Modeling Employment Transitions in the GTAP-RD model: an illustration of CUSMA (or USMCA)

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Abstract

Trade plays an important role in driving economic growth and job creation. However, the gains from trade can be unequally distributed across countries, sectors and workers with consequent effects on household incomes. In recent years, countries, like Canada, committed to pursuing an inclusive approach to trade, which to ensure the benefits that flow from trade are more widely shared, including with under-represented groups, such as women. To understanding the economic link between changes in global trade and specific labour force requires the use of a global economic model capable of capturing economic interactions and detailed labour market mechanisms. This paper extends the standard labour market specification in the GTAP Recursive Dynamic (GTAP-RD) model by incorporating an employment transition matrix approach which captures employment reallocation across occupation types following earlier work by Dixon and Rimmer (2008) for the United States and Chen and Xiao (2018) for Canada. We highlight the usefulness of this new labour market specification in GTAP-RD by tracking employment reallocation across various occupation types by genders, into and out of the labour force in response to changing trade policies in North American Countries.

1. INTRODUCTION

Employment and income distribution are an integral part of the general equilibrium effects of international trade. However, in the CGE literature, unlike trade liberalization and climate policy, the labour market has not been one of the main points of attention. A lot of time a simplest set of assumption about labour market, such as fix employment, elastic or unitary labour supply, are adopted in some classical CGE works.

In recent years, countries, like Canada, committed to pursuing an inclusive approach to trade, which to ensure the benefits that flow from trade are more widely shared, including with under-represented groups, such as women. To understanding the economic link between changes in global trade and specific labour force requires the use of a global economic model capable of capturing economic interactions and detailed labour market mechanisms. In this paper, we incorporate a mechanism which endogenises labour supply in disaggregated labour market groups to the GTAP Recursive Dynamic (GTAP-RD) model. These groups are defined by relevant labour market characterisitics, such as genders, occupations, and age. By doing so, we not only can answer the questions about "What are the effects on wages and unemployment?", but also about "Who gains and who loses?"

There are some studies link CGE model with some microsimulation to analyse the impacts of external shocks to income distribution, e.g. Hérault (2007) for South Africa, Bourguignon and Savard (2008) for the Philippines, Cogneau and Robilliard (2008) for Madagascar, and Bussolo et al (2008) for Latin America. And more recently, Zhang et al. (2022) applied similar framework to study the unequal effect of the COVID-19 pandemic on labour market in China. One of the drawback of such a linked

microsimulation-CGE approach is no feedback loop to the macro model, ie, lack of labour supply response.

Another stream of framework was firstly introduced by Dixon and Rimmer (2008), who analysed the labour market effects of restricting employment of illegal immigrants in the U.S. by either stricter border controls or higher fines for employers. This framework is subsequently modified and applied by Tran et al.(2012) for Australia and Chen and Xiao (2018) for Canada. Under this framework, the start-of-year stocks of persons thus classified are based on labour market activities undertaken in the previous year, after taking account of relevant exogenous transitions between labour market categories, such as the gradual transition from younger age categories to older age categories. Having determined start-of-year stocks of persons in each category, labour supplies to various labour market activities in the current year are guided by movements in relative wage rates across those activities. Full details of the labour market theory are provide in Section 2.

In Section 3 of the paper, we will take a closer look at the data for this labour module. An illustrative example of CUSMA will be discussed in Section 4. Section 5 concludes our study and lays out some potential research directions.

2. MODEL FRAMEWORK FOR LABOUR MARKET

2.1 Key concepts

This section defines the key concepts underpinning the modelling of the labour market in GTAP-LAB. Since the labour market mechanism are the same for all regions, we drop the regional dimension for the discussion in this section to simplify the notation. For example, the labour supply of occupation o, gender g, age group a in region r, $L_t(o,g,a,r)$, is simplified to $L_t(o,g,a)$.

2.1.1 Characteristics of the working age population

The working age population (WAP) includes all persons 15 and older. The WAP from the International Labour Organization (ILO) is divided into groups based on common characteristics such as labour market activities, gender and age. The WAP is defined according to the following characteristics:

Labour market function[1]	(1) Managers; (2) Professionals; (3) Technicians and associate professionals; (4) Clerical support workers; (5) Service and sales workers; (6) Skilled agricultural, forestry and fishery work; (7) Craft and related trades workers; (8) Plant and machine operators, and assemblers; (9) Elementary occupations; (10) unemployment; (11) Not in the labour force.
Gender	Male and Female.
Age	(1) 15-24; (2) 25-34; (3) 35-44; (4) 45-54; (5) 55-64; (6) 65+.

We aggregated the 9 occupations into the 5 occupations: 1) Officials and mangers, 2) Technicians/Associate Professional, 3) Service/Shop workers, 4) Clerks, 5) Agricultural and Unskilled Labour. Table 2.1 shows the mapping between two classifications.

Table 2.1. Mapping of 9 occupations to 5 occupations

Occupation from ILO (ISOC)	Occupation from GTAP	Abbreviation
1. Managers	Officials and managers	off_mgr_pros
2. Professionals	Techinicians/AssocProfessional	tech_aspros
3. Technicians and associate professionals	Techinicians/AssocProfessional	tech_aspros
4. Clerical support workers	Clerks	clerks
5. Service and sales workers	Service/Shop workers	service_shop
6. Skilled agricultural, forestry and fishery work	Agricultural and Unskilled	ag_othlowsk
7. Craft and related trades workers	Agricultural and Unskilled	ag_othlowsk
8. Plant and machine operators, and assemblers	Agricultural and Unskilled	ag_othlowsk
9. Elementary occupations	Agricultural and Unskilled	ag_othlowsk

2.1.2 Categories

People are assigned to "categories" at the start of year t. These categories are based on common characteristics, namely: gender, age, and labour-market activity performed during year t-1. The five labour market categories are:

- employment in occupation o, where o is one of the 5 occupations (OCC) in GTAP-RD model;
- unemployed(UNEMP) that is unemployed in both year t-1;
- "not in the labour force" (NILF), that is people not part of any employment or unemployment activity in year t-1; and
- new entrants (NEWENT) into the WAP. The new entrant category is not based on any activity performed in year t-1. This category is added exogenously at the start of year t, reflecting demographic factors and immigration.

2.1.3 Activities

The description of the activities and categories matrices is quite similar. Both matrices are defined by labour-market function, gender and age. There are three main differences between the two matrices. First, the matrices relate to different points in time. The activities matrix relates to what a person is doing during year t, while the categories matrix is defined at the start of year t on the basis of the previous year's activities. An adult's activity during the year depends in part on the category into which they were grouped at the start of year t. Second, it is helpful to view new entrants (NEWENT) as an additional category that is added exogenously at the start of each year. The activities matrix does not include new entrants as an activity. Rather, new entrants perform a specific activity (such as being employed as a manager) during their year of entry into the WAP.

The main activities undertaken during year t are:

- employment in occupation o, where o is one of the 5 occupations (OCC);
- unemployed (UNEMP), that is unemployed in year t;

- "not in the labour force" (NILF), that is people not part of any employment or unemployment activity in year t.

2.1.4 Flows from categories to activities

Once categories have been specified, the people within these categories supply labour to an activity during year t. These supplies are based on category-specific solutions to utility maximisation problems. The flows from categories to activities are sensitive to changes in both occupation-specific relative wages and personal preferences.

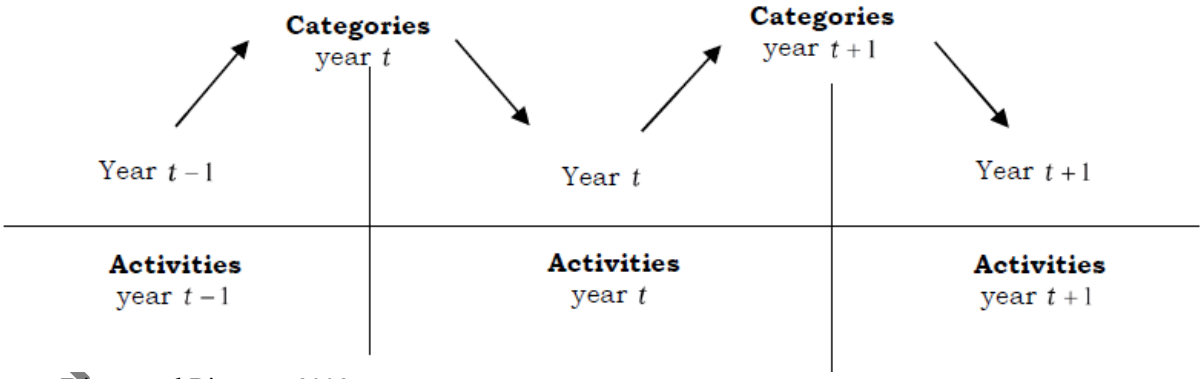
2.2 The Functioning of the Labour-Market Specification

The following key ingredients are specified in the labour-supply model:

- Assignment of the WAP to categories at the start of each year. We define equations linking the number of people in **activity** in year t-1 to the number of people in **category** at the start of year t.
- Identification of workforce activities during the year.
- Determination of the supply of labour by each category to each activity.
- Determination of the demand for labour for each employment activity.

At the start of year t, people are divided into categories based on common characteristics. These characteristics are gender, age and labour-market activity performed during year t-1. People in categories make labour supplies to activities. In Figure 2.1, this flow is illustrated by the downward sloping arrow between categories and activities. Some people leave the WAP due to death. This transition is illustrated by the upward sloping arrow in Figure 2.1. After this transition, people are again grouped into categories, based on common characteristics. The process of labour supply from a category to an activity is then repeated. Figure 2.1 abstracts from a large number of labour market flows.

Figure 2.1. Movement of labour-supply from year t-1 to year t



Source: Dixon and Rimmer, 2008.

A person's recent workforce function refers to what he or she did in the labour market in the previous year, year t-1. The functions we identify are:

1) employed in occupation o, where o is one of the 5 occupations(OCC);

2) unemployed (UNEMP);

3) living in Canada but not in the workforce (NILF);

A final concept that we need to explain before setting out the algebra of the labour-market specification is activity. Activities are defined by age group, gender and workforce function in the current year. Examples of activities in year t are: working as a 35-44 age group male manager; a 25-34 age group female clerk, etc.

TABLE 2.3. GTAP-RD-LAB REPRESENTATION OF THE LABOUR MARKET

Numbers in each category at the beginning of year t

$$CAT_t(o,g,a) = \sum_{aa \in AGE} ACT_{t-1}(o,g,aa) * T(o,g,aa,a) \qquad o \in EUF, g \in GEN, a \in AGE \qquad (T2.1)$$

$$CAT_t("New",g,a) = \text{exogenous} \qquad g \in GEN, a \in AGE \qquad (T2.2)$$

$$LOF_t(g,a) = \sum_{o \in EUNF} CAT_t(o,g,a) \qquad g \in GEN, a \in AGE \qquad (T2.3)$$

Planned labour supply

$$L_t(o,g,a) = LOF_t(g,a) * \left[\frac{\left(B_t(o,g,a) * ATW_t(o,g,a)\right)^{\eta}}{\sum_q \left(B_t(q,g,a) * ATW_t(q,g,a)\right)^{\eta}} \right] \qquad o \in EUF, g \in GEN, a \in AGE \qquad (T2.4)$$

Demand for labour and employment in Canada

$$D_t^1(j) = f_j^1\left(BTW_t^1(j); K_t(j); A_t(j)\right) \qquad j \in IND \qquad (T2.5)$$

$$BTW_t^1(j) = g_j^1\left(BTW_t(o,g,a) \; \forall \, o \in OCC, g \in GEN, a \in AGE\right) \qquad j \in IND \qquad (T2.6)$$

$$D_t(o,g,a,j) = D_t^1(j) * h_{o,g,a,j}\left(BTW_t(oo,gg,aa) \quad \forall \, oo \in OCC, gg \in GEN, aa \in AGE\right)$$

$$o \in OCC, g \in GEN, a \in AGE, j \in IND \qquad (T2.7)$$

$$D_t(o,g,a) = \sum_j D_t(o,g,a,j) \qquad o \in OCC, g \in GEN, a \in AGE. \qquad (T2.8)$$

Relationship between after-tax and before-tax wage rates

$$ATW_t(o,g,a) = BTW_t(o,g,a) * \left(1 - T_t(g,a)\right) \qquad o \in OCC, g \in GEN, a \in AGE \qquad (T2.9)$$

$$ATW_t(o,g,a) = BTW_t^{ave}(g,a) * F_t(g,a) \qquad o \in UF, g \in GEN, a \in AGE \qquad (T2.10)$$

Wage adjustment

$$\frac{ATW_t(o,g,a)}{ATW_t^{base}(o,g,a)} - \frac{ATW_{t-1}(o,g,a)}{ATW_{t-1}^{base}(o,g,a)} = \beta \left(\frac{D_t(o,g,a)}{D_t^{base}(o,g,a)} - \frac{L_t(o,g,a)}{L_t^{base}(o,g,a)} \right),$$

$$o \in OCC, g \in GEN, a \in AGE \qquad (T2.11)$$

Table 2.3 continues …

Table 2.3 continued

Not in the labour force and Unemployment

$$ACT_t("NLF", g, a) = L_t("NLF", g, a) \qquad g \in GEN, a \in AGE \qquad \text{(T2.12)}$$

$$ACT_t("UEMP", g, a) = LOF_t(g, a) - \sum_{o \in OCC} D_t(o, g, a) - \sum_{o \in NLF} L_t(o, g, a)$$

$$g \in GEN, a \in AGE \qquad \text{(T2.13)}$$

Notation

$CAT_t(o, g, a)$ is the number of people at the start of year t who are in gender g, at age group a and who performed workforce activity o.

$CAT_t("New", g, a)$ is the number of people at the start of year t who are in gender g, at age group a and were not in the extended workforce in year t-1.

$LOF_t(g, a)$ is the total number of people at the start of year t who are in gender g, at age group a (including new entrants).

$ACT_t(o, g, a)$ and $ACT_{t-1}(o, g, a)$ is the number of people in activity (o, g, a) in year t and t-1.

$T(o, g, aa, a)$ is the proportion of people in activity (o, g, aa) in year t-1 who are allocated to category (o, g, a) at the start of year t.

$L_t(o, g, a)$ is the labour supply that people in gender g, at age group a to activity o.

$L_t^{base}(o, g, a)$ is the base or forecast value of $L_t(o, g, a)$.

β is a positive parameter.

$ATW_t(o, g, a)$ is the real after-tax wage rate of labour in activity o (for non-employment activities it is a social security payment or other support).

$ATW_t^{base}(o, g, a)$ is the base or forecast value of $ATW_t(o, g, a)$.

η is a parameter reflecting the ease with which people feel that they can shift between activities.

$B_t(o, g, a)$ is a variable reflecting the preference of people in category for earning money in activity in year t.

$K_t(j)$ is industry j's capital stock.

$BTW_t^1(j)$ is the overall real before-tax wage rate to the industry.

$A_t(j)$ is a vector of variables that influence industry j's demand for labour.

$D_t^1(j)$ is labour input to industry j.

$BTW_t(o, g, a,)$ is the real before-tax wage rate of workers of gender g, age group a and occupation o.

$D_t(o, g, a, j)$ is j's input of labour of gender g, age group a and occupation o.

$D_t(o, g, a)$ is aggregate demand for (o,g,a) labour.

Table 2.3 continues …

Table 2.3 continued

$D_t^{base}(o,g,a)$ is the base or forecast value of $D_t(o,g,a)$.

$E_t(o,g,a)$ is employment of (o,g,a) labour.

$T_t(g,a)$ is the payroll and income-tax rate applying to all (g,a) workers in Canada

$BTW_t^{ave}(g,a)$ is the average real before-tax wage rate of (g,a) workers in Canada.

$F_t(g,a)$ is the fraction of $BTW_t^{ave}(g,a)$ that (g,a) people receive in unemployment activities from social security payments or other support.

2.3 Determining Categories at the Start of Year t

At the beginning of each year, we allocate people in the WAP to categories according to their recent labour-market activity, gender and age, which describing the upward arrows in Figure 2.1. Every year we allow a small proportion of people to leave the WAP through death. Those who do survive are assumed to progress one year in age. Since our age groups comprise ten year spans, this is implemented by moving one tenth of each age group into the higher age category. A person's recent labour-market activity refers to what a person did as an activity in year t-1.

Categories at the start of the year are specified in (E2.1):

$$CAT(o,g,a) = \sum_{aa \in AGE} \mathrm{ACT\_L}(o,g,aa) \quad * \mathrm{T}(o,g,aa,a) \qquad \text{(E2.1)}$$

$o \in EUF$[2]$;\ g \in GEN;\ a \in AGE.$

New entrants are determined exogenously:

$$CAT(N,g,a) = exogenous \qquad g \in GEN;\ a \in AGE \qquad \text{(E2.2)}$$

$$LOF(g,a) = \sum_{o \in EUNF} \mathrm{CAT}(o,g,a) \qquad g \in GEN;\ a \in AGE \qquad \text{(E2.3)}$$

Where

- $\mathrm{CAT}(o,g,a)$ is the level of the number of people in category o, in gender g and age a at the start of year t;
- $\mathrm{ACT\_L}(o,g,aa)$ is the level of people who performed activity o during t-1, given their gender g, and age aa;
- $\mathrm{T}(o,aa,a)$ is the proportion of people who were in age aa in t-1, who are allocated to age a at the start of year t.
- $\mathrm{CAT}(N,g,a)$ is the level of the number of new entrants at the start of year t, gender g, and age a.
- $\mathrm{LOF}(g,a)$ is the total number of people in gender g, and age group a, at the start of year t.

[2] EUF is the set of all employment, unemployment and "not in the labour force" categories.

2.4 Labour supply from Categories to Activities

Following Dixon and Rimmer (2008), we assume that people in category choose their labour supplies across activities a by solving a utility maximisation problem. The utility function takes a CES form. The general maximisation problem is defined as an adult choosing L(o,g,a) to:

$$\text{Max } U = [\sum_{l \in \text{EUF}} (B(o,g,a) * ATW(o,g,a) * L(o,g,a))^{\frac{n}{1+n}}]^{\frac{1+n}{n}} \quad \text{(E2.4)}$$

$$\text{subject to } \sum_{l \in \text{EUF}} L(o,g,a) = LOF(g,a) \quad \text{(E2.5)}$$

Where

- EUF is the set for all activities describing employment, unemployment, and not in the labour force;
- U(g,a) is a specific utility function for people in gender g, and age group a;
- B(o,g,a) capture exogenous non-wage factors, such as preferences, that may motivate people in gender g, and age group a, choosing activity o.
- ATW(o,g,a) is the real after-tax wage rate in activity o;
- L(o,g,a) is labour supply in gender g, and age group a, who choose activity o; and

In specifying utility from labour allocation according to a CES function[3] in (E2.4), we implicitly assume that people in gender g, and age group a treat dollars earned in different activities as imperfect substitutes. Based on Equations (E2.4) and (E2.5), we can find the solution for L(c;a), which is the labour supply depicted in the downward arrows in Figure 2.1.

$$L_t(o,g,a) = LOF_t(g,a) * \left[\frac{\left(B_t(o,g,a) * ATW_t(o,g,a)\right)^{\eta}}{\sum_q \left(B_t(q,g,a) * ATW_t(q,g,a)\right)^{\eta}} \right] \quad \text{(E2.6)}$$

In our case, the explicit form of labour supply L(o,g,a) in (E2.6), is a function of LOF, ATW, and B.

The total labour supply in occupation o is defined as

$$L\_ga(o) = \sum_{g \in \text{GEN}} \sum_{a \in \text{AGE}} L(o,g,a) \quad \text{(E2.7)}$$

For understanding what this means, it is useful to express (E2.6) in percentage change form as:

$$l_t(o,g,a) = lof_t(g,a) + \eta * \left(atw_t(o,g,a) - atw_t^{ave}(g,a)\right) + \eta * \left(b_t(o,g,a) - b_t^{ave}(g,a)\right) \quad \text{(E2.8)}$$

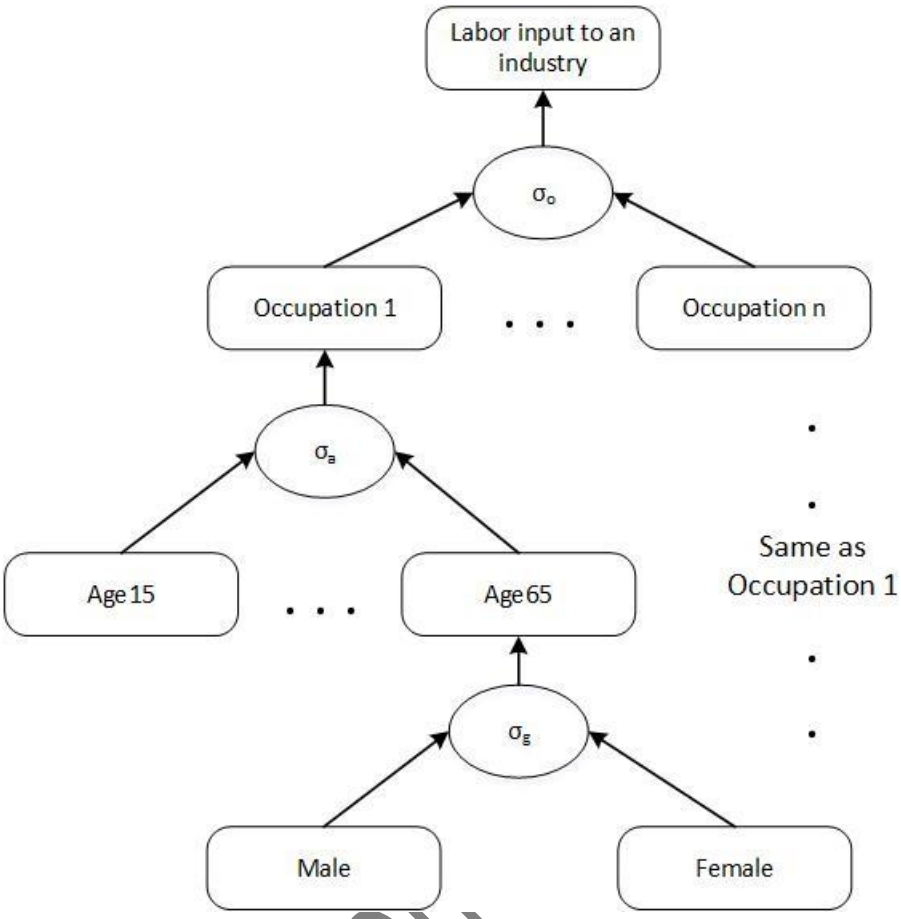
[3] For the simplification, we use the Constant Elasticity of Substitution (CES) function in the discussion. In modelling, we adopt the Constant Ratios of Elasticity of Substitution (CRESH) function to reflect the various ability of shifting activities.

In (E2.8), the lowercase symbols $l_t(o,g,a)$, $lof_t(g,a)$, $atw_t(o,g,a)$ and $b_t(o,g,a)$ are percentage changes in the variables denoted by the corresponding uppercase symbols, and $atw_t^{ave}(g,a)$ and $b_t^{ave}(g,a)$ are weighted averages of the $atw_t(q,g,a)$ and $b_t(q,g,a)$ with the weights reflecting the share of activity q in the offers from people in gender g and age group a. Thus (E2.8) implies that people will switch their offers towards activity o if the wage rate in activity o rises relative to an average of the wage rates across all the activities. In the model, we adopt the CRESH function and the η's range from 1 to 3 to reflect the various ability to shift activities. For example, low-skilled workers are harder to offer their labour to get into high-skilled occupations even thought the rises in wage in high-skilled occupation. Similarly, the unemployed people might be more sensitive to wage changes than the people are not in the labour force.

2.5 Demand for labour in Canada, Linking Labour module to GTAP-RD

In GTAP-RD model, there is cost minimisation mechanism that determines the demand for primary factors in sector j. Usually, we have two type of labour, skilled and unskilled. In this project, we propose to firstly aggregate these two types of labour into one labour factor. We introduce the nesting structure as shown in Figure 2.2. to disaggregate the labour matrix to include the characteristics, such as occupation, gender, and age. The labour input to each industry from GTAP-RD model is the top of the nesting.

Figure 2.2. Nesting assumptions in the creation of the labour input to each industry



The labour input, $D_t^1(j)$, to industry j in year t is specified in GTAP-RD along conventional CGE lines as a function of: the industry's capital stock, Kt(j); the overall real before-tax wage rate to the industry, $BTW_t^1(j)$; and other variables, At(j), that influence industry j's demand for labour, including technology and commodity prices:

$$D_t^1(j) = f_j^1\left(BTW_t^1(j); K_t(j); A_t(j)\right) . \qquad \text{(E2.9)}$$

The overall real wage rate to industry j is determined as a suitable average of the real wage rates applying to the types of labour that the industry employs:

$$BTW_t^1(j) = g_j^1\left(BTW_t(o,g,a) \text{ for all } g, a \text{ and occupations } o\right) , \qquad \text{(E2.10)}$$

where

$BTW_t(o,g,a)$ is the real before-tax wage rate of workers of gender g, age a and occupation o.

Within industry j's labour input, the demand for labour by gender, age and occupation is determined by a nested CES cost minimization problem. The nesting and the substitution elasticities are indicated in Figure 2.2. We assume that there are low substitution possibilities between occupations (substitution elasticity of 0.35) but high substitution possibilities across different age groups of the

same occupation (substitution elasticity of 5) and between male and female workers of the same occupation (substitution elasticity of 7.5). The substitution elasticities represent judgments. We may need to do some econometric studies regarding these parameters.

In algebraic terms, we assume that industry j satisfies its labour requirements by choosing:

$D_t(o,g,a,j)$, j's input of labour of gender g, and age group a, and occupation o,

$D_t^3(o,a,j)$, j's input of labour of age group a and occupation o, defined as a CES aggregate over g of (o,g,a, j) inputs, and

$D_t^2(o,j)$, j's input of labour of occupation o, defined as a CES aggregate over a of (o,a, j) inputs,

to minimize $\sum_{o,g,a} BTW_t(o,g,a) * D_t(o,g,a,j)$ (E2.11)

subject to $D_t^1(j) = CES_o\left[D_t^2(o,j)\right]$ (E2.12)

$D_t^2(o,j) = CES_a\left[D_t^3(o,a,j)\right]$ for all occupations o, (E2.13)

and $D_t^3(o,a,j) = CES_g\left[D_t(o,g,a,j)\right]$ (E2.14)

for all occupations o and age a.

From problem (E2.12) – (E2.14) we obtain demand functions of the form

$$D_t(o,g,a,j) = D_t^1(j) * h_{o,g,a,j}\left(BTW_t(gg,aa,oo) \ \forall\ gg,aa \text{ and occupations } oo\right)$$

for all g, a and occupations and industries o and j. (E2.15)

These can be aggregated across industries to determine aggregate demand for (g,a) workers in occupation o as

$$D_t(o,g,a) = \sum_j D_t(o,g,a,j) \quad \text{for all g, a and occupations o.} \qquad \text{(E2.16)}$$

2.6 Wage adjustment

In policy runs, we assume that wage rates adjust according to the equation:

$$\frac{ATW_t(o,g,a)}{ATW_t^{base}(o,g,a)} - \frac{ATW_{t-1}(o,g,a)}{ATW_{t-1}^{base}(o,g,a)} = \beta \left(\frac{D_t(o,g,a)}{D_t^{base}(o,g,a)} - \frac{L_t(o,g,a)}{L_t^{base}(o,g,a)} \right) ,$$

for all (g,a) and all occupations o (E2.17)

where the superscript "base" refers to values in the basecase forecast and β is a positive parameter (we set it as 1 in the paper). This equation implies that if a policy causes the market for (o,g,a) employment in year t to be tighter than it was in the basecase forecast (i.e., if the policy causes a larger percentage deviation in demand than supply), then there will be an increase between years t-1 and t in the deviation in (o,g,a)'s real after-tax wage rate. In other words, in periods in which a policy has elevated demand relative to supply, real wages will grow relative to their basecase values.

This wage-adjustment process is compatible with a search model [see for example, Bohringer et al. (2005)] and the efficiency-wage theory, see for example, Layard et al. (1994, pp. 33-45).

2.7 The determination of not in the labour force and unemployment

So far, we have discussed the supply of workforce activities (including non in the labour force and unemployment) and demand for occupations. There is no demand for not in the labour force. Those who want to move out of the labour force, such as, retirement, are fully accepted as show in (E2.18).

$$ACT_t("NLF",g,a) = L_t("NLF",g,a) \qquad g \in GEN, a \in AGE \qquad \text{(E2.18)}$$

Under the sticky-wage mechanism described by (E2.17), we know markets for occupations do not clear and supply does not always equal to demand. Consequently, those who offers to employment for different occupations are not accepted would become unemployed. So unemployment includes those voluntary or involuntary unemployed, which works like the buffer in the workforce activities. Equation (E2.19) shows that the number of unemployed equals the total number of people in gender g, and age group a, minuses the number of people who have jobs (no matter what occupations), and minuses the number of people who move out of the labour force.

$$ACT_t("UEMP",g,a) = LOF_t(g,a) - \sum_{o \in OCC} D_t(o,g,a) - \sum_{o \in NLF} L_t(o,g,a)$$

$$g \in GEN, a \in AGE \qquad \text{(E2.19)}$$

In terms of Figure 2.1, these are the downward sloping arrows for activities not in the labour force and unemployment. This concludes our description of the labour supply module of the GTAP-RD-LAB model. The next section discussed the database.

2.8 Monash-style Investment Function

The GTAP-RD model adopts ORANI-style investment function in which capital growth has a positive relationship with rate of return.

$$K\_GR_r = (RORC_r/RORE_r)^{\beta} \qquad \text{(E2.20)}$$

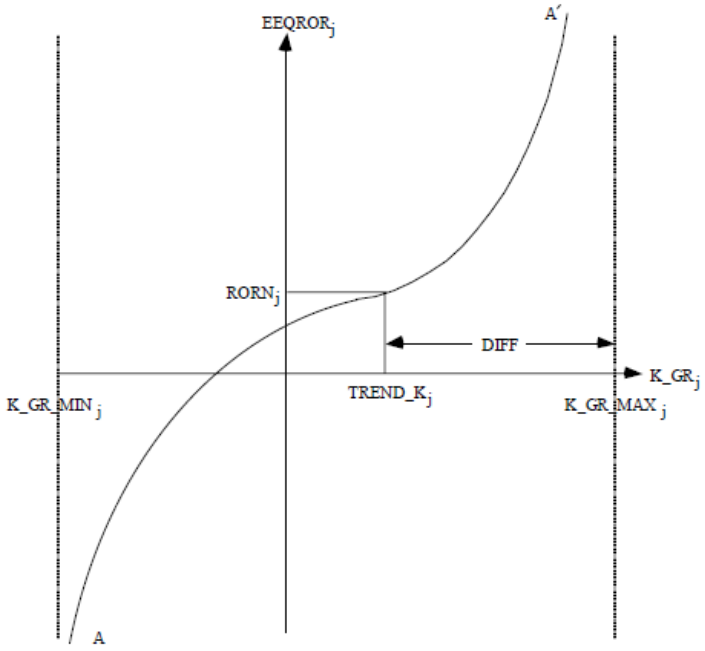
$$\mathrm{RORC_r} = \psi_{\mathrm{RORC}}(\mathrm{Q_r}, \mathrm{PI_r}) \qquad \text{(E2.21)}$$

Where $\mathrm{K\_GR_r}$ is the capital growth rate in region r; RORC_r is the rate of return on capital in region r; RORE_r is the expected rate of return on capital in region r, which equals to the expected rate of return on global capital RORG; $\mathrm{Q_r}$ is the rental of capital in region r; $\mathrm{PI_r}$ is the replacement cost of capital in region r; ψ_{RORC} is a monotonically increasing function.

The Monash-style investment function has an inverse-logistic functional form, ψ_{KG}, which shown in Figure 2.3. The advantage of this investment function is that the response of investment is less sensitive to rates of return in the extreme cases. For example, when rate of return in the far right or left, the growth rate of capital is contained within the range between K_GR_Min and and K_KR_MAX. This captures the behavior of risk aversion of investors.

$$\mathrm{K\_GR_r} = \psi_{\mathrm{KG}}(\mathrm{RORC_r}) \qquad \text{(E2.22)}$$

Figure 2.3. The inverse-logistic relationship between capital growth rates and rates of return



3. LABOUR DATA

3.1 Data Required for modeling the Labour-Market Module

This section describes the data required for preparing the labour-market module described above. In each region, this database should have the following characteristics:

- It should contain detailed information regarding the structure of the working age population (WAP) in the base year 2019.
- It should be the initial solution to the labour-market specification described in Section 2.
- It should include a transition matrix that allows adults to change their age between year and year t-1 and t. And mortality rates in each age groups are also required to construct this matrix.
- It should have the wage bills for all occupations, genders and age groups.

The model requires a number of coefficients. They are matrices describing: activities undertaken during the base year; categories at the start of the base year; flows between categories and activities; and a transition matrix. The coefficients are listed in Table 3.1. Each matrix is defined by a number of dimensions. The sets in these dimensions are listed in Table 3.2.

Table 3.1 Coefficients and Parameters

Coefficient	Dimension	Description
ACT(o,g,a,r)	EUF *GEN *AGE * REG	The activity matrix in year *t*. This matrix refers to the number of adults in each labour market activity *o* by gender *g*, and age *a* in region *r*.
ACT_L(o,g,a,r)	EUF *GEN *AGE * REG	The lagged activity matrix for year t-1. This matrix is similar in dimensions to ACT(o,g,a,r), but is defined for the preceding year.
CAT(o,g,a,r)	NEWENT *GEN *AGE * REG	The number new entrant in gender g, age a in region r at the start of year *t*. It is determined by demographic and immigrant factors.
W(o,i,g,a,r)	OCC * IND * GEN *AGE * REG	Wage bill matrix for occupation o, gender g, age a in region r in year *t* .
T(o,g,aa,a,r)	EUF *GEN*AGE*AGE * REG	Transition matrix shows the proportion of people who were in age aa in t-1, who are allocated to age a at the start of year t.

Table 3.2 Sets

Symbol	Dimension	Description/Elements
OCC	5	1)Officials and mangers, 2)Technicians/Associate Professional, 3) Service/Shop workers, 4)Clerks, 5)Agricultural and Unskilled Labour.
UNEMP	1	Unemployed.
NEWENT	1	New entrants (NEWENT), which includes domestic residents who turn 15 and new overseas arrivals.
NILF	1	Not in the labour force (NILF).
EU	6	Labour force (OCC + UN).
EUNF	8	Domestic labour categories (OCC + UNEMP + NILF + NEWENT).
EUF	7	Domestic labour activities (OCC + UNEMP + NILF).
GEN	2	Male and Female.
AGE	6	(1) 15-24; (2) 25-34; (3) 35-44; (4) 45-54; (5) 55-64; (6) 65 +.

3.2 Labour Data

The main data source for our labour module is the International Labour Organization (ILO). For Canada, we use the information from StatsCan because ILO has the occupational data only for USA, Mexico and ROW. The reference year is 2019 for the labour data. Since the reference year of the GTAP v11 data is 2017, we ran the model dynamically to bring the base data to 2019 and incorporate the labour data.

Table 3.1 Number of people over age 15 (WAP) in different activities and regions in 2019

2019	Canada		USA		Mexico		ROW	
('000 people)	Male	Female	Male	Female	Male	Female	Male	Female
tech_aspros	2,235	2,746	29,396	31,405	4,451	4,607	276,338	224,650
clerks	390	1,642	4,592	11,748	1,656	1,842	73,954	81,747
service_shop	2,463	3,239	11,299	17,834	5,704	6,110	280,079	252,952
off_mgr_pros	1,485	955	10,925	7,266	967	504	106,640	64,007
ag_othlowsk	3,413	488	33,036	8,425	22,059	7,479	1,132,861	413,441
Unemployment	641	503	3,526	2,919	1,199	777	121,098	78,354
Not in the labour Force	4,534	6,006	40,872	58,439	8,820	26,717	684,859	1,568,600
Total	15,161	15,579	133,646	138,036	44,856	48,035	2,675,827	2,683,751
Unemployment Rate	6.0%	5.3%	3.8%	3.7%	3.3%	3.6%	6.1%	7.0%
Participation Rate	70%	61%	69%	58%	80%	44%	74%	42%

Source: International Labour Organization (ILO), StatsCan, Authors' calculation

From Figure 3.2, we see that there is a huge gap between male and female in developing countries. Over 55% of female in the working age population (WAP) in Mexico and ROW are not in the labour force, while this number for male only about 20%. Compared to Canada and USA, there are more agricultural and Unskilled labour in Mexico and ROW.

Figure 3.2 Distribution of labour activities in each region in 2019

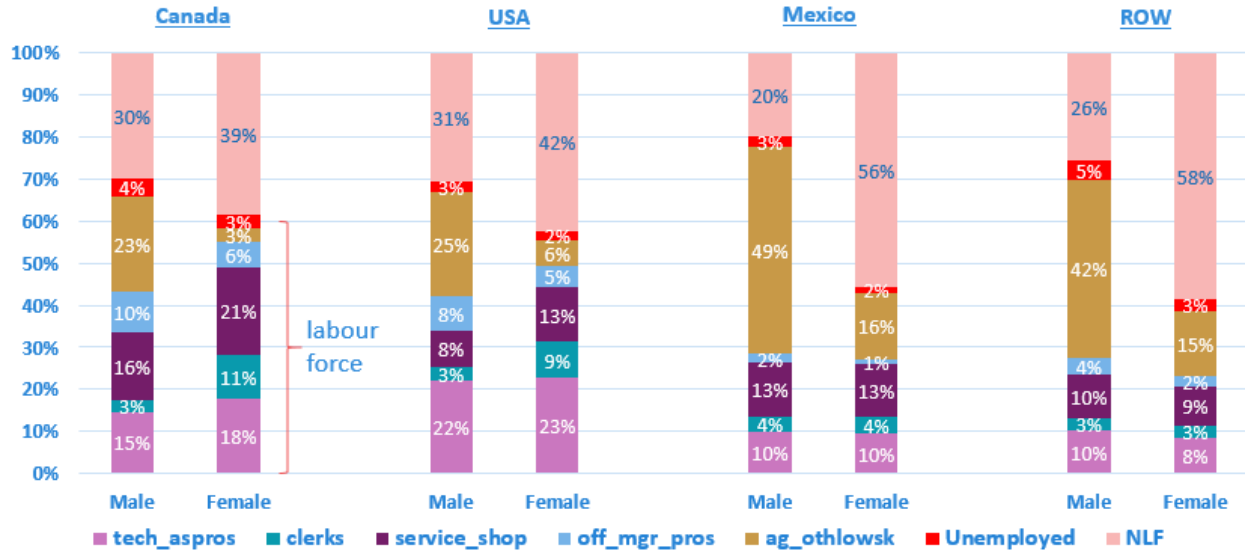


Table 3.3 Number of people in different activities by age group in each region (Unit: '000 people)

Canada													
	Male						Female						Total
(000 people)	Age15-	Age25-	Age35-	Age45-	Age55-	Age65+	Age15-	Age25-	Age35-	Age45-	Age55-	Age65+	
tech_aspros	165	563	574	471	351	112	226	771	725	563	378	83	4,981
clerks	41	90	87	77	69	27	117	315	348	403	361	97	2,032
service_shop	609	522	422	401	367	142	796	642	564	592	511	133	5,702
off_mgr_pros	41	261	391	402	307	84	47	218	258	248	156	28	2,441
ag_othlowsk	410	759	702	708	650	184	64	83	99	124	99	18	3,901
Unemployment	178	143	102	87	108	23	134	111	90	79	75	14	1,144
Not in the Labor Force	809	246	178	222	698	2,382	742	440	405	378	1,009	3,031	10,540
Total	2,253	2,583	2,455	2,367	2,548	2,954	2,126	2,581	2,489	2,387	2,590	3,405	30,739
Unemployment Rate	12.3%	6.1%	4.5%	4.1%	5.8%	4.1%	9.7%	5.2%	4.3%	3.9%	4.7%	3.9%	5.7%
Participation Rate	64.1%	90.5%	92.8%	90.6%	72.6%	19.4%	65.1%	82.9%	83.7%	84.2%	61.0%	11.0%	65.7%

USA													
	Male						Female						Total
(000 people)	Age15-	Age25-	Age35-	Age45-	Age55-	Age65+	Age15-	Age25-	Age35-	Age45-	Age55-	Age65+	
tech_aspros	2,183	7,110	6,761	6,382	4,835	2,124	2,626	7,606	7,101	7,110	5,138	1,824	60,802
clerks	944	959	912	861	658	257	1,682	2,427	2,265	2,268	2,260	845	16,340
service_shop	2,810	2,217	2,108	1,990	1,491	683	4,941	3,282	3,064	3,068	2,462	1,017	29,132
off_mgr_pros	320	2,525	2,401	2,266	2,393	1,020	320	1,768	1,651	1,653	1,427	447	18,191
ag_othlowsk	5,197	7,303	6,945	6,555	5,393	1,643	1,380	1,750	1,634	1,636	1,546	480	41,461
Unemployment	1,189	776	509	506	375	171	868	652	468	433	353	146	6,445
Not in the Labor Force	9,695	2,554	1,982	2,672	6,019	17,950	9,612	5,321	5,191	5,191	8,937	24,188	99,312
Total	22,338	23,444	21,619	21,232	21,164	23,848	21,429	22,805	21,372	21,359	22,124	28,948	271,682
Unemployment Rate	9.4%	3.7%	2.6%	2.7%	2.5%	2.9%	7.3%	3.7%	2.9%	2.7%	2.7%	3.1%	3.7%
Participation Rate	56.6%	89.1%	90.8%	87.4%	71.6%	24.7%	55.1%	76.7%	75.7%	75.7%	59.6%	16.4%	63.4%

Source: International Labour Organization (ILO), StatsCan, Authors' calculation

Table 3.3 Number of people in different activities by age group in each region (Unit: '000 people, continued)

Mexico

	Male						Female						Total
(000 people)	Age15-	Age25-	Age35-	Age45-	Age55-	Age65+	Age15-	Age25-	Age35-	Age45-	Age55-	Age65+	
tech_aspros	454	1,441	1,065	821	430	240	521	1,462	1,246	860	363	155	9,058
clerks	368	519	341	257	112	59	457	600	404	252	89	40	3,498
service_shop	1,212	1,292	1,190	1,019	600	391	1,237	1,391	1,365	1,144	712	262	11,814
off_mgr_pros	66	220	272	211	130	67	30	173	141	105	34	21	1,471
ag_othlowsk	4,055	5,143	4,899	4,010	2,390	1,562	1,158	1,580	1,915	1,640	884	302	29,538
Unemployment	417	333	203	118	88	41	297	237	134	72	20	16	1,976
Not in the Labor Force	4,181	610	401	447	1,014	2,167	7,006	4,614	3,837	3,461	3,263	4,537	35,537
Total	10,753	9,558	8,372	6,884	4,763	4,526	10,706	10,056	9,041	7,534	5,364	5,333	92,891
Unemployment Rate	6.3%	3.7%	2.5%	1.8%	2.3%	1.7%	8.0%	4.4%	2.6%	1.8%	1.0%	2.0%	3.4%
Participation Rate	61.1%	93.6%	95.2%	93.5%	78.7%	52.1%	34.6%	54.1%	57.6%	54.1%	39.2%	14.9%	61.7%

ROW

	Male						Female						Total
(000 people)	Age15-	Age25-	Age35-	Age45-	Age55-	Age65+	Age15-	Age25-	Age35-	Age45-	Age55-	Age65+	
tech_aspros	17,627	81,909	74,425	63,529	31,062	7,786	17,189	61,276	62,066	56,502	23,590	4,027	500,988
clerks	9,025	20,341	18,483	15,777	8,309	2,019	10,977	20,155	20,415	18,585	9,247	2,368	155,701
service_shop	40,495	73,580	66,858	57,069	29,901	12,175	35,240	60,047	60,821	55,369	30,132	11,343	533,031
off_mgr_pros	4,170	29,519	26,822	22,895	16,812	6,423	3,237	16,565	16,779	15,274	8,104	4,048	170,647
ag_othlowsk	154,875	89,241	262,815	224,338	139,983	61,609	50,214	93,745	94,953	86,440	59,281	28,808	1,546,302
Unemployment	46,915	38,049	15,647	12,112	6,849	1,525	27,176	26,716	12,443	8,136	3,312	572	199,452
Not in the Labor Force	316,770	43,953	23,098	31,322	75,942	193,775	408,344	270,650	205,303	184,518	190,865	308,921	2,253,459
Total	589,877	576,592	488,148	427,042	308,858	285,311	552,377	549,154	472,779	424,823	324,531	360,087	5,359,579
Unemployment Rate	17.2%	7.1%	3.4%	3.1%	2.9%	1.7%	18.9%	9.6%	4.7%	3.4%	2.5%	1.1%	6.4%
Participation Rate	46.3%	92.4%	95.3%	92.7%	75.4%	32.1%	26.1%	50.7%	56.6%	56.6%	41.2%	14.2%	58.0%

Source: International Labour Organization (ILO), StatsCan, Authors' calculation

Table 3.4 Labour income across sectors in each region

	Canada		USA		Mexico		ROW		Total
(USD mn)	Male	Female	Male	Female	Male	Female	Male	Female	
Agriculture	11,318	4,480	73,824	19,547	30,733	2,798	3,399,915	1,317,585	4,860,200
Mining	22,041	3,622	36,283	5,293	1,351	125	125,923	16,185	210,824
Manufacturing	48,222	11,900	518,192	168,065	34,128	15,678	1,878,219	758,041	3,432,447
Electricity Gas and Distribution	6,224	1,827	67,690	15,673	689	152	145,515	23,663	261,432
Water	461	98	26,189	4,969	1,244	255	72,638	18,489	124,344
Construction	46,874	5,054	519,693	44,726	28,541	801	1,918,766	125,223	2,689,679
Trade	49,642	31,244	427,855	216,028	31,268	18,980	1,763,623	820,726	3,359,367
Accommodation, Food and service	10,214	8,504	170,354	127,243	8,843	8,808	335,155	248,624	917,745
Transportation and storage	23,402	5,719	374,126	100,594	14,705	1,035	1,226,930	83,105	1,829,616
Communication	8,490	4,663	192,403	67,749	1,621	593	220,733	68,412	564,665
Finance and Insurance	24,521	18,492	256,037	178,588	2,037	1,471	232,706	121,870	835,722
Real estate activities	3,308	1,832	84,466	54,673	761	424	91,489	34,456	271,409
Business services nec	24,125	13,365	442,449	241,707	11,645	4,978	596,954	219,419	1,554,643
Recreational and other services	32,993	19,154	150,847	146,034	9,601	12,532	600,048	560,593	1,531,802
Public Administration and defense	29,105	42,037	113,670	90,861	8,284	4,028	498,784	194,128	980,896
Education	17,330	29,036	178,074	318,374	5,873	7,233	410,208	525,357	1,491,486
Human health and social work	27,272	38,106	205,305	557,545	3,171	4,368	232,580	427,344	1,495,690
Total	385,542	239,133	3,837,456	2,357,671	194,496	84,261	13,750,186	5,563,222	26,411,966

Source: International Labour Organization (ILO), StatsCan, Authors' calculation

Table 3.5 Distribution of labour income across sectors in each region

	Canada		USA		Mexico		ROW		Total
%	Male	Female	Male	Female	Male	Female	Male	Female	
Agriculture	3%	2%	2%	1%	16%	3%	25%	24%	18%
Mining	6%	2%	1%	0%	1%	0%	1%	0%	1%
Manufacturing	13%	5%	14%	7%	18%	19%	14%	14%	13%
Electricity Gas and Distribution	2%	1%	2%	1%	0%	0%	1%	0%	1%
Water	0%	0%	1%	0%	1%	0%	1%	0%	0%
Construction	12%	2%	14%	2%	15%	1%	14%	2%	10%
Trade	13%	13%	11%	9%	16%	23%	13%	15%	13%
Accommodation, Food and service	3%	4%	4%	5%	5%	10%	2%	4%	3%
Transportation and storage	6%	2%	10%	4%	8%	1%	9%	1%	7%
Communication	2%	2%	5%	3%	1%	1%	2%	1%	2%
Finance and Insurance	6%	8%	7%	8%	1%	2%	2%	2%	3%
Real estate activities	1%	1%	2%	2%	0%	1%	1%	1%	1%
Business services nec	6%	6%	12%	10%	6%	6%	4%	4%	6%
Recreational and other services	9%	8%	4%	6%	5%	15%	4%	10%	6%
Public Administration and defense	8%	18%	3%	4%	4%	5%	4%	3%	4%
Education	4%	12%	5%	14%	3%	9%	3%	9%	6%
Human health and social work	7%	16%	5%	24%	2%	5%	2%	8%	6%
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%

Source: International Labour Organization (ILO), StatsCan, Authors' calculation

4. AN ILLUSTRATION OF "CUSMA" (OR "USMCA")

The North-American Free Trade Agreement (NAFTA) between Canada, Mexico, and the United States has been in force since January 1994. It was the most comprehensive free trade agreement ever negotiated back then. The agreement eliminated almost all tariffs between the three countries and created the world's largest market for goods and services. NAFTA fundamentally reshaped the economies in North America.

The new version of NAFTA, CUSMA, entered into force on July 1, 2020. The agreement aims at supporting higher-paying jobs and the growth of the North American economy. It includes tighter rules of origin in the automobile, textile, and apparel sectors, a new labour value content requirement in auto sector, further goods trade facilitation, updated provision related to financial services, as well as new chapters covering digital trade, etc.

In this study, we conduct a counterfactual experiment to investigate the potential economic impact of CUSMA compared to "no-NAFTA" under which the U.S. withdraws from NAFTA and continues to impose Section 232 tariffs on steel and aluminum. The net incremental changes under the CUSMA to be assessed include: new TRQs market access for agricultural products; customs administration and trade facilitation, and origin procedures.

The macro results in Table 4.1 show that CUSMA had a considerable impact on its member's economies, in particular for Mexico. In 2020, Canada has 0.51% real GDP gain and 0.45% terms of trade gain. Employment increases by 0.79%. In 2025, the GDP gain reduce to 0.18% due to employment gradually converge to its baseline. For Mexico, even though employment reduce to 1.06% over the base in 2025 from 1.72% in 2020, the capital stock increase by 1%, which contribute to its long-term growth in GDP. Mexican labour market benefits the most from CUSMA. It raises it real wage by 2% and employment by 1% by 2025. Figure 4.1 shows the deviations of the aggregated employment and real wage in each region. Due to the stick-wage mechanism, employment increase in the short-term and gradually fall back to its new equilibrium when real wages rise.

Table 4.2 shows that, in % change term, the policy is favour female works in north America, especially in Mexico. Table 4.3-4.5 show that age 15-24, and 55+ are more responsive to the growth in labour demand due to the higher share of people are not in the labour force within these age groups. This story applies to all three North American economies.

Table 4.6 shows that there is about 47,000 job gain in total in Canada in 2025. Who are the winner and loser by industries in terms of job creation? Textile, wearing apparel, leather, motor vehicles gain most due to the CUSMA. Otherwise if the economies withdraw from NAFTA, it would push up the tariff back to the MFN levels. Also due to the CUSMA, it avoids the Section 232 tariffs on steel and aluminum, so we see ferrous metals sector also benefit. Meanwhile, majority of the service sectors gain due to the expansion of the overall economic activities. Table 4.7 shows that there is about 158,000 job gain in U.S. in 2025. Similar to Canada, textile, wearing apparel, leather, motor vehicles

are biggest winners in term of job creation. In contrast, ferrous metals in US suffer a loss in job because the tariff protection on the domestic producers in steel and aluminum is removed. Table 4.8 shows that Mexico has 627,000 more jobs (about 2/3 of the gain is female jobs) compare to the base. Similar to Canada, textile, wearing apparel, leather, motor vehicles and ferrous metals gain the most. Service sectors also benefit to the expansion of the overall economy.

Table 4.1. Macro impacts of CUSMA in 2020 and 2025 (%Deviation from the baseline)

% change	2020				2025			
	Canada	USA	Mexico	ROW	Canada	USA	Mexico	ROW
Real GDP	0.51	0.05	0.42	-0.02	0.18	0.08	0.86	-0.03
Terms of trade	0.45	-0.16	1.95	-0.03	0.37	-0.08	1.77	-0.03
GDP by expenditure								
Consumption	0.93	0.04	1.38	-0.04	0.45	0.05	1.61	-0.05
Investment	1.19	0.47	4.91	-0.20	0.58	0.78	6.66	-0.20
Government Spending	0.55	-0.02	0.98	-0.03	0.07	-0.05	0.58	-0.03
Total exports	1.92	2.19	3.05	0.09	2.32	1.84	4.02	0.05
Total imports	3.11	2.22	7.73	-0.11	2.55	2.59	8.22	-0.12
Factor markets								
Capital stock	0.00	0.00	0.00	0.00	0.16	0.15	1.02	-0.05
Real wages	0.45	0.09	1.03	-0.02	0.57	0.18	1.97	-0.04
Jobs	0.79	0.16	1.72	-0.04	0.23	0.10	1.06	-0.03

Figure 4.1. Impacts of CUSMA on wages and labour (%Deviation from the baseline)

Table 4.2. Potential Gender impacts of CUSMA across occupations in 2025

	Canada		USA		Mexico		ROW	
	Male	Female	Male	Female	Male	Female	Male	Female
tech_aspros	**-224**	**2,699**	**20,423**	**29,308**	**23,192**	**61,474**	**-50,815**	**-77,944**
% change	*-0.01*	*0.09*	*0.07*	*0.09*	*0.48*	*1.25*	*-0.02*	*-0.03*
clerks	**-64**	**2,985**	**1,887**	**9,279**	**7,620**	**33,721**	**-11,514**	**-35,356**
% change	*-0.02*	*0.17*	*0.04*	*0.08*	*0.42*	*1.72*	*-0.01*	*-0.04*
service_shop	**3,597**	**10,177**	**7,437**	**18,128**	**27,750**	**113,098**	**-47,282**	**-111,207**
% change	*0.14*	*0.30*	*0.07*	*0.10*	*0.45*	*1.73*	*-0.02*	*-0.04*
off_mgr_pros	**2,672**	**2,696**	**9,333**	**7,861**	**6,304**	**7,304**	**-20,685**	**-22,916**
% change	*0.17*	*0.27*	*0.09*	*0.11*	*0.61*	*1.37*	*-0.02*	*-0.03*
ag_othlowsk	**17,703**	**5,045**	**40,688**	**14,068**	**182,213**	**164,811**	**-281,428**	**-216,484**
% change	*0.49*	*1.00*	*0.12*	*0.17*	*0.77*	*2.08*	*-0.02*	*-0.05*
Total	**23,685**	**23,601**	**79,767**	**78,644**	**247,080**	**380,409**	**-411,723**	**-463,907**
% change	*0.22*	*0.25*	*0.09*	*0.10*	*0.66*	*1.74*	*-0.02*	*-0.04*

Table 4.3. Potential impacts in age groups of CUSMA across occupations in Canada

	Age15-24	Age25-34	Age35-44	Age45-54	Age55-64	Age65+
tech_aspros	**645**	**391**	**-40**	**-145**	**851**	**774**
% change	*0.17*	*0.03*	*0.00*	*-0.01*	*0.12*	*0.36*
Clerks	**424**	**301**	**183**	**101**	**1,046**	**866**
% change	*0.27*	*0.07*	*0.04*	*0.02*	*0.25*	*0.62*
service_shop	**5,255**	**1,630**	**1,010**	**879**	**2,764**	**2,234**
% change	*0.38*	*0.13*	*0.09*	*0.08*	*0.32*	*0.72*
off_mgr_pros	**289**	**968**	**1,119**	**1,034**	**1,292**	**665**
% change	*0.34*	*0.19*	*0.16*	*0.15*	*0.29*	*0.54*
ag_othlowsk	**3,416**	**4,018**	**3,745**	**4,031**	**5,111**	**2,428**
% change	*0.74*	*0.44*	*0.42*	*0.45*	*0.70*	*1.09*
Total	**10,029**	**7,308**	**6,017**	**5,901**	**11,065**	**6,967**
% change	*0.41*	*0.16*	*0.13*	*0.14*	*0.35*	*0.69*

Table 4.4. Potential impacts in age groups of CUSMA across occupations in USA

	Age15-24	Age25-34	Age35-44	Age45-54	Age55-64	Age65+
tech_aspros	**5,727**	**9,715**	**9,028**	**9,243**	**9,690**	**6,330**
% change	*0.12*	*0.07*	*0.06*	*0.07*	*0.10*	*0.16*
Clerks	**3,027**	**1,231**	**1,070**	**1,189**	**2,538**	**2,111**
% change	*0.11*	*0.04*	*0.03*	*0.04*	*0.09*	*0.19*
service_shop	**10,218**	**2,736**	**2,395**	**2,639**	**4,031**	**3,547**

% change	*0.13*	*0.05*	*0.05*	*0.05*	*0.11*	*0.21*
off_mgr_pros	**858**	**3,339**	**3,096**	**3,164**	**4,199**	**2,537**
% change	*0.13*	*0.08*	*0.07*	*0.08*	*0.11*	*0.18*
ag_othlowsk	**13,438**	**8,813**	**7,745**	**8,287**	**10,847**	**5,625**
% change	*0.20*	*0.10*	*0.09*	*0.10*	*0.16*	*0.28*
Total	**33,268**	**25,834**	**23,334**	**24,521**	**31,304**	**20,149**
% change	*0.15*	*0.07*	*0.07*	*0.07*	*0.12*	*0.20*

Table 4.5. Potential impacts in age groups of CUSMA across occupations in Mexico

	Age15-24	Age25-34	Age35-44	Age45-54	Age55-64	Age65+
tech_aspros	**13,167**	**24,041**	**18,153**	**13,929**	**9,572**	**5,804**
% change	*1.33*	*0.79*	*0.73*	*0.75*	*1.00*	*1.43*
Clerks	**15,157**	**10,668**	**6,174**	**4,370**	**2,949**	**2,023**
% change	*1.79*	*0.90*	*0.77*	*0.77*	*1.21*	*1.96*
service_shop	**43,405**	**24,291**	**20,321**	**19,139**	**20,577**	**13,116**
% change	*1.74*	*0.86*	*0.74*	*0.80*	*1.30*	*1.95*
off_mgr_pros	**1,327**	**3,522**	**3,094**	**2,534**	**1,868**	**1,265**
% change	*1.37*	*0.86*	*0.70*	*0.73*	*0.95*	*1.46*
ag_othlowsk	**99,194**	**57,306**	**53,424**	**49,606**	**51,362**	**36,134**
% change	*1.89*	*0.81*	*0.73*	*0.80*	*1.31*	*2.00*
Total	**172,249**	**119,827**	**101,166**	**89,577**	**86,327**	**58,342**
% change	*1.78*	*0.83*	*0.74*	*0.79*	*1.25*	*1.90*

Table 4.6. Potential impacts of CUSMA in occupation by industry in Canada

	tech_ aspros	clerks	Service_ shop	off_mgr _pros	ag_ othlowsk	Total
Agriculture	-105	-45	-118	-221	-1,001	-1,489
Mining	-806	-192	-120	-388	-890	-2,394
Beverages and tobacco	-5	-4	-15	-20	-48	-92
Textiles	159	138	308	366	1,382	2,352
Wearing apparel	1,294	965	3,441	2,100	8,835	16,635
Leather products	237	230	718	362	1,466	3,014
Wood products	-44	-23	-37	-80	-462	-647
Paper products, publishing	-711	-216	-323	-491	-1,129	-2,870
Petroleum, coal products	-10	-3	-4	-21	-29	-66
Chemical products	311	129	208	359	987	1,995
Basic pharmaceutical	134	56	89	154	417	850
Rubber and plastic products	570	237	381	661	1,824	3,673
Mineral products	3	3	3	-1	-21	-13

Ferrous metals	558	230	385	723	3,094	4,990
Other Metals	152	43	82	195	614	1,087
Metal products	-64	-50	-56	-99	-592	-860
Computer, electronic products	-373	-93	-129	-229	-478	-1,302
Electrical equipment	-147	-37	-51	-91	-197	-522
Machinery and equipment	28	10	9	11	11	70
Motor vehicles and parts	645	233	388	820	4,489	6,575
Transport equipment	-371	-83	-89	-165	-538	-1,245
Manufactures	-175	-100	-154	-219	-913	-1,560
Electricity, Gas distribution	181	71	48	108	112	521
Water	5	4	3	12	7	31
Construction	749	813	388	991	6,554	9,495
Trade	462	446	4,616	1,084	407	7,016
Accommodation, Food	188	83	3,592	236	24	4,122
Transport and storage	71	98	114	29	-113	198
Communication	-206	-80	-278	-147	-196	-907
Finance and Insurance	-68	-54	-57	-156	-6	-341
Real estate activities	50	36	15	9	-5	105
Business services	36	64	32	-94	-110	-72
Recreational	256	90	262	-76	-159	372
Public Admin and defense	1,029	262	788	55	-10	2,125
Education	188	139	162	-37	-31	421
Human health & social work	-1,749	-478	-831	-371	-548	-3,976
Total	2,476	2,921	13,774	5,367	22,749	47,287

Table 4.7. Potential impacts of CUSMA in occupation by industry in USA

	tech_ aspros	**clerks**	**Service_ shop**	**off_mgr _pros**	**ag_ othlowsk**	**Total**
Agriculture	7,055	1,645	3,144	2,384	5,865	20,094
Mining	16	16	29	0	18	79
Beverages and tobacco	330	84	154	110	284	961
Textiles	4,423	986	1,853	1,455	3,655	12,372
Wearing apparel	2,718	607	1,137	893	2,240	7,594
Leather products	431	97	182	142	357	1,208
Wood products	676	160	301	226	568	1,931
Paper products, publishing	534	139	266	155	429	1,524
Petroleum, coal products	-44	-9	-17	-16	-36	-122
Chemical products	1,169	280	525	379	967	3,319
Basic pharmaceutical	-710	-149	-281	-238	-587	-1,967
Rubber and plastic products	2,548	582	1,094	836	2,106	7,167
Mineral products	540	128	240	168	440	1,516
Ferrous metals	-15,457	-3,423	-6,439	-5,112	-12,797	-43,228
Other Metals	-426	-86	-170	-140	-351	-1,173

Metal products	15,556	3,491	6,570	5,142	12,870	43,629
Computer, electronic products	-1,645	-316	-595	-547	-1,331	-4,434
Electrical equipment	6,709	1,500	2,834	2,212	5,548	18,804
Machinery and equipment	12,509	2,813	5,280	4,111	10,344	35,058
Motor vehicles and parts	8,206	1,845	3,462	2,706	6,778	22,998
Transport equipment	1,990	464	875	652	1,661	5,642
Manufactures	2,650	725	1,274	843	2,197	7,689
Electricity, Gas distribution	-881	-144	-287	-311	-751	-2,374
Water	-8	22	22	-13	-2	21
Construction	25,570	4,826	10,330	8,949	25,731	75,407
Trade	-132	332	1,082	-277	-23	982
Accommodation, Food	-1,813	-428	-678	-557	-1,287	-4,764
Transport and storage	-2,159	-250	-678	-836	-1,969	-5,892
Communication	-1,050	-138	-276	-448	-1,035	-2,948
Finance and Insurance	-5,054	-1,281	-1,908	-1,552	-3,187	-12,982
Real estate activities	-487	-70	-69	-177	-293	-1,096
Business services	10,818	3,101	5,698	3,187	7,601	30,406
Recreational	-5,222	-1,410	-2,320	-1,585	-2,961	-13,499
Public Admin and defense	-2,331	-473	-666	-755	-1,396	-5,622
Education	-6,546	-1,637	-2,334	-1,864	-2,878	-15,259
Human health & social work	-10,750	-2,863	-4,072	-2,929	-4,014	-24,628
Total	49,732	11,169	25,559	17,193	54,759	158,412

Table 4.8. Potential impacts of CUSMA in occupation by industry in Mexico

	tech_ aspros	clerks	Service_ shop	off_mgr _pros	ag_ othlowsk	Total
Agriculture	-6,829	-1,756	-6,389	-1,585	-27,883	-44,442
Mining	-1,021	-345	-1,136	-206	-4,148	-6,856
Beverages and tobacco	-1,001	-339	-1,169	-164	-3,056	-5,728
Textiles	6,904	2,775	9,088	1,110	22,978	42,855
Wearing apparel	27,301	10,871	35,720	4,422	90,722	169,036
Leather products	1,027	427	1,399	170	3,520	6,543
Wood products	-1,070	-389	-1,277	-172	-3,417	-6,326
Paper products, publishing	-1,836	-698	-2,252	-306	-5,959	-11,051
Petroleum, coal products	-43	-6	-21	-9	-76	-154
Chemical products	-5,324	-2,020	-6,612	-872	-17,278	-32,106
Basic pharmaceutical	6	20	67	-1	92	183
Rubber and plastic products	109	102	339	10	599	1,158
Mineral products	1,439	603	1,979	229	4,923	9,174
Ferrous metals	840	357	1,201	132	2,917	5,446
Other Metals	-1,906	-748	-2,468	-309	-6,268	-11,699

Metal products	-2,026	-752	-2,403	-334	-6,334	-11,850
Computer, electronic products	-5,455	-1,556	-5,390	-870	-15,646	-28,917
Electrical equipment	-12,027	-4,433	-14,729	-1,931	-38,512	-71,631
Machinery and equipment	-5,104	-1,906	-6,427	-844	-16,376	-30,656
Motor vehicles and parts	43,993	17,700	57,818	7,110	146,610	273,229
Transport equipment	-826	-316	-1,044	-134	-2,670	-4,989
Manufactures	-3,957	-1,376	-4,771	-652	-12,612	-23,368
Electricity, Gas distribution	-13	7	18	-3	10	20
Water	93	87	213	10	480	883
Construction	32,251	12,319	41,628	6,706	153,352	246,256
Trade	28,594	12,992	46,089	4,115	96,378	188,169
Accommodation, Food	-5,173	-1,477	-4,303	-763	-10,118	-21,833
Transport and storage	-6,055	-1,914	-6,631	-1,345	-25,144	-41,090
Communication	-303	-72	-263	-65	-1,094	-1,797
Finance and Insurance	-708	-199	-520	-115	-1,786	-3,329
Real estate activities	33	44	181	1	291	549
Business services	4,670	2,272	7,741	699	17,296	32,679
Recreational	-1,757	87	570	-343	88	-1,355
Public Admin and defense	1,634	942	3,678	225	6,422	12,902
Education	-1,276	-34	396	-216	-1,204	-2,333
Human health & social work	-517	74	524	-91	-79	-89
Total	84,669	41,341	140,847	13,609	347,020	627,485

5. CONCLUSIONS AND FUTURE RESEARCH

In this paper, we incorporate a mechanism which endogenises labour supply in disaggregated labour market groups to the GTAP Recursive Dynamic (GTAP-RD) model. These groups are defined by relevant labour market characterisitics, such as genders, occupations, and age. By doing so, we not only can answer the questions related to the aggregated impacts to labor markets, but also the distributional effects. This model is potentially useful for the countries, like Canada, that are committed to pursuing an inclusive approach to trade. They try to ensure the benefits that flow from trade are more widely shared, including with under-represented groups such as women.

In addition, by explicitly introduced labour supply, we are able to model some supply shock in the labour market. For example, during the COVID-19 pandemic, people in the age group of 50+ leave the labour force earlier. We can change the taste variable B's for certain age groups in Equation (E2.6). This dynamic labour model with the overlapping generations (OLG) structure and the detailed demographic data, we can use it to analysis issues like the impacts of population ageing on labour market as well.

Apart from adding more sub-groups (indigenous people, etc), one of the direction of the future studies is to extend the labour database and labour module to more regions including those emerging markets.

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Appendix: A.1 Linking the Labour Module to GTAP-RD model

In standard GTAP or GTAP-RD model, labour is a mobile endowment. That means it can move across different sectors easily and there will be only single wage level for labour. If any sector offers different wages, then labour will leave from the sector with lower wages to the ones with higher wages to ensure only one wage level exist. As described by the following two equations, the sector-specific wages, *pfe*, are linked to the generic wages, pm. The supply of labour, *qo*, is equal to the weighted average of sector-specific labour demand, *qfe*. This market clearing condition is not in the sectoral level, only in the regional level. When labour demand, *qfe*, is determined by other part of the model, these two equations will determine the generic wages, *pm*.

Equation E_pfe
#links basic and firm demand prices for mobile endowments#
(**all**,e,ENDW)(**all**,a,ACTS)(**all**,r,REG)
pfe(e,a,r) = peb(e,a,r)+tfe(e,a,r);

Equation E_pe1
#mkt clearing for perfectly mobile endowments in each r#
(**all**,e,ENDWM)(**all**,r,REG)
qe(e,r) = **sum{**a,ACTS,ENDWMSHR(e,a,r)*qfe(e,a,r)**}**+endwslack(e,r);

In the model with detail labour market specification, we believe wages can be various across different sectors. Higher demand in some expanding sectors will offer higher wages, and this will attract more supply of labour and lower the wages. The more sophisticated sticky wages dynamics is described by Equation (E2.17).

To disconnect the original mechanism of labour market for each region in the GTAP-RD model and connect to the labour module, we need to have a market clearing condition in a more detail level.

1. disconnect the sector-specific wages and the generic wages by adding a shift variable f_pfe.

Equation E_pfe
#links basic and firm demand prices for mobile endowments#
(**all**,e,ENDW)(**all**,a,ACTS)(**all**,r,REG)
pfe(e,a,r) = peb(e,a,r)+*tfe*(e,a,r)+**f_pfe**(e,a,r);

2. link the sector-specific wages in GTAP-FDI to the labour module

Equation E_pfe_Lab1
#link to GTAP wages#
(**all**,e,ENDWL)(**all**,a,ACTS)(**all**,r,REG)
pfe(e,a,r) = p1lab_oi(e,a,r)+*f_p1lab*(e,a,r);

3. link the sector-specific labour demand in labour module to GTAP-FDI

Equation E_x1lab_e
(**all**,i,IND)(**all**,r,REG)
sum{e,ENDWL,EVFP(e,i,r)**}***x1lab_e(i,r) = **sum{**e,ENDWL,EVFP(e,i,r)*qfe(e,i,r)**}**;

4. others equations to close the model

Equation E_LAB_PRICE
#eq'n generates the composite price for sluggish endowments(HT50)#
(**all**,e,ENDWL)(**all**,r,REG)
pe(e,r) = **sum**(k,ACTS,REVSHR(e,k,r)*pfe(e,k,r))+*f_pm_lab*(e,r);

To active these equations and the linkages, we need to swap the following variables in the closure.

swap qe(ENDWL,REG) = f_pm_lab(ENDWL,REG);
swap f_p1lab(ENDWL,ACTS,REG) = f_pfe(ENDWL,ACTS,REG);

The first swap is to turn on Equation E_LAB_PRICE and turn off Equation E_pe1. The second swap is to turn on Equation E_pfe_Lab1 and turn off Equation E_pfe.