SGS	Services	31	27	42	high
UTL	Utilities	30	45	25	medium
MIN	Mining	35	44	21	medium
CON	Construction	29	59	13	medium
WRF	Wholesale	47	23	30	low
M3	Machinery	48	34	18	low
M2	Chemicals	50	35	15	low
ACE	Accommodation	51	34	15	low
FFT	Forestry	49	44	7	low
AGR	Agriculture	45	53	2	medium
M1	Food	65	24	10	low
TRN	Transportation	73	18	9	low

Table 2.5: Net Exports of Crude Oil and Refined Petroleum Products ($M)

Code	Region	Crude Oil (CRU)	Refined Petroleum Products (RPP)
NF	Newfoundland	1,099	555
PEI	Prince Edward Island	0	-120
NS	Nova Scotia	-890	249
NB	New Brunswick	-3,074	2814
QC	Québec	-4,941	-145
ON	Ontario	-6,921	-892
MB	Manitoba	42	-1,025
SK	Saskatchewan	3,354	-52
AB	Alberta	11,916	5468
BC	British Columbia	589	-2,096
TR	Territories	339	-167

Table 2.6: Regional Shares of National Sectoral Output (%)

Region	Utilities UTL	Agriculture AGR	Mining MIN	Construct CON	Forestry FFT	Social SGS
Newfoundland	1.7	0.3	3.4	2.1	5.1	1.8
Prince Edward Island	0.1	0.8	0.0	0.3	1.4	0.5
Nova Scotia	2.5	1.3	1.8	2.7	7.7	3.4
New Brunswick	3.8	2.1	0.7	1.7	5.8	2.4
Québec	26.3	16.3	3.1	17.2	19.7	22.4
Ontario	36.7	23.1	5.7	33.4	10.9	38.1
Manitoba	4.6	9.6	1.0	2.8	1.2	3.9
Saskatchewan	3.4	14.7	9.9	3.9	2.5	3.3
Alberta	11.7	22.9	62.7	22.3	4.8	10.1
British Columbia	8.8	8.9	9.8	12.4	40.8	13.2
Territories	0.4	0.1	1.9	1.3	0.1	0.9

Region	Food M1	Chemicals M2	Machinery M3	Wholesale WRF	Transport TRN	Accomm ACE
Newfoundland	1.1	0.8	0.1	1.0	1.0	1.0
Prince Edward Island	0.6	0.1	0.1	0.3	0.2	0.3
Nova Scotia	2.4	1.7	0.6	2.2	2.2	2.3
New Brunswick	3.6	2.9	0.3	1.6	2.4	1.7
Québec	30.4	24.8	18.9	19.9	18.7	20.9
Ontario	34.4	48.2	71.3	44.6	35.4	40.6
Manitoba	3.1	1.7	1.6	3.0	5.0	3.3
Saskatchewan	1.8	1.8	0.5	2.5	3.8	2.7
Alberta	8.4	13.3	3.8	11.9	15.0	12.4
British Columbia	14.4	4.8	2.7	12.6	15.9	14.2
Territories	0.0	0.0	0.0	0.3	0.5	0.4

3 Fuel Price Increase Experiment

This counterfactual experiment introduces a shock of 20% increase in world prices for both imports and exports of two main types of fuels, namely, crude oil (CRU) and refined petroleum products (RPP). With the exception of the recent unexpected enormous fuel price jumps in summer 2008, a 20% price increase can be considered fairly significant in more ‘normal’ times.

We briefly explain the findings, focusing on the labour market impacts, but also noting other broader trends. Of particular concern is the extent to which the shock causes a shift of demand for labour away from the least skilled. The extent to which the shock causes a change in the pattern of production towards energy production and away from energy-intensive manufacturing will also be part of the story.

Table 2.7: Trade Orientation of Goods Demand and Supply (%)

Code	Commodity	Source of Demand Domestic	Source of Demand Imports	Destination of Supply Domestic	Destination of Supply Exports
ELY	Electricity	94.3	5.7	87.1	12.9
OMP	Other manufactures	27.7	72.3	52.8	47.2
TRS	Transportation	88.4	11.6	75.9	24.1
UTL	Utilities	93.6	6.4	94.8	5.2
COL	Coal	5.9	94.1	65.9	34.1
CRU	Crude oil	48.9	51.1	64.9	35.1
GAS	Natural gas	51.4	48.6	20.5	79.5
ORP	Other petroleum	11.3	88.7	59.4	40.6
RPP	Refined petroleum	96.8	3.2	84.4	15.6
AGR	Agriculture	78.1	21.9	77.3	22.7
MIN	Mining	69.3	30.7	65.8	34.2
CON	Construction	100.0	0.0	100.0	0.0
FFT	Forestry	92.4	7.6	88.5	11.5
FBT	Food	72.3	27.7	77.1	22.9
TCL	Textiles	23.9	76.1	46.9	53.1
LWP	Lumber	68.6	31.4	50.5	49.5
MMP	Metal	51.9	48.1	59.4	40.6
MEV	Machinery	14.1	85.9	22.9	77.1
CFS	Commercial	96.1	3.9	94.7	5.3
AFB	Accommodation	88.4	11.6	89.1	10.9
SGS	Social services	99.5	0.5	99.5	0.5

3.1 Welfare Impacts

Table 3.1 reports the welfare impacts of the shock across the regions as well as on Canada as a whole. The percentage welfare change (%) corresponds to the percentage change in the welfare of the representative agent. The dollar value welfare change ($M) is calculated by multiplying this percentage welfare change (%) with the total benchmark expenditure on consumption plus investment.

Similarly, the dollar value GDP change ($M) is calculated as the sum of the (benchmark) dollar values of all changes in real private consumption and investment as well as real government expenditure and investment (by all levels of government). The percentage GDP change (%) is this dollar value GDP change divided by the benchmark GDP.

As expected, the welfare effects of the shock coincide with each province's net trade position in crude oil and fuels (Tables 2.5, 3.1). For example, Alberta and Saskatchewan experience a marked welfare improvement (over 1% for both). Welfare losses for other regions are typically less dramatic, with the maximum loss being near 1% for Prince Edward Island and Nova Scotia.

Table 3.1: Fuel Price Increase: Welfare Summary

Region	Welfare Change		GDP Change	
	(%)	($M)	(%)	($M)
Newfoundland	1.29	174.72	1.02	179.99
Prince Edward Island	-1.08	-31.71	-0.59	-23.60
Nova Scotia	-0.72	-162.89	-0.26	-78.71
New Brunswick	1.10	188.71	0.68	153.11
Québec	-0.51	-869.68	-0.29	-633.37
Ontario	-0.12	-398.06	0.02	93.75
Manitoba	-0.27	-73.33	-0.09	-30.90
Saskatchewan	2.18	558.21	1.99	650.40
Alberta	1.45	1559.62	1.31	1685.44
British Columbia	-0.23	-249.88	-0.09	-122.88
Territories	-0.54	-19.94	-0.25	-15.17
Canada	0.08	675.76	0.18	1858.06

Although Alberta's welfare and GDP effects are much larger than those in Saskatchewan (roughly three times as big) they are larger in percentage terms in Saskatchewan. This is due to the relative size of crude oil output relative to refined products output in Saskatchewan. The refining industry in Alberta is bigger, both absolutely *and* relative to crude oil mining in Alberta than Saskatchewan. Alberta produces about four times as much crude and *ten* times as much refined products as Saskatchewan. Because of the composition of Saskatchewan's economy (relatively small refining sector) that province does not experience the dampening effect of higher crude oil prices on refining.

3.2 Real Wages

Table 3.2 presents the impacts of the price shock on real wages by province and skill level. The increase in energy prices causes total real labour income to fall Canada-wide. Real wages fall in most regions and skill classes. Further, the wage reductions tend to be largest in the low skill classes. Among provinces, the losses in real wages of low-skilled workers are *highest* in the energy-exporting provinces of Western Canada. This is partially attributable to higher than average increases in the consumer price index in these energy-exporting regions. To the extent that there are real wage gains, they tend to be among high-skilled workers in energy-importing regions of Eastern Canada.

3.3 Sectoral Employment

Table 3.3 reports the change in total employment (all skill classes) by sector and region. Even at this relatively aggregated level, the story is mixed due to a number of factors such as:

Table 3.2: Fuel Price Increase: Real Wage Change (%)

Region	Skill Level		
	Low	Med	High
Newfoundland	0.59	1.88	1.19
Prince Edward Island	-1.85	-0.73	0.65
Nova Scotia	-1.57	-1.07	0.66
New Brunswick	-4.27	17.31	-2.52
Québec	-0.81	-0.66	0.29
Ontario	-0.23	-0.41	0.21
Manitoba	-0.56	-0.65	0.26
Saskatchewan	-5.93	-1.54	-1.36
Alberta	-2.87	0.01	0.02
British Columbia	-0.73	-0.73	-0.34
Territories	-0.89	-0.55	-0.55

- differing fuel input intensities,
- differing output mix (especially in terms of crude oil or fuels),
- different skill mix (if skilled wages rise relative to unskilled, this will tend to hurt employment in sectors whose employment is mostly skilled workers),
- different net trade stance of a given industry in different regions,
- susceptibility to income effects (sectors which produce largely final goods are more subject to income effects than those which produce mostly intermediate goods).

With this array of different influences, it is perhaps not surprising that the pattern of employment changes is so mixed. Some broad trends emerge, but they are rarely universal.

Employment in the Agriculture (AGR) and Transportation (TRN) sectors declines in almost all provinces. These sectors are fuel-intensive with a very low skill mix. Mining (MIN) is also fuel (input) intensive, and declines except for those provinces whose mining sectors produce significant crude oil, which expand. Canada-wide, mining expands over 14%, driven by crude exporters.

Employment in the Forestry, Fishing and Trapping (FFT) sector declines everywhere except Ontario and Québec. The input mix of this sector is dramatically different in Ontario and Québec than in Atlantic Canada and Western Canada. The fuel intensity of this sector in Atlantic Canada, for example, is much higher than in Ontario or Québec.

Employment in the two largest service sectors, namely, Social, Health and Government Services (SGS) and Wholesale, Retail, Financial and Commercial Services (WRF) expands overall. These sectors are among the largest sectors in the economy and also among the least fuel intensive. As well, they are in the more skilled segment of sectors nationally.

Canada-wide, all three manufacturing sectors decline. Having said this, the variation among provinces is very large, even within a given sector. The Chemicals, Rubber, Plastic and Metals (M2) sector is a case in point. This sector is very energy intensive. Primary metals, metal products and mineral products tend to use a lot of natural gas and electricity.

Table 3.3: Fuel Price Increase: Sectoral Employment Change (%)

Code	Sector	NF	PE	NS	NB	QC	ON
UTL	Utilities	-1.1	18.5	-0.7	3.6	-0.1	0.2
AGR	Agriculture	-3.0	-7.9	-4.8	-31.4	-4.1	2.0
MIN	Mining	4.1	-3.0	-2.5	649.2	-10.5	-1.2
CON	Construction	0.8	-0.5	-0.2	3.0	-0.3	0.1
FFT	Forestry	-4.4	-3.9	-1.9	-47.4	1.5	1.9
SGS	Social services	0.2	0.5	0.9	-0.7	0.3	0.5
M1	Food	-8.3	-4.4	0.4	-31.8	2.1	1.0
M2	Chemicals	31.0	-2.7	-12.8	-54.3	-8.0	1.3
M3	Machinery	-17.6	4.9	6.6	-100.0	6.1	-4.4
WRF	Wholesale	-1.7	0.8	0.9	-2.0	0.5	0.4
TRN	Transportation	8.1	-4.1	-4.4	-18.5	-4.3	1.7
ACE	Accommodation	1.0	2.9	-0.9	-12.9	-1.1	-1.0

Code	Sector	MB	SK	AB	BC	TR	CD
UTL	Utilities	-0.1	8.0	1.1	-0.3	-0.8	0.4
AGR	Agriculture	0.3	-24.0	-4.2	6.2	21.5	-2.7
MIN	Mining	1.0	36.7	5.5	3.1	0.2	14.4
CON	Construction	0.1	2.8	1.7	0.1	-0.3	0.5
FFT	Forestry	-0.6	-17.2	-6.9	-0.2	-4.6	-3.3
SGS	Social services	0.4	2.3	1.0	0.4	0.3	0.5
M1	Food	-2.2	-21.8	-5.4	-0.1	0.0	-1.0
M2	Chemicals	-0.9	-1.3	-1.8	10.2	-5.2	-1.6
M3	Machinery	-4.0	-50.6	-4.2	-14.5	0.0	-3.4
WRF	Wholesale	0.7	-1.5	-0.7	0.4	0.7	0.2
TRN	Transportation	0.8	-16.9	-6.4	-1.9	-0.7	-2.3
ACE	Accommodation	-0.7	9.5	1.0	-0.4	-3.1	-0.6

Chemical production (including refining) tends to use a lot of crude oil and fuels. As a result, the sector's costs go up sharply. Having said this, the value of one of their outputs (fuels) also goes up. For provinces where fuel production is a more dominant part of production, the price increase of fuels leads to higher employment (as in Newfoundland and British Columbia). In all other provinces where refining is a smaller share of production, employment declines.

The other two manufacturing sectors decline in most provinces. Although these sectors are less energy intensive than M2, they are still more energy-intensive than the (large) service sector.

Table 3.4: Fuel Price Increase: Macroeconomic Overview (%)

Region	Labour Income	Investment	Total Exports	Total Imports
Newfoundland	1.1	0.9	5.4	1.8
Prince Edward Island	-0.9	-0.6	-3.0	0.1
Nova Scotia	-0.9	-0.3	-2.5	-2.0
New Brunswick	2.3	0.4	-13.5	-18.7
Québec	-0.5	-0.3	-0.1	-0.3
Ontario	-0.2	0.0	-2.0	-0.7
Manitoba	-0.4	-0.1	-1.7	0.1
Saskatchewan	-3.4	2.1	1.7	-1.4
Alberta	-1.2	1.5	0.9	0.8
British Columbia	-0.6	-0.1	-0.4	0.5
Territories	-0.9	-0.4	-0.5	0.4
Canada	-0.5	0.3	-1.1	-0.7

3.4 Summary for Fuel Price Experiment

The impact of the fuel price increase varies from province to province, but some general pattern emerge. First, real labour incomes decline in most provinces, including the two whose percentage welfare increase was largest (Alberta and Saskatchewan). Second, real wages decline in all provinces except Newfoundland, and even there the increase in real wages for low-skilled workers is still markedly less than the increase for their medium and high-skilled counterparts. The reductions is real wages of the least skilled are not dramatic, tending to be in the range of 2-6%.

4 Manufactures Price Drop Experiment

This section explores the consequences of a counterfactual experiment in which both export and import prices drop by 10% for four manufactured goods, namely, Textiles, Clothing and Apparel (TCL), Metal and Metal Products (MMP), Other Manufactured Products (OMP), and Machinery Equipment, Vehicles and Furniture (MEV). These goods are produced by all three manufacturing sectors (M1, M2, M3). Note, however that the output composition of a given sector differs across regions.

The direct effect of this shock will be to reduce consumer prices, thereby increasing welfare and real wages. The shock's indirect effects will come as the demands for capital and different skill classes of labour shift relative to one another. One would expect this to have a larger effect in regions where manufacturing is a large share of the provincial economy, and smaller impacts where manufacturing is a small share

Table 4.1: Manufactures Price Drop: Welfare Summary

Region	Welfare Change (%)	Welfare Change ($M)	GDP Change (%)	GDP Change ($M)
Newfoundland	3.57	482.76	2.43	430.33
Prince Edward Island	2.52	73.78	1.14	46.08
Nova Scotia	1.99	448.22	0.38	115.52
New Brunswick	2.73	466.89	1.57	355.17
Québec	0.75	1280.83	0.46	1024.17
Ontario	0.00	-11.14	-0.24	-939.13
Manitoba	0.92	247.66	0.79	278.52
Saskatchewan	2.69	688.12	2.29	747.98
Alberta	2.73	2933.36	2.45	3148.28
British Columbia	2.47	2625.31	2.01	2679.97
Territories	2.94	109.37	2.09	127.93
Canada	1.14	9345.15	0.78	8014.84

4.1 Welfare Impacts

The welfare impacts in Table 4.1 indicate that welfare improves in all regions except Ontario, which experiences a very small welfare loss. Ontario is a significant net exporter of manufactured goods to the rest of Canada and the rest of the world. For Ontario in particular, reduced world prices of manufactured goods poses a significant competitive threat, but even there, the welfare gains from lower prices almost balance the losses

4.2 Real Wages

Total labour income in Canada falls slightly by 0.3% (Table 4.5) which is somewhat similar to the previous experiment (Table 3.4). In this case, this change result is driven by the decline of real wages in Ontario and Québec. Unlike the previous experiment, there is a more significant impact on the structure of real wages.

In this case, in contrast to the fuel price experiment, *the overall trend is for lower skilled wages to rise and the higher skilled wages to fall* (Table 4.2). In the provinces where low-skill real wages fall, the changes are all less than 1.4%. Notably, in two provinces where low-skill real wages fall (Ontario and Manitoba), real wages fall across the range of skill levels.

It is important to remember that, in contrast to the energy price shock, this shock's direct effect is to increase real wages. To cause some group's real wages to fall, the shift against that factor would have to exceed the direct effect of the price changes on consumer prices.

The goods whose prices fell are those which tend to constitute a higher share of output of the more processed manufacturing sectors. This is summarized in Table 4.3. Even

Table 4.2: Manufactures Price Drop: Real Wage Change (%)

Region	Skill Level		
	Low	Med	High
Newfoundland	5.34	2.45	0.60
Prince Edward Island	4.33	-0.83	-6.09
Nova Scotia	0.94	-1.35	-5.15
New Brunswick	2.44	3.48	-3.54
Québec	2.37	-3.16	-1.69
Ontario	-0.35	-2.46	-0.56
Manitoba	-1.37	-4.27	-1.99
Saskatchewan	1.02	0.93	0.24
Alberta	-0.82	2.18	0.93
British Columbia	3.23	-0.80	-1.22
Territories	1.94	-2.28	-2.28

though the Food, Textiles and Publishing (M1) sector includes clothing and textiles (whose world prices also fall) this commodity accounts for a small share of the sector's output (20% or less) for all provinces. By contrast, the affected goods usually account for well in excess of 50% of the output of the other two sectors, and in several cases over 80% of the output share. Recall also that the Food, Textiles and Publishing sector (alone among manufacturing sectors) has a very high proportion of low-skilled workers. The change in wage structure reflects the combination of the sectoral output patterns and skill intensities within manufacturing.

Table 4.3: Manufactures Price Drop: Shares of Sectoral Output (%)

Region	Manufacturing Sector		
	Food M1	Chemicals M2	Machinery M3
Newfoundland	1.8	14.0	85.7
Prince Edward Island	1.4	81.7	87.5
Nova Scotia	9.0	53.0	82.2
New Brunswick	4.0	21.1	54.3
Québec	20.3	77.0	82.5
Ontario	11.3	78.9	89.9
Manitoba	13.1	91.8	78.4
Saskatchewan	4.4	56.8	67.5
Alberta	14.7	58.7	77.1
British Columbia	5.8	79.1	75.9

4.3 Sectoral Employment

Table 4.4: Manufactures Price Drop: Sectoral Employment Change (%)

Code	Sector	NF	PE	NS	NB	QC	ON
UTL	Utilities	-2.1	4.3	2.8	2.5	5.1	2.1
AGR	Agriculture	4.3	21.6	3.8	0.7	1.1	22.8
MIN	Mining	-2.6	-2.8	12.0	113.3	29.7	57.3
CON	Construction	2.3	1.4	1.7	1.8	1.2	0.9
FFT	Forestry	17.0	19.8	19.4	10.8	21.2	3.9
SGS	Social services	-1.0	-1.4	-2.6	-1.6	-0.1	-0.5
M1	Food	18.0	26.2	18.6	15.0	23.6	23.1
M2	Chemicals	8.2	-29.6	-1.1	-9.1	-5.7	-3.3
M3	Machinery	-21.3	-36.2	-30.9	-100.0	-43.0	-35.9
WRF	Wholesale	-1.3	-4.2	-0.2	-2.8	2.5	3.9
TRN	Transportation	1.5	-4.7	3.2	-4.4	3.0	11.2
ACE	Accommodation	-7.3	3.8	4.8	0.3	-0.1	4.6

Code	Sector	MB	SK	AB	BC	TR	CD
UTL	Utilities	5.6	-1.3	-0.5	14.7	-0.6	3.7
AGR	Agriculture	35.2	25.6	5.5	-2.4	340.0	12.1
MIN	Mining	-29.5	-5.1	4.1	9.6	3.4	11.8
CON	Construction	2.9	2.7	2.6	2.2	3.3	1.6
FFT	Forestry	17.1	-9.5	-14.6	21.5	-21.9	16.1
SGS	Social services	1.1	1.0	1.1	0.7	0.6	-0.1
M1	Food	28.0	4.7	-15.8	25.1	0.0	18.6
M2	Chemicals	-40.7	8.9	2.8	-16.0	-0.1	-5.0
M3	Machinery	-37.0	-55.9	-9.0	-69.1	0.0	-38.9
WRF	Wholesale	0.7	-0.5	-1.9	-0.6	-3.2	2.0
TRN	Transportation	8.0	7.2	4.9	0.2	-10.1	5.8
ACE	Accommodation	9.5	-3.1	5.0	-1.2	-4.7	2.5

The sectoral employment changes of the manufacturing sector exhibit a number of regularities (Table 4.4).[2] First, employment in all provinces' Machinery, Equipment, Vehicles and Furniture sectors (M3) declines.[3] Employment in Food, Textiles and Publishing (M1) expands in all provinces except Alberta. Employment in Chemicals, Rubber, Plastic and Metals (M2) declines in all provinces except Newfoundland, Saskatchewan and Alberta.

[2]One surprising finding is the 340% increase in employment in the Territories' agriculture sector. This sector is very small (accounts for less than 1/10 of one percent of employment). In dollar terms, this expansion means that employment goes from \$2 million to about \$7 million.

[3]Because of the small size of the territories' manufacturing sector, it was not disaggregated. The entire sector was allocated to M2.

Note that in all three cases, the output share of affected goods is below the arithmetic average for that sector (61%). They are well below five provinces whose shares exceed 75% (Table 4.3). The pattern of employment changes within manufacturing falls naturally from the combination of output patterns and skill patterns mentioned before. Because of the high exposure to trade influences in some sectors, the reductions in employment in some sectors and provinces are quite large

This experiment also has considerable effects on each province's volume of (total) international trade. The changes in world prices modeled amount to a change in what trade economists call the terms of trade. As a general rule, one can not say whether this will cause total trade to rise or fall. In simple models, movements of the terms of trade toward the autarky (no trade) price ratio reduce total trade volume, whereas those that move economies away from their autarky price ratio increase trade. In the absence of trade, a province whose economy is dominated by manufacturing would tend to have relatively inexpensive manufactured goods. This is what we mean by autarky relative prices. In the absence of trade, we would expect manufactured goods in resource-based economies like Alberta and British Columbia to be relatively expensive

Given the relative manufacturing intensities of their economies, one would expect that the fall in prices of manufactured goods would represent a movement towards autarky relative prices for Québec and Ontario, and a movement away from their autarky price ratios for most if not all of the rest of Canada. This explanation seems be consistent with the findings in Table 4.5

Table 4.5: Manufactures Price Drop: Macroeconomic Overview (%)

Region	Labour Income	Investment	Total Exports	Total Imports
Newfoundland	3.3	3.2	7.6	2.9
Prince Edward Island	0.3	2.0	14.4	3.5
Nova Scotia	-1.3	2.0	6.2	1.1
New Brunswick	1.4	2.6	4.5	-1.7
Québec	-0.4	1.0	-6.8	-5.5
Ontario	-1.0	0.2	-14.0	-10.3
Manitoba	-2.3	1.3	-2.4	-1.1
Saskatchewan	0.8	2.8	3.9	4.7
Alberta	0.6	3.0	1.5	2.4
British Columbia	0.9	2.6	4.6	0.9
Territories	1.9	3.1	3.5	2.8
Canada	-0.3	1.5	-7.0	-5.8

4.4 Summary for Manufactures Price Experiment

The result of price reductions for the range of goods considered here are to improve welfare for most regions, but to reduce real labour incomes by a relatively small amount. More significant is the improvement of real earnings for low-skilled workers in most provinces. The goods whose prices were reduced tended to be more processed and tended to be produced by more skilled labour. Those two factors help explain the inter-sectoral movements of employment and the shift in the structure of real wages. In this case, the volume of international trade falls, driven largely by a large reduction in Ontario and Québec's trade volume. Outside of those two provinces trade volume rises, as expected.

5 Summary and Conclusions

The simulation results seem to suggest that a fuel price shock is likely to have a more marked negative impact on real wages and the skill-distribution of real wages (i.e., low-skilled wages decline relative to high skilled). By contrast, even though the manufactured goods price shock reduces real earnings, its distributional impacts favour the less skilled. In terms of policy, this paper suggests that *rising energy prices may represent a greater threat to unskilled workers than cheap imports of manufactured goods*.

Several caveats (including parameter uncertainty and data issues) should be added to these findings, but another important one comes to mind. The manufactured goods scenario focused on a wide range of manufactured goods, but they tended to be at the higher skill end of the spectrum. If the price reductions were concentrated among goods produced by low-skilled workers, the result might be different.

The paper can be extended in a number of possible directions as follows:

- Labour markets respond to many sorts of economic shocks. Changes in the trade policy environment, the regulatory environment or terms of trade have indirect impacts on the labour market. Because the nature of these shocks is through other markets, CGE models have frequently been used to analyse their labour market impacts.
- While it is always tempting to make a model dynamic, it is important to gauge the relative return to making the model dynamic, versus turning one's attention to other issues or adding other refinements which might not be supportable in a dynamic model. It seems that there are a number of fruitful extensions of this work that would be well-suited to the static framework.
- One critical empirical issue not investigated in this paper is the nature of the substitution possibilities between and among the classes of labour and capital. We are unaware of significant empirical evidence on this topic. The structure used in this paper is that there is substitution among labour classes and that this labour composite substitutes for capital in production. It would seem highly likely, however that the nature of complementarities and substitutability among these factors is more complex than this.
- Another possible extension would be to consider an interim-run version of the model to reflect unemployment (through wage rigidities) and/or some degree of sector-specificity of primary inputs. These changes could reduce the sectoral reallocations, but exacerbate welfare effects and income loss (through unemployment).
- In the longer term, some mobility issues come to mind as topics of interest:
  - occupational/skill mobility: in the current model, workers are unable to upgrade their skills if skill premia increase. It might be useful to investigate the process and impact of skill acquisition in either a static or dynamic setting.

– regional mobility: in the current model, workers are inter-regionally immobile. It would be interesting to investigate the process of interregional migration in either a dynamic or static setting.

References

[1] Armington, Paul S. (2007). "A Theory of Demand for Products Distinguished by Place of Production," *International Monetary Fund Staff Papers*, 16:2, 159-176.

[2] Brooke, Anthony, David Kendrick, Alexander Meeraus, and Ramesh Raman (2007). *GAMS A User's Guide*. Washington, DC: GAMS Development Corporation.

[3] Census of Canada (2001). *Employment and Employment Income by Province and Sector: Custom Tables from the 2001 Census Provided to Human Resources and Skills Development Canada*. Statistics Canada, Technical Report.

[4] Harris, Richard G. and Peter E. Robertson (2007). "The Dynamic Effects of Skilled Labour Targeting in Immigration Program." University of New South Wales, School of Business, Discussion Paper 2007/21.

[5] Jung, Hong-Sang and Erik Thorbecke (2003). "The Impact of Public Education Expenditure on Human Capital, Growth, and Poverty in Tanzania and Zambia: A General Equilibrium Approach." *Journal of Policy Modeling*, 25, 701–725.

[6] Nguyen, Trien T., Krista Phillips, Karen Huff, Tracy Snoddon, and Randall M. Wigle (2007). "CREAP 2001 Verion 3.0 Data Documentation and Methods." University of Waterloo and Wilfrid Laurier University, Technical Report, October 2007.

[7] Nguyen, Trien T., Tracy Snoddon, and Randall M. Wigle (2007). "BMRT 2001 Verion 3.0 Model Documentation." University of Waterloo and Wilfrid Laurier University, Technical Report, October 2007.

[8] Rutherford, Thomas F. (2007). *MPSGE Manual*. Washington, DC: GAMS Development Corporation.

[9] Statistics Canada Input-Output Division (2005). *The Input-Output Structure of the Canadian Economy 2000-2001*. Statistics Canada, Technical Report 15-201-XIE.

A Theoretical Model Structure

This section describes the analytical structure of the basic model used in the paper. In this multi-regional framework, Canada consists of several provinces producing goods and engaging in trade with each other as well as with the rest of the world (ROW). Each province has one representative agent denoted by $h \in H$. Goods are denoted by $i \in I$ and sectors denoted by $j \in J$. Primary factors include capital (K) and labor (L). In particular, labor can be used either for leisure to increase utility or for work to earn income. Factors are mobile within any given province but immobile across provincial boundaries.

Note that, for convenience, we use both styles of index notations, say, $a \in A$ and $a = 1, \ldots, A$ interchangeably although strictly speaking, the second style should be written as $a = 1, \ldots, \aleph_A$ where $\aleph_A$ denotes the number of elements in the index set A.

A.1 Demand

Each representative agent $h \in H$ has a two-level nesting utility structure with the first level being a constant elasticity of substitution (CES) aggregator of demands for leisure Λ_h and composite good C_h

$$U_h = \text{CES}(\Lambda_h, C_h) \tag{A.1}$$

At the second level, the composite good C_h is defined by a Cobb-Douglas (CD) aggregator of demands for all final goods C_{hi} with $i \in I$

$$C_h = \text{CD}(C_{h1}, \ldots, C_{hI}) \tag{A.2}$$

Consumer demands are derived from maximizing utility subject to the budget constraint $E_h \leq I_h$, namely, the expenditure E_h must not exceed the endowment income I_h. On the expenditure side, consumers take goods prices p_{hi} plus sales taxes tc_{hi} as given

$$E_h = \sum_{i \in I} p_{hi}(1 + tc_{hi})C_{hi} \tag{A.3}$$

while on the income side, they receive incomes from endowments $\overline{K}_h$ of capital and $\overline{L}_h$ of labor (net of demands for leisure Λ_h). In addition, they receive government tax transfers R_h and foreign exchange transfers E_h^e (denominated in domestic currency). Factor prices (r_h, w_h) minus direct factor taxes (tk_h, tl_h) are taken as given.

$$I_h = r_h(1 - tk_h)\overline{K}_h + w_h(1 - tl_h)(\overline{L}_h - \Lambda_h) + E_h^e + R_h \tag{A.4}$$

A.2 Production

Each sector $j \in J$ in province $h \in H$ is denoted by the double index hj and its outputs $i \in I$ are denoted by the triple index hji. Each sector hj has a multi-product activity described by a constant elasticity of transformation (CET) aggregator $\mathcal{F}_{hj}$ of several outputs on the left-hand side and a two-level nesting structure of inputs on the right-hand side

$$\mathcal{F}_{hj}(Y_{hj1}, \ldots, Y_{hjI}) = F_{hj}(\text{IG}_{hj}, \text{VA}_{hj}) \tag{A.5}$$

On the input side, the top level F_{hj} is a Leontief fixed-coefficient (FC) aggregator of intermediate goods IG_{hj} and value-added VA_{hj} which are in turns constructed as FC aggregators of intermediate inputs I_{hji} (eq. A.6) and CES aggregators of factor inputs K_{hj} and L_{hj} (eq. A.7)

$$\text{IG}_{hj} = \text{FC}(I_{hj1}, \ldots, I_{hjI}) \tag{A.6}$$
$$\text{VA}_{hj} = \text{CES}(K_{hj}, L_{hj}) \tag{A.7}$$

On the output side, sectoral output Y_{hji} is further fed into an additional CET aggregator and split in domestic goods Q_{hji} and exports X_{hji}

$$Y_{hji} = \text{CET}(Q_{hji}, X_{hji}) \tag{A.8}$$

This domestic-export transformation thus divides sectoral outputs Y_{hji} into two components, namely, Q_{hji} destined for domestic usages and X_{hji} for exports.

Firms take output prices p_{hi} and factor prices r_h, w_h as given which include applicable taxes to_{hji} on outputs, ti_{hji} on intermediate inputs, and tk_{hj}, tl_{hj} on primary factors. Under perfect competition and constant returns to scale, zero profit conditions require that each sector hj must balance its total revenue R_{hj} with total cost C_{hj}

$$R_{hj} = \sum_{i \in I} p_{hi}(1 - to_{hji})Y_{hji} \tag{A.9}$$
$$C_{hj} = \sum_{i \in I} p_{hi}(1 + ti_{hji})I_{hji} + r_h(1 + tk_{hj})K_{hj} + w_h(1 + tl_{hj})L_{hj} \tag{A.10}$$

Provincial aggregates are obtained by summing the supplies of domestic goods Q_{hji} and exports X_{hji} over all sectors

$$Q_{hi} = \sum_{j \in J} Q_{hji} \tag{A.11}$$
$$X_{hi} = \sum_{j \in J} X_{hji} \tag{A.12}$$

A.3 Trade

On the import side, domestic goods and imports are combined into Armington composite goods A_{hi} according to the following two-level nesting structure:

$$A_{hi} = \text{CES}(M^w_{hi}, D_{hi}) \tag{A.13}$$
$$D_{hi} = \text{CES}(M^1_{hi}, \ldots, M^H_{hi}, Q_{hi}). \tag{A.14}$$

The first level is a CES aggregator of imports M^w_{hi} from ROW and domestic composites D_{hi}. The second level is an additional CES aggregator of domestic goods Q_{hi} and imports $M^1_{hi}, \ldots, M^H_{hi}$ from other provinces (no imports from own sources, i.e., $M^h_{hi} = 0$).

On the export side, the supplies of provincial export goods X_{hi} produced must add up to the total amounts of exports $X_{hi}^1, \ldots, X_{hi}^H$ to other provinces (no exports from own sources, i.e., $X_{hi}^h = 0$) and exports X_{hi}^w to ROW

$$X_{hi} = \sum_{h' \in H} X_{hi}^{h'} + X_{hi}^w. \tag{A.15}$$

A.4 Balance of Payment

The link between world prices $\overline{\pi}_i^w$ (in foreign currency) and domestic prices $\overline{p}_i^w$ (in domestic currency) is defined by the price relationship

$$\overline{p}_i^w = \varepsilon \, \overline{\pi}_i^w \tag{A.16}$$

where ε denotes the real foreign exchange rate (e.g., relative price of the Canadian dollar against the American dollar).

At the provincial level, trade imbalances between imports M_{hi}^w from ROW and exports X_{hi}^w to ROW can lead to the following excess demands (or excess supplies) BP_h of foreign exchange

$$\mathrm{BP}_h = \sum_{i \in I} \overline{\pi}_i^w \left(M_{hi}^w - X_{hi}^w \right) \gtreqless 0 \tag{A.17}$$

These excess demands are linked to consumer incomes I_h by an equivalent amount of foreign exchange transfers E_h^e (denominated in domestic currency)

$$E_h^e = -\varepsilon \, \mathrm{BP}_h \lesseqgtr 0 \tag{A.18}$$

That is, provinces with an excess demand for foreign exchange ($\mathrm{BP}_h > 0$) must offset it with a negative foreign exchange transfer to consumers ($E_h^e < 0$), and vice versa. Each province thus achieves an "extended" foreign exchange market equilibrium by

$$\mathrm{BP}_h + \frac{E_h^e}{\varepsilon} = 0 \tag{A.19}$$

At the national level, the excess demands for foreign exchange BP_i are derived by aggregating values of imports and exports of all provinces

$$\mathrm{BP}_i = \overline{\pi}_i^w \sum_{h \in H} \left(M_{hi}^w - X_{hi}^w \right) \tag{A.20}$$

Summing over all goods, we have the balance of payment at the national level

$$\sum_{i \in I} \mathrm{BP}_i = \sum_{i \in I} \overline{\pi}_i^w \sum_{h \in H} \left(M_{hi}^w - X_{hi}^w \right) = \sum_{h \in H} \sum_{i \in I} \overline{\pi}_i^w \left(M_{hi}^w - X_{hi}^w \right) = \sum_{h \in H} \mathrm{BP}_h. \tag{A.21}$$

Since provinces offset their foreign exchange deficits/surpluses by equivalent amounts of transfers E_h^e to their consumers, we can aggregate (eq. A.19) to the national level as follows:

$$\sum_{i \in I} \mathrm{BP}_i = \sum_{h \in H} \mathrm{BP}_h = -\frac{1}{\varepsilon} \sum_{h \in H} E_h^e \tag{A.22}$$

Therefore, the condition for a national balance of payment equilibrium becomes

$$\varepsilon \sum_{i \in I} \mathrm{BP}_i + \sum_{h \in H} E_h^e = 0 \tag{A.23}$$

which can be solved for the equilibrium foreign exchange ε.

A.5 Government Revenues

Government revenues T_h are defined by

$$T_h = T_h^c + T_h^p \tag{A.24}$$

where T_h^c denotes revenues from sales taxes on consumer final demands for goods and direct taxes on factor endowment incomes (net of leisure)

$$T_h^c = \sum_{i \in I} tc_{hi}\, p_{hi}\, C_{hi} + tk_h\, r_h\, \overline{K}_h + tl_h\, w_h\, (\overline{L}_h - \Lambda_h) \tag{A.25}$$

and T_h^p denotes revenues from producer taxes on primary factors, intermediate inputs, and outputs

$$\begin{aligned} T_h^p = \sum_{j \in J} tk_{hj}\, r_h\, K_{hj} + \sum_{j \in J} tl_{hj}\, w_h\, L_{hj} + \sum_{j \in J} \sum_{i \in I} ti_{hji}\, p_{hi}\, I_{hji} \\ + \sum_{j \in J} \sum_{i \in I} to_{hji}\, p_{hi}\, Y_{hji} \end{aligned} \tag{A.26}$$

A.6 Market Clearings

At equilibrium, the following market clearing conditions must be satisfied:

$$\sum_{j \in J} K_{hj} = \overline{K}_h \qquad \text{capital market} \tag{A.27}$$

$$\sum_{j \in J} L_{hj} = (\overline{L}_h - \Lambda_h) \qquad \text{labor market} \tag{A.28}$$

$$\sum_{j \in J} I_{hji} + C_{hi} = A_{hi} \qquad \text{Armington goods market} \tag{A.29}$$

$$\varepsilon \sum_{i \in I} \mathrm{BP}_i + \sum_{h \in H} E_h^e = 0 \qquad \text{foreign exchange market} \tag{A.30}$$

$$R_h = T_h \qquad \text{government budget} \tag{A.31}$$