THE BRITISH COLUMBIA MACROECONOMIC MODEL

December 2016

Occasional Working Paper

Economic Forecasting and Analysis Branch

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http://www.fin.gov.bc.ca/

0. Introduction

The original version of the British Columbia Macroeconomic Model (BCMM) was completed in 1990 by WEFA Canada and Ministry of Finance staff. Since then, the BCMM has been used by the Ministry of Finance for macroeconomic forecasting and policy analysis. The model has gone through many rounds of revision since its original version, most recently to adapt to the new Canadian System of National Accounts (CSNA12). This report documents the structure and theoretical underpinnings of the 2014 version of the model.

Model design is constrained by the need to serve two purposes: forecasting and simulation analysis. It has been recognized that there is a trade-off between having a model with theoretical simulation properties that reflect the most recent trends in economic theory and one that performs well in forecast mode.[1] The current design of the BC Macroeconomic Model strikes a balance between theory and practicality according to its purpose of providing medium term forecasts and policy simulation analyses of economic activity in BC. The simulation properties of the BC Macroeconomic Model exhibit accepted theoretical results along the lines of the "Neoclassical Synthesis", which represents a combination of Keynesian and classical theories.[2]

The BCMM currently consists of about 350 equations and 120 exogenous variables. The model is closely related to the IHS Global Insight Canadian model, which provides forecasts for some of the exogenous variables[3], enabling national trends and policies to be fed through to the provincial level.

In common with many mainstream macroeconomic models, the BCMM assumes, on theoretical grounds, a set of long run structural relationships. The parameters of these relationships and their short run dynamics are generally estimated econometrically, on the basis of past experience, or calibrated based on the literature available. The standard 'general-to-specific' approach is used to develop statistically significant and economically meaningful equations.[4]

Model equations are reviewed during each forecast in terms of performance, and are re-estimated at least every two years.[5] In addition, intermittent reviews of the model's structure and dynamics are held and revisions made to ensure that the model remains up to date relative to current economic thinking and research. Throughout, the focus is on ensuring that, regardless of the innovations made, the model remains a practical tool for economic forecasting.

The rest of the paper is structured as follows. Section 1 provides a brief description of the forecast process within the Ministry of Finance. Section 2 provides a non-technical

[1] See Robidoux and Wong (1998).
[2] See Heijdra and van der Ploeg (2002) pages 18-22.
[3] Exogenous assumptions also come from year-to-date growth calculations, average private sector forecasts and other sources.
[4] See for example Westaway (2000), Robidoux and Wong (1998) or Fagan et al (2001).
[5] Staff is continuously engaged in the task of ensuring the database is current, consistent and accurate.

overview of the model. Due to the technical nature of macro-econometric models, the remaining sections of the paper delve into the model in detail and are largely aimed at academics and specialists who are familiar with large scale economic models.

1. The Economic Forecast Process in the Government of British Columbia

Timetable: The Ministry of Finance typically produces three medium-term (five-year) economic forecasts per year as follows:

- Budget (January)
- Summer (August)
- Winter (November) internal planning scenario

The economic forecast used in the budget process is generally produced in January, after the fall meeting of the Economic Forecast Council.[6] The summer forecast is completed in August, and is used to produce the First Quarterly Report in September. The November planning scenario is internal, and is used as a first step toward the Budget forecast.

Responsibility: The Economic Forecasting and Analysis Branch (EFA) in the Ministry of Finance is responsible for the development of the provincial government economic forecast. The Minister of Finance reviews key economic assumptions and recommendations from staff throughout the forecast process.

How the Forecast is Done: The forecast is produced using the BCMM. Model runs are then fine-tuned by EFA staff, with various adjustments reflecting recent economic intelligence or more up-to-date monthly data, or where staff judge that the model-generated results are out of line with likely trends. This review produces the final forecast, which is documented and published in government documents such as the *Budget Reports* and first *Quarterly Reports*.

First, the model requires assumptions to be made by staff, in consultation with the private sector and other ministries, about the outlook for key external factors that will affect the British Columbia economy, including the following:

- economic indicators for the rest of Canada, the US and other major trading partners;
- interest rates and exchange rates;
- commodity prices; and
- government fiscal policy.[7]

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[6] See pages 5-6 for a description of the Economic Forecast Council.

[7] In regards to the incorporation of government fiscal policy assumptions, the model requires assumptions to be made about total government expenditures and provincial government expenditures over the five-year forecast horizon. The practice generally followed has been to adopt the plans of the provincial government. In the case of spending by other levels of government, the practice has been to adopt assumptions that are in line with those employed by national forecasting organizations such as IHS Global Insight Canada and the Policy and Economic Analysis Program at the University of Toronto. Although the model can generate forecasts of provincial government revenue, these estimates are not used for budget purposes since they are derived on a national economic accounts basis rather than the public accounts basis used in revenue forecasting, and the formulas used are broad in nature. The actual revenue forecasts are generated separately by the Fiscal Planning and Estimates branch of Treasury Board Staff using more detailed analysis, and are consistent with provincial accounting policy.

At this stage, the degree of prudence is assessed using the balance of risks to the current outlook, and the views of private sector forecasters. Prudence is typically introduced into the forecast by setting external assumptions, such as Canadian and US real GDP growth. A further discussion on this is provided later in this section.

EFA staff review private sector forecasts of external assumptions. Branch staff consults a variety of outside experts, other divisions of the Ministry, and other government ministries such as Natural Gas Development, Energy and Mines, and Forests, Lands and Natural Resource Operations. Much of the ongoing gathering of economic intelligence by EFA helps in this process. EFA also consults with private sector economists, such as members of the Economic Forecast Council. In many cases, external assumptions are set based on the average of established private sector forecasts.

Once the review of external assumptions is complete, they are incorporated in the model and an initial model forecast is produced. EFA staff then review and discuss the results. Generally the forecast is done using a team approach. One group of staff will operate the model while a second set offer a 'third-party' view. The forecast is also presented to the Assistant Deputy Minister, Treasury Board Staff, who offers a 'third-party' review of the results as well. Typically, multiple runs will be required before EFA is satisfied with the model's forecasts. Adjustments are made based on the professional judgement of staff, to arrive at the base case forecast. EFA staff are careful not to over-adjust the model's results.[8]

EFA then produces a written document and a set of forecast tables that are reviewed by senior management. Finally, once the forecast has been reviewed by the Minister, the document becomes the government's official economic forecast.

External Review of Forecasts: The Ministry's economic forecast is publicly available in print and on the Internet. The documentation and tables are extensive, providing more public information than most other provincial governments.

Since the late 1990s, EFA has been organizing the annual Economic Forecast Council (EFC) conference hosted by the Minister of Finance. These meetings constitute an additional forum providing external feedback on the economic outlook in general. The council is made up of economic experts from the private sector or academia. They are brought together prior to the budget to meet with the Minister to discuss the economic outlook. Participants are polled on their detailed forecasts and their opinions on the key issues that will affect the outlook.

The proceedings and survey findings from the conference are published in the budget with the Ministry's economic forecast. The Ministry continues to produce and publish its own economic forecast, taking the survey results into consideration. This permits the public to compare the Ministry's forecast to the survey results. A report on the advice of the EFC is mandatory as required by the *Budget Transparency and Accountability Act*.

[8] Research shows that forecasters have a tendency to excessively over-adjust model forecasts with their own judgements. See McNees (1990).

The Ministry's economic outlook will typically differ from the average outlook provided by the EFC. The Ministry instils an explicit degree of prudence into its external economic assumptions. This practice is based on the set of recommendations published in *A Review of the Estimates Process in British Columbia* (Auditor General of British Columbia, 1999). In addition, the Ministry is able to use additional non-public information in developing its forecast (such as the current government's fiscal plan) which will also lead to differences between the Finance and EFC outlook. EFA staff maintain close contact with numerous private sector economists, industrial representatives and other experts regarding the outlook for various areas of the economy. These relationships support the development of the Ministry's economic outlook.

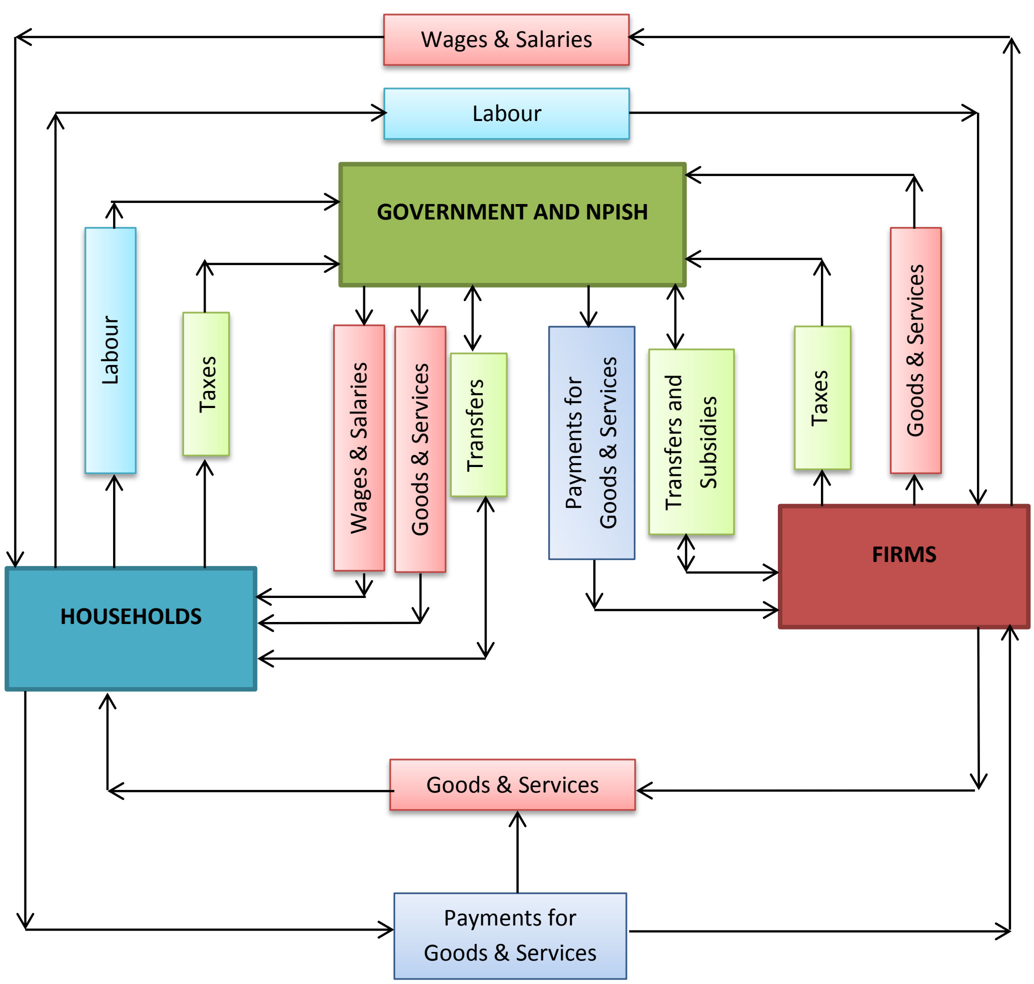
2. BC Model Overview

Section 2 provides a non-technical overview of the model. This is followed by a description of each sector of the model, containing the underlying economic theory as well as general forms of the equations. Section 12 notes data issues relevant to the operation of the model. Section 13 discusses potential future directions for the model.

The BC model reflects British Columbia's small open economy, one that produces goods and services and consumes domestic and foreign-produced goods and services. Domestic producers are assumed to be price takers in foreign and domestic markets, while foreign goods and services are assumed to be imperfect substitutes for domestic goods and services.

In the model, the economy is separated into five broad sectors: firms, households, non-profit institutions serving households (NPISH), governments, and the external sector. Figure 1 shows the interactions among four of these sectors (firms, households, NPISH and government) that make up the domestic economy.

Figure 1: Domestic Economy



Firms employ capital and labour to produce a profit-maximizing output under a Cobb-Douglas[9] production function with constant-returns-to-scale technology. Households consume domestic and foreign products and supply labour under the assumption of utility maximization. Governments collect taxes, make transfers to other sectors, employ labour, purchase domestic and foreign products, and produce output. The NPISH sector receives transfers from the government, firms and households, pays taxes and supplies goods and services to households. The external sector purchases domestic products and supplies imports.

There are three main markets represented in the model: the market for goods and services (also referred to as products), the labour market and financial markets. Each of the markets determines demand, supply and price for its products. Although generally government products are not sold in the marketplace, the income generated from the supply of these products, and their impact on the economy, are fully integrated into the model. Financial markets are not modelled explicitly and financial variables are exogenous. Figure 7, located at the end of this section, provides a schematic description of the structure of the model.

Market for Goods and Services

Domestic and foreign goods and services are incorporated in a number of different ways in the model. These goods and services can be consumed, used as residential and non-residential investments, held as inventories, or purchased by governments and foreigners. The demand for products stems from these uses. The supply of products originates from production, imports and inventory change. Market clearing (supply and demand balance) in the model comes via both quantity and price adjustments. However, quantity adjustment plays the more important role in the short run, due to the assumption that prices adjust slowly. In the long run, economic agents (particularly consumers) in BC are considered to be price takers.

Demand

Final demand is disaggregated into consumption, investment, government expenditures, net exports and the value of physical change in inventories (Figure 7, blocks C and K).

Consumption

Household demand is derived from a modified version of the permanent income model.[10] Figure 2 shows the variables that determine household expenditures on the left and the types of household expenditures on the right. Household expenditures depend on

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[9]The Cobb-Douglas production function is of the form:

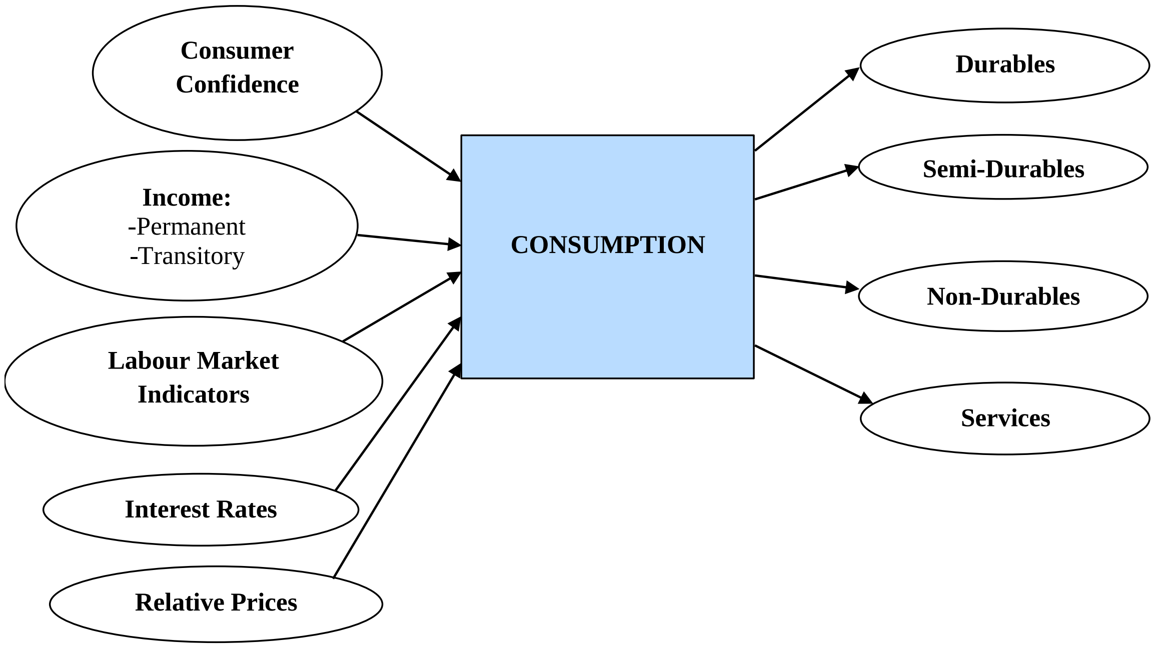
$$Q=AL^{\alpha}K^{1-\alpha}e^{\lambda t},\ \ 0<\alpha<1$$

where L is the amount of labour and K is the amount of capital used to produce a given amount of output (Q), and λ is a total factor productivity (A) growth coefficient.

[10] The general premise of the permanent income model is that households determine their annual consumption expenditures based on what they earn on average over a number of years. This means that a spike in income in a particular year will cause a much smaller change in annual consumption expenditures.

short-term (transitory) income and longer-term (permanent) income. The nominal short term interest rate and price levels also affect household expenditure, reflecting both credit constraints and inter-temporal substitution. The Conference Board consumer confidence index and changes in the unemployment rate are used as indicators of consumer confidence.

Figure 2: Consumption

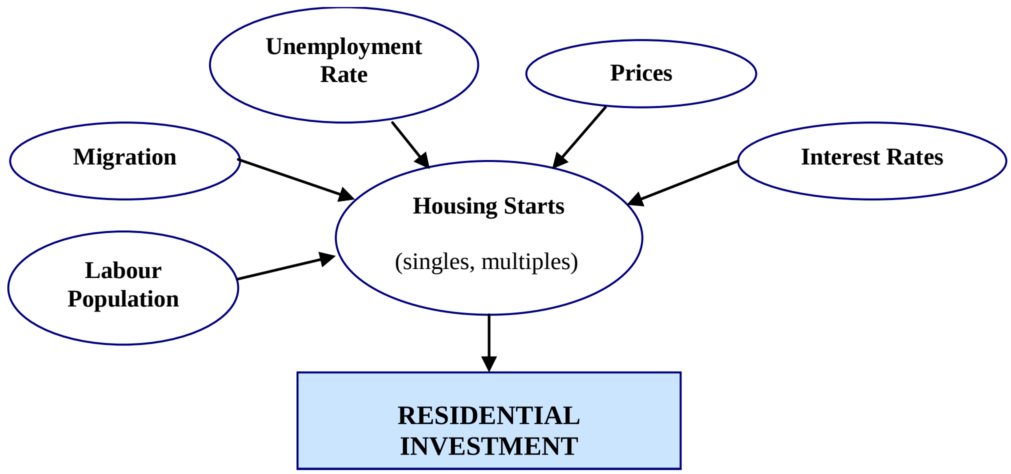


The NPISH sector is completely integrated in the model despite being a relatively small sector. Agents in the NPISH sector pay taxes, receive transfers (from firms, households and government), make investments, purchase goods and services from firms and provide goods and services to households. Due to the relatively small size of NPISH in the overall economy, some variables are exogenous.

Investment

Investment consists of residential construction, non-residential construction, intellectual property investment, and machinery and equipment investment.

Figure 3: Residential Investment



Total residential construction expenditures are based on the number of single and multiple housing starts. Both starts equations are determined from a reduced form supply function for the particular type of starts.

The desired stock of housing is dependent on those factors that determine the consumption of housing services, which are essentially the same as those for consumption above. However, demographic trends in migration play an important role in the determination of new housing investment.

Non-residential investment demand (for non-residential construction, machinery and equipment, and intellectual property investment) is based on firms' factor demands. The demand for capital and thus investment is derived from the assumption that firms seek to maximize profits. The long run desired capital stock is dependent on expected output, plus expected relative factor prices. Real investment in the NPISH sector is exogenous.

Government

This sector of the model incorporates the impact of government fiscal activity on the BC economy. The government sector is broken down into revenues and expenditures for federal, provincial, local and aboriginal government, and the Canadian Pension Plan. The income statement of the provincial government is considered in detail in the model. For the other three levels of government, only those aspects of the government necessary to determine the major economic relationships, such as personal disposable income, are included.

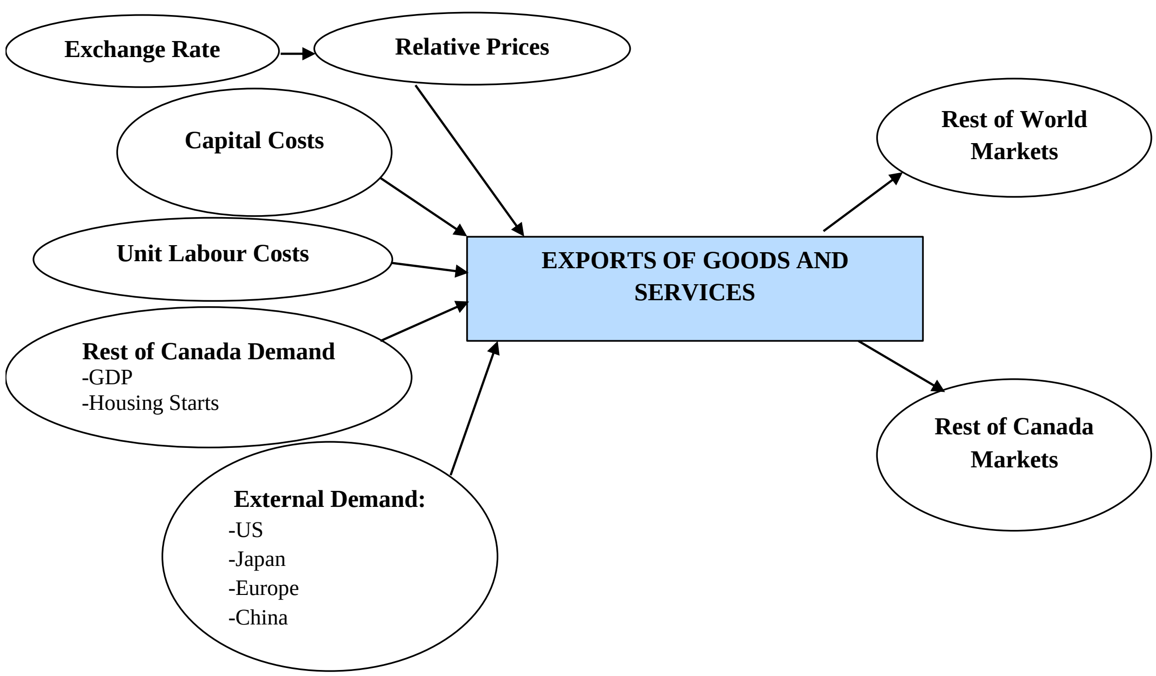
The major categories of government expenditures are total government spending on current goods and services, and transfers. Transfer payments occur between households, businesses, different levels of government and the NPISH sector. These expenditures are either determined outside the model or modelled using simple simulation rules.

The main types of revenues included in the model are personal direct taxes, business direct taxes, indirect taxes and investment income. These revenues are modelled using synthetic tax bases[11] and exogenous tax rates. Revenues are forecast on a system of national accounts basis, as opposed to the public accounts basis used in provincial budgeting. Therefore, the model's revenue forecast cannot be used directly for revenue forecasting on a public accounts basis. However, they do provide "ballpark" growth rates for analysing the effects of policy changes.

Exports

Exports are broken down by commodity and by broad market area (to the rest of Canada and to the rest of the world). As seen in Figure 4, the sector explicitly models exchange rate effects. Other factors that influence exports are external demand, relative prices and unit labour costs. External demand factors include housing starts, GDP, and industrial production indices for Japan, Europe, China and the U.S.

Figure 4: Exports

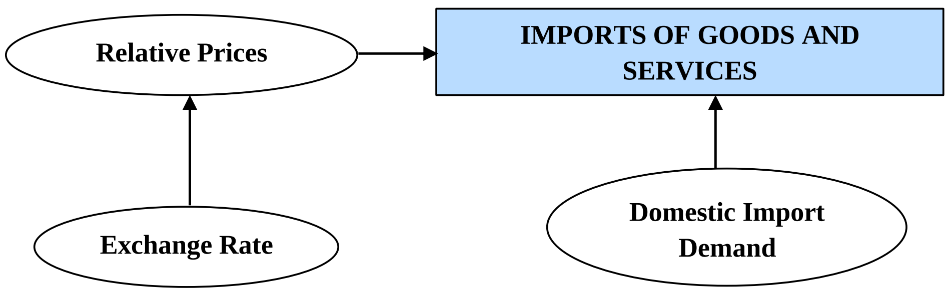


[11] Synthetic tax bases are aggregates that most closely match the source expenditure or income that a tax is assessed against to simulate the tax base, rather than using explicit data on actual taxpayers. For example, household income is a synthetic tax base for personal income tax.

Imports

Imports are divided into those originating from the rest of world and rest of Canada, for both goods and services. Each equation assumes price taking behaviour on the part of firms and households. The real value of each import category is primarily determined by a domestic demand variable and the relative price or cost of imports (Figure 5).

Figure 5: Imports



Supply

The model has one sector of production, and hence is considered a “one-sector” model. There is a consistent integration of output (Figure 7, block F), factor demands (block G), output prices and factor prices (block E). A Cobb-Douglas production function is specified for the good, and corresponding factor demands are derived under an assumption of profit maximizing[12] behaviour on the part of firms. These factor demands respond to output prices and relative factor prices.

A key assumption regarding the supply side of the model is that factors of production are quasi-fixed due to adjustment costs. Firms are assumed to maximize profits subject to the production function. This production structure is expected to hold on average and not on a period-to-period basis.[13] In addition, marginal conditions associated with profit maximization are expected to hold on average and not in each period.

With quasi-fixed factors of production, firms are assumed to design their production process to enable them to produce over a range of feasible operating rates. They will then choose factor quantities to maximize profits at the chosen point within the expected range of operating rates.

The values of output computed from the production function are defined as normal output. This represents the level of output that firms would produce if they were operating on their production function at an average level of factor utilization.

[12] Cost minimization may also be used.
[13] This type of model is outlined in Helliwell and Chung (1984).

While firms are generally assumed to be price-takers in the model, it is assumed that profit margins in some non-tradable industries[14] will vary somewhat under conditions of excess demand or supply. Firms will also adjust inventories in line with market conditions thus leading to changes in output. Changes in demand will be met by changes in inventories, output, imports and prices with almost all of the adjustment coming through quantities rather than prices in the short run. In the long run, migration and wage changes play the key role in clearing markets.

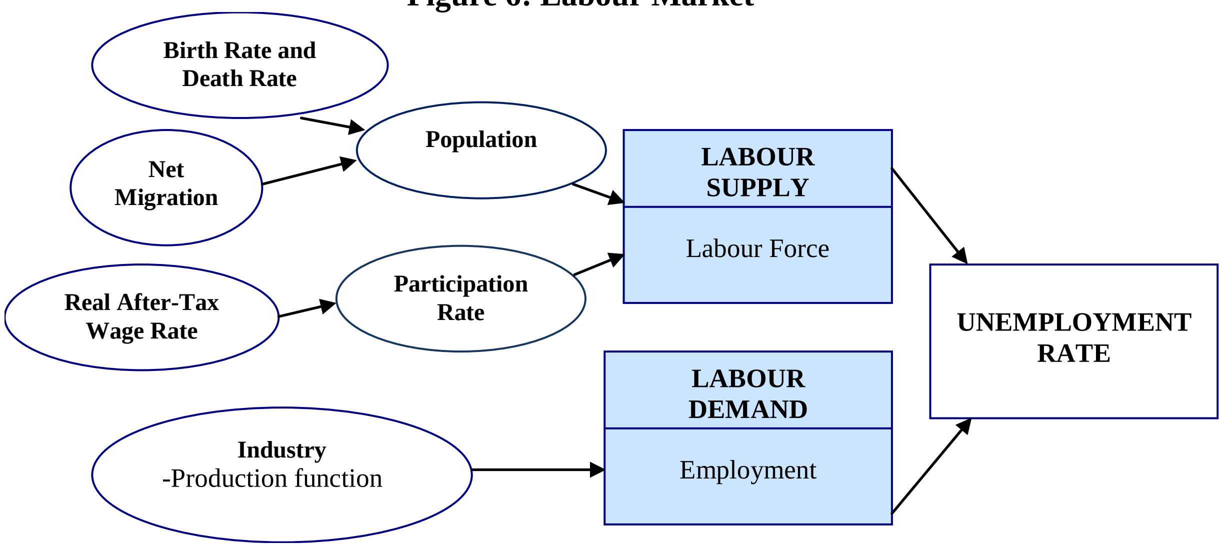
Inventory changes are based on a flexible accelerator model. According to this model, firms have a desired stock of inventories that depends on the real cost of inventories and expected sales. Inventories will change in response to changes in these factors.

Labour Market

Labour demand in the model is based on the industrial production function and is determined by the value of total output, wages and previous employment demand.

The labour force, which is the measure of labour supply in the model, is determined from source population and the participation rate. Population is determined from birth and death rates and net in-migration. Net in-migration consists of international and inter-provincial migration. International migration is exogenous and inter-provincial net migration is determined endogenously as a function of BC-Alberta unemployment rate and labour income differentials. The participation rate is derived from an equation relating the labour force participation rate to the real after-tax wage rate and the employment rate.

Figure 6: Labour Market



The impact of labour supply on real wages is also incorporated in the wage rate equations. These equations are augmented Phillips curve formulations relating the

[14] The market for housing services is an example.

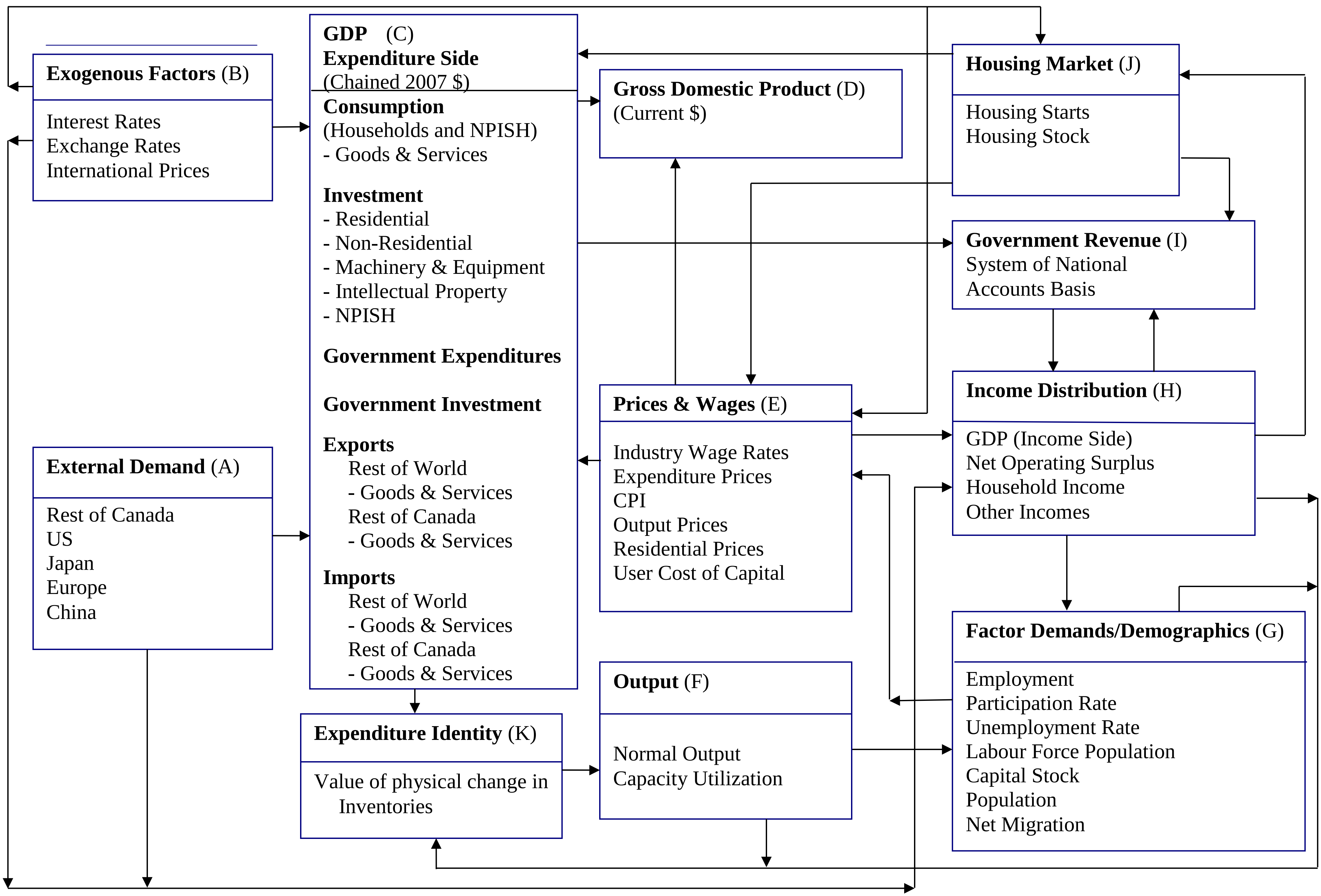
percentage change in the economy's wage rate to expected inflation and the change in the unemployment rate.

Financial Markets

The small open economy assumption for BC extends to financial markets, the same as for markets for goods and services. In goods and services markets this assumption manifests itself as price-taking behaviour. In terms of the financial market, it means that interest and exchange rates are determined outside of the model. Economic agents in BC take interest rates and exchange rates as given and they are consequently exogenous variables in the model. Therefore, unlike models of the Canadian economy, where interest rates and exchange rates may be determined internally, the BC Macroeconomic Model does not have a full monetary sector.

As a result, for simulations involving the effect of changing monetary conditions on British Columbia, impacts from a national model such as IHS Global Insight’s can be input into the BC model to generate province-specific impacts.

FIGURE 7: BC ECONOMETRIC MODEL



3. Consumption

The consumer sector of the model is concerned with determining the expenditure decisions of households. Consumer spending is broken down into four main categories: expenditure on services (including paid and imputed rent, restaurants and hotels, and other services), non-durables (including food and beverages, motor fuels and lubricants, electricity, gas and other fuels, alcoholic beverages, tobacco and other non-durables), semi-durables (including clothing and footwear and other semi-durable goods) and durables (including autos and parts and other durable expenditures). Real expenditures are modelled using stochastic equations,[15] while nominal expenditure values are determined from identities containing real expenditures and the corresponding price deflators (which are stochastic equations). Note that lower case variables indicate natural logs in all the equations that follow.

The determination of consumer expenditures is part of the overall household sector. This sector is concerned not only with consumer expenditures, but also with decisions regarding labour supply and savings. First households decide how much labour to provide. Given the wage rate, households decide how they will divide their time between work and leisure. Next, households decide how to divide their disposable income between consumption and savings,[16] and subsequently between various services, as well as durable, semi-durable and non-durable goods.

Consumption behaviour in the model is based on a version of the permanent income model,[17] where households smooth their consumption expenditures over time based on permanent versus transitory income. Allowances are made in the model for the impact of changes in consumer confidence[18] on expenditures through employment uncertainty and the Conference Board of Canada's consumer confidence index.

The equations for the categories of expenditures are of the general form:

$$ck_{i,t} - lp_t = \gamma_0 + \gamma_1 ypermk_t + \gamma_2 \Delta YTRANSK_t + \gamma_3 \Delta LUR_{t-1} + \gamma_4 (pc_{i,t} - pc_t) \quad (3.0)$$

where CK_i is real expenditures for a given category i, *LP* is labour force population, *YPERMK* is per capita real permanent income, *YTRANSK* is per capita real transitory income, ΔLUR is the change in the BC unemployment rate, PC_i is the price deflator for the consumption category i, and *PC* is the deflator for total consumption. For some consumption categories the Conference Board of Canada's consumer confidence index for BC (*CCONF*), the user cost of durable goods (*UCD*) – a function of short term interest rates and expected inflation – or a time trend are included. Not all variables are

[15] A stochastic equation is one that is estimated using regression analysis, which describes or estimates the value of one variable (the dependent variable) using one or more other variables (independent or explanatory variables).
[16] For a discussion of the consumption-savings decision see Romer (2006) pages 361-365.
[17] For a discussion of the permanent income model see Romer (2006) pages 347-352.
[18] See Dées and Brinca (2011) for an analysis of the impact of consumer confidence on consumption.

used in all equations, and distributed lags of some of these variables are employed in some equations.

The labour force population variable is included as a proxy for the number of households. Changes in household formation rates are assumed to be captured by changes in the independent variables in the equations. The relative price term is employed to allow for the substitution of consumption categories. The unemployment rate variable is included as a proxy for consumer confidence. As the unemployment rate rises, households are assumed to become less confident and reduce spending.

The permanent income per capita variable used in the model, *YPERMK*, is an extrapolative expectations formulation of the following form:

$$YPERMK_t = \gamma_0 + \gamma_1 TIME_t \quad (3.1)$$

where γ_0 and γ_1 are time varying coefficients estimated from the five-year moving average regression:

$$YDPPK_{t-1} = \gamma_0 + \gamma_1 TIME_{t-1} \quad (3.2)$$

where *YDPPK* is real per capita disposable income.

The transitory income per capita variable is defined as follows:

$$YTRANSK_t = YDPPK_t - YPERMK_t \quad (3.3)$$

Real per capita disposable income (*YDPPK*) is calculated as follows:

$$YDPPK_t = \left(\frac{YPD_t}{PC_t}\right)/LP_t \quad (3.4)$$

where *YPD* is household disposable income, and is defined as follows:

$$YPD_t = YPHI_t + YTR_t - YTP_t \quad (3.5)$$

and where *YPHI* is household income, *YTR* is household transfers received and *YTP* is household transfers paid.

4. Residential Investment

This sector of the model is concerned with determining the various measures of housing activity in the model. They include housing starts, housing stocks and residential construction expenditures. The real expenditure categories are modelled using stochastic equations, while the nominal expenditure values are determined from identities containing real expenditures and the corresponding price deflators.

Two markets for housing are distinguished in the model: the existing housing market and the new housing market. Within these markets a distinction is made between single-detached housing and multiple housing.

Residential construction expenditures are made up of three broad components: new construction, real estate commissions, and major renovations. The latter two components are not separated out in the model, but it is assumed that their growth follows that of new construction. Therefore, residential construction expenditures are based solely on new housing. New housing expenditures are derived from the production of new housing.

All real variables in the housing sector, except for housing starts, are expressed in millions of 2007 dollars.

Housing Starts

The equations for housing starts in the model use a reduced form model which includes demand variables such as interest rates and unemployment rates and supply variables such as user costs. The equation for single-detached starts is of the general form:

$$\begin{aligned} hss_t - lp_t = \gamma_0 + \gamma_1(netmig_t - lp_t) + \gamma_2(RTBCA_t - PEINF_t) \\ + \gamma_3 \Delta LUR_t + \gamma_4 uchss_t \end{aligned} \tag{4.0}$$

where *HSS* is the number of single-detached housing starts, *LP* is labour force population, *NETMIG* is total net migration into British Columbia, *RTBCA* is the interest rate on the Canadian 3-month Treasury Bill, *PEINF* is expected inflation, *ΔLUR* is the change in the BC unemployment rate, and *UCHSS* is the user cost of investment in single-detached houses.

The expected inflation variable is an adaptive expectations measure of inflation defined as follows:

$$PEINF_t \;=\; \text{MOVAVG}(3,\ (PCPI_t \,/\, PCPI_{t-1}\text{ -}1)\cdot 100) \tag{4.1}$$

where *PCPI* is the total BC consumer price index and MOVAVG(x,…) denotes a moving average function over x years (x=3 in this case).

Similarly, the equation for multi-unit housing starts is of the general form:

$$hsm_t - lp_t = \gamma_0 + \gamma_1(netmig_t - lp_t) + \gamma_2(RTBCA_t - PEINF_t) + \gamma_3 \Delta LUR_t + \gamma_4 uchsm_t \quad (4.2)$$

where *HSM* is the number of multi-unit housing starts and *UCHSM* is the user cost of investment in multi-unit houses.

The equations for user cost of investment in single-detached and multi-unit houses are presented with other user cost equations in section 5.

Housing Stock

The net housing stock variables in the model refer to the real dollar value of housing units. These are defined according to the accumulation rules:

$$KHSK_t = (1 - RDRINVSK_t) \cdot KHSK_{t-1} + (HSS_t / HS_t) \cdot IRTOTK_t \quad (4.3)$$

$$KHMK_t = (1 - RDRINVMK_t) \cdot KHMK_{t-1} + (HSM_t / HS_t) \cdot IRTOTK_t \quad (4.4)$$

where *HS* is the total number of BC housing starts, *IRTOTK* is total residential construction investment, and *RDRINVMK* and *RDRINVSK* are the depreciation rates for multi-unit and single-detached houses, respectively.

Residential Structures Investment

Residential structures investment (*IRTOTK*) includes the construction of new dwellings, additions, major renovations, conversions, permanently built-in equipment, site preparation and transfer costs such as real estate commissions. It is modelled as an Error Correction Model (ECM) based on housing starts activity in the province.

$$\Delta irtotk_t = \gamma_0 + \gamma_1 \Delta \mathrm{LN}(HSS_t + HSM_t) + \gamma_2 \left(irtotk_{t-1} - \gamma_3 \mathrm{LN}(HSS_{t-1} + HSM_{t-1})\right) \quad (4.5)$$

5. Non-Residential Investment and Inventories

The investment sector of the BC econometric model is based on the neoclassical theory of investment. This sector is concerned with the determination of investment expenditures by businesses, the NPISH sector and governments, the stock of capital and total inventory change.

Business investment is separated into different business investment categories: machinery and equipment, intellectual property and non-residential structures. Intellectual property is a category that Statistics Canada has reported separately since 2012 and includes investments in research and development, software, and mineral exploration. Business and NPISH investment expenditures are endogenous variables.

The government investment categories are machinery and equipment, non-residential structures and other investments and are determined outside of the model. Total investment is determined by an identity which adds all endogenous and exogenous investment categories.

Business Investment

The equations for investment are based on a variant of the neoclassical investment model[19], and are consistent with the supply-side framework adopted for the model as described in the overview. The demand for investment is derived from profit-maximization formulations for capital. For the Cobb-Douglas production technology adopted, the profit- maximization conditions are as follows:

$$K_{ME}^{*} = \beta \cdot (1-\alpha)\mathrm{MOVAVG}\left(3, \frac{PGDPBP_t \cdot GDPBPK_t}{U_{ME,t}}\right) \quad (5.0)$$

$$K_{NR}^{*} = (1-\beta) \cdot (1-\alpha)\mathrm{MOVAVG}\left(2, \frac{PGDPBP_t \cdot GDPBPK_t}{U_{NR,t}}\right) \quad (5.1)$$

$$K_{IP}^{*} = (1-\beta) \cdot (1-\alpha)\mathrm{MOVAVG}\left(2, \frac{PGDPBP_t \cdot GDPBPK_t}{PIBIP_t}\right) \quad (5.2)$$

where K^*_i is the desired capital stock for category *i*, β is the share of machinery and equipment in the total capital stock, α is labour's share in nominal output, *PGDPBP* is the deflator for gross domestic product at basic prices, *GDPBPK* is real GDP at basic prices, U_i is the user cost for investment category *i*, *PIBIP* is the price deflator for investment in intellectual property and is used as a proxy for the user cost of intellectual property and MOVAVG(x,…) denotes a moving average function over x years (x=2 or 3 years in this case).

While the above conditions are expected to hold in the long run, they may not do so in the short run due to adjustment costs, lags in the adjustment process, and other factors.

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[19] For example, see Mankiw and Scarth (2004) pages 501-511.

Actual capital stocks are related to long run desired stocks in a stock adjustment framework.

Standard stock-adjustment equations are employed in the model (see 5.3 and 5.4). Assuming proportionate replacement investment, the equations for gross investment in machinery and equipment and, non-residential construction and intellectual property[20] are generally as follows:

$$\frac{IB_{i,t}}{KBK_{i,t-1}} - \delta_i = \zeta_0 + \zeta_1 \frac{K^*_{i,t}}{KBK_{i,t-1}} \qquad (5.3)$$

where IB_i is investment in category i, K^*_i is the desired capital stock for category i, δ_i is the depreciation rate for category i, and KBK_i is the stock of capital for category i.

The equations for the actual capital stocks are as follows:

$$KBK_{i,t} = (1 - \delta_i) \cdot KBK_{i,t-1} + IB_{i,t} \qquad (5.4)$$

A key concept in the neoclassical theory of investment is the user cost of capital, or the implicit rental cost associated with using the services supplied by a unit of capital. The user cost equations result from assuming a profit maximizing firm for a typical industry. User costs reflect the three costs associated with owning capital: forgone interest from the sale of the asset, capital depreciation, and the price of capital changing.[21] The user cost of capital measures for machinery and equipment (U_{ME}), non-residential construction (U_{NR}), investment in single-detached houses (U_{HSS}), and investment in multi-unit houses (U_{HSM}) are calculated as follows:

$$U_{ME,t} = P_{ME,t} \cdot (RRATE + \delta_{ME} + TRI_{CCTP})_t \cdot \frac{(1 - R_{ITC} - (1 - MM \cdot R_{ITC}) \cdot R_{TDB} \cdot Z_{ME} - R_{TDB} \cdot PVINT_{ME})_t}{(1 - R_{TDB})_t} \qquad (5.5)$$

$$U_{NR,t} = P_{NR,t} \cdot (RRATE + \delta_{NR} + TRI_{CCTP})_t \cdot \frac{(1 - R_{ITC} - (1 - MM \cdot R_{ITC}) \cdot R_{TDB} \cdot Z_{NR} - R_{TDB} \cdot PVINT_{NR})_t}{(1 - R_{TDB})_t} \qquad (5.6)$$

$$U_{HSS,t} = P_{IRTOT,t} \cdot (RRATE + \delta_{HSS} + TRI_{CCTP})_t \cdot \frac{(1 - R_{TYC} \cdot Z_{ME} - R_{TYC} \cdot PVINT_{MENM})_t}{(1 - R_{TYC})_t} \qquad (5.7)$$

[20] Although not explicitly included in the production function, and therefore excluded from the calculation of capacity utilization (see section 11), intellectual property investment is estimated under the same profit maximizing conditions as machinery and equipment and non-residential structures.

[21] See Romer (2006) page 387-388.

$$U_{HSM,t} = P_{IRTOT,t} \cdot (RRATE + \delta_{HSM} + TRI_{CCTP})_t \cdot \frac{(1-R_{TYC} \cdot Z_{ME} - R_{TYC} \cdot PVINT_{MENM})_t}{(1-R_{TYC})_t} \quad (5.8)$$

where P_{ME}, P_{NR}, and P_{IRTOT} are the investment price deflators for machinery and equipment, non-residential construction, and residential construction, respectively; *RRATE* is the real corporate interest rate; δ_{ME}, δ_{NR}, δ_{HSS}, and δ_{HSM} are the respective capital depreciation rates; TRI_{CCTP} is the rate of corporation capital tax; R_{ITC} is the rate of investment tax credit (note that this is zero from 1989 to present); *MM* is a dummy variable; R_{TDE} is the appropriate expected corporate tax rate; Z_{ME} and Z_{NR} are the present values of tax depreciation for machinery and equipment and non-residential investment, respectively; R_{TYC} is the corporate tax rate on business income; and $PVINT_{ME}$, $PVINT_{NR}$ and $PVINT_{MENM}$ are the present values of interest deductions for machinery and equipment, non-residential construction, and machinery and equipment in the non-manufacturing sector, respectively.

For a detailed mathematical derivation of the user cost of capital equations including taxation see Jorgenson's (1967) seminal paper.[22]

The expected real corporate interest rate variable is computed as follows:

$$RRATE_t = \text{MOVAVG}(10, RCGB10_t - PEINF_t) \quad (5.9)$$

where *RCGB10* is the Government of Canada ten-year bond rate, *PEINF* is expected inflation and MOVAVG(x, …) denotes a moving average function over x years (x=10 in this case).

The present value formulations for the interest deductions are computed using a simple approximation:

$$PVINT_{ME,t} = (RRATE_t + PEINF_t / 100) / ((RRATE_t + PEINF_t / 100) + RCCA_{ME,t}) \quad (5.10)$$

$$PVINT_{NR,t} = (RRATE_t + PEINF_t / 100) / ((RRATE_t + PEINF_t / 100) + RCCA_{NR,t}) \quad (5.11)$$

$$PVINT_{MENM,t} = (RRATE_t + PEINF_t / 100) / ((RRATE_t + PEINF_t / 100) + RCCA_{MENM,t}) \quad (5.12)$$

where $RCCA_{ME}$, $RCCA_{NR}$ and $RCCA_{MENM}$ are the tax depreciation rates for machinery and equipment, non-residential construction, and machinery and equipment in the non-manufacturing sector.

[22] See also Hall and Jorgenson (1967) and Boadway (1980).

Business Inventories

In this model, firms accumulate inventory when real GDP exceeds demand. The real change in inventories, *VPCK*, is thus determined as follows:

$$VPCK_t = GDPMPK_t - (CK_t + FCNPK_t + IK_t + GCGSK_t + XK_t - MK_t + EXP_{RESIDK_t}) \quad (5.13)$$

where all variables are in real terms and *GDPMPK* is GDP at market prices, *CK* is household expenditures, *FCNPK* is final consumption of the NPISH sector, *IK* is total investment, *GCGSK* is total government expenditures on goods and services (all levels), *XK* is total exports, *MK* is total imports, and *EXP_RESIDK* is a residual.

The actual stock of inventory (*DBVK*) is then defined as follows:

$$DBVK_t = DBVK_{t-1} + VPCK_t \quad (5.14)$$

Following this, investment in inventories (*VPC*) is defined as follows:

$$VPC_t = \left(P_{SALES,t} \cdot DBVK_t\right) - (P_{SALES,t-1} \cdot DBVK_{t-1}) \quad (5.15)$$

where *PSALES* is the price deflator for sales of domestically produced goods.

The desired stock of inventories, *DBVKD*, is defined as follows:

$$DBVKD = RDBVKB \cdot \text{MOVAVG}(2, SALESK) \quad (5.16)$$

where *RDBVKB* is the stock-to-sales ratio, *SALESK* is total real domestic sales and MOVAVG(x, …) denotes a moving average function over x years (x=2 in this case). The moving average of the sales variable represents expected sales.

6. Trade

The trade sector of the model determines the imports and exports of goods and services. Exports are broken into rest of world (ROW) and rest of Canada (ROC) exports. ROW exports of goods are comprised of seven categories: wood and logs, pulp and paper, natural gas, other energy, other mining, other primary goods, plus an ‘other goods’ category. Aggregate goods exports are combined with services exports to obtain total ROW exports. ROC goods exports are made up of three categories (wood, energy, and other goods). Total ROC exports are obtained by adding services exports to goods exports. Imports are made up of ROW and ROC goods and services. All the trade variables are modelled in real terms with nominal values determined from the real values using their respective price deflators. Exchange rate effects are captured in the trade sector through the price deflators. Since BC is a price-taker, trade price deflators are viewed in terms of U.S. dollars. An exogenous Canada/U.S. exchange rate is used to convert trade price deflators into Canadian dollars.

Goods Exports

A significant share of production by BC’s major industries is exported to Canada and the rest of the world. Under the approach adopted in the model, exports of an industry depend on profitability and foreign demand. A market share approach is used in that the long run elasticity of goods exports with respect to foreign demand is constrained to unity. The equations for ROW goods exports are error correction models of the general form:

$$\begin{aligned} \Delta xk_{w,t} - \Delta exactk_t &= \gamma_0 + \gamma_1 \Delta\big(px_{w,t} - cost_t\big) \\ &-\gamma_2(xk_{w,t-1} - \gamma_3(px_{w,t-1} - cost_{t-1}) - exactk_{t-1}) \end{aligned} \tag{6.0}$$

where *XK* is ROW exports for a particular industry *w*, *EXACTK* is a measure of foreign demand, *PX* is the world price of the export, and *COST* is a measure business costs.

The measures of foreign demand are constructed from measures of economic activity for BC’s major trading partners. They are of the following form:

$$EXACTK_t = usgdpk_t^{\sigma} \cdot jpgdpk_t^{\tau} \cdot eugdpk_t^{\varphi} \cdot chngdpk_t^{\omega} \tag{6.1}$$

where *USGDPK* is real GDP in the United States, *JPGDPK* is real GDP in Japan, *EUGDPK* is real GDP in the euro zone, *CHNGDPK* is real GDP in China and σ, τ, φ and ω are the trade shares for a particular good with each trading partner. In some cases, industrial product indexes or annual housing starts are used instead of GDP.

The *COST* variable is defined as follows:

$$\begin{aligned} COST_{t-1} = \alpha \cdot lcost_{t-1} + (1-\alpha) \\ \cdot LN\left(\frac{IB_{NR,t-1}}{IB_{ME,t-1}+IB_{NR,t-1}} \cdot U_{NR,t-1} + \frac{IB_{ME,t-1}}{IB_{ME,t-1}+IB_{NR,t-1}} \cdot U_{ME,t-1}\right) \end{aligned} \tag{6.2}$$

where *LCOST* is a measure of the unit cost of labour, IB_{NR} and IB_{ME} are investment in non-residential structures and machinery and equipment (the ratios represent the relative size of non-residential and machinery and equipment, respectively) and U_{NR} and U_{ME} are user costs.

The *LCOST* variable is defined as:

$$lcost_t = \left(\frac{wr_t \cdot le_t}{gdpmpk_t}\right) \tag{6.3}$$

where *WR* is the wage rate, *LE* is employment and *GDPMPK* is real GDP at market prices.

These cost variables capture the long run wage and investment costs which influence export firm profitability. It can be seen from these equations that exports will rise as export prices or foreign demand rise. Rising labour and investment costs will increase business costs and reduce exports.

ROC exports are explained by 'foreign' demand measured by Canadian real GDP at market prices. The exception is wood exports, which are explained by Canadian housing starts.

Service Exports

Service exports include travel, freight and shipping, business services, government transactions, financial intermediation and other services.[23] These types of exports are difficult to measure and consequently there are data limitations in terms of availability and quality. Due to these limitations, only total ROC and ROW exports of services are modelled.

ROW service exports are modelled using the same structure as goods exports. ROC service exports are explained by the export price, lagged service exports to the rest of Canada and Canadian real GDP at market prices.

Imports

Real imports of goods and services assume price-taking behaviour on the part of firms and households. The real value of imports is determined by a domestic demand variable and the relative price or cost of imports. The general form of the equation for goods is as follows:

$$\Delta mk_{i,t} = \gamma_0 + \gamma_1 \Delta \frac{pm_{i,t}}{\left(\frac{fdd_t - ti_t}{fddk_t}\right)} + \gamma_2 \Delta salesk_t \tag{6.4}$$

where MK_i is real imports of category *i*, *SALESK* is real sales of goods produced in BC, PM_i is the price deflator for the import category, *FDD* is final domestic demand, *TI* is

[23] Guide to the Income and Expenditure Accounts, Statistics Canada Catalogue no. 13-017 (2008).

indirect tax and *FDDK* is real final domestic demand. For services, the general form is the same but *SALESK* is replaced with *CSK*, which is real household consumption of services.

7. Population, Employment, and Labour Force

The population and real labour market variables are determined in this sector of the model. The total labour force is determined in the model using male and female participation rates. Unemployment and the unemployment rate are computed through identities using total labour force and total employment.

Population

Total population is determined in the model using the component method. Population in the current year is equal to population in the previous year plus births minus deaths plus net in-migration (7.0). The latter is separated into international and inter-provincial migration.

The population equation is an identity employing aggregate synthetic birth and death rates and international and inter-provincial migration. International migration is exogenous, while net inter-provincial migration is determined endogenously. The equation for population is of the form:

$$POPBC_t = POPBC_{t-1} + BIRTHS_t - DEATHS_t + NETMIG_t + RESPOP_t \qquad (7.0)$$

where $POPBC$ is total population (July 1st basis), $BIRTHS$ is the birth rate, $DEATHS$ is the death rate, $NETMIG$ is total net migration and $RESPOP$ is a residual.

Total net migration is separated into net international migration and net inter-provincial migration:

$$NETMIG_t = NATNET_t + PROVNET_t \qquad (7.1)$$

where $NATNET$ is net international migration and $PROVNET$ is net inter-provincial migration.

Net international migration is specified as:

$$\begin{aligned} NATNET_t &= NATIN_t - NATOUT_t - NETTA_t \\ &\quad + POPNONPERM_t + POPRETURN_t \end{aligned} \qquad (7.2)$$

where $NATIN$ is international in-migration, $NATOUT$ is international out-migration, $NETTA$ is the net number of residents who are temporarily abroad, $POPNONPERM$ is the net change in non-permanent residents and $POPRETURN$ is returning Canadians.

The equation for net inter-provincial migration is:

$$PROVNET_t = PROVIN_t - PROVOUT_t \qquad (7.3)$$

where *PROVIN* is interprovincial migrants moving to BC and *PROVOUT* is interprovincial migrants moving out of BC.

The factors that influence migration of Canadians from other provinces to BC are as follows:

$$\Delta provin_t = \gamma_0 + \gamma_1 \Delta provin_{t-1} + \gamma_2\big(\Delta(wr_t) - \Delta(wrab_t)\big) + \gamma_3 \Delta(LUR_t - LURAB_t)$$
$$-\gamma_4 \Big(provin_{t-1} + \gamma_5(LUR_{t-1} - LURAB_{t-1}) - \gamma_6\big(\Delta(wr_{t-1}) - \Delta(wrab_{t-1})\big)\Big) \quad (7.4)$$

where *WR* is the wage rate in BC (wages and salaries divided by employment), *WRAB* is the wage rate in Alberta, *LUR* is the BC unemployment rate, and *LURAB* is the Alberta unemployment rate. Migration of people from BC to other parts of Canada, *PROVOUT*, is a stochastic equation with the same general form and explanatory variables as *PROVIN*.

Female population, *POPBCF*, is modelled as a ratio of total population as follows:

$$POPBCF_t = RPOPBCF_t \cdot POPBC_t \quad (7.5)$$

where *RPOPBCF* is generated by the other two variables. Male population is then determined as a residual.

Labour force population by gender is determined from the identities:

$$LPF_t = RLPF_t \cdot POPBCF_t \quad (7.6)$$

$$LPM_t = RLPM_t \cdot POPBCM_t \quad (7.7)$$

where *RLPF* and *RLPM* are the exogenous ratios of the female and male population variables, respectively.

Employment

Employment is derived using the industrial production function. The following specification based on profit maximization is used to determine employment (*LE*):

$$le_t = \gamma_0 + \gamma_1 le_{t-1} + \gamma_2 LN\left(\frac{\text{MOVAVG}(3, PGDPBP_t \cdot GDPBPK_t)}{WR_t}\right) \quad (7.8)$$

where *WR* is the economy-wide wage rate, *PGDPBP* is the deflator for GDP at basic prices, *GDPBPK* is real GDP at basic prices and MOVAVG(x,…) denotes a moving average function over x years (x=3 in this case).

Labour Force and Unemployment

The labour force is derived in the model through identities including labour force population and the participation rate. Male and female participation rates are determined under the assumption that the supply of labour depends on the real after-tax wage rate and other factors reflecting social and cultural change. The equations are of the form:

$$\Delta(lpr_t) = \gamma_0 + \gamma_1 \Delta LN\left(\text{MOVAVG}\left(5, \left(\frac{YPD_t}{YP_t}\right)\left(\frac{WR_t}{PC_t}\right)\right)\right)$$
$$+\gamma_2\left[\Delta(le_t - lp_t) - \text{MOVAVG}\left(5, \Delta(le_t - lp_t)\right)\right] \quad (7.9)$$

where LPR is male or female labour force participation, MOVAVG(x,…) denotes a moving average function over x years (x=5 in this case), YPD is household disposable income, YP is household income[24], PC is the household expenditure deflator, and LP is labour force population.

The labour force (LF) is determined as follows:

$$LFF_t = LPRF_t / 100 \cdot LPF_t \quad (7.10)$$

$$LFM_t = LPRM_t / 100 \cdot LPM_t \quad (7.11)$$

$$LF_t = LFF_t + LFM_t \quad (7.12)$$

where $LPRF$ and $LPRM$ are the participation rates for females and males respectively, LFF is female labour force, LPF is female labour force population, LFM is male labour force and LPM is male labour force population.

Unemployment (LU) and the unemployment rate (LUR) are computed from the following identities:

$$LU_t = LF_t - LE_t \quad (7.13)$$

$$LUR_t = LU_t / LF_t \cdot 100 \quad (7.14)$$

[24] See section 10 for a definition of YP, which is calculated on a national basis and includes compensation earned by BC residents abroad and excludes compensation earned by non-residents in BC.

8. Wages and Prices

This sector of the model is concerned with the determination of the wage rate and the various price deflators in the model. The price deflators are those for the various categories of expenditures described above.

The Wage Rate

The wage rate for labour in the model is determined using an augmented Phillips curve formulation. The equation is expressed in year-over-year percentage change form, with wage inflation as a function of expected inflation and the change in the BC unemployment rate. It is of the following form:

$$\Delta wr_t - PEINF_t/100 = \gamma_0 + [\textstyle\sum_{i=0}^{m} \theta_i \cdot (LUR_{t-1} - LUR_{t-2})_i\,] \quad (8.0)$$

where *PEINF* is a measure of expected inflation, *LUR* is the BC unemployment rate, *m* is the number of polynomial lags, and θ denotes coefficients. From the wage rate we are able to determine wages and salaries (*YW*):

$$YW_t = WR_t \cdot LE_t \quad (8.1)$$

where *WR* is the wage rate and *LE* is employment in BC. Wages and salaries (*YW*) plus employers social contributions (*YSLI*) determine compensation of employees (*YCE*):

$$YCE_t = YW_t + YSLI_t \quad (8.2)$$

Prices

Prices are determined in the model under the assumption that economic agents in BC are price takers. There is some allowance, however, for inflation differentials between BC and the rest of the world in response to changes in the degree of excess demand. That is, if unemployment rates or industry utilization rates change relative to that for Canada or the rest of the world, BC inflation may differ from that in these locations. In modelling prices, it is assumed that prices in Canada as a whole are representative of those in the rest of the world.

Consumer Prices

The equations for consumer price inflation are of the general form:

$$\Delta\left(pc_t - tic_t\right) - \Delta\left(pcca_t - ticca_t\right) = \gamma_0 + \gamma_1\left(LUR_t - LURCA_t\right) \quad (8.3)$$

where *PC* is the relevant BC deflator for a particular consumption category i, *PCCA* is the corresponding deflator for Canada as a whole, *TIC* and *TICCA* are terms containing taxable proportions of the commodity in BC and Canada, respectively, and *LUR* and *LURCA* are the unemployment rates for BC and Canada, respectively.

Other Domestic Deflators

Other domestic demand deflators are modelled similarly to the consumption price deflators, in that they are assumed to grow at the same rate as the Canadian deflator with some allowance for inflation differentials between BC and the rest of the world in response to changes in the degree of excess demand.

Trade Prices

The bulk of BC exports are priced in U.S. dollars and as a result the return to exporters depends on the Canada/U.S. exchange rate. In the BC Macroeconomic Model, U.S. dollar export prices are exogenous, as is the Canada/U.S. exchange rate. Export prices for BC trade with the rest of the world are assumed to grow at the same rate as those of Canadian exports. Canadians are also assumed to be price takers, therefore export and import deflators are assumed to grow at the same rate as the relevant foreign price deflators. These trade prices are then adjusted using an assumed Canada/U.S. exchange rate (because the Provincial Economic Accounts are denominated in Canadian dollars).

The trade prices for each industry are generally built up using various sub-categories. In the cases where no relevant sub-category exists, prices of related goods are used as proxies. The general form of the export price equations is as follows:

$$PX_{i,t} = EXP\left(px_{i,t-1} + \gamma_0 \Delta\left(prx_{i,t} \cdot exrca_t\right)\right) \qquad (8.4)$$

where *PX* is the deflator for sub category *i* for BC, *PRX* is the underlying price deflator for the sub-category (in US dollars), and *EXRCA* is the Canadian/US exchange rate. The exchange rate is dropped from the equation when the price of related goods or the underlying price deflator is already in Canadian dollars.

For each export category, price deflators are multiplied by real exports to determine nominal exports. Total nominal exports is the sum of nominal export categories and total real exports is the chain-weighted sum of real export categories. The price deflator for total exports is calculated as total nominal exports divided by total real exports.

GDP Deflator

The GDP deflator is determined by the identity relationship between nominal and real GDP:

$$PGDPMP_t = \frac{GDPMP_t}{GDPMPK_t} \qquad (8.5)$$

where *GDPMP* is nominal GDP at market prices and *GDPMPK* is real GDP at market prices.

9. Government

This sector includes revenues and expenditures for the various levels of government in the model. These levels include the federal government, provincial government, local and aboriginal governments, and Canada Pension Plan. The various categories of revenues and expenditures included in the model for each level of government are described below. A large number of the equations used in this sector to model revenues and expenditures are simulation rules or identities. In many cases these equations include statutory tax rates, while others use exogenous growth rates and effective tax rates[25] and tax bases.

Current expenditures for the federal government include expenditures on goods and services, compensation of employees, transfers, subsidies and interest on debt. Expenditures on transfers are further broken down to include transfers to persons (including employment insurance, old age security and other transfers), provincial governments, local and aboriginal governments. Total revenues are divided into direct taxes (including taxes from persons and businesses) and indirect taxes (including the GST, custom import duties, excise taxes and other taxes). Other categories of revenue are other personal, provincial and NPISH transfers to the federal government, investment income, as well as contributions to social insurance plans.

For the provincial government, current expenditures are divided into spending on goods and services, compensation of employees, transfers, subsidies, and interest on debt. Expenditures on transfers include transfers to persons (through social assistance or other means), the federal government and local governments. Provincial government revenues come from direct taxes (on persons and businesses), contributions to social insurance plans and indirect taxes (from gasoline, retail sales, liquor commissions, tobacco, property, gaming profits and others). Other personal transfers, federal transfers, local transfers, NPISH transfers and investment income are also sources of revenue for the provincial government in the model.

Local and aboriginal government expenditures in the model include spending on goods and services, compensation of employees, transfers (including transfers to persons, the provincial government and NPISH), subsidies and interest on debt. Revenues are generated from indirect taxes on property, other personal transfers, federal transfers, provincial transfers, NPISH transfers and investment income.

Expenditures in the Canada Pension Plan sector include spending on goods and services and transfers to persons. Revenue comes from direct taxes and investment income.

[25] Effective tax rates are calculated as observed revenues divided by the observed tax base.

Federal Government

In general, a share approach is taken to model federal government expenditures and some revenues. This means that federal government expenditures in the province for a particular category are assumed to be an exogenous share of federal government expenditures for Canada as a whole. In some cases, revenues are calculated using effective and/or statutory tax rates and synthetic[26] tax bases.

Federal personal income taxes (*TDPYF*) are modelled as follows:

$$TDPYF_t = TRDPYF_t \cdot YP_t \tag{9.0}$$

where *TRDPYF* is an effective tax rate and *YP* is household income.

Other personal direct taxes (*TDPSIF*), which include contributions to social insurance plans, are determined as:

$$TDPSIF_t = TRDSIF_t \cdot YCE_t \tag{9.1}$$

where *TRDSIF* is an effective tax rate and *YCE* is compensation of employees.

Direct taxes on businesses (*TDBF*) are modelled as a function of net operating surplus as follows:

$$TDBF_t = TRDBF_t \cdot YNOS_t \tag{9.2}$$

where *TRDBF* is an effective tax rate and *YNOS* is net operating surplus.

Federal indirect taxes are split into custom duties, GST, excise, and other taxes. Custom duties (*TICF*) are modelled as a simulation rule based on imports as follows:

$$TICF_t = TRICF_t \cdot M_t \tag{9.3}$$

where *TRICF* is an effective tax rate and *M* is nominal imports. Excise and other taxes (*TIOF*) are modelled as a simulation rule based on consumption of goods as follows:

$$TIOF_t = \frac{(TRIOF_t)}{(1 + TRIOF_t)} \cdot (CND_t + CSD_t + CD_t) \tag{9.4}$$

where *CND*, *CSD* and *CD* are consumption of non-durable, semi-durable and durable goods, respectively, and *TRIOF* is the effective tax rate for the category.

[26]For a definition of synthetic tax bases please see Section 2, footnote 11.

GST revenue (*TIGST*) is modelled as a function of expenditure as follows:

$$TIGST_t = RTIGST_t \cdot RRTIGST_t \cdot \sum_{i=1}^{n}\left[\delta_{GST,i,t} \cdot EXP_{i,t} / (1+\delta_{RST,i,t} \cdot RRST_t + \delta_{GST,i,t} \cdot RTIGST_t)\right] \quad (9.5)$$

where *RTIGST* is the GST tax rate, *RRST* is the retail sales tax rate, *RRTIGST* is an effective tax rate, EXP_i is expenditure category *i*, $\delta_{RST,i}$ is the taxable proportion of expenditure category EXP_i for the retail sales tax, and $\delta_{GST,i}$ is the taxable proportion of expenditure category EXP_i for the GST.

Other household transfers to the federal government (*TOPTF*) are determined as follows:

$$TOPTF_t = TROPTF_t \cdot YP_t \quad (9.6)$$

where *TROPTF* is an effective tax rate on household income (*YP*).

Total revenues, expenditures and the overall federal balance in the province are determined through identities.

Provincial Government

A more detailed approach is employed to model revenues and expenditures for the provincial government. Expenditures are generally modelled as being determined by exogenous growth rates, while revenues are generally a function of exogenous tax rates and endogenous tax bases. Revenues are determined on a system of national accounts basis, as opposed to a public accounts basis. The model calculates the budget deficit given the exogenous assumptions made about provincial revenues and expenditures. These estimates are used as “ballpark” measures only and are not used for revenue forecasting.

Current provincial government expenditures on goods and services, and capital formation are exogenous in the model.

Transfers to households (*GTPPP*) are split into social assistance (*GTPPRELP*) and other (*GTPPOP*), and are specified as follows:

$$GTPPP_t = GTPPRELP_t + GTPPOP_t \quad (9.7)$$

Transfers to the federal government, local and aboriginal government, NPISH, and transfers in the form of subsidies are exogenous. Expenditures to finance interest on debt are also determined exogenously.

Revenue from personal income tax (*TDPYP*) is determined as follows:

$$TDPYP_t = TRDPYP_t \cdot YP_t \tag{9.8}$$

where $TRDPYP$ is the effective tax rate, and YP is household income.

Provincial direct taxes on business (*TDBP*) are modelled as follows:

$$TDBP_t = TRDBP_t \cdot RTYC\_P_t \cdot YNOS_t \tag{9.9}$$

where $TRDBP$ is an effective tax rate, $RTYC\_P$ is the provincial corporate tax rate and $YNOS$ is the net operating surplus of corporations.

Contributions to provincial social insurance plans (*TDPSIP*) are modelled as follows:

$$TDPSIP_t = TRDPSIP_t \cdot YW_t \tag{9.10}$$

where $TRDPSIP$ is an effective tax rate and YW is wages and salaries.

Indirect taxes are modelled for each category as an effective tax rate times a proxy for the tax base. For example, the equation for gasoline taxes (*TIGASP*) is as follows:

$$TIGASP_t = \frac{TRIGASP_t}{\left(1 + TRIGASP_t\right)} \cdot CND_t \tag{9.11}$$

where $TRIGASP$ is an effective tax rate and CND is the consumption of non-durables. Tobacco and liquor taxes are calculated similarly.

The general form for the retail sales tax revenue (*TIRSP*) is:

$$TIRSP_t = RRST_t \cdot RRRST_t \cdot \sum_{i=1}^{n}\left[\delta_{RST,i,t} \cdot EXP_{i,t} / \left(1 + \delta_{RST,i,t} \cdot RRST_t + \delta_{GST,i,t} \cdot RTIGST_t\right)\right] \tag{9.12}$$

where $RRST$ is the retail sales tax rate, $RRRST$ is an effective tax rate, EXP_i is expenditure category i, $\delta_{RST,i}$ is the taxable proportion of expenditure category EXP_i for the retail sales tax, $\delta_{GST,i}$ is the taxable proportion of expenditure category EXP_i for the GST.

Property taxes (*TIPP*) are determined as follows:

$$TIPP_t = TRIPP_t \cdot (PIRTOT_t \cdot (KHSK_t + KHMK_t) + PIBNR_t \cdot KBNRK_t) \tag{9.13}$$

where $TRIPP$ is an effective tax rate, $PIRTOT$ is the price deflator for housing, $\left(KHSK + KHMK\right)$ is the stock of housing (singles and multiples), $PIBNR$ is the price deflator for non-residential construction and *KBNRK* is the stock of non-residential construction.

The corporate capital tax on businesses is modelled as a function of the capital stock of non-residential construction and machinery and equipment, as well as their respective deflators:

$$TICCTP_t = TRICCTP_t \cdot [\text{MOVAVG}(2, PIBNR_{t-1}) \cdot KBNRK_{t-1} + \text{MOVAVG}(2, PIBME_{t-1}) \cdot KBMEK_{t-1}] \quad (9.14)$$

where $TRICCTP$ is the effective tax rate, PIBNR is the price deflator for non-residential construction investment, PIBME is the price deflator for machinery and equipment investment, KBNRK and KBMEK are the stock of non-residential structures and machinery and equipment, respectively, and MOVAVG(x,…) denotes a moving average function over x years (x=2 in this case).

Other indirect taxes (*TIOOP*) are modelled as a function of net domestic income at basic prices (*YNDIBP*):

$$TIOOP_t = TRIOOP_t \cdot YNDIBP_t \quad (9.15)$$

where $TRIOOP$ is an effective tax rate.

Other household transfers to the provincial government (*TOPTP*) are determined according to the following equation:

$$TOPTP_t = TROPTP_t \cdot YP_t \quad (9.16)$$

where $TROPTP$ is an effective tax rate on household income (YP).

Investment income (*TYIP*) in the province is split into royalties and other income. Royalty income (e.g. stumpage, petroleum and natural gas, water resources, and minerals) is modelled as a function of the value of resource exports (*XRES*) and an effective tax rate (*TRYROYP*):

$$TYROYP_t = TRYROYP_t \cdot XRES_t \quad (9.17)$$

Other investment income, deflated by the final domestic demand deflator, is a function of the real interest rate, accounting for government-held public funds:

$$\Delta tyiop_t - \Delta pfdd_t = \gamma_0 + \gamma_1 \Delta(RTBCA_t - PEINF_t) \quad (9.18)$$

where $TYIOP$ is other investment income, $PFDD$ is the final domestic demand deflator, and (*RTBCA – PEINF)* is a measure of the real interest rate where *PEINF* is expected inflation and *RTBCA* is the interest rate on the Canadian 3-month Treasury Bill.

Total revenues and expenditures in addition to the overall provincial balance in the province are determined through identities.

Local and Aboriginal Governments, and Canada Pension Plan

These levels of government are modelled in a manner similar to that for the provincial government. Expenditures are generally determined by exogenous growth rates, while revenues are a function of exogenous tax rates and endogenous tax bases.

10. Income

The income sector of the model is concerned with the determination of gross domestic product, the components of net domestic income, household income, and corporate income (net operating surplus). The domestic income components included in the model are wages and salaries, employers' social contributions, property income, household mixed income, transfers and corporate operating surplus before tax. These components are modelled in current dollars. Net operating surplus (corporate operating surplus before taxes) is calculated so as to ensure equality between income and expenditures in the model. The equations for many of the components for household and corporate income are identities as these categories are largely determined from variables in other sectors of the model.

Current Dollar Gross Domestic Product

For current dollar GDP a standard summation is used:

$$GDPMP_t = FDD_t + VPC_t + X_t - M_t + EXP\_RESID_t \qquad (10.0)$$

where all variables are in current dollars and *GDPMP* is GDP at market prices, *FDD* is final domestic demand, *VPC* is value of business investment in inventories, *X* is total exports, *M* is total imports and *EXP_RESID* is a statistical discrepancy.

Final domestic demand is the sum of the domestic expenditure categories:

$$FDD_t = CC_t + GCGS_t + FCNP_t + I_t \qquad (10.1)$$

where *CC* is household consumption, *GCGS* is government consumption of goods and services, *FCNP* is final consumption by the NPISH sector, and *I* is business, government and NPISH sector investment.

Domestic Income

In the Provincial Income and Expenditure Accounts, Gross Domestic Product and Gross Domestic Expenditures are always equal. To ensure this equality in the model, the income side is treated as the residual. Net Domestic Income (*YNDIBP*) is determined from the following identity:

$$YNDIBP_t = GDPBP_t - YCCA_t - Y\_RESID_t \qquad (10.2)$$

where *GDPBP* is nominal GDP at basic prices, $YCCA$ is total consumption of fixed capital, and Y_RESID is the residual error of the estimate for the income side.

Consumption of fixed capital allowance is made up of consumption of fixed capital for corporations, governments, the NPISH sector, and unincorporated businesses.

Consumption of fixed capital for corporations are determined in this section and consumption of fixed capital for unincorporated businesses are assumed to grow at the same rate as corporations. Consumption of fixed capital for the government and NPISH sectors are exogenous in the model.

For corporations, consumption of fixed capital is modelled as a linear function of nominal investment expenditures. This procedure approximates a declining balance method calculation for the depreciation of capital assets. The equation is of the following form:

$$yccabus_t = \gamma_0 + \gamma_1 yccabus_{t-1} + \gamma_2 LN(IBME_t + IBNR_t + IBIP_t + IRTOT_t) \qquad (10.3)$$

where *IBME* is nominal business investment in machinery and equipment, *IBNR* is nominal business investment in non-residential construction, *IBIP* is nominal investment in intellectual property, and *IRTOT* is nominal investment in residential construction.

Compensation of employees (*YCE*)[27] is determined from an identity incorporating wages and salaries (*YW*) and employers' social contributions (*YSLI*):

$$YCE_t = YW_t + YSLI_t \qquad (10.4)$$

Employers' social contributions are determined from a simulation rule linking the growth rate in such income to the growth rate in wages and salaries:

$$YSLI_t = YSLI_{t-1} \cdot EXP(\Delta(yw_t)) \qquad (10.5)$$

Property income (*YPROPR*) accrues to the owners of financial assets, land or natural resources when these assets are managed by other institutional units; income received from financial assets is called investment income while income from land or natural resources is called rent[28]. Property income is a stochastic equation of the following form:

$$\Delta ypropr_t = \gamma_0 + \gamma_1 \Delta rtbca + \gamma_2 \Delta rgcb10 \qquad (10.6)$$

where *RTBCA* is the Canadian 3-month Treasury bill interest rate and *RGCB10* is the 10-year Canadian Government bond interest rate.

Mixed income is a balancing item that includes income whose mix of labour and capital income is not possible to determine. For some unincorporated businesses, it is not possible to estimate compensation of employees, consumption of fixed capital and a return to capital separately. Net mixed income (*YNMI*) is an identity of the form:

$$YNMI_t = YNMINONFARM_t + YNMIFARM_t + YRENT_t \qquad (10.7)$$

[27] YCE is calculated on a domestic basis and excludes compensation earned by BC residents abroad and includes compensation earned by non-residents in BC.
[28] European Commission, International Monetary Fund, OECD, United Nations, World Bank (2009). System of National Accounts 2008, paragraph 7.107.

where *YNMINONFARM* is non-farm mixed income, *YNMIFARM* is mixed income from farming and *YRENT* is rental income of households.

As mentioned above, net operating surplus is the variable in the model that is used to ensure equality between income and expenditure. This variable is determined from the identity:

$$YNOS_t = YNDIBP_t - YCE_t - YNMI_t - TILSFP_t \quad (10.8)$$

where *YNOS* is net operating surplus, *YNDIBP* is net domestic income at basic prices, *YCE* is compensation of employees, *YNMI* is net mixed income and *TILSFP* is taxes less subsidies on production.

Household and Corporate Income

The components of household income include compensation of employees, mixed income, property income received, and received transfer payments. Corporate income can be approximated by net operating surplus after tax (*YNOSAT*) which is calculated as follows:

$$YNOSAT_t = YNOS_t - TDBF_t - TDBP_t \quad (10.9)$$

where *YNOS* is net operating surplus before tax, and *TDBF* and *TDBP* are direct federal and provincial business taxes, respectively.

Household income (*YP*) is determined from an identity in the model:

$$YP_t = YCE\_H_t + YNMI_t + YPROPR_t + YTR_t \quad (10.10)$$

where *YCE_H* is compensation of employees for households[29], *YNMI* is net mixed income, *YPROPR* is property income and *YTR* is transfers received by households.

Household disposable income (*YPD*) is defined as follows:

$$YPD_t = YPHI_t + YTR_t - YTP_t \quad (10.11)$$

where *YPHI* is primary household income, *YTR* is transfers received by households and *YTP* is transfers paid by households.

Primary household income (*YPHI*) is determined by the following identity:

$$YPHI_t = YCE\_H_t + YNMI_t + YPROPNET_t \quad (10.12)$$

[29] YCE_H is calculated on a national basis and includes compensation earned by BC residents abroad and excludes compensation earned by non-residents in BC.

where *YPROPNET* is property income received net of property income paid for the use of financial assets, land or natural resources.

The determination of permanent and transitory income is discussed in the section on consumer expenditures (section 3).

11. Output and Normal Output

The determination of aggregate output in the model is based on the utilization rate approach (see Helliwell (1987)). This approach emphasizes the joint role of inventories, operating rates and price changes in meeting unexpected or temporary changes in demand. Thus real GDP (*GDPMPK*) at market prices is defined by the following identity:

$$GDPMPK_t = CAPU_t \cdot CGDPMPK_t \qquad (11.0)$$

where *CAPU* is the factor utilization rate and *CGDPMPK* is normal output.

Normal output is defined as the level of output that would be produced according to the production function, given the amount of labour and capital available in the economy. The difference between the level of actual output and normal output is called the normal output gap. Assuming a Cobb-Douglas production function[30], normal output (*CGDPMPK*) is determined by the identity:

$$CGDPMPK_t = A_t \cdot \left(LE_t^{\alpha} KBMEK_t^{(1-\alpha)\beta} KBNRK_t^{(1-\alpha)(1-\beta)} \, e^{\lambda \cdot TIME} \right) \qquad (11.1)$$

where *A* is an index of technical progress that increases exponentially at rate λ, *LE* is employment, *KBMEK* is the capital stock for machinery and equipment, *KBNRK* is the capital stock for non-residential structures, β is the share of machinery and equipment in the total capital stock, α is labour's share in nominal output, and *TIME* is a time trend.

The factor utilization rate (*CAPU*) is modelled as a function of the sales to normal output ratio, the inventory disequilibrium (the difference between the desired inventory level and the actual level) and short-term profitability.

$$capu_t = \gamma_0 + \gamma_1 LN\left(\frac{SALESK_t - MK_t}{CGDPMPK_t}\right) + \gamma_2\left(MOVAVG(2, rprof_t)\right)$$
$$+\gamma_3 LN\left(\frac{DBVKD_t}{DBVK_{t-1}}\right) + \gamma_4 TIME \qquad (11.2)$$

where *SALESK* is total domestic sales (which includes purchases by the domestic sector and export sales), *MK* is total real imports from the rest of Canada and from abroad, MOVAVG(x,…) denotes a moving average function over x years (x=2 in this case), *RPROF* is the availability of short-term profitability, *DBVKD* is the desired stock of inventories, *DBVK* is the actual stock of inventories, and *TIME* is a time trend.

The sales terms acts to capture any effects that temporary increases in demand conditions have on factor utilization. The utilization rate also reacts to eliminate any gap that exists between the actual and desired level of inventories.

When firms are able to achieve short-term higher levels of profitability, factor utilization will increase. The availability of short-term profitability is defined as follows:

[30] Refer to Section 2 for an overview of the Cobb-Douglas production function.

$$RPROF_t = \frac{(GDPBP_t)}{(YCE_t + U_{ME,t} \cdot KBMEK_{t-1} + U_{NR,t} \cdot KBNRK_{t-1})} \quad (11.3)$$

where *GDPBP* is nominal GDP at basic prices, *YCE* is compensation of employees, *KBMEK* is the stock of machinery and equipment, *KBNRK* is the stock of non-residential structures, and *UME* and *UNR* are user costs of capital for machinery and equipment and non-residential structures, respectively.

Nominal GDP at basic prices is defined as follows:

$$GDPBP_t = GDPMP_t - TILSP_t \quad (11.4)$$

where *GDPMP* is nominal gross domestic prices at market prices and *TILSP* is indirect taxes less subsidies on products.

12. Data Issues

The BC Macroeconomic Model is maintained and simulated using EViews [31] software. The model uses annual calendar year data obtained from a variety of sources, primarily BC Stats, Statistics Canada and IHS Global Insight Canada. BC Stats provides provincial economic accounts data and estimates, as well as population estimates and data required for the formulation of external assumptions. The population forecast for British Columbia is obtained using an iterative consultation process with the Population Forecasting unit of BC Stats. The BC Macroeconomic Model is linked to the IHS Global Insight Canadian model as the growth rates of certain provincial variables (e.g. price deflators) are determined using the corresponding Canadian variables.

There are three main data issues concerning the maintenance and use of the BC Macroeconomic Model: data quality and accuracy, timeliness, and confidentiality. In terms of data quality and accuracy, every effort is made to minimize human error. Data acquired from non-official outside sources is validated. Data from official sources such as BC Stats, Statistics Canada and the Bank of Canada is accepted as being accurate. The timeliness of provincial accounts data is a major factor in the model updating process. The model is generally updated at least every two years to ensure the equations are current and continue to track well. The schedule for the update varies depending on data availability from Statistics Canada, BC Stats, and on the planned forecast schedule. Although most of the data used is public, a portion of the data used in the model is deemed confidential by Statistics Canada and BC Stats.

[31] EViews is a registered trademark of IHS Global Insight Inc. The EViews software is used by many organizations including the Conference Board of Canada, and the US Federal Reserve Board in their FRB/US macroeconomic model.

13. Future Directions

Econometric models provide a framework for empirical quantification of how the economy behaved on average in the past and the extent to which its future behaviour might differ from the past and present. The British Columbia Macroeconomic Model is the Ministry of Finance's most important economic forecasting tool.

This paper has provided a snapshot of a model that is evolving over time to reflect developments in the real economy and new economic theories. For this reason, the paper has focussed on the general structure of the model and how it works, rather than specific coefficient estimates or model simulation properties that change over time.

As with most macro models, the BC model is continually undergoing updating in light of new data releases, and also because of the periodic revisions to series, particularly the economic accounts. Data changes such as these often cause a relationship in the model to break down because some structural change has shown up in the data and caused the original specification to fail, or because more recent information suggests that an alternative specification more convincingly explains past behaviour. The BCMM has been restructured and re-estimated to reflect the widespread changes made to the Canadian System of National Accounts in 2012.

In addition, the overall design of the model will be continually re-appraised in the light of new research results and improvements in macroeconomic methodology. This will ensure that the model is a forecasting tool that is able to produce reasonable forecasts that are supported by currently accepted economic theory.

The following are some potential changes to the model that EFA staff will investigate in the coming years:

- Update the housing starts equations so that they are operational if net migration becomes negative.
- Incorporate demographics into key sectors.
- Incorporate a measure of labour productivity into the determination of the wage rate.
- Incorporate explicit liquidity constraints into the consumption equations.
- The potential to remove capacity utilization from the calculation of output.

Appendix 1: Liquefied Natural Gas (LNG)

In order to adapt the BCMM to the possibility of including Liquefied Natural Gas (LNG) development into the economic forecast, adjustments had to be made. Due to the unusual nature of the LNG industry, a single good model is no longer appropriate. For example:

1. The share of machinery and equipment (M & E) investment in the LNG industry is lower than the rest of the BC economy where M & E accounts for over 50 per cent of business investment[32].

2. LNG investment requires a large share of imports. LNG development requires specialized machinery, materials, and engineering and design expertise for which there are few international firms who supply these goods and services[32].

3. The capital-labour ratio in the LNG industry is much higher than for the overall economy.

The difference in the above parameters would imply a very large bias if LNG was introduced into the single good BCMM. Therefore, it was decided to introduce LNG as a separate good. Due to the difference in the overall impacts between the construction phase and continuing operations phase of LNG development, employment and investment numbers are divided into construction and operations.

The construction phase includes the LNG plant construction, new pipeline construction and potential investment from BC Hydro to provide adequate electricity to the plants. These activities will have direct, indirect and induced effects in the economy through employment and investment in M & E and non-residential construction.

The operations phase will have direct, indirect and induced effects on production, employment, LNG export prices and volumes, and LNG tax revenue. Many of these values are assumed to be exogenous and will be obtained from statistical estimates or industry data when available. All production is assumed to be exported and a proxy for the LNG income tax has also been added to the model for completeness.

Currently, LNG is not included in the BC Ministry of Finance forecasts; all LNG adaptions are currently dormant in the model. LNG will not be included in the forecasts until a Final Investment Decision (FID) is made by an LNG industry proponent.

[32] Songhurst, B. LNG Plant Cost Escalation. Oxford Institute for Energy Studies, OIES Paper 83 pp. 14-16 (2014).

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