A COMPARISON OF ECONOMIC IMPACT ASSESSMENT METHODS: THE CASE OF FORESTRY DEVELOPMENTS IN ALBERTA

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A comparison of economic impact assessment methods: The case of forestry developments in Alberta

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Abstract

Economic impacts of forestry developments in Alberta are estimated using two inter-industry approaches. The results suggest that estimates derived from input-output (I-O) models differ from those of computable general equilibrium (CGE) models. Employment and GDP estimates derived from CGE models are much smaller than those of I-O models. Unlike I-O estimates, estimates derived from CGE models are not unidirectional because of general equilibrium effects. The results also indicate that CGE models provide greater flexibility and have more potential for forest policy analysis when compared to I-O models but they should be used with caution.

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Introduction

The input-output (I-O) approach, a class of inter-industry analysis, is by far the most commonly used technique used in estimating economic impacts of changes in the forest sector. It rests on the idea that the economy is a system of interdependent industrial sectors and emphasizes incorporation of intersectoral linkages (Parmenter 1982). Consider an increase in the exports of pulp and paper products. This probably causes an increase in the supply of pulp and paper products. In order to produce more pulp, more logs and chemicals are demanded and the logging and chemical industries have to increase their outputs to meet this increased demand. In order to increase their outputs, logging and chemical industries have to buy more inputs from other industries causing an expansion in those industries. This implies that policy analysis may lead to erroneous conclusions if it is done on only one sector of interest.

Many researchers have applied I-O models to examine economy-wide impacts of changes in the forest sector. For example, Jacques (1988) has applied I-O analysis to estimate the impacts of forestry activity on the economy of Canada and its provinces. Horne et al. (1991) used an I-O model to assess the impacts of a 10% reduction in forest related supplies on employment and gross domestic product (GDP) in British Columbia. Ernst and Young (1994) and Price Waterhouse (1994) have studied the economic importance of the forest sector in the economy of Alberta using an I-O approach. Simens and Kulshreshtha (1995) have estimated the impacts of changes in the use of the forest sector in Saskatchewan using an I-O model. More recently Alavalapati and Adamowicz (1997) have examined the economic impacts of changes in the forest sector in Alberta using a supply side I-O analysis. The information derived from I-O analysis often plays a key role in forest policy making thereby influencing the management of Canadian forests.

A closer look at the underlying assumptions of I-O models raises serious concerns about the validity of the information derived from these models. For example, the assumptions that prices of inputs and outputs are fixed in the economy; production is based on a technology in which fixed amounts of inputs are required in order to produce a unit of output; there are no constraints on the supply of factor inputs; and final demand for the output of each industry is exogenous may generate estimates that are biased. Forest policy decisions which are based on these estimates may be erroneous.

Each of these assumptions may limit the applicability of I-O model in deriving socio-economic impacts of a change in policy. First, the assumption of fixed prices would not allow I-O models to capture the behavior of producers and consumers with respect to changes in prices of inputs and outputs. According to this assumption, the supply of inputs or outputs has no influence on factor or product prices. Second, the fixed inputs assumption rules out the possibility of substitution between factors of production. According to this assumption, for example, an industry cannot expand its output in the short-run by combining increasing amounts of labor with its fixed capital stock. Third, if sectors are not directly linked by inter-industry flows of commodities, it is possible that they will still be interdependent since they compete for scarce primary factors (labor, capital, and land). With no constraints on the supply of primary factors, I-O models will not be able to account for these forms of interdependence. In other words, I-O models work well only for an economy in which producing sectors have excess capacity and primary factors are less than fully employed (Parmenter 1982). Finally, the exogeneity of final demand suggests that trading activity does not depend on relative prices. In consequence, I-O models are limited usefulness for the analysis of international trade. All these assumptions may either overstate or understate the economy-wide impacts of any changes in the forest sector. In sum, I-O models are demand driven and do not incorporate supply constraints or substitution possibilities (Robinson and Roland-Holst 1988). These concerns have prompted economic modelers to propose an alternative inter-industry analytical tool, computable general equilibrium (CGE) model, for policy analysis. This approach is thought to provide a greater flexibility and generate less biased estimates when compared to I-O analysis. In this study, we compare the performance of I-O model with CGE model in evaluating the effects of forest policies on Alberta's economy.

Similar to an I-O model, a CGE model assumes that producing sectors of the economy are interdependent by supplying produced inputs to other sectors. However, this approach permits prices of inputs to vary with respect to changes in output prices and thus capture the behavior of economic agents. It incorporates a variety of flexible production functions which allow producers to substitute cheaper inputs for more expensive inputs. This model also can accommodate constraints on the availability of primary inputs and accounts for additional intersectoral linkages. For example, if factors of production are limited in supply, the expansion in some sectors will draw factors of production from other sectors thereby causing a contraction in those industries. Finally, a CGE model can explain final demand variables within the model rather than treating them as exogenous. Because of these assumptions, CGE models generate results that may be different from those of an I-O model.[1] Furthermore, depending upon the nature of the economy under investigation, each of these assumptions can be modified to a desired level. For example, the substitution between inputs can vary from no substitution to

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[1]Recently, Zhou et al. (1997) and Waters et al. (1997) have noted that economic impacts derived from I-O analysis are significantly larger than those of CGE analysis.

perfect substitution.[2] Similarly, the supply of primary inputs also can vary from highly inelastic through elastic to highly elastic. Each modification will provide policy analyst a certain degree of flexibility to specify models that fit the economy under investigation.[3] In sum, CGE models include relative prices that reflect the economic scarcity of outputs and inputs and allow greater flexibility in the specification of economic behavior of agents (Waters et al. 1997).[4]

In spite of these attractive features, CGE models are less common, when compared to I-O models, in the Canadian forest sector.[5] In this study, we demonstrate the differences between I-O and different variants of CGE models and show that CGE models are less restrictive when

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[2]No substitution between inputs implies that relative changes in the prices of inputs have no effect on the proportion of inputs employed in the production process. On the other hand, perfect substitution suggests that for any change in relative prices of inputs producers will replace relatively more expensive input with relatively cheaper input.

[3]See Dervis et al. (1982) for details.

[4]CGE models are not without their problems. Shoven and Whalley (1992) have noted that elasticities and other key parameter values play a pivotal role in the model specification, but no consensus exists regarding such values; large amounts of data are required, besides I-O data, to specify CGE models; and the results may be quite sensitive to the key assumptions underlying the model such as full employment, capital mobility, and perfect competition. See Hazledine and MacDonald (1992) for a detailed critique on general equilibrium models.

[5]This is not to suggest that CGE models have not applied to analyze the forestry sectors in Canada. For example, Percy (1986), Binkley et al. (1994), Alavalapati et al.(1997), and Waters et al. (1997) have applied the CGE approach to estimate the impacts of changes in the forest sector of British Columbia.

compared to I-O models in estimating the impacts of changes in the forest sector. Specifically we analyze the impacts of a 22% increase in exports of pulp and paper products and a 1% decrease in exports of wood products from Alberta. We have chosen these two changes for the following reasons.

In 1996, the government of Alberta and Grande Alberta Paper (GAP) reached an agreement subject to environmental impact assessment to construct and operate a light weight paper mill. This $900-million project is expected to increase pulp and paper products exports by 22% thereby providing additional employment and gross domestic product.[6] While this development is being considered, the forest industry in Alberta is facing an institutional constraint which restricts the volumes of wood exports to the United States (U.S.). In 1995, the U.S. accused Canada of trading unfairly by subsidizing its lumber producers and flooding the U.S. market with cheaper wood and wanted to retaliate with a temporary duty. In order to stop a trade war over Canadian softwood exports, after a series of negotiations, a five-year deal was reached which allows about 90% of the softwood from British Columbia, Alberta, Ontario, and Quebec to enter to the U.S. duty-free (The Edmonton Journal 1996). The rest would be subject to a tax. Any exporter willing to pay $100 US per 1,000 board feet will be able to ship unlimited quantities. Consequently, the government of Canada in consultation with the forest companies and provincial governments has allocated quotas to softwood producers. As a result Alberta's softwood lumber exporters may have to decrease their exports to the U.S. by almost 14 percent.

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[6]In 1994, the total exports of wood pulp and paper products from Alberta were 1.33 million tonnes (Canadian Forest Service 1995). Assuming the annual capacity of the mill is 0.3 million tonnes, we note that the exports would increase by 22%.

Of course Alberta lumber producers may have options such as finding alternate export markets, linking up with secondary manufacturers not covered by the trade agreement, and finding a home for their products in the domestic market. Since the U.S. is a major market for Alberta wood exporters, we think that the current lumber trade policy will cause an overall reduction in Alberta's lumber exports and thereby a decrease in the employment and gross domestic product in the province.[7]

The paper is organized as follows. The details of the data and I-O and CGE models are provided in the next section. Simulation results are presented and discussed in the third section. A brief summary with conclusions is provided in the last section.

Data and model specifications

The I-O and CGE models used here are kept as simple as possible so that emphasis can be made on the differences in their estimates. Input-output data (1990) for Alberta were aggregated into 7 producing sectors. They include: 1) Agricultural; 2) Logging; 3) Energy; 4) Wood products; 5) Pulp and paper; 6) Manufacturing; and 7) Services sectors. It is assumed that each sector produces only one type of output. Final demand categories were aggregated into intermediate demand, domestic demand, imports and exports. For the sake of simplicity, we assume that a sector is a net exporter if the trade balance is positive and a net importer if the trade balance is negative. Therefore, we consider that sectors 1-5 are exporting and sectors 6-7 are importing. Primary factor categories are aggregated into labor and composite capital. Sectoral

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[7]In 1994, the total softwood lumber exports from Alberta were worth $164 million of which the exports to the United States were worth $100 million (Canadian Forestry Service 1995).

employment values are taken from census data (1990).

Depending upon whether leakages[8] considered or not in the analysis, two types of I-O models are specified. The first model, IOWOL (I-O without leakages), does not include leakages. In other words this model assumes that the demand for commodities is met completely by domestic production. The second model, IOWL (I-O with leakages), assumes that the demand for commodities is met by both domestic production and imports. To the extent that imports share with domestic industries in the supply of a commodity, the impact of a change in the final demand on domestic industries will be reduced (Alberta Treasury 1974). Both I-O models are closed in the sense that the stimulating effects of changes in household income, associated with changes in sectoral output, on the final demand are considered.[9] The technical description of these models is given in Appendix 1.

Three types of CGE models are specified based on the assumptions about the supply of labor. The first CGE model assumes that the supply of labor is infinitely elastic. Under this assumption, any change in the demand for labor does not cause a change in the wage rate. However, in this Keynesian scenario, a change in the demand for labor will cause a change in the

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[8]Three types of leakages exist in the economy: imports, withdrawals from inventories and government production of goods and services. In this study we consider only imports as leakages and the other two forms of leakages are aggregated as part of the domestic demand.

[9] If changes in the household income are not included in the analysis, I-O models produce only direct and indirect impacts of a change in the final demand. On the other hand, inclusion of household income in the analysis generates direct, indirect, and induced effects of a change in the final demand (See Van Kooten 1993 for more details).

employment level. Furthermore, in this model, it is assumed that labor is mobile across sectors while capital is sector specific. In the short-run, these assumptions may be appropriate because it is hard for firms to move capital from one industry to another and for labor unions to influence the wage rate in response to changes in the demand for labor. We refer this model as the Short-run Computable General Equilibrium (SCGE).

The second CGE model considers that labor supply is responsive to the wage rate. This suggests that both firms and labor unions can influence the wage rate through changes, respectively, in the demand for and supply of labor. The magnitudes of changes in employment and the wage rate, however, depends on the values of supply elasticity of labor.[10] In this model a change in the demand for labor will cause a change not only in the employment but also in the wage rate. Furthermore, in this model we assume that capital is mobile across producing sectors of the economy. Under this assumption, firms can move their capital from one industry to another so long as a difference exists in the rental rates of capital in the economy. In equilibrium, there would be one rental rate for capital. We call this model the Medium-run Computable General Equilibrium (MCGE).[11] The final model is based on the assumption that full employment exists in the economy and the supply of labor is completely inelastic. In this neo-classical economy, wages are expected to adjust such that no changes in employment occur in the

[10]Boskin (1973) found that the values of labor supply elasticities range from 0 to 1.6 for various groups with in the U.S. Later in the analysis we use a value of 1.

[11]The market responsiveness of workers differs with industry. Daniels et al. (1991) have noted that skilled forest workers are less responsive than those workers in other sectors.

economy.[12] Similar to the medium-run scenario, in this scenario, it is assumed that capital is mobile across sectors. We call this model the Long-run Computable General Equilibrium (LCGE).

In all the three CGE models, it is assumed that no substitution can be made between intermediate inputs (e.g. wood products is one of the intermediate inputs in the manufacturing sector) and primary factors (labor and capital). However, substitution is allowed between labor and capital. Furthermore, it is assumed that intermediate inputs are used in fixed proportions. In all three CGE models, domestic demand is modeled as a function of income and commodity prices. A technical description of the CGE models is given in Appendix 2. GEMPACK (5.1) software was used to conduct the simulations.[13] Sources of parameters and data used in CGE models include input-output data (1990) for Alberta, past studies, and researchers' judgement.[14]

Results and discussion

Both I-O and CGE models described in the foregoing discussion are used to estimate the impacts of changes in the exports of forest products from Alberta.[15] Table 1 presents the changes

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[12]This does not address the issue of voluntary unemployment in the economy.

[13]See Codsi and Pearson (1988) for details on the GEMPACK software.

[14]One of the costs of using CGE models is that more data are required when compared to I-O models.

[15]It should be noted that the results of I-O analysis will be unidirectional. For example, an increase in exports of pulp and paper products will generate net positive impacts on the economy of the province. In the case of CGE analysis, it is hard to say *a priori* the direction of net impacts of the specified shocks. In this approach, a contraction in one sector may cause some sectors to contract and others sectors to expand simultaneously. This is largely due to the endogeneity of

Table 1. Changes in output and primary factor prices in response to a 22% increase in exports of pulp and paper sector (Values are expressed in % changes)

Change in	IOWL	IOWOL	SCGE	MCGE	LCGE
Agricultural sector output (X1)	0.1572	0.3114	-0.2505	-0.3509	-0.3594
Logging sector output (X2)	4.9720	5.0353	4.6314	4.7823	4.7769
Energy sector output (X3)	0.0632	0.1153	-0.0655	-0.1013	-0.1047
Wood products sector output (X4)	0.1337	0.2082	-0.0291	-0.0849	-0.0909
Pulp and paper sector output (X5)	18.3978	18.4128	18.0061	18.3550	18.3535
Manufacturing sector output (X6)	0.2286	0.4766	-0.4924	-0.5936	-0.6067
Service sector output (X7)	0.1665	0.2405	0.0947	-0.0097	-0.0182
Wage rate	-	-	-	0.0175	0.0212
Overall capital rent	-	-	-	-0.0095	-0.0174
Rental rate of capital in X1	-	-	-1.1309	-	-
Rental rate of capital in X2	-	-	7.4308	-	-
Rental rate of capital in X3	-	-	-0.2262	-	-
Rental rate of capital in X4	-	-	-0.0362	-	-
Rental rate of capital in X5	-	-	35.7032	-	-
Rental rate of capital in X6	-	-	-0.8871	-	-
Rental rate of capital in X7	-	-	0.1961	-	-
Overall output	0.2565	0.3581	0.0510	-0.0371	-0.0453

in sectoral output and factor prices in response to a 22% increase in the exports of pulp and paper products. The results indicate that estimates derived from I-O models differ from those of CGE models in different ways. I-O results reported in columns 2 and 3 suggest that an increase in the exports of pulp and paper products would cause an increase in the output of all the sectors in the

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prices, limitations on factor supplies, and factor substitution.

provincial economy. This result is apparent because of the assumption that an increase in the demand for output i causes a proportional increase in the supply of output i. The increase in the supply of output i causes an increase in the demand for intermediate input j and a corresponding increase in the outputs of sector j. In order to increase sectoral output, the model assumes that there is an unlimited supply of labor and capital. Since prices are fixed in I-O models, it is shown that there is no change in the wage rate and rental rates of capital. The results indicate that estimates with leakages (IOWL) are smaller than those derived without leakages (IOWOL). This suggests that the share of imports in domestic production is significant in the economy of Alberta.

The results derived from the CGE models tell a different story. In the short-run scenario (SCGE) where the wage rate is assumed to be fixed and capital is sector specific, the results show that a 22% increase in the exports of pulp and paper products causes over 18% of increase in the output of pulp and paper products. Since large quantities of logs are used as an intermediate input in the pulp and paper products sector, an expansion in the pulp and paper products sector is shown to have a positive effect (4.63%) on the logging sector. Therefore, we notice an increase in the rental rates of capital in these sectors. However, the expansion in the pulp and paper sector is shown to cause a contraction in other resource sectors (agricultural, wood products, and energy sectors) and a corresponding decrease in rental rates of capital in those sectors. The results show that overall output will increase by 0.051%. This analysis suggests that if the economy is similar to the short-run scenario, the use of I-O models will overstate the impacts of policy.

The medium-run CGE model differs from the short-run CGE model by assuming that the demand for and supply of labor influence the wage rate. Furthermore, in this model, it is assumed that capital is mobile across sectors. Results reported in column 5 of Table 1 show that the increase in the exports of pulp and paper products will cause an increase in the wage rate and a decrease in the rental rate of capital. The increase in the wage rate is shown to have a depressing effect on all the sectors in the economy except the logging and pulp and paper sectors. The expansion in the logging and pulp and paper sectors does not offset the contraction in other sectors. Therefore, we notice a small reduction in the provincial output.

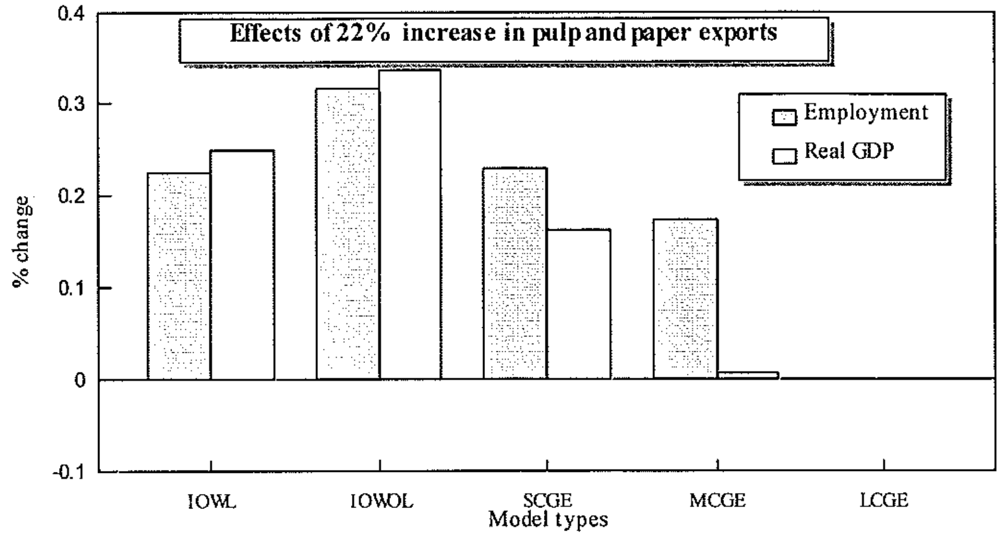
The results of the long-run CGE model are reported in column 6 of Table 1. In this model, it is assumed that the wage rate adjusts in response to changes in the demand for labor such that there is no change in overall employment. Under these circumstances, the expansion in some sectors has to be at the expense of other sectors in the economy. Therefore, we notice a large contraction in the energy and wood products sectors. The overall output drops more in this scenario than that of the medium-run CGE.

Table 2 presents the changes in sectoral output and factor prices in response to a 1% decrease in the exports of wood products. Since the values are reported in percentage changes, they can be interpreted as elasticities of variables with respect to changes in wood products exports. Notice that the estimates derived using I-O models are negative. This result is expected because the decrease in the output causes a decrease in the demand for intermediate inputs and a corresponding decrease in the output of other sectors. Within the CGE models, when the supply of labor is highly elastic and capital is sector specific (short-run CGE), the decrease in wood products is shown to have a positive impact on the agricultural, energy, pulp and paper, and manufacturing sectors. However, this expansion cannot offset the contraction of other sectors in the economy. Therefore, we notice a reduction (0.0016%) in the overall output. Under the medium-run CGE scenario, the shock is shown to have a negative effect on the wage rate and a

Table 2. Changes in output and primary factor prices in response to a 1% decrease in exports of wood products sector (Values are expressed in % changes)

Change in	IOWL	IOWOL	SCGE	MCGE	LCGE
Agricultural sector output (X1)	0.1572	0.3114	0.0034	0.0061	0.0065
Logging sector output (X2)	4.9720	5.0353	-0.2022	-0.2069	-0.2066
Energy sector output (X3)	0.0632	0.1153	0.0009	0.0017	0.0018
Wood products sector output (X4)	0.1337	0.2082	-0.3914	-0.3915	-0.3912
Pulp and paper sector output (X5)	18.3978	18.4128	0.0002	0.0001	0.0002
Manufacturing sector output (X6)	0.2286	0.4766	0.0070	0.0107	0.0114
Service sector output (X7)	0.1665	0.2405	-0.0013	-0.0004	0.0000
Wage rate	-	-	-	-0.0006	-0.0011
Overall capital rent	-	-	-	0.0005	0.0009
Rental rate of capital in X1	-	-	0.0156	-	-
Rental rate of capital in X2	-	-	-0.3200	-	-
Rental rate of capital in X3	-	-	0.0030	-	-
Rental rate of capital in X4	-	-	-0.4875	-	-
Rental rate of capital in X5	-	-	0.0004	-	-
Rental rate of capital in X6	-	-	0.0127	-	-
Rental rate of capital in X7	-	-	-0.0028	-	-
Overall output	-0.0057	-0.0079	-0.0016	-0.0002	0.0003

positive effect on the rental rate of capital. In this scenario, the expansion in other resource sectors is not shown to offset the contraction in the logging, wood products, and service sectors. Therefore, we notice a slight reduction in the overall output. In the long-run CGE scenario, the shock is shown to have a slight positive effect on sectoral output. This suggests that the expansion of other resource sectors will offset the contraction in the logging and wood products sector.



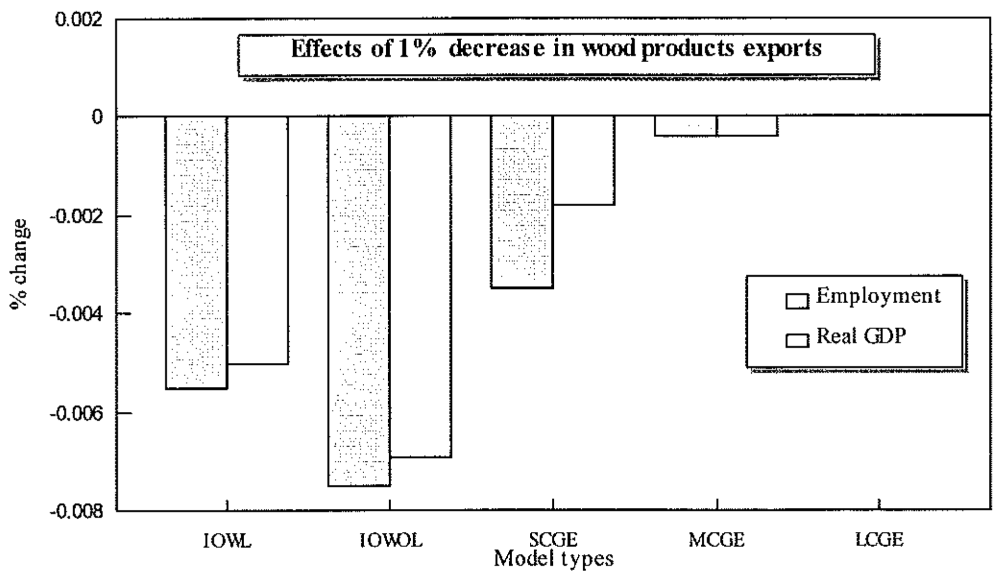


Figure 1. Changes in employment and GDP in response to, respectively, 22% increase in pulp and paper products exports and 1% decrease in wood products exports.

The models described are also used to estimate the effect of changes in the provincial employment and GDP. Results reported in Figure 1 suggest that estimates derived from I-O analyses differ from those of CGE models. It is shown that the changes in employment in response to a 22% increase in the exports of pulp and paper products (upper panel) are generally higher in I-O models when compared to CGE models. Notice that in the LCGE scenario there is no change in employment since we assumed that the wage rate adjusts fully such that full employment is assumed in the economy. The GDP estimates derived from CGE models are smaller than those of I-O models. Under the long-run CGE scenario, we notice very little change in GDP. This is because there will be no changes in the employment of capital and labor; and the shock has opposite effects on the wage rate and rental rate of capital. The changes in employment and the GDP in response to 1% decrease in wood products exports are reported in the lower panel of Figure 1. The results indicate that changes in both employment and GDP derived under the CGE models are much smaller than those of I-O models.

Summary and policy implications

Forest policy decisions are instrumental for sustainable forest management in Canada. I-O analysis is the most commonly used technique in evaluating forest policies. Close scrutiny of I-O's underlying assumptions raises concerns about the validity of these models. For example, the assumptions that prices of inputs and outputs are fixed in the economy; production is based on a technology in which fixed amounts of inputs are required in order to produce a unit of output; there are no constraints on the supply of factor inputs; and final demand for the output of each industry is exogenous, may generate estimates that are biased. In this study, we demonstrate that CGE models allow modelers to relax the underlying assumptions of I-O models and produce more moderate results when compared to I-O analysis.

The results from I-O analysis suggest that a 22% increase in pulp and paper products causes an increase in overall output, employment, and GDP. On the other hand, CGE models generate results that are different from I-O models. Unlike I-O estimates, estimates derived from CGE models are not unidirectional. This is largely due to the general equilibrium effects which suggest that inputs are limited in supply and contraction/expansion in some sectors will cause expansion/contraction in some other sectors. Estimates derived from CGE models are smaller when compared to those of I-O models and thus support the findings of Zhou et al. (1997) and Waters et al. (1997).[16] This is largely due to the changes in the prices of inputs and outputs in response to changes in their demand.

The results of this study have a series of implications for forest policy analysis. For example, if the economy under investigation resembles that of the short-run CGE scenario, the choice of I-O models to estimate regional impacts of a policy change will result in biased estimates. The study shows that there is little scope for adjustment in I-O models to accommodate different economic situations. On the other hand, there is vast scope to modify CGE models to accommodate a variety of economic conditions. The scope of adjustment is limited only by the investigator's imagination and capabilities. The results also point out that in certain cases CGE models produce estimates that may be "more biased" than those of I-O models. For example, if the economy is similar to the SCGE scenario, the use of the long-run CGE model will produce estimates that are more biased than those of I-O models. Taken together the results suggest that CGE models have greater potential for policy analysis when compared to

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[16]It may be possible that incorporation of labor migration, hours worked, and job seeking into I-O models tend to reduce the income response thereby resulting in smaller multipliers.

I-O models but they should be used with caution.

We have specified a set of CGE models that are similar to I-O models. For example, no substitution was allowed between intermediate inputs and primary factors. Furthermore, it is assumed that intermediate inputs are used in fixed proportions. Models can be developed without these restrictions. Depending upon the region and issue under investigation several extensions can be made. We assumed a Cobb-Douglas functional form for production and utility functions. A variety of flexible functional forms can be used to specify production technology and household preferences. They include Constant Elasticity of Substitution (CES), Constant Ratio of Elasticity of Substitution Homothetic (CRESH), Generalized Leontief, and Translog functions. CGE models are useful to explore market power issues in forest products trade. For the sake of simplicity we did not consider savings, investment, and other types social accounts. It is straight forward to incorporate those issues in CGE models.

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Appendix 1

Technical description of I-O models:[17]

The I-O model begins with the assumption that producers minimize the total cost of producing any output level. The technological assumption of the model is

$$X_j = Min_{(i,k)} \frac{X_{ij}}{A_{ij}}, \frac{F_{kj}}{L_{kj}} \quad i,j = 1,....,n; \quad k = 1,.....,m \tag{1}$$

where X_j is the output of industry j, X_{ij} is the output from industry i to the production process of industry j; F_{kj} is the primary factor k to the production process of industry j, A_{ij} and L_{kj} are fixed coefficients showing, respectively, the minimum output from industry i and primary factor k required per unit of industry j, n is the number of industries, and m is the number of primary factor categories. Equation (1) shows that fixed minimum amounts of all inputs are required in order to produce a unit of output in industry j. In other words, producers cannot substitute one input for the other input. Producers' demand functions for inputs are given by

$$X_{ij} = A_{ij} X_j \tag{2}$$

Equation (2) determines the demand for inputs as a function of output only. Final demand for the output of each industry (Y_j) is determined as follows

$$D_j + E_j - M_j = Y_j \tag{3}$$

where D_j, E_j, and M_j are domestic demand, exports, and imports for the output of industry j. The

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[17]Some of the description closely follows Parmenter (1982).

final step in the construction of the I-O model is to impose a market clearing condition for each industry's output.

$$X_i = \sum_{j=1}^{n} X_{ij} + Y_i \qquad i = 1,\ldots,n \tag{4}$$

By substituting equation (2) into equation (4), we have

$$X = A X + Y \tag{5}$$

Equation (5) can be rearranged as follows:

$$X = (I-A)^{-1} Y \tag{6}$$

where X is an (nx1) vector of the X_i, Y is an (nx1) vector of the Y_i, A is an (nxn) matrix of the input-output coefficients, A_{ij}, and I is the identity matrix. The typical, ij^{th}, element of $(I-A)^{-1}$ matrix shows the total amount of intermediate inputs of type i directly and indirectly required per unit delivery to final demand of the output of industry j. Equation (6) does not account for leakages ie imports. By incorporating leakages equation (6) can be written as

$$X = (I-(I-\mu)A)^{-1} Y \tag{7}$$

Where μ is fixed share of coefficients of imports in the total demand.[18] Equations (6) and (7) are used to calculate the effect of changes in sectoral output for a change in final demand.

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[18]See Alberta Treasury (1974) for details of calculating coefficients of imports. Also see Miller and Blair (1985) for more details on I-O models.

Appendix 2

Technical description of CGE models:[19]

When compared to I-O models, CGE models will have a number of additions to their theoretical structure (Parmenter 1982). CGE models which are used in this study can be described under five sets of equations: 1) Demand for intermediate inputs and primary factors; 2) Unit cost of production; 3) Final demand for industries' output; 4) Market clearing conditions for outputs and primary factors; and 5) other equations. The salient features of the short-run CGE model are given below.

1) Demand for intermediate inputs and primary factors:

Assuming that producers minimize their cost of production subject to the Cobb-Douglas production function, the following input demand functions are derived. For the sake of simplicity, the equations of CGE are expressed in proportional changes. For example, W in equation (8) represents the percentage change in the wage rate.[20]

$$L_j = X_j - [W - (\alpha_W W + \alpha_R R_j)] \qquad j = 1,....,7 \tag{8}$$

$$K_j = X_j - [R_j - (\alpha_W W + \alpha_R R_j)] \qquad j = 1,....,7 \tag{9}$$

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[19]See Parmenter (1982) for more details.

[20] Proportional change in variable X can be expressed as dx/x where x is expressed in level form. See Johansen (1960) for details on linearization. There is a concern that the proportional format results in linearised errors. However, we have estimated CGE models following a multi-step procedure which accounts for linearised errors (See Hertel et al. 1992 for more details).

$$X_{ij} = X_j \qquad i, j = 1,....,7 \tag{10}$$

L_j, X_j, R_j, and K_j are, respectively, labor demand, output, rental rate of capital, and sector specific capital in sector j; X_{ij}s are output i used as intermediate input in sector j; W is the wage rate; and α_W and α_R are, respectively, the share of wage and rental rate of capital in the total primary cost of sector j. Recall the assumption that producers cannot substitute intermediate inputs to primary inputs but they can substitute labor for capital and vice a versa. Therefore, prices of intermediate inputs do not appear in primary factor demand equations.[21]

2) Unit costs of production

Unit cost equations are derived by assuming a perfectly competitive situation. Under this assumption producers cannot earn pure profits in equilibrium which suggests that factor payments equal the product price;

$$P_j = \sum_{i=1}^{7} \delta_{ij} P_i + [\delta_{Wj} W + \delta_{Rj} R_j] \qquad i, j = 1,....,7 \tag{11}$$

where P_j is the unit price of output j; δ_{ij} is share of intermediate input i in total cost of sector j; and δ_{Wj} and δ_{Rj} are, respectively, share of wage and rental rate of capital in total cost of sector j.

3) Final demand for industries' output:

Assuming that households maximize their Cobb-Douglas utility function subject to their income, the following demand functions for commodities are derived.

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[21]It should be noted that intermediate input demand equations (10) are necessary because they enter in product market equilibrium conditions (equations 14).

$$D_j = Y - P_j \qquad j = 1,\ldots.,7 \tag{12}$$

Where D_j is the domestic demand for output j and Y is the household income.

4) Market clearing conditions:

When supply of input/output equals the total demand for inputs/output, it is said that the market is clear;

$$TL = \sum_{j=1}^{7} \beta_j L_j \qquad j = 1,\ldots.,7 \tag{13}$$

where TL is total labour demand in the economy, and β_j is the share of sector j in total employment,

$$X_i = \sum_{j=1}^{7} \psi_{ij} X_{ij} + \eta_i D_i + \theta_i E_i \qquad j = 1,\ldots.,7;\ i = 1,\ldots..,5 \tag{14}$$

where ψ_{ij}, η_i, and θ_i are, respectively, shares of intermediate inputs, consumption, and exports; and E_i is the quantity of exports. Recall that sectors 1-5 are export oriented.

$$X_i = \sum_{j=1}^{7} \psi_{ij} X_{ij} + \eta_i D_i - \zeta_i M_i \qquad j = 1,\ldots.,7;\ i = 7 \tag{15}$$

Here ζ_i is the share of imports, and M is the quantity of imports. It should be noted that there is no market clearing condition for sector 6. This is the result of Walras' law which suggests that if n-1 markets are cleared it is implied that the other market is also cleared.

5) Other equations

This set of equations include household income, general price level, and the numeraire. The household income equation is specified as the sum of share weighted labor and capital income. The general price level is specified as the sum of output share weighted sectoral prices. The general price level is chosen as a numeraire.

For the medium-run CGE scenario, provision should be made such that labor supply is responsive to the wage rate. Therefore, the following equation should be added

$$TL = \gamma W \tag{16}$$

where γ is the elasticity of labour supply. For the long-run scenario, we assume that the wage rate adjusts such that full employment is assured in the economy and capital is mobile across sectors and regions. Because of full employment assumption equation (16) should be dropped and TL should be considered as exogenous. Also, we add the following equation when capital is assumed to be mobile across sectors

$$\bar{K} = \sum_{j=1}^{7} \rho_j K_j \qquad j = 1,....,7 \tag{17}$$

where K bar is the total capital demand and ρ_j is the share of sector j in total capital. It should be noted that in this scenario, there will be only one rental rate.