Incorporating Natural Capital into Economy-Wide Impact Analysis: A Case Study from Alberta

Mike N. Patriquin[1]

Janaki R.R. Alavalapati[2]

Wiktor L. Adamowicz[3]

and

William A. White[4]

[1] Natural Resource Economist, Canadian Forest Service, Northern Forestry Centre 5320-122 St Edmonton, AB T6H 3S5
[2] Assistant Professor, School of Forest Resources and Conservation, University of Florida 365 Newins-Ziegler Hall, PO Box 110410, Gainesville, FL 32611-0410
[3] Professor, Department of Rural Economy, University of Alberta 515 General Services Building Edmonton, Alberta T6G 2H1
[4] Senior Economist and author to whom all correspondence should be addressed, Canadian Forest Service, Northern Forestry Centre 5320-122 St Edmonton, AB T6H 3S5 Tel: (780) 435 7315 Fax: (780) 435 7359 Email: bwhite@nrcan.gc.ca

Abstract

Traditionally, decision-makers have relied on economic impact estimates derived from conventional economy-wide models. Conventional models lack the environmental linkages necessary for examining environmental stewardship and economic sustainability, and in particular the ability to assess the impact of policies on natural capital. This study investigates environmentally extended economic impact estimation on a regional scale using a case study region in the province of Alberta known as the Foothills Model Forest (FMF). Conventional economic impact models are environmentally extended in pursuit of enhancing policy analysis and local decision-making. It is found that the flexibility of an environmentally extended computable general equilibrium (CGE) approach offers potential for environmental extension. The CGE approach may be the tool of the future for more complete integrated environment and economic impact assessment.

Economy-Wide Impact Analysis and the Environment

The environmental extension of economic impact models is critical for more complete policy analysis. Environmentally integrated economic policy analysis, from a sustainable development perspective, requires a leap from conventional thinking and modeling approaches. There has been significant effort devoted to the construction of natural capital accounts or resource accounts (e.g., Haener and Adamowicz, 1999) However, in order to integrate natural resource accounting and policy analysis, these accounts must be integrated into impact assessment models. Furthermore, to employ active adaptive management, at a regional level, to assess policy alternatives, resource account values must be "projectable". Ideally, indicators of sustainability, including natural resource accounts, are best when they can be projected in order to predict the effect of policy options on levels of the indicator. Our goal in this paper is to link components of a regional resource account, or measure of natural capital, with a conventional economic model and examine the response of the economic system and the environmental system to policy options.

General equilibrium methods are commonly used to inform policy-makers of the estimated economic impacts from a proposed change in policy or change in the economy (Hewings and Jensen, 1988). Recognition of the limitations of conventional general equilibrium economic impact analysis and increasing impact on the environment continues to fuel improvements in approaches to socio-economic policy analysis. Even so, few analytical models have been developed that extend economic impact analysis to include the environment.

Computable general equilibrium (CGE) modeling is emerging as the most prolific tool for economy-wide impact analysis. Under many circumstances CGE models provide the most realistic or unbiased estimates of economy-wide policy impacts (Alavalapati et al., 1998; Alavalapati et al., 1999). Compared to input-output models, which are limited by inherent assumptions, CGE models are limited only by the capabilities of the analyst and the availability of data (Parmenter, 1982; Shoven and Whalley, 1992). The flexibility of this tool allows the examination of a wider scope of policy analysis including, but not limited to, environmental policy and natural capital. The wide range of possible functional forms and model specifications lends the CGE technique to the environmental extension of conventional economic impact analysis. Unlike other general equilibrium models, the CGE approach offers promise with respect to the inclusion of non-market values and natural capital stocks.

One of the problems with conventional[1] general equilibrium economic impact analysis is the lack of explicit linkages between the economy and the environment (Golan et al., 1995). As a result, the full impacts of economic activities on the environment are not reflected in the model. Without the inclusion of explicit environmental linkages, general equilibrium economic impact analysis may not send the correct signals to decision-makers.

Many environmental problems, although global in nature, manifest themselves at a local or regional scale (Eder and Narodoslawsky, 1999). The regional variation in environmental and economic impacts suggests the need for regional environmentally extended economic impact analysis. Few analytical models have been developed on regional or sub-national scales that

[1] For the purpose of this paper the terms 'traditional' and 'conventional' will be used interchangeably to describe general equilibrium economic analysis techniques without explicit environment-economy linkages.

environmentally extend economic impact analysis. This study examines the introduction of a regional environmentally integrated economic impact model using the CGE framework. The results of this report should facilitate the use of CGE techniques for regional impact analysis in Canada and abroad.

The objective of this study is to present an integrated economic and environmental model based on the CGE approach. This environmentally extended CGE methodology is applied to a regional natural resource dependent economy known as the Foothills Model Forest (FMF) in west-central Alberta. Various components of natural capital, such as nonmarket benefits of nature, carbon equivalent emissions, and carbon sequestration/dissipation, are incorporated into a conventional CGE framework.

The environmentally extended CGE framework is used to evaluate the effect the inclusion of the environment has on policy evaluation. In this study we examine impacts from the closing of a mining operations and the impacts from an increase in visitor activity. These economic changes will have impacts on output, household income, and environmental quality. The results of the research contribute to the methodology of economic impact assessment and integrated economic and environmental CGE modeling. This application and analysis builds upon previous research of this type done for the FMF. To the authors' knowledge this is the first application of this type of research to be done for a sub-national economic region in Canada.

The paper is organized as follows. In Section 2, the theoretical literature as well as the methods used in the development of environmental extensions to economic analysis is reviewed. In

Section 3, the methodology and data used to construct a consistent economic and environmental database for a case study region known as the Foothills Model Forest (FMF) are discussed. In Section 4, the model results from a variety of simulations are presented. The model results are compared and discussed. In the concluding section of the study, the findings, modeling implications, and policy implications arising from the study are summarized. Limitations of this study and an examination of further research needs made apparent by this work are also included.

Literature Review

Three primary approaches are used to estimate economy-wide or general equilibrium socioeconomic impacts of changes in an economy: the input-output (I-O) model, the Social Accounting Matrix (SAM) model, and the computable general equilibrium (CGE) model (Miller and Blair, 1985; Adelman and Robinson, 1986; Dixon et al., 1992). Each approach is valid under certain circumstances and the less flexible approaches represent valuable building blocks. For example, I-O and SAM are important steps in the construction of a CGE model.[2]

Policy changes may have significant effects on the environment and the structure of an economy including prices and quantities. Therefore, an argument can be made that the analysis of these effects can only be done in a general rather than partial equilibrium framework. The extension of general equilibrium economic analysis to include the environment has its roots in Leontief's stylized I-O table that incorporated a pollution-cleaning sector and a physical account of

[2] For a detailed discussion of economy-wide models see Patriquin et al. (2000a) or Patriquin et al. (2000b).

pollutants (Leontief, 1970). Since then, various attempts have been made to endogenize pollution effects into production or utility functions in one way or another.

Gross National Product (GNP), or the measure of total product of an economy, is the principal statistic used to gauge economic progress. Many economists use this measure despite wide criticisms. One criticism is that GNP is a gross measurement and should therefore be replaced by net national product (NNP) to account for depreciation of human-made capital. Another criticism of these measurements is that even when depreciation is deducted, NNP may still be an inappropriate welfare measure, especially pertaining to the environmental side effects of economic activity and the measurement of other nonmarket activities (Maler, 1991). Natural capital is not sufficiently represented in conventional national accounting schemes and even less so on a regional spatial level (Eder and Narodoslawsky, 1999).

The lack of linkages between environmental data and other policy variables means that policy-makers cannot generally make direct use of environmental data (Atkinson et al., 1997). Environmental indicators, like those being developed by the Organization for Economic Cooperation and Development (1998), are one attempt at making environmental data meaningful in policy analysis. However, this poses the problem of determining which indicators are appropriate and how to aggregate indicators into an overall environmental index. It has been recognized that an integrated environmental index that indicates to what extent environmental quality is changing is unlikely to be realized (Atkinson et al., 1997).

A second attempt, and part of the focus of this study, is based on natural resource or "green" accounting. Green accounting is a particular way to summarize and aggregate environmental data into a form that facilitates the integration with traditional economic data. Green accounts may also be used for identifying and constructing environmental indicators of sustainability. At the very least, green accounts provide an efficient framework for the organization of a small number of indices that characterize the state of the environment and economy.

Many researchers have concluded that NNP is an appropriate base for the calculation of a welfare measure that includes environmental values (Haener and Adamowicz, 1999; Maler, 1991; Atkinson et al., 1997). Green NNP is a modification of conventional NNP that incorporates the value of the net change in natural capital, and how changes in the environment affect the present value of utility. In the context of environmental sustainability, green NNP can increase over time if total capital stock increases (or with technological improvement); however, if green NNP falls the economy is no longer operating at a sustainable level and the overall productive capacity of the economy is declining (Haener and Adamowicz, 1999).

In 1987, the Brundtland Commission shifted policy focus towards the achievement of sustainable development (Atkinson et al., 1997). Since that time, many countries have been researching and developing concepts and methods for green accounting.[3] Green accounts have been developed in a variety of forms that Atkinson et al. (1997) have classified into three categories. The first category consists of natural resource accounts that emphasize balance sheet items such as the opening and closing of resource stocks. The second category is resource and pollutant flow

[3] Agenda 21 of the Earth Summit (1992) explicitly called for the establishment of integrated environmental and economic accounts as a complement to the United Nations SNA (Atkinson et al., 1997).

accounts that are typically measured in physical quantities and are often explicitly linked to I-O accounts. The third category is environmental expenditure accounts that consist of detailed data on capital and operating expenditures by economic agents for the protection and enhancement of the environment. Although these accounts attempt to value the depreciation of natural capital and the cost of environmental degradation, they still appear to inadequately address nonmarket values.

Although the explicit linkage to observable activities is one of the strengths of the system of national accounts (SNA) framework, it is also a limitation when the concerns are with externalities. According to Atkinson et al. (1997), environmental problems often characterized as external to the market are not adequately dealt with when traditional accounting frameworks are used as a measure of the welfare consequences of human activities. This implies that incorrect policy signals may be sent to decision-makers if better forms of integrated analysis are not in place. Green accounts are a step toward transcending many of the inadequacies of traditional economic analysis as it relates to environmental impacts.

Several researchers have developed schematic representations of social accounting matrices that include resources and the environment (Maler, 1991; Xie, 1996; Atkinson et al., 1997). Table 1 is a modified version of the schematic ESAM developed by Atkinson et al. (1997). An ESAM has two additional accounts compared to a conventional SAM. The two accounts introduced in the ESAM are a ‘resource’ account and an ‘environment’ account.

<Insert Table 1 Here>

Note that the measure of green NNP (GNNP) can be obtained in two different ways from this table. These two methods derived by Atkinson et al. (1997) are given by Equations 1 and 2 below:

Equation 1: Calculation of Green NNP as Total Supply of Product

$$GNNP = C + S + PB$$

Equation 2: Calculation of Green NNP as Total Disposition of Product

$$GNNP = NNP + NRP + NEP$$

One of the limitations of this framework is the necessity for estimates of the marginal social costs of emissions and the value of environmental services. These estimates are not generally known and therefore researchers have had to resort to using average costs that may vary from marginal costs.

Xie (1996) provides an overview of some of the ways environmental components can be incorporated into CGE models. The first extension technique is to provide a more detailed description of the production process to include environmental components. This method generally requires the estimation of pollution emissions using fixed pollution coefficients per unit of sectoral outputs or intermediate inputs, or exogenously changing prices or taxes concerning environmental regulations. These environmental extensions, although requiring additional environmental data, are relatively straightforward since they do not involve any changes in the behavioural specification of the standard CGE model.

The second extension technique discussed by Xie (1996) is the introduction of environmental feedbacks into economic systems. The basic idea that drives this technique is the further specification of production functions and/or household utility functions to include environmental quality. For example, an environmental quality index can be incorporated into a production function to capture the effects of pollution emissions on productivity. The effects of pollution emissions and abatement activities on consumption can also be represented by the incorporation of environmental effects in utility functions.

Several attempts have been made to incorporate environmental components and nonmarket values into CGE models. For example, Espinosa and Smith (1995) use modified Stone-Geary utility functions to develop a CGE model of international trade patterns that consistently reflects the impacts of environmental quality changes on consumers' preferences. Alavalapati and Adamowicz (2000) incorporate environmental damage functions in a hypothetical scenario to analyze linkages between tourism and the environment. This section will discuss the stylized environmentally extended computable general equilibrium models (ECGE) models developed by Xie (1996) and Alavalapati and Adamowicz (2000) to conduct integrated environment-economy policy analysis.

CGE models have both a supply side and a demand side details. On the supply side, model specification requires information with respect to production and the producer's optimal choice of inputs. If environmental impacts are not considered, commodity supply functions are generally derived from the minimization of total costs, subject to a production function. However, when environmental impacts occur, the optimization problem must be changed. Xie

(1996) assumes that no change in production technology is required but suggests that environmental degradation causes productivity to decrease. Therefore, the total cost function must be altered to reflect the cost of pollution emission and the cost of pollution abatement.

On the demand (or consumption) side households maximize their utility subject to a budget constraint. The solution to this optimization problem yields the household demand functions for commodities. Xie (1996) argues that changes in environmental quality may influence households' decisions via decreasing utility or changes in household income. The optimization problem can be altered via the utility function and/or the household income constraint. The utility function can be altered to include the impacts of environmental quality changes.[4] In addition, the net cost of waste disposal (cost less any compensation) can be subtracted from the household income constraint.

The general equilibrium solution simultaneously determines the composition of production, the allocation of production factors, the prices of goods and factors, and the levels of pollution emissions and abatement. Xie (1996) applied the above modifications to a model of the Chinese economy and concluded that integrated CGE models can be very useful in analyzing environment-economy interactions. Past studies that integrate environment-economy interactions have concentrated on the examination of pollution and natural resource depreciation. Few studies have examined the impact of policies related to recreation and the non-timber values associated with forests. Alavalapati and Adamowicz (2000) is an example of a study that examines the model impacts of environmental policies related to tourism. They suggest that an obvious source of environmental damage is the activities related to the resource sectors. However, tourism activities may also have an impact on the quality of the local environment through increased visitation, construction of tourism facilities, and vehicle emissions. For example, in the US environmental policies have been implemented that restrict access to wilderness areas due to damage from vehicle emissions (Alavalapati and Adamowicz, 2000).

The study by Alavalapati and Adamowicz (2000) provides a theoretical framework for modeling the interactions among tourism, other economic sectors, and the environment. A model of a hypothetical regional economy demonstrates the theoretical framework. Their study considered two alternative environmental damage functions specified as a function of output and the extent of land use in the production process. Based on their findings, Alavalapati and Adamowicz (2000) suggested several possibilities for extensions to the study. First, they suggest the development of a SAM that distinguishes a tourist sector. This will allow modelers to consider multisector and multifactor CGE models. Second, factor markets can be modeled under different assumptions with respect to factor mobility depending on knowledge of the regional economy. Third, a variety of functional forms could be considered for production technology and household utility. Based on their suggestions, a multisector and multifactor SAM that distinguishes a tourist sector is developed in this study.

General Methodology

The integration of environmental values with traditional economic modeling techniques is increasingly important in examining more complete policy tradeoffs in a complex world. Figure 1 demonstrates an example of one process leading to more complete policy analysis. The light

[4] Note this assumes individuals have perfect information with respect to the environmental change.

gray arrows represent the path chosen by several researchers seeking to integrate environmental values into economy-wide analysis and represent the approach that is discussed in this report.

<insert Figure 1 here>

An Alberta Case Study

The Foothills Model Forest (FMF) is a primarily resource dependent region located in the west-central foothills of Alberta. Heavy reliance on natural resources raises concerns about economic and environmental sustainability. Community sustainability, environmental stewardship, and economic development are prevalent issues in the FMF. Economy-wide models are one set of tools that have been proposed to aid and inform local decision-makers. The models developed in this study attempt to improve upon conventional economy-wide models through the integration of environmental variables.

Green accounts have been developed to address some of the previously unaccounted for linkages between the environment and the economy. However, Hamilton (1994) and Hamilton and Lutz (1996), suggest that the policy uses of green accounting have not been well defined. Therefore, the integration of green accounts with SAMs increases the policy usefulness by providing a modeling framework that emphasizes the detail of the green accounts and extends the analysis to include economy-environment interactions missing in conventional techniques. In addition, part of the reason for the development of green accounts is the concern that costs and benefits of environmental exploitation are unfairly distributed (Golan et al., 1995). Environmentally extended social accounting matrices (ESAMS) can be used to explicitly address these issues in modeling exercises. The development of a green account for the region will provide insight regarding the sustainability of income flows in the region. Activity levels for the nature-related recreational component of the green account were obtained using the "Survey of the Importance of Wildlife to Canadians Database".[5] Three distinct categories of net benefits or net economic value (NEV) were examined. Net benefits derived by individuals originating in the FMF from trips to the FMF, net benefits derived by individuals originating in the FMF from trips to outside the FMF, and net benefits derived by people originating outside the FMF from trips to the FMF. The values obtained from the survey are summarized in Table 2. The table demonstrates that nature-related activities have a significant value or net benefit above and beyond the observable market value. For example, Table 2 identifies that residents of the FMF derive a NEV of $ 3.74 million from nature-related activities in the region. The identification of this value is important in the construction of an ESAM.

In addition to recreational and commercial use, the forest of the FMF region has also been identified as an important carbon sink (Apps and Price, 1997). Due to the lack of environmental data and pollution relationships, carbon sequestration will be used as a measure of environmental dissipation capacity.[6] As a result, emissions generated from the region will be examined in carbon equivalents. In addition, very little data exists in terms of pollution and emissions in the region. Therefore, estimates of carbon equivalent emissions from the province of Alberta are scaled to the region and used as a proxy for regional emissions.[7]

[5] For a summary of the survey results see Minister of Public Works and Government Services Canada (1999).
[6] Annual carbon sequestration estimates were derived from Apps and Price (1997).
[7] Provincial emission estimates were derived from SENTAR Consultants Ltd. (1993)

Table 3 provides a summary of carbon dioxide equivalent emissions and assimilation in the FMF region. The values indicated in Table 3 provide the remaining data required for the construction of a rudimentary ESAM for the region. Although some environmental linkages have been identified for the region, there is a lack of data on resources. For example, no information was obtained on the value of natural growth and resource depletion. As a result, the ‘resource’ account was omitted from the ESAM and the focus turned to the ‘environment’ account.

Note in Table 3 that the visitor sector and the rest of the economy sector (ROE sector) account for nearly 60% of all emissions in the region. This can be explained by the nature of the economic activity in the region. The resource sectors are primarily concentrated on natural resource extraction but not processing. The extracted primary resources are exported outside the region for refining and manufacturing activities. This accounts for the low levels of emissions from the resource sectors. On the other hand the visitor sector and the ROE sector are associated with transportation emissions.

The incorporation of the environment-related dollar values with the existing conventional SAM poses several difficulties. First, the NEV estimates derived from the “Survey of the Importance of Wildlife to Canadians Database” are based on measures of personal income and not household income. This is a significant problem since the SAM identifies expenditures at the household income level. In addition, most expenditure studies are conducted based on household income. To the authors’ knowledge no empirical work has been done that links levels of personal income to levels of household income. As a result, assumptions were made in order to disaggregate the total NEV derived for all households in the region among the three household income categories found in the SAM.

The final entry required for the ESAM is a measure of net environmental product (NEP). NEP is equivalent to the addition of the value of environmental services and the value of the net rate of change in environmental quality (Atkinson et al., 1997). Revisiting Table 1 (the ESAM schematic), this is calculated as:

Equation 3: Calculation of NEP

$$NEP = PB + \sigma(d - e)$$

where PB is the value of environmental services, σ is the marginal social cost of emissions, d is the dissipation of environmental degradation, and e is pollution emissions. The value of NEP is essentially the adjustment factor for converting a conventional product measure, such as NNP, to an environmentally adjusted or 'corrected' product measure that accounts for environmental values and externalities. The environmental adjustments in this case are quite modest due to data constraints.

An Environmentally Extended Computable General Equilibrium Model for the Foothills Model Forest

The CGE model developed in this study divides the FMF economy into six sectors: forest, mining, crude petroleum and natural gas, wood, visitor, and rest of the economy. The first four sectors rely primarily on natural resource extraction. The visitor sector has been made distinct from the rest of the economy sector following the procedure described earlier in this paper. This was done to separate domestic impacts from visitor impacts and to allow the potential for modeling tourism impacts on the environment and economy. The rest of the economy sector is comprised of all remaining domestic services, manufacturing, and agriculture.

The model specified in the following section is deterministic in nature and based on the small, open economy of the FMF region. Unlike the standard features of a conventional CGE model, this model incorporates environmental components in the form of a more detailed production process. This method outlines estimates of pollution emissions using fixed pollution coefficients per unit of sectoral outputs or intermediate inputs. This modification is relatively straightforward since it does not involve behavioural changes.

Conventional Model Specification

Before integrating any environmental components a conventional CGE model for the FMF was specified. The conventional model specification follows Johansen (1974), Parmenter (1982), and more recently Alavalapati et al. (1996). The complete generalized set of linear equations for the conventional CGE model is specified in Table 4. The condensed model contains 40 equations and 75 variables. Therefore, the under identification in the model required 35 variables set as exogenous. Table 5 is a list of variables chosen as endogenous to the model. Table 6 is a list of variables chosen as exogenous to the model in order to achieve model closure. Different model closure regimes could be specified depending on the issues the modeler would like to address.

<insert Tables 4-6 here>

The six-sector economy is modeled with three factors of production. These primary inputs consist of labour, capital, and land. Various assumptions are made with respect to the treatment of these variables in the model. The labour market is modeled under two scenarios. First, the Keynesian assumption of a rigid wage rate is examined. Under this assumption, adjustments in the labour market occur from changes in employment levels. Second, the neo-classical assumption of full employment is examined. Under this alternate assumption employment levels are fixed and wages become the adjustment mechanism. The other two primary inputs, capital and land, are assumed to be sector specific. It is also assumed that land is used only in forestry, mining, and crude petroleum and natural gas sectors.[8]

Environmentally Extended Model Specification

The next step involves the integration of the environmental components into the CGE model. In this step, carbon equivalent emissions, carbon equivalent assimilation, and non-market recreational benefits estimated for the region are added to the model without making any behavioural modifications. The lack of behavioural modifications means that the relationship between the environment and the economy is one-sided. Impacts on the economy will have environmental repercussions but there is no environmental feedback. Three additional equations are needed to identify three additional endogenous variables. The three additional equations are specified in Table 7.

<insert Table 7 here>

[8] These three sectors are assumed to be land using since they make actual factor payments for this resource. No land

As depicted in Table 7, NEP is a measure of net environmental product. EB is the estimated measure of non-market environmental benefit. ED is the estimated measure of non-market environmental damage. Pc is an estimated price of carbon per metric tonne, NMRB is the non-market recreational benefits, λ^B is a conversion factor of sectoral output to carbon sequestration, and λ^D is a conversion factor of sectoral output to emissions. NEP, EB, and ED comprise the three additional endogenous variables while Pc, NMRB, and output to sequestration/emission conversions factors total nine additional exogenous variables. These functions assume that the value of carbon equivalent emissions is a function of sectoral output, the price of carbon, and the conversion factor of output to emissions. It is also assumed that carbon equivalent sequestration is a function of forestry sector output. This assumption is derived from the results of a study by Apps and Price (1997) that demonstrates higher sequestration values from managed forest scenarios versus unmanaged forest scenarios.

Results

Many policy changes are currently being considered in the FMF. For example, one of the four coal mines currently operating in the FMF is being phased out of production due to diminishing supplies. This change in the region has raised serious public concerns ranging from community sustainability to environmental integrity. Following Equation 3, the NEP in the FMF equals -$344,357.08. Following Equations 1 and 2, the NNP calculated from the conventional SAM was $694,011,596.46 for the FMF region in 1995. Taking account of environmental linkages, the adjusted green NNP is $693,667,239.30. Therefore, the conventional measure of product overstates the value of NNP by $344,357.08 (i.e., NNP is overstated by the value of NEP). This

payments are made in the visitor sector.

is similar to the results found in a study by Golan et al. (1995) who show that the level of economic activity portrayed in the unadjusted SAM is higher than when the correct environmental prices are considered. This measure is useful since it provides a benchmark for monitoring environmental stewardship and the sustainability of economic development in the region.

Two ECGE models are developed in this study to simulate hypothetical changes in the FMF economy. The only difference between the two models is the assumptions made with respect to the endogeneity of employment and the wage rate. In the short-run environmentally extended CGE model (SRECGE), employment is the major adjustment mechanism. Conversely, in the longer-run environmentally extended CGE model (LRECGE), the wage rate is the major adjustment mechanism.

Model Results

Two hypothetical scenarios are examined for the purpose of comparing the results from the models. First, a 22% reduction in mining exports is examined. This scenario is the result of the phasing out of an existing coalmine within the region without replacement. Second, a hypothetical 7% increase in tourism activity in the region is examined. This hypothetical scenario could result from a spill over of visitors into Jasper National Park due to increasing park use restrictions being placed on the adjacent Banff National Park

Table 8 presents the percentage changes in sectoral output, household income, wages, employment, and NEP in response to a 22% decrease in mining sector exports. The results from the SRECGE show a decrease in the output of all sectors in response to the shock. However, the results from the LRECGE do not show a decrease in output of all the sectors in the FMF economy. Instead, the results of the LRECGE show an increase in the output of all sectors except the mining sector and the ROE sector. Under this scenario, each model shows a resulting decrease in household income. This is due to decreased employment in the short-run scenario and decreased wages in the longer-run scenario.

As reported in Table 8, the estimated economy-wide reduction in output obtained from the SRECGE is 5.8201%. This is slightly higher than the estimate obtained from the LRECGE (5.1002%). In this scenario, the negative impacts on economy-wide output are moderated or buffered somewhat in the SRECGE by the change in employment. In the LRECGE, the multidirectional impacts on the output of individual sectors and the wage rate act as a buffer against the large negative impact of the reduction of mining sector exports.

In the SRECGE scenario, all the sectors suffer and unemployment increases. Since the wage rate is fixed each sector is forced to release labour due to a decreased demand for intermediate inputs that results from the initial decrease in mining sector exports and output. In the LRECGE model, the decreased exports in the mining sector leads to a decrease in mining sector output. This causes a release of labour from the mining sector. Since employment is fixed, a decreased wage rate results in labour shifting to non-mining sectors. This results in a positive output effect in the non-mining sectors. However, these positive effects are not sufficient to offset the negative mining impact on the overall economy.

The results reported in Table 8 indicate a 133.8548% decrease in the NEP using the SRECGE and a 141.8765% decrease using the LRECGE. Since the actual value or level of the NEP for the FMF was initially negative this is interpreted as a decrease in the value of the negative number to the point where it flips to a positive number. In other words, the originally negative value of NEP becomes a positive value with a 22% decrease in mining sector exports. NEP becomes a positive value due in part to the decreased output emissions in the mining sector. In addition to the decreased output emissions from the mining sectors, the general equilibrium impacts lead to a reduction of output and emissions in the composite ROE sector. This can potentially be explained by decreased transportation related to the mining sector. As a result, the environmental benefits now outweigh the environmental damage and in addition to the improvement in environmental quality, the NEP becomes a positive value.

<insert Table 8 here>

Table 9 presents the percentage changes in sectoral output, household income, wages, employment, and NEP in response to a 7% increase visitor activity. The results from the SRECGE show an increase in the output of all sectors in response to the shock. However, the results from the LRECGE do not show an increase in output of all the sectors in the FMF economy. Instead, the results of the LRECGE show a decrease in the output of all sectors except the visitor sector and the ROE sector. Unlike the first scenario, each model shows a resulting increase in household income. This is due to the positive changes to the adjustment mechanisms. In the short-run, increased employment levels at a fixed wage rate leads to an increase in household income. In the longer-run, employment levels are fixed and the wage rate increase leads to the increase in household income.

In the SRECGE model, the increased visitor activity leads to increased employment since the wage rate is fixed. The increased demand for intermediate inputs in the visitor sector has a positive effect on the output of all the other sectors. In the LRECGE model, the increased visitor activity results in excess demand for labour in the visitor sector causing wages to rise. As a result, labour shifts from the resource sectors into the service sectors. This causes output to increase from the service sectors. The negative output effect on the resource sectors does not offset the positive effect in the service sectors and the overall economy benefits.

The results reported in Table 9 indicate an 80.8956% increase in the NEP using the SRECGE and a 108.6443% increase using the LRECGE. Since the actual value or level of the NEP for the FMF was initially negative this is interpreted as a greater negative number. In other words, an increase in visitor sector activity has a negative net influence on the NEP in the region. One explanation for this is increased vehicle traffic and transportation emissions associated with increased park visits.

<insert Table 9 here>

Discussion

Growing concern surrounding environmental stewardship has prompted the search for tools that assist the decision-making process of both private and public agencies. I-O models are by far the most common conventional tools for evaluating the economic impacts of public policies. Although conventional CGE models represent an improvement over these I-O techniques, they are still lacking with respect to the treatment of natural capital and the environment. The CGE approach offers unlimited flexibility in the relaxation of the I-O assumptions and the most promise with respect to the analysis of natural resource and environmental policy.

Examinations of the case study scenario results demonstrate several implications for the FMF region. In the short-run, the phasing out of an existing coalmine leads to negative impacts throughout the regional economy. However, in the longer-run, forest related sectors and the visitor sector benefit from this tradeoff. Similarly, an increase in visitor activity appears to benefit the entire economy of the region in the short-run. However, all the resource sectors are hurt by an expansion of visitor activity in the longer-run.

The models also provide an indication of environmental change in response to exogenous economic shocks. An increase of visitor activity results in environmental degradation due to decreased carbon sequestration in forestry and increasing vehicle emissions from visitors. Conversely, the closing of a coal mine results in a positive effect on the quality of the environment as measured in this report by carbon equivalent emissions.

Despite the improvements this study represents over the current common practice, there are still many limitations. The environmental adjustments made in the CGE models are quite modest. In other words, the natural capital accounts are quite limited. The lack of environmental data for the region was a serious limitation to this study. Better information on baseline environmental data and an accounting of changes in environmental quality would aid in the estimation of a damage function that links recreational use to environmental quality and sectoral output. In addition, there is an asymmetric impact of output on environment. In other words, there are currently no environmental feedbacks in the general equilibrium system. Future research is needed to incorporate a natural resource account and to identify environmental feedbacks.

Other limitations include the assumptions used in the CGE model, the static nature of the CGE model, and the lack of time series data for the region. Better time series data would allow the econometric estimation of model parameters. This would reduce the reliance on a single year of data. An ex post examination following a change to the region would be another way to assess the reliability of these modeling techniques. Despite these limitations, the approach adopted in this study represents state-of-the-art techniques for regional economic impact analysis.

In this article, a preliminary environmentally extended CGE model of the FMF economy was constructed that identifies the impact of economic changes on natural capital as well as economic conditions. However, due to a lack of information, environmental feedbacks into the economic system were not incorporated into the model. Further study is required to identify and quantify these relationships.

References

Adelman, I., and S. Robinson. 1986. *The Application of General Equilibrium Models to Analyze US Agriculture*. Working Paper No. 423. University of California-Berkeley.

Alavalapati, J. and W. Adamowicz. 2000. Tourism Impact Modelinf for Resource Extraction Regions. *Annals of Tourism.* 27(1):188-202.

Alavalapati, J., W. White and M. Patriquin. 1999. Economic Impacts of Changes in the Forestry Sector: A Case Study of the Foothills Region in Alberta. *Forestry Chronicle.* 75(1):121-127.

Alavalapati, J., W. Adamowicz, and W. White. 1998. A Comparison of Economic Impact Assessment Methods: The Case of Forestry Developments in Alberta. *Canadian Journal of Forest Research.* 28(5):711-719.

Alavalapati, J., W. White, P. Jagger, and A. Wellstead. 1996. Effect of Land Use Restrictions on the Economy of Alberta: A Computable General Equilibrium Analysis. *Canadian Journal of Regional Science.* 19(3):349-365.

Apps, M. and D. Price. 1997. *Estimating the Annual Carbon Budget of the Foothills Model Forest.* Foothills Model Forest Information Report. 17p.

Atkinson, G., R. Dubourg, K. Hamilton, M. Munasinghe, D. Pearce, and C. Young. 1997. *Measuring Sustainable Development: Macroeconomics and the Environment.* Edward Elgar Publishing. 252p.

Dixon, P., B. Parmenter, A. Powell, and P. Wilcoxen. 1992. *Notes and Problems in Applied General Equilibrium Economics.* Elsevier Science Publishers. 392p.

Eder, P. and M. Narodoslawsky. 1999. What Environmental Pressures are a Region's Industries Responsible For? A Method of Analysis with Descriptive Indices and Input-Output Models. *Ecological Economics.* 29:359-374.

Espinosa, J. and V. Smith. 1995. Measuring the Environmental Consequences of Trade Policy: A Nonmarket CGE Analysis. *American Journal of Agricultural Economics*, 77:772-777.

Golan, E., I. Adelman, and S. Vogel. 1995. *Environmental Distortions and Welfare Consequences in a Social Accounting Framework*. Department of Agricultural and Resource Economics, University of California at Berkeley. Working Paper No. 751. 95p.

Haener, M. and W. Adamowicz. 1999. *Regional Forest Resource Accounting: A Northern Alberta Case Study*. SFM Network Project Report No. 2. 35p.

Hamilton, K. 1994. Green Adjustments to GDP. *Resources Policy.* 20(3):155-168.

Hamilton, K. and E. Lutz. 1996. *Green National Accounts: Policy Uses and Empirical Experience*. World Bank. 48p.

Hewings, G. and R. Jensen. 1988. Emerging Challenges in Regional Input-Output Analysis. *Annals of Regional Science.* XXII(special issue):43-53.

Johansen, L. 1974. *A Multi-Sectoral Study of Economic Growth.* North-Holland Publishing Company. 274p.

Leontief, W. 1970. Environmental Repercussions and the Economic Structure: An Input-Output Approach. *Review of Economics and Statistics.* 52(3):262-71.

Maler, K. 1991. National Accounts and Environmental Resources. *Environmental and Resource Economics,* 1: 1-15. Kluwer Academic Publishers.

Miller, R. and P. Blair. 1985. *Input-Output Analysis: Foundations and Extensions*. Prentice-Hall, New Jersey.

Minister of Public Works and Government Services Canada. 1999. *The Importance of Nature to Canadians: Survey Highlights.* Environment Canada. 55p.

Organisation for Economic Co-Operation and Development. 1998. *Towards Sustainable Development: Environmental Indicators*. Organisation for Economic Co-Operation and Development. 129p.

Parmenter, B. 1982. Inter-Industry Analysis; in L. Webb and R. Allan (eds.), *Industrial Economics.* George Allan and Unwin. 69-110p.

Patriquin, M., J. Alavalapati, A. Wellstead, and W. White. 2000a. Impact Analysis from a Hybrid Regional Database: A Case Study of the Foothills Model Forest. *Annals of Regional Science* (Under Review).

Patriquin, M., J. Alavalapati, A. Wellstead, W. Adamowicz, and W. White. 2000b. *A Computable General Equilibrium Impact Model of the Foothills Models Forest Economy*. Foothills Model Forest Information Report.

SENTAR Consultants Ltd. 1993. *Alberta Greenhouse Gas Emission and Sinks Estimates for 1990*. Alberta Energy.

Shoven, J. and J. Whalley. 1992. *Applying General Equilibrium*. Cambridge University Press. 299p.

Xie, J. 1996. *Environmental Policy Analysis: A General Equilibrium Approach*. Avebury. 152p.

Figure 1: A Process of More Complete Policy Analysis

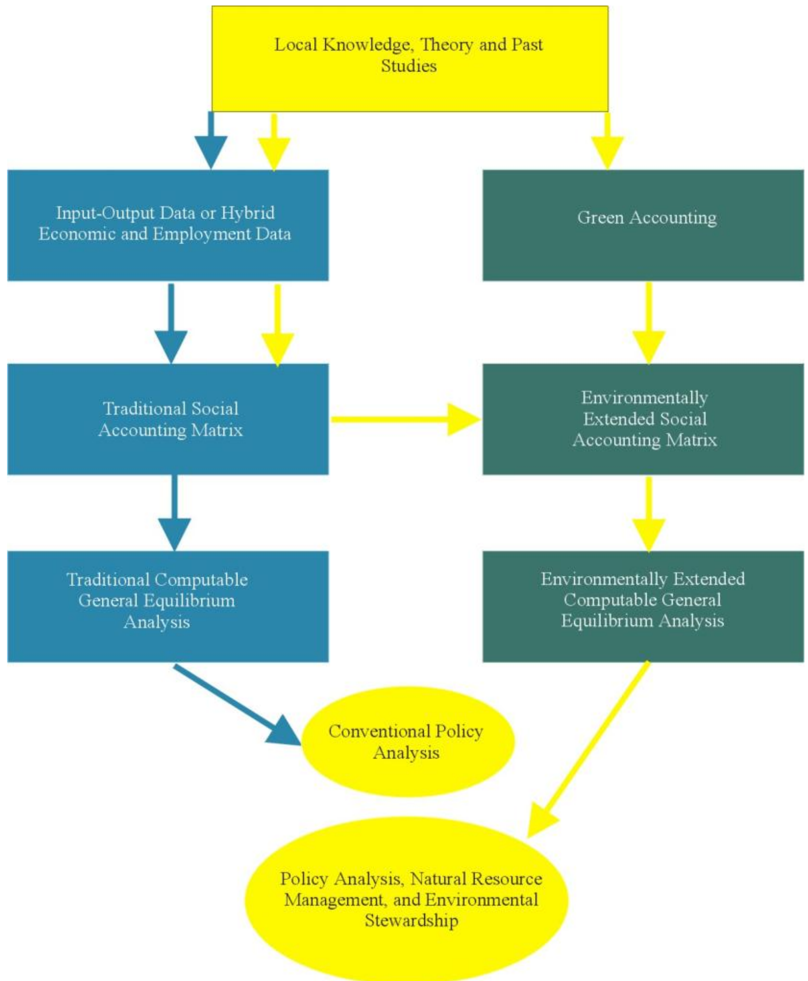

Table 1: Simplified Schematic of an ESAM

	Inflows (receipts)→								
←Outflows (payments)		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
	1	-	-	C	I	X	-	-	
	2	NNP	-	-	-	-	-	-	
	3	-	NNP	-	-	-	NRP	NEP	
	4	K	-	S	-	-	NR	RE	
	5	M	-	-	X-M	-	-	-	
	6	-	-	-	NG	-	-	-	
	7	-	-	PB	RD	-	-	-	
	8								

1 = Production
2 = Factors
3 = Institutions
4 = KF
NNP = Net National Product
C = Consumption
I = Investment
X = Exports
M = Imports
KF = Capital formation
ROW = Rest of the world
K = Depreciation of human-made capital
S = Genuine savings rate

5 = ROW
6 = Resources
7 = Environment
8 = Total
NRP = Net Resource Product
NEP = Net Environmental Product
PB = Value of environmental services
NG = Growth of resources valued at rent
RD = Dissipation of environmental degradation valued at marginal social cost of emissions
NR = Resource depreciation valued at rent
RE = Environmental damage valued at marginal social cost of emissions

Table 2: 1996 Net Economic Values (NEV) of Nature-Related Activities (Dollars)[9]

Regional Summary					
	Total NEV of Outdoor Activities	**Total NEV of Wildlife Viewing**	**Total NEV of Rec Fishing**	**Total NEV of Hunting**	**Total NEV of All Nature-Related Activities**
FMF Origin/ROW Destination	668,060	59,528	191,546	117,253	1,036,386
FMF Origin/FMF Destination	2,424,002	850,930	350,151	115,335	3,740,419
FMF Sub-Total	3,092,062	910,458	541,697	232,588	4,776,805
ROW Origin/FMF Destination					
AB(Outside FMF)	7,152,270	231,031	1,614,297	141,433	9,139,031
BC	733,501	157,882	45,614	51,293	988,290
SK	208,848	13,007	0	0	221,855
MB	208,247	11,752	0	0	219,999
ONT	354,097	27,646	0	0	381,743
QB	289,179	32,273	0	0	321,452
NFLD	13,676	0	0	0	13,676
YK	2,149	0	0	0	2,149
ROW Sub-Total	8,961,967	473,591	1,659,911	192,726	11,288,195
Total	12,054,029	1,384,049	2,201,608	425,314	**16,065,000**

[9] The survey reports willingness to pay (or net economic value) on an individual basis for a sample group. The values reported in Table 7 represent an aggregation over the sample and they are adjusted for the population. Frequencies were calculated using SPSS statistical software.

Table 3: Summary of Levels and Value of Carbon Dioxide Equivalent Emissions and Sequestration in the FMF

Levels and Value of Carbon Dioxide Equivalent Emissions				
Sector	**Emissions (KT/yr)**	**Annual Value ($1996/yr)***		
		Low Estimate (0.34$/T)	**High Estimate (16.6$/T)**	**Average (8.47$/T)**
Forest	63.88	21,717.50	1,060,325.00	541,021.25
Wood	40.00	13,600.00	664,000.00	338,800.00
Mining	222.29	75,578.94	3,690,030.60	1,882,804.77
CPNG	148.19	50,385.96	2,460,020.40	1,255,203.18
Visitor	418.40	142,254.50	6,945,366.96	3,543,810.73
ROE	278.93	94,836.34	4,630,244.64	2,362,540.49
Total	1,171.69	398,373.24	19,449,987.60	**9,924,180.42**
Level and Value of Carbon Equivalent Sequestration or Assimilation				
	Sequestration (T/yr)	**Annual Value ($1996/yr)**		
		Low Estimate (0.34$/T)	**High Estimate (16.6$/T)**	**Average (8.47$/T)**
Total	689,422.00	234,403.48	11,444,405.20	**5,839,404.34**
* Annual value estimates for carbon equivalents is from Haener and Adamowicz (1998)				

Table 4: Generalized Specification of the Complete Conventional CGE Model

1. $L_j = X_j - (W - (\alpha_w W + \alpha_{Kr} R_j^K + \alpha_{Dr} R_j^D))$	j = 1,2,3
2. $L_j = X_j - (W - (\alpha_w W + \alpha_{Kr} R_j^K))$	j = 4,5,6
3. $ELF = \sum_{j=1}^{6} \beta_j L_j$	j = 1,2,…,6
4. $K_j = X_j - (R_j^K - (\alpha_w W + \alpha_{Kr} R_j^K + \alpha_{Dr} R_j^D))$	j = 1,2,3
5. $K_j = X_j - (R_j^K - (\alpha_w W + \alpha_{Kr} R_j^K))$	j = 4,5,6
6. $D_j = X_j - (R_j^D - (\alpha_w W + \alpha_{Kr} R_j^K + \alpha_{Dr} R_j^D))$	j = 1,2,3
7. $X_{ij} = X_j$	i,j = 1,2,…,6
8. $X_{jc} = Y - P_j$	j = 1,2,…,6
9. $X_i = \sum_{j=1}^{6} \varphi_{ij} X_{ij} + \eta_i X_{ic} + \theta_i E_i + \eta_g G_j$	i = 1,2,…,5 j = 1,2,…,6
10. $E_i = -\phi(P_i - Wp_i + er)$	i = 1,2,…,5
11. $P_j = \sum_{n=1}^{6} \delta_{nj} P_n + (\delta W_j + \delta_{Krj} R_j^K + \delta_{Drj} R_j^D + \delta_m PM_j + \delta_T GT_j)$	j = 1,2,3
12. $P_j = \sum_{n=1}^{6} \delta_{nj} P_n + (\delta W_j + \delta_{Krj} R_j^K + \delta_m PM_j + \delta_T GT_j)$	j = 4,5,6
13. $Y = \alpha_i ELF_i + \alpha_i W + \varsigma_i K_i + \varsigma_i R_i^K + \lambda_j D_j + \lambda_j R_j^D + \lambda_g G$	i = 1,2,…6 j = 1,2,3

Table 5: Endogenous Variables in the Model

L_i i=1,…,6	Labour employed in sector i
X_i i=1,…,6	Output of sector i
R^k_i i=1,…,6	Rental rate of capital in sector i
R^D_i i=1,…,3	Rental rate of land in sector i
D_i i=3	Land employed in sector i
X_{ic} i=1,…,6	Final demand for output from sector i
Y	Household income
P_i i=1,…,6	Domestic price of output from sector i
E_i i=1,…,5	Exports from sector i
ELF*	Employed Labour Force
W*	Wage rate
* If W is endogenous ELF is exogenous and vice versa	

Table 6: Exogenous Variables in the Model

K_i i=1,…,6	Capital employed in sector i
D_i i=1, and 2	Land employed in sector i
X_{ic} i=1,…,6	Final demand for output from sector i
WP_i i=1,…,6	World price of output from sector i
er	Foreign exchange rate
G_i i=1,…,6	Government expenditure in sector i
PM_i i=1,…,6	Price of imports in sector i
GTi i=1,…,6	Indirect taxes in sector i
WLE	World labour export
GTF	Government transfers to households

Table 7: Environmental Extension Equation Specification

14. $NEP = EB - ED$	-
15. $EB = \delta_i Pc + \delta_i \left[X_i \right] + \delta_i \lambda_i^B + \delta_N NMRB$	i = 1
16. $ED = \sum_{i=1}^{6} \pi_i \left[Pc + X_i + \lambda_i^D \right]$	i = 1,…,6

Table 8: Impacts of a 22% Reduction in Mining Sector Exports

Percentage Change in	SRECGE	LRECGE
Forestry	-0.0435	1.5529
Mining	-18.4378	-18.4121
CPNG	-0.5240	0.3348
Wood	-0.0947	0.9303
Visitor	-0.4642	1.0271
ROE	-3.9258	-4.3755
All Households	-3.5820	-6.6010
W	0.0000	-6.7397
L1	-0.0453	4.6503
L2	-20.0390	-17.6692
L3	-0.6455	4.6524
L4	-0.0947	2.7687
L5	-0.4642	3.2634
L6	-3.9258	-1.2461
ELF	-3.5120	0.0000
NEP	-133.8548	-141.8765
Economy-Wide	-5.8201	-5.1002

Table 9: Impacts of a 7% Increase in Visitor Activity

Percentage Change in	SRECGE	LRECGE
Forestry	0.0325	-2.2414
Mining	0.1468	-1.7530
CPNG	0.1028	-1.1400
Wood	0.1091	-1.3240
Visitor	6.1551	6.3295
ROE	2.3675	3.5073
All Households	3.3324	8.5495
W	0.0000	9.6336
L1	0.0339	-6.6697
L2	0.1595	-5.2526
L3	0.1266	-7.4649
L4	0.1091	-3.9519
L5	6.1551	3.1329
L6	2.3675	-0.9658
ELF	3.8956	0.0000
NEP	80.3694	108.6443
Economy-Wide	1.5052	0.4462