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Environmentally Extended Regional Economic Impact Modeling

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A Joint Report for the
Sustainable Forest Management Network and the Foothills Model Forest

Environmentally Extended Regional Economic Impact Modeling

M.N. Patriquin, J.R.R. Alavalapati, W.L. Adamowicz, and W.A. White

Project Report

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Abstract

Many regional economies within the Canadian provinces are dependent on natural resources and amenities. 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. The results from this study suggest that the flexibility of the CGE approach offers potential for environmental extension. The CGE approach may be the tool of the future for more complete integrated regional economic impact assessment.

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1 Economy-Wide Impact Modeling and the Environment

1.1 Background

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 archaic modeling approaches. Sustainable development is a prevalent issue facing public and private decision-makers at a regional, national, and global scale. This issue is resulting in the introduction of environmental and natural resource policies aimed at mitigating environmental problems and promoting environmental stewardship.

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., 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. The flexibility of this tool allows the examination of a wider scope of policy analysis including, but not limited to, environmental policy. 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.

One of the problems with conventional[1] general equilibrium economic impact analysis is the lack of explicit linkages between the economy and the environment. As a result, the full impacts of economic activities on the environment are not reflected in the model. The existence of externalities[2] (positive or negative) implies that prices in the market do not reflect the actual marginal values to society. 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. The regional variation in environmental and economic impacts suggests the need for regional environmentally extended economic impact analysis. Therefore, a broad range of economic theory must be drawn upon in the development of comprehensive models at the

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[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.

[2] An externality exists whenever there is a deviation between marginal private costs (or benefits) and marginal social costs (or benefits).

regional scale. Few analytical models have been developed on regional or sub-national scales that environmentally extend economic impact analysis. This report 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.

1.2 Objectives of the Study

There are four main objectives of this study. The first objective is to highlight the development of a regional economic database via hybrid regionalization techniques. Although it is difficult to test the robustness of the hybrid approaches, the hybrid estimates are compared to a synthetically regionalized model as a check for significant variation between the two. It is assumed that if variation exists, the hybrid approach provides a more accurate picture of the regional economy since it contains primary regional data. The second objective is to demonstrate that variation exists in the impact estimates derived from I-O based and CGE impact models. Under certain economic conditions, commonly used I-O models may provide less accurate results compared to CGE models.

The third objective is to show the efficacy of CGE models in estimating economic impacts at a regional scale. Not only are the results of a CGE potentially less biased but they can also be produced in an efficient and cost effective manner. The fourth objective 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. At present, there is no fully accepted integration method readily available. Various environmental components, such as nonmarket benefits of nature, carbon equivalent emissions, and carbon sequestration/dissipation, are incorporated into a conventional CGE framework. An environmentally extended social accounting matrix representing a consistent equilibrium data set needed for calibrating the CGE model is also presented. This report discusses results related to the fourth objective. Findings related to the first three objectives are discussed in a journal article (Patriquin et al., 2000a) and a Foothills Model Forest Information Report (Patriquin et al., 2000b).

The environmentally extended CGE framework is used to evaluate the effect the inclusion of the environment has on policy evaluation. The types of impact examined include: changes to land use allocation, the phase-out of an existing mining operation, and increased 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 regionalizing economic data, 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 author's knowledge this is the first application of this type of research to be done for a sub-national economic region in Canada.

1.3 Outline of the Report

In Section 2, the theoretical literature as well as the methods used in the past to construct regional economy-wide models are reviewed and examined. The section builds on past work to define a method for constructing a regional database for the purpose of enhancing the application of integrated models to regional economies. Also, the theory behind the development of environmental extensions to economic analysis is reviewed. This includes an examination of the foundation of greener product or welfare measures, natural resource accounting, and past studies that attempt to environmentally extend economic analysis.

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 focused on. The database is used to construct a conventional social accounting matrix and an environmentally extended social accounting matrix for the case study region. The matrices are used to construct preliminary general equilibrium models to ensure data consistency. Preliminary policy evaluation is conducted via hypothetical simulations and the results are used to create benchmark boundaries against which the results derived from an environmentally extended computable general equilibrium model are compared. Finally, a conventional and an environmentally extended computable general equilibrium model of the Foothills Model Forest economy are constructed.

In Section 4, the model results from a variety of simulations using both conventional and environmentally extended models are presented. The model results are compared and discussed. Finally, the model comparisons are used to answer questions regarding the integration of environmental data into economic models. These questions include: How does the addition of environmental linkages influence policy evaluation and household welfare? Are these models practical at a regional scale?

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.

2 Literature Review

In this section, a brief review of the main topics in this study is presented. First, a review of general equilibrium modeling techniques is provided. Second, a review of past studies involving the integration of the economy and the environment is provided. These topics are examined from the perspective of studying small regional economies.

2.1 General Equilibrium Modeling

2.1.1 Overview of General Equilibrium Approaches

There are three primary approaches 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. In the past, these three approaches were viewed as competitors (Hewings and Jensen, 1988). However, these approaches should be viewed as complimentary rather than competitive.

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. In this section, each method is briefly outlined and its function in analyzing economic impacts and policy issues is discussed. Note that the quality of the analysis obtained from all three approaches is subject to the quality of the data obtained from primary and secondary sources. Table 1 offers a comparison of the general features of the three model approaches at a glance. These features are discussed in detail in the subsequent sections.

Table 1: Overview of General Model Features

	I-O	SAM	CGE
Occurrence	Common	Less common	Rare
Complexity	Simple	Simple	Complex
Data Requirements	Least	More	Most
Role of Prices	Fixed	Fixed	Endogenous
Technology	Fixed	Fixed	Not necessarily fixed
Supply of Inputs	Excess capacity	Excess capacity	Constraints possible
Time Frame	Extreme short-run	Extreme short-run	Variable
Sectoral Impacts	Unidirectional	Unidirectional	Multidirectional
Theoretical Structure	Linear	Linear	Non-linear
Costs to Implement	Inexpensive	More costly	Costly

2.1.1.1 Input-Output

Input-output models are the most common types of economy-wide impact models. They are relatively simple, provide quick results and demonstrate the flow of intermediate goods between producing sectors in an economy (Davar, 1994; Adelman and Robinson, 1986; Miller and Blair, 1985). However, for a number of reasons, the underlying assumptions of I-O models often limit their usefulness in policy analysis (Miller and Blair, 1985).

First, these models do not capture the behaviour of producers and consumers with respect to changes in the prices of inputs and outputs since prices are assumed fixed. Second, technology is assumed to have fixed input proportions resulting in no possibility of substitution between factors of production. Third, it is assumed there are no constraints on the supply of inputs. This is of particular concern since sectors that are not linked by commodity flows may still be linked through competition for scarce resources.

The first and second assumptions mean that I-O models are only appropriate in the extreme short-run. The third assumption implies that I-O models may only be appropriate where producing sectors have excess capacity and primary factors are less than fully employed. Despite these limitations, I-O models, generally developed from data contained in the public accounting frameworks, provide an important base for other modeling techniques.

2.1.1.2 Social Accounting

Social Accounting is a form of double-entry bookkeeping that provides a detailed account of the incomes and expenditures in a specified economy (Pyatt and Round, 1985; Pyatt, 1988; de Melo, 1988; Roland-Holst and Sancho, 1995). The SAM framework can be used to model not only economic impacts, similar to I-O models, but also the distributional impacts (who gains and who loses). For example, households can be disaggregated according to a categorization by household income levels (Stone, 1985). This allows the examination of impacts on households by household income level.

Developing a regional model requires a SAM for two reasons. First, the construction of a SAM will be particularly useful where the economy in question does not conform to census boundaries. If census data are not readily conformable to the region, existing data will be drawn from a variety of sources, including knowledgeables from the region. According to Johnson (1996) SAMs are particularly useful when data from disparate and inconsistent sources must be sorted out.[3] Second, additional data, beyond what is conventionally collected by statistical agencies, may be added to achieve greater detail. For example, survey data on regional household expenditures were incorporated into the FMF SAM. The SAM structure provides a convenient framework for ensuring data consistency.

SAM models are based on similar assumptions to I-O models (i.e., fixed coefficients and no role for prices).[4] These assumptions limit the applicability of the SAM model in deriving economic impacts of policy changes. These models are demand driven and do not account for supply constraints or the possibility of substitution (Adelman and Robinson, 1986). This is of particular concern because if the supply of inputs is limited, the technical coefficients would change and rising prices would cause a substitution effect. In the study region, land is an example of an input that has a supply constraint. Land in the FMF is totally allocated and there is no excess capacity. Therefore, sectors are directly competing for this scarce resource.[5] While I-O and SAM models cannot handle these complexities, CGE models can.

2.1.1.3 Computable General Equilibrium

Computable general equilibrium models have been proposed as an alternative analytical tool for policy analysis (Xie, 1996; Alavalapati et al., 1998). The CGE approach allows more flexibility and may generate less biased estimates when compared to other modeling techniques (Shoven and Whalley, 1992). The CGE approach permits prices of inputs to vary with respect to changes in output prices and thus allows it to capture the behavior of economic agents. It incorporates a variety of flexible production functions that allow producers to substitute cheaper inputs for more expensive inputs.

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[3] This feature is unique to the square or double-entry accounting stance.

[4] One underlying assumption of both I-O and SAM models is that technical coefficients (or the ratios of input from one sector to output from another sector) are fixed. This implies constant returns to scale. For example, if output from one sector doubles then the inputs that sector purchases from other sectors must also double.

[5] The direct competition for land is complicated by government allocation in some sectors.

This approach can also 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. This type of interaction cannot be demonstrated in I-O and SAM models. The impacts reflected by I-O and SAM models are necessarily unidirectional (i.e., an expansion in the exports of one sector causes an economy-wide expansion in all sectors). CGE models generate results that may be different from those of an I-O model (Adelman and Robinson, 1986; Alavalapati et al., 1998). Furthermore, depending upon the nature of the economy under investigation, each of the assumptions contained in I-O models can be modified to a desired level. For example, the substitution between inputs can vary from no substitution, as found in I-O models, to perfect substitution.

Recently, Alavalapati et al. (1998) use two interindustry approaches to show that the results from I-O models differ from those of CGE models. An I-O model and a CGE model were compared in estimating the impacts of changes in the exports of forest products from Alberta. The results indicate that employment and gross domestic product (GDP) impacts are generally higher in I-O models when compared to CGE models. In addition, the impacts on overall output conflict in direction between the two models due to the unidirectional nature of I-O models. In other words, a 22% increase in exports of forest products shows an increase in overall output in the I-O model. Conversely, the CGE model results from an identical 22% increase in the exports of forest products shows a decrease in overall output. Although there is no baseline to determine the accuracy of these estimates, this study demonstrates that CGE models provide greater flexibility and have more potential for policy analysis when compared with the more commonly used I-O approach (Alavalapati et al., 1998).

CGE models themselves have several limitations (Xie, 1996). First, most CGE models are deterministic in nature. Thus, these models do not allow for uncertainty. Second, most CGE models are calibrated on a benchmark data set of a given year. This may make the model very sensitive to single-year data. Finally, most CGE models are static. In other words, the models do not account for inter-temporal behaviour such as investment behaviour. However, these problems are not unique to the CGE approach. They characterize all general equilibrium models including I-O and SAM.

Various attempts have been made to address some of these limitations. First, econometric approaches have been more widely adopted in estimating the parameters of behavioural equations. This reduces the sensitivity to a single year of data. Second, attempts have been made to develop dynamic CGE models[6]. A static CGE model is developed in this study. The previously discussed limitations are not seen as prohibitive since the model is an improvement on the current standard practice of static I-O modeling. In addition, a static CGE model represents a good compromise in the tradeoff between complexity and practicality.

[6] See Vennemo (1997); Nordhaus and Yang (1996); and Chung et al. (1997) for more details on the specification of dynamic CGE models.

2.2 Alternative Approaches

In addition to CGE, there are a number of alternative approaches that have been applied in the study of regional economic impact analysis. Although the CGE approach is recognized as a more flexible analytical tool, I-O analysis remains the most widely used approach to impact estimation. In addition to the I-O approach, econometric models are another alternative to CGE estimation. This section will briefly review the alternative approaches to CGE analysis.

The Impact Analysis System for Planning (IMPLAN) is an extensive I-O database that facilitates the use of general equilibrium models for impact analysis and study in the US (Rose et al., 1988). The IMPLAN promotes the use of general equilibrium techniques at a regional level where it would be too costly to undertake primary data collection (i.e., as fine a spatial scale as the county level in the US). The low cost and easy access to regional data makes I-O models a popular tool for both private and public consultants investigating economic impacts. There is no program similar to IMPLAN in Canada.

Despite a lack of regional data, attempts have been made in Canada to construct I-O models that are adaptable to smaller regions and that facilitate their use as decision-making tools. For example, Kubursi et al. (1996) developed an analytical economic model designed to address some of the difficulties planners face in strategic planning for community development. Their Community Development Impact Model (CDIM) integrates I-O analysis and location theory and captures demand and supply side impacts at both the community level and the provincial level. However, even with the convenient interface for decision-makers the CDIM is still limited by the weaknesses (and in many cases the implausibility) of the I-O framework.

Econometric modeling is another approach to the construction of analytical economic models. These models are capable of detailing alternative configurations of the economy and are useful for policy analysis. In response to an economic downturn in Alberta and a renewed demand for stabilization policies, Mansell and Percy (1990) developed a 1,200 equation econometric model of the Alberta economy. The Model of the Alberta Economy (MAE) incorporated most of the driving forces, linkages and adjustments in the economy and was useful in establishing the general role of various factors in Alberta’s economic performance.

The MAE functions by comparing historical performance with that predicted by the model under various hypothetical conditions. Although this approach is valid, it is extremely data intensive compared to general equilibrium techniques and neither cost effective or efficient for small regional economies. These models rely on time-series data not usually available on a regional scale.

2.3 Towards the Integration of Environment and Economy

The United Nations System of National Accounts (SNA) is the international standard for national accounting. The information used in the construction of these accounting systems is precisely the same data needed to construct the economic impact models discussed in the previous section. The accounting data, in Canada, is collected by Statistics Canada on a detailed level and then aggregated to form provincial accounts and finally, a national account. The SNA also includes standardized definitions and methods of measuring gross national product (GNP).

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). Environment and ecological features are 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 combine disaggregated 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 response, 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.

2.3.1 Theoretical Foundations for Greener Product Measurements

Net national product (NNP) has been discussed as the best theoretical product or welfare measure (i.e., in efficiency terms) available in current accounting frameworks (Hartwick, 1990; Maler, 1991; Atkinson et al., 1997; Haener and Adamowicz, 1999). This concept of conventional NNP is based on consumption of marketed goods, public expenditures and the value of the net change of human-made capital (Haener and Adamowicz, 1999). In other words, without environmental concerns, NNP is what a social planner would choose to maximize at each point in time (Atkinson et al., 1997). The basic notion is that we are maximizing the present value of consumption. This interpretation relies on NNP being derived as a transformation of the current value Hamiltonian function[7] that seeks to maximize the present value of utility (Atkinson, et al., 1997). Therefore, without considering the environment to this point, NNP is the most theoretically consistent measure of welfare in the conventional accounting frameworks.

[7] Hamiltonian functions arise from optimal control theory. Hamiltonian functions represent dynamic optimization over either discrete or continuous time. For example, Atkinson et al. (1997) discuss a series of independent models that examine the treatment of natural resources and pollution in the measure of NNP. The models all derive expressions for NNP by maximizing the present value of utility subject to various accounting constraints using Hamiltonian functions.

Many researchers have concluded that NNP is an appropriate base for the calculation of a welfare measurement 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).

2.3.2 The Emergence of Natural Resource Accounting

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.[8] 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 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.

Part of a government's resource policy does show up directly in the traditional accounts. Royalty schemes are devised in an attempt to capture resource rents from commercial resources that are frequently government owned but leased for private exploitation. However, deterioration of environmental quality shows up indirectly through a variety of forms such as loss of tourism, lost productivity of natural resources, and others. Therefore, policies aimed at abating pollution and preserving ecosystems have an effect on the level of intermediate expenditures and the mix between investment in environmental protection and conventional assets. Atkinson et al. (1997) find that the use of the environment and resource represents an asset use that is not explicitly illustrated in the measures of product. This represents a serious concern for individuals attempting to provide decision-makers with the results of policy impact analysis that are based on the best available data and tools for policy analysis.

Although the explicit linkage to observable activities is one of the strengths of SNA frameworks, 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

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[8] 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).

toward transcending many of the inadequacies of traditional economic analysis as it relates to environmental impacts.

Market linkages exist with the environment in a variety of forms. Some examples of environment-economy linkages are summarized in Table 2. Some linkages enter the accounts directly through market activities while others are only contained implicitly.

Table 2: Summary of Environment-Economy Linkages

Value of environmental services	Value of resource discoveries
Value of environmental damages	Value of resource depletion
Value of household defensive expenditures	Value of non-market net benefits to households
Value of resource rents	Value of Disposal Services

For example, commercial natural resources are directly measured; however, the value of the natural resource depreciation as a result of exploitation does not enter the calculation of conventional NNP. Table 3 is a summary of some potential economic damages from environmental impacts (Dixon et al., 1994). The value of the damages listed in Table 3 appears in economic markets. There may also be nonmarket values associated with these environmental impacts.

Table 3: Examples of Some Economic Damages From Environmental Impacts

Environmental Impact	Economic Damage
Air Pollution	
Illness	Medical Expense
Vegetation Effects	Reduced Crop Yields
Aesthetic Degradation	Property Value
Water Pollution	
Toxins in Drinking Water	Medical Expense/Water Treatment
Fisheries Effects	Lowered Catch
Water Recreation	Tourism Revenues
Ecosystem Degradation	
Forest Lands	Sedimentation
Monoculture Plantations	Loss of Biodiversity

The value of environmental services like clean water lies outside the market system. In the past, inclusion of nonmarket values may have been dismissed due to controversy surrounding valuation techniques, lack of available data, and no standardized method for their inclusion. The advancement of nonmarket valuation techniques facilitates the inclusion of nonmarket values in socio-economic analysis and results in a more complete analysis.

A study by Haener and Adamowicz (1999) demonstrates that regional forest resource accounting is feasible and offers valuable information to decision-makers. They identify several forest services both commercial and nonmarket, in a study region of northeastern Alberta. Table 4 is a summary of the forest services valued by Haener and Adamowicz (1999).

Table 4: Examples of Ecosystem Services Valued in Previous Studies

Commercial	Non-Market
Forestry	Recreational fishing
Trapping	Recreational hunting
Fishing	Recreational camping
	Subsistence resource use
	Carbon sequestration
	Biodiversity maintenance

Note that the services valued in Haener and Adamowicz (1999) are related only to the forest. However, a regional green account may include many more sectors and activities such as mining and crude petroleum. Other aspects that need to be quantified and valued are emissions (environmental assimilation and damage) and resource depreciation (or appreciation). The potential exists for valuing the net benefits of many different environmental services specific to a given study region. For example, bird watching may be a significant activity in only one of many smaller regions that comprise a province or country.

2.3.3 Past Studies in Environmentally Extended Analysis

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

As previously discussed, SAMs are an alternative way to represent data contained in the conventional national accounts – with an emphasis on the distribution of income via the disaggregation of household income. Therefore, conventional SAMs, at the very least, are useful for analyzing distributional consequences of policy changes. CGE models are recognized as being more powerful than SAMs. However, neither type of economy-wide analysis (in its conventional form) adequately account for the environment and natural resources. The primary focus in the development of environmentally extended modeling techniques is to examine the inclusion of the value of natural resource depreciation, environmental damage and environmental services.

Golan et al. (1995) develop a SAM framework to evaluate the impact that environmental externalities have on welfare. They evaluate changes in the levels of consumer and producer surpluses accruing to different activities and agents in both current and future economies. This type of analysis makes environmental distortions explicit and attempts to derive a correct evaluation of the ‘true’ value-added in each sector. The environmentally corrected SAM and SAM multiplier results derived are used to calculate an environmentally corrected NNP measure. The results show that the level of economic activity portrayed in the unadjusted SAM is higher than when the correct environmental prices are considered. In addition, the major burden of the cost of the externality is borne by the future economy.

Although the framework presented by Golan et al. (1995) incorporates natural resource depletion and environmental damage, the nonmarket value of environmental services is not explicitly addressed. Other researchers have examined the issue of incorporating nonmarket values into a SAM framework. For example, Bojo et al. (1990) and Maler (1991) develop schematic representations of ESAMs, although no empirical attempts were made to incorporate nonmarket values into an actual SAM. Current work involving the integration of environmental values into a SAM framework has focused on the role of ESAMs as the basis for environmentally extended CGE analysis.

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.

Although several attempts have been made to integrate nonmarket values with the CGE framework, the use of ECGEs is still in its relative infancy. In addition to the standard limitations of conventional CGE models, Xie (1996) suggests two other possible constraints to the development of sophisticated ECGE models for policy analysis. First, model specifications of economy-environment interactions are relatively incomplete and unsophisticated. In other words, the specification of an ECGE is only as good as the characterization of the interactions between the economy and the environment.

For example, the environment is both a source of materials for production and a recipient of wastes from the production process. Therefore, environmental degradation will occur if the generation of wastes exceeds the assimilative capacity of the environment (Eder and Narodowslowsky, 1999). If the assimilative capacity of the environment is exceeded, environmental degradation may have direct negative effects on both the utility of consumers and the stock of resources. In addition, there may also be indirect impacts on utility by a reduction in production. These interactions need to be studied and quantified in order to ameliorate the use of ECGEs for policy analysis.

The second limitation on the development of sophisticated ECGEs identified by Xie (1996) is the lack of well-defined environmental frameworks that provide a solid basis for the numerical specification of an ECGE model. As previously discussed, this is the area where both green accounting and ESAMs can be used to facilitate the construction of ECGEs. Xie (1996) addressed the numerical specification issue by first constructing a consistent equilibrium data set for the Chinese economy that includes relevant environmental data in an ESAM framework. Parameter estimation was then conducted by calibrating the ECGE model to the consistent equilibrium data set arranged in the ESAM framework.

2.3.3.1 ESAM

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 5 is a modified version of the schematic ESAM developed by Atkinson et al. (1997). Unlike a conventional SAM structure, the ESAM schematic reveals the incorporation of two additional accounts. The two accounts introduced in the ESAM are a ‘resource’ account and an ‘environment’ account.

Table 5: 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

Note that the measure of green NNP 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:[9]

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.

2.3.3.2 ECGE

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 (1999) incorporate environmental damage functions in a hypothetical scenario to analyze linkages between tourism and the environment. This section will discuss the stylized ECGE models developed by Xie (1996) and Alavalapati and Adamowicz (1999) to conduct integrated environment-economy policy analysis.

CGE models have both a supply side and a demand side. On the supply side, model specification requires information with respect to production and the producer's optimal choice (minimize costs and maximize profits). If environmental impacts are not considered, commodity supply functions are derived from the minimization of total costs, subject to a production function, and maximization of profit. However, when environmental impacts occur, the optimization problem must be changed. Xie 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 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.[10] In addition, the net cost of waste disposal (cost less any compensation) can be subtracted from the household income constraint.

[9] The variables are defined in the legend to Table 5.
[10] Note this assumes individuals have perfect information with respect to the environmental change.

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 the integrated CGE models can be very useful in analyzing environment-economy interactions.

The 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 (1999) 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 (Healy, 1994).

The study by Alavalapati and Adamowicz (1999) 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.

The first environmental damage function assumes that only economic activity related to the resource sectors affects the local environment. The alternative environmental damage function assumes that economic activity from both the resource sectors and tourism affect the local environment. The results of their simulation experiments showed that the effect of policy change (i.e., an environmental tax on either the resource sector or the tourism sector) is not the same under the two assumptions. The authors claim that these results cannot be generalized since the economic structures of regions generally differ. They also suggest that the application of CGE models to small regions would require various modifications to the assumptions they used. For example, an assumption used in their study is that the supply of labour is fixed. This may be unreasonable for many small, regional economies.

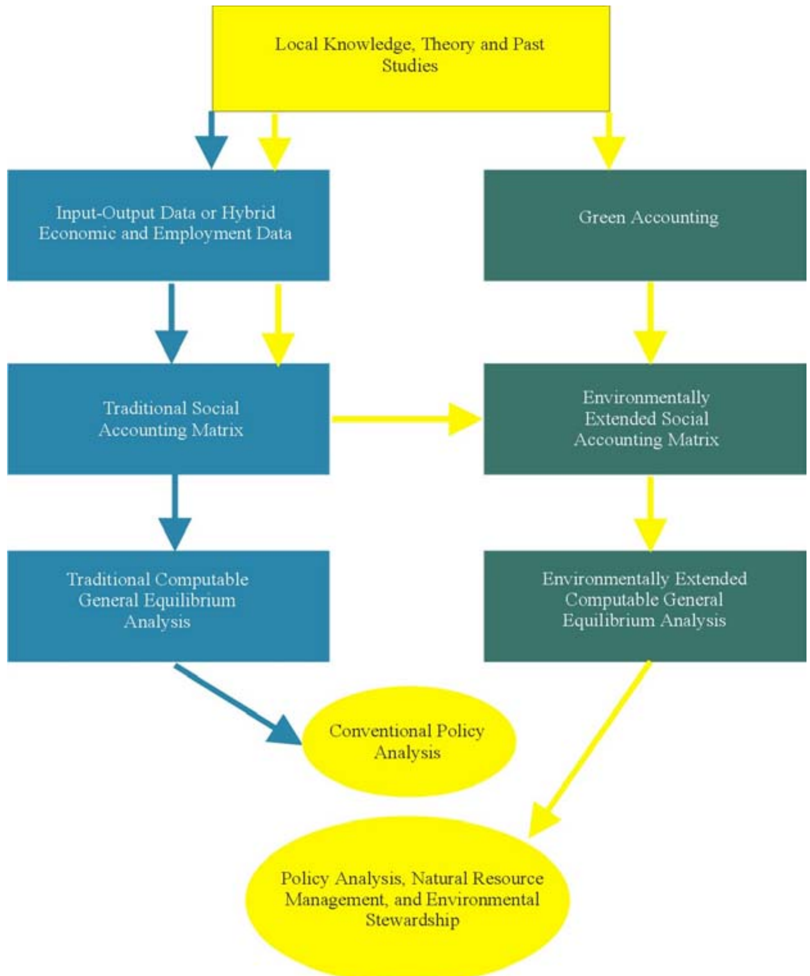
Based on their findings, Alavalapati and Adamowicz (1999) suggested several possibilities for extensions to the study. First, they suggest the development of a SAM that distinguishes a tourist sector. This will allow modelers to consider multisector and multifactor CGE models. Second, factor markets 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.

2.3.4 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 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.

Figure 1: A Process of More Complete Policy Analysis



The studies discussed in previous sections demonstrate that green[11] accounts are a useful exercise and organize the data necessary for the construction of an ESAM. In turn, ESAMs can be used as the basis for more prolific ECGE analysis. ECGE analysis, even with its drawbacks, is the most theoretically consistent and the most flexible general equilibrium tool for policy evaluation.

[11] The term 'Green' is used to describe the integration of natural resources, environmental services and pollution. In the past researchers have tended to examine each of these subsections of 'green' on an individual basis (i.e., a natural resource account separate from a pollution account etc.). The approach of the author is holistic and combines all environment-economy linkages under the umbrella of 'green.'

3 A Case Study of the Foothills Model Forest

3.1 Introduction

The Foothills Model Forest (FMF)[12] 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 tool that has 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.

Many regional models rely on the use of provincial data as proxies for the region. However, purely synthetic approaches to regionalizing data leave the reliability of impact estimates derived from these models in question. Special attention is directed towards the collection and incorporation of regionally specific data for two main reasons. The first reason is the different input mix and source of inputs between the provincial and regional economies (Alavalapati et al., 1999; Patriquin et al., 2000). The second reason is the local or spatially differentiated nature of environmental impacts.

3.2 Description of the Region

The FMF is comprised of three distinct areas: Weldwood of Canada's Hinton Forest Management Area, Jasper National Park, and Wilmore Wilderness Park. The region is located in the west central foothills and the Rocky Mountains in the province of Alberta. Figure 3 demonstrates the location of the study region in relation to the province of Alberta. Primary activities such as coal mining, crude petroleum and natural gas production, and logging, characterize the FMF economy. For example, the mining sector alone accounts for approximately 27% of the estimated $1.8 billion of total output from the region (Patriquin et al., 2000). This contrasts with the provincial average of 2.4%. Combined, the resource sectors account for over 67% of the value of total output from the FMF.

[12] For an overview of the Foothills Model Forest program please visit Http://www.fmf.ab.ca

Figure 2: Location of the FMF Study Region

3.3 The Data

3.3.1 Framework of a Regional Database

3.3.1.1 Market Data and Construction of a Conventional SAM

Existing regional level data based on census divisions do not conform to the boundaries of the study region. Therefore, a hybrid modeling approach for the FMF was selected due to the high costs of a pure survey approach and the strong likelihood of obtaining inaccurate results from a purely top-down synthetic method based on provincial averages.

3.3.1.1.1 Hybrid Regionalization

The five major sectors identified in the FMF, the forest sector, the wood sector, the mining sector, the crude petroleum and natural gas sector, and the visitor sector account for approximately 85% of the value of output from this regional economy.[13] When looking at the provincial economy these five major sectors, as identified in the FMF economy, account for less than 19% of the value of output from the province. For example, both agriculture and manufacturing are negligible activities in the FMF but are major provincial economic activities. Agriculture and manufacturing account for a large portion of the difference in the comparative size of the rest of the economy sector between the province and the FMF.

[13] Aggregation of sectors was performed for the sake of simplicity.

Three different types of information were collected in developing a hybrid economic impact model for the study region (Patriquin et al., 2000). First, instead of conducting a lengthy I-O study, dominant industries with small numbers of firms were contacted directly for financial information. Second, a visitor sector was developed using the results of two separate studies. A visitor expenditure study was conducted to obtain the total value of output for the sector (Wellstead et al., 1998). A visitor sector employment study was also conducted to identify the number of people employed in the sector and to determine the visitor sector total wage bill (Wellstead et al., 1999). Third, household expenditure data were collected from a FMF household expenditure survey (Jagger et al., 1998). This information was used to disaggregate households into income classes and to identify local expenditures versus leakages.

3.3.1.2 Environmental Data and an ESAM for the Foothills Model Forest

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). 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.

Several nonmarket values associated with recreational use can be estimated for the FMF. Camping has been identified as a major recreational activity within the FMF. McFarlane and Boxall (1998) conducted a study to estimate the nonmarket value of camping in the FMF. They conclude that the estimated consumer surplus per camping trip is $58 resulting in a total benefit flow of $436, 600 (1995 dollars) per year. Similar studies can be done in order to obtain nonmarket net benefits of other recreational activities including hunting and fishing in the region.

Once a green account is constructed for the FMF, the environmental linkages can be incorporated into the existing hybrid conventional FMF SAM through the addition of a resource sector and an environment sector. The formation of an FMF ESAM can be used to conduct preliminary economic impact analysis. Preliminary impact estimates provide a means for comparison as well as the boundaries within which more accurate measures should fall. The FMF ESAM also provides a consistent equilibrium data set for the calibration of parameter estimates required for an ECGE model.

Other 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".[14] Three distinct categories of net benefits 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

[14] For a summary of the survey results see Minister of Public Works and Government Services Canada (1999).

from trips to the FMF. The values obtained from the survey are summarized in Table 6. The table demonstrates that nature-related activities have a significant value or net benefit above and beyond the observable market value. For example, Table 6 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.

Table 6: 1996 Net Economic Values (NEV) of Nature-Related Activities (Dollars)[15]

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**

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.[16] 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 emission in the regions. Therefore, estimates of carbon equivalent emissions from the province of Alberta are scaled to the region and used as a proxy for regional emissions.[17]

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[15] 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.

[16] Annual carbon sequestration estimates were derived from Apps and Price (1997).

[17] Provincial emission estimates were derived from SENTAR Consultants Ltd. (1993)

Table 7 provides a summary of carbon dioxide equivalent emissions and assimilation in the FMF region. The values indicated in Table 7 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. Future research should be undertaken to provide a more complete green account for the region.

Table 7: 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)				

Note in Table 7 that the visitor sector and the 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 author's 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 first assumption is that NEV has a positive relationship with personal income. In other words, individuals with higher personal income derive greater benefit from nature-related activities. This relationship is somewhat supported by a regression of NEV against personal income categories.

The second assumption that must be made, given a lack of empirical evidence, is that personal income categories can be directly translated over to household income categories. In other words, the previously mentioned properties of personal income will also hold for household income. Personal income categories were translated into household income categories using a conversion factor derived from the Statistics Canada 1996 Census. The conversion factor for the FMF is reported in Table 8.

Table 8: Conversion of Personal Income to Household Income

Region	Average Personal Income ($)	Average Household Income ($)	Conversion Factor*
FMF	26,732	54,021	2.02
Alberta	26,138	51,118	1.96
Canada	25,196	48,552	1.93
* Conversion factor calculated as (avg. household income / avg. personal income)			

Using a conversion factor of 2.02, the personal income category groupings of 15,000 or less, 15,000-35,000, and 35,000+, are roughly equivalent to the household income categories found in the conventional FMF SAM ($30,000 or less, $30,000-$59,999, and $60,000 or greater). The proportions of NEV that correspond to these income categories are respectively, 0.19, 0.30, and 0.51. Therefore, high-income households in the FMF derive the majority of the total NEV.

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 5 (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.

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

3.4.1 Introduction

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.

3.4.2 Conventional Model Specification

Before integrating any environmental components a conventional CGE model for the FMF was specified. The complete generalized set of linear equations for the conventional CGE model is specified in Table 9. The condensed model contains 40 equations and 75 variables. Therefore, the under identification in the model required 35 variables set as exogenous. Table 10 is a list of variables chosen as endogenous to the model. Table 11 is a list of variables chosen as exogenous to the model in order to achieve model closure. Alternatively, different model closure regimes could be specified depending on the issues the modeler would like to address.

Table 9: 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 10: 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 11: 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

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. Following Alavalapati et al. (1996) the labour supply is assumed fixed (i.e., the migration of labour between the region and the rest of the world is not considered). It should be noted that labour mobility between the region and the rest of the world is likely to be high. This issue is not dealt with in this study since the regional border is assumed closed to labour migration for the purpose of simplicity.

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.[18]

3.4.3 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 12.

Table 12: 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

As depicted in Table 12, NEP is the same measure of net environmental product as discussed with respect to the ESAM. 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

[18] These three sectors are assumed to be land using since they make actual factor payments for this resource. No land payments are made in the visitor sector.

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.

4 Results

4.1 Introduction

Many policies or changes are currently being considered in the FMF. For example, one of the four coalmines 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. An exogenous land use reduction in the resource sectors is also under consideration by public agencies as a means to address public concerns for the environment. For example, a proposed 2% reduction in Weldwood of Canada's Forest Management Area (FMA) was proposed under the Government of Alberta's Special Places 2000 policy.

The models discussed earlier in this study are used to simulate hypothetical changes in the FMF economy. A total of seven models were developed in this study. Table 13 provides a summary of some of the basic features of the models. The first two models, the synthetic conventional SAM (SCSAM) and the hybrid conventional SAM (HCSAM), are used to determine whether the hybrid regionalization approach is more appropriate than the purely synthetic approach for the development of the remaining models. The five remaining models, the hybrid environmentally extended SAM (HESAM), the short-run hybrid conventional CGE (SRHCCGE), the long-run hybrid conventional CGE (LRHCCGE), the short-run hybrid environmentally extended CGE (SRHECGE), and the long-run hybrid environmentally extended CGE (LRHECGE), are used to examine the differences between general equilibrium techniques and the integration of economy and environment.

Table 13: Summary of Model Features

	Role of Prices	Direction of Impacts	Major Adjustment Mechanism	Role of Environment
HCSAM	No Role	Unidirectional	-	-
HESAM	No Role	Unidirectional	-	Used to Calculate Green NNP
SRHCCGE	Prices Endogenous	Multidirectional	Employment	-
LRHCCGE	Prices Endogenous	Multidirectional	Wages	-
SRHECGE	Prices Endogenous	Multidirectional	Employment	Indicator of Sustainability
LRHECGE	Prices Endogenous	Multidirectional	Wages	Indicator of Sustainability

4.2 Green Adjustments to NNP

Following Equation 3, the NEP in the FMF equals -$344,357.08. Similar to NEV, the NEP was also partitioned among the three household income. The ESAM for the FMF is reported in Table 17 of Appendix A.

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).[19] This is similar to the results found 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.

4.3 Model Results

Three hypothetical scenarios are examined for the purpose of comparing the results from the various models. First, a 2% reduction of the land area available to the forestry sector is examined. This hypothetical scenario could result from a proposed land area within Weldwood of Canada's FMA being taken out of production and designated as a protected area under the Government of Alberta's Special Places 2000 policy. Second, 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. Third, a hypothetical 7% increase in tourism activity in the region is examined. This hypothetical scenario could result from increasing park use restrictions being placed on Banff National Park. Increasing restrictions may cause a shift of visitors to the FMF region.

Table 14 presents the percentage changes in sectoral output, household income, wages, employment, and NEP (i.e., the indicator of environmental quality) in response to a 2% decrease in the land area used in the forestry sector. The results indicate that the estimates derived from the SAM models differ from those of the CGE models. The SAM results reported in column 2 and 3 indicate that a decrease in forestry sector land use causes a decrease in output of all the sectors in the FMF economy. The negative land use shock also results in a decrease in income for the regional households. Since prices are fixed in SAM models there is no change in the wage rate. The results demonstrate that the output impacts are smaller in the HESAM compared to the HCSAM. This suggests that the exclusion of environmental adjustments overestimates the impacts on the regional economy.

The results from the conventional CGE models tell a somewhat different story. Similar to the results from the SAM models, both the SRHCCGE and the LRHCCGE results show a decrease in output of all the sectors in the FMF economy resulting from the decrease in available land in the forestry sector. Contrary to the results from the SAM models both the SRHCCGE and

[19] Although the work in this study is pioneering, note that the environmental adjustments are quite modest or small due to the limited data available.

LRHCCGE results show an increase in the income of regional households. The increase in household income can be explained by the substitution of labour for land in the forestry sector[20]. Since wages are fixed in the SRHCCGE model the increased employment level results in higher total household income. In the LRHCCGE the total employment level is fixed therefore, the increase in household income can be explained by the increase in the wage rate.

Regardless of whether the FMF economy is similar to the short-run or longer-run scenario, the use of SAM models (i.e., I-O based assumptions) will overstate the impacts of policy changes. As reported in Table 14, the estimated economy-wide reduction in output obtained from the SAM models is between 0.8854% and 0.8889%. Although the overall impact remains negative, these values are two orders of magnitude larger than the estimate obtained from either the SRHCCGE (0.0080%) or the LRHCCGE (0.0093%). Similar to the SAM results, the HCCGE results under both the short-run and longer-run assumptions still show negative impacts on the output of all six sectors. Under this scenario, this phenomenon can be explained by the fact that there is no tradeoff for land. Land is being exogenously removed from the forestry sector but it is not being made available to any of the other sectors. In addition, labour is being substituted for land in the forestry sector and therefore labour is being drawn away from all the other sectors.

In the short-run CGE model, labour is drawn out of all the other sectors and moves towards the forestry sector in substitution for the lost land. This results in decreased output from all non-forestry sectors since the wage rate is held constant. However, forestry sector output also decreases since the positive impact of the influx of labour cannot offset the negative impact of the land reduction. In the longer-run model, labour is still drawn into the forestry sector and away from the other sectors. This again causes a negative output impact for all non-forestry sectors. However, since overall employment is fixed, the wage rate is driven up causing a negative impact on forestry sector output. Again, the substitution of labour cannot compensate for the lost land area.

There is only one difference between the results obtained from the HCCGE models and the HECGE models. The HECGE models provide a measure of the percentage change in the NEP of the FMF economy for a given scenario. Without environmental feedbacks there is only a simple one-way relationship between the environmental variables and economic variables. For example, a change in the output of the forest sector will have an impact on the amount of emissions and sequestration but there is no feedback effect of emissions and sequestration on output.

The results reported in Table 14 indicate a 0.4933% increase in the NEP using the SRHECGE and a 0.4914% increase using the LRHECGE. Since the actual value or level of the NEP for the FMF was initially negative this is interpreted as an increase in the value of the negative number. In other words, the NEP is becoming more negative with a 2% decrease in forestry sector land use. This can be explained by the decrease in forestry sector output. There will be a slight decrease in forestry sector emissions and the emissions from all other sectors having a slight benefit on environmental quality or NEP. However, the benefits of reduced emissions are offset

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[20] The substitution of labour for land is a condition resulting from the assumed functional form in the model. With Cobb-Douglas functions the elasticity of substitution between labour and land is assumed to be unity. This may not be an accurate reflection of reality in the region.

by a large reduction in carbon sequestration (assimilative capacity) resulting from decreased forestry sector output. In addition to the assumptions made about the relationship between forest sector output and emissions/assimilation, this result can also be explained as a reduction of turnover in tree growth and forest products that act as carbon sinks. It has also been found that young trees sequester carbon at a higher rate than older trees (Apps and Price, 1997).

Table 14: Impacts of a 2% Decrease in Forestry Sector Land Use

Percentage Change in	HCSAM	HESAM	SRHCCGE	LRHCCGE	SRHECGE	LRHECGE
Forestry	-2.2532	-2.2530	-0.0330	-0.0348	-0.0330	-0.0348
Mining	-0.0187	-0.0182	-0.0001	-0.0016	-0.0001	-0.0016
CPNG	-0.0470	-0.0467	-0.0006	-0.0016	-0.0006	-0.0016
Wood	-0.4338	-0.4332	-0.0062	-0.0073	-0.0062	-0.0073
Visitor	-0.0682	-0.0658	-0.0001	-0.0018	-0.0001	-0.0018
ROE	-0.5372	-0.5208	-0.0008	-0.0006	-0.0008	-0.0006
H1	-0.3772	-0.4367	--	--	--	--
H2	-0.5907	-0.5669	--	--	--	--
H3	-0.5966	-0.6344	--	--	--	--
All Households	-1.5645	-1.6379	0.0054	0.0086	0.0054	0.0086
W	--	--	0.0000	0.0077	0.0000	0.0077
L1	--	--	0.0487	0.0433	0.0487	0.0433
L2	--	--	-0.0001	-0.0044	-0.0001	-0.0044
L3	--	--	-0.0007	-0.0068	-0.0007	-0.0068
L4	--	--	-0.0062	-0.0094	-0.0062	-0.0094
L5	--	--	-0.0001	-0.0044	-0.0001	-0.0044
L6	--	--	-0.0008	-0.0042	-0.0008	-0.0042
ELF	--	--	0.0043	0.0000	0.0043	0.0000
NEP	--	--	--	--	0.4933	0.4914
Economy-Wide	-0.8889	-0.8854	-0.0080	-0.0093	-0.0080	-0.0093

Table 15 presents the percentage changes in sectoral output, household income, wages, employment, and NEP in response to a 22% decrease in mining sector exports. The SAM results reported in column 2 and 3 indicate that a decrease in mining sector exports causes a decrease in output of all the sectors in the FMF economy. The negative export shock also results in a decrease in income for the regional households. Since prices are fixed in SAM models there is no change in the wage rate. Again, the results demonstrate that the output impacts are smaller in the HESAM compared to the HCSAM.

Similar to the results of the first scenario, the results from the SRHCCGE also show a decrease in the output of all sectors in response to the shock. However, the results from the LRHCCGE do not show a decrease in output of all the sectors in the FMF economy. Instead, the results of the

LRHCCGE show an increase in the output of all sectors except the mining sector and the ROE sector. Unlike the first 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.

Again, the use of SAM models (i.e., I-O based assumptions) overstates the impacts of policy changes. As reported in Table 15, the estimated economy-wide reduction in output obtained from the SAM models is between 8.0523% and 8.0256%. Although the overall impact remains negative, these values are somewhat larger than the estimate obtained from either the SRHCCGE (5.8201%) or the LRHCCGE (5.1002%). In this scenario, the negative impacts on economy-wide output are moderated or buffered somewhat in the SRHCCGE, compared to the SAM models, by the change in employment. In the LRHCCGE, 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 short-run CGE 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 longer-run CGE 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 15 indicate a 133.8548% decrease in the NEP using the SRHECGE and a 141.8765% decrease using the LRHECGE. 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.

Table 15: Impacts of a 22% Reduction in Mining Sector Exports

Percentage Change in	HCSAM	HESAM	SRHCCGE	LRHCCGE	SRHECGE	LRHECGE
Forestry	-0.0553	-0.0540	-0.0435	1.5529	-0.0435	1.5529
Mining	-18.4828	-18.4786	-18.4378	-18.4121	-18.4378	-18.4121
CPNG	-0.6006	-0.5983	-0.5240	0.3348	-0.5240	0.3348
Wood	-0.1265	-0.1218	-0.0947	0.9303	-0.0947	0.9303
Visitor	-0.5986	-0.5793	-0.4642	1.0271	-0.4642	1.0271
ROE	-4.7459	-4.6161	-3.9258	-4.3755	-3.9258	-4.3755

H1	-3.0084	-3.5583	--	--	--	--
H2	-5.0367	-4.8297	--	--	--	--
H3	-5.2158	-5.5638	--	--	--	--
All Households	-13.2609	-13.9518	-3.5820	-6.6010	-3.5820	-6.6010
W	--	--	0.0000	-6.7397	0.0000	-6.7397
L1	--	--	-0.0453	4.6503	-0.0453	4.6503
L2	--	--	-20.0390	-17.6692	-20.0390	-17.6692
L3	--	--	-0.6455	4.6524	-0.6455	4.6524
L4	--	--	-0.0947	2.7687	-0.0947	2.7687
L5	--	--	-0.4642	3.2634	-0.4642	3.2634
L6	--	--	-3.9258	-1.2461	-3.9258	-1.2461
ELF	--	--	-3.5120	0.0000	-3.5120	0.0000
NEP	--	--	--	--	-133.8548	-141.8765
Economy-Wide	-8.0523	-8.0256	-5.8201	-5.1002	-5.8201	-5.1002

Table 16 presents the percentage changes in sectoral output, household income, wages, employment, and NEP in response to a 7% increase visitor activity. The SAM results reported in column 2 and 3 indicate that an increase in visitor activity causes an increase in output of all the sectors in the FMF economy. The shock of increased activity also results in an increase in income for the regional households.

The results from the SRHCCGE show an increase in the output of all sectors in response to the shock. However, the results from the LRHCCGE do not show an increase in output of all the sectors in the FMF economy. Instead, the results of the LRHCCGE show a decrease in the output of all sectors except the visitor sector and the ROE sector. Unlike the first two scenarios, each model shows a resulting increase in household income. In the CGE models, 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 case of this scenario, the use of SAM models (i.e., I-O based assumptions) seems to predict the economy-wide impact on output reasonably well under short-run assumptions. However, under longer-run assumptions the SAM models overstate the impacts of policy changes. As reported in Table 16, the estimated economy-wide increase in output obtained from the SAM models is between 1.4936% and 1.5745%. This is compared to 1.5052% from the SRHCCGE and 0.4462% from the LRHCCGE.

In the short-run CGE 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 longer-run CGE 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 16 indicate an 80.8956% increase in the NEP using the SRHECGE and a 108.6443% increase using the LRHECGE. 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.

Table 16: Impacts of a 7% Increase in Visitor Activity

Percentage Change in	HCSAM	HESAM	SRHCCGE	LRHCCGE	SRHECGE	LRHECGE
Forestry	0.0191	0.0200	0.0325	-2.2414	0.0325	-2.2414
Mining	0.1018	0.1047	0.1468	-1.7530	0.1468	-1.7530
CPNG	0.0804	0.0820	0.1028	-1.1400	0.1028	-1.1400
Wood	0.0614	0.0644	0.1091	-1.3240	0.1091	-1.3240
Visitor	5.5321	5.5451	6.1551	6.3295	6.1551	6.3295
ROE	1.0163	1.1049	2.3675	3.5073	2.3675	3.5073
H1	0.5007	0.7200	--	--	--	--
H2	0.8064	0.9830	--	--	--	--
H3	0.8178	1.1261	--	--	--	--
All Households	2.1249	2.8290	3.3324	8.5495	3.3324	8.5495
W	--	--	0.0000	9.6336	0.0000	9.6336
L1	--	--	0.0339	-6.6697	0.0339	-6.6697
L2	--	--	0.1595	-5.2526	0.1595	-5.2526
L3	--	--	0.1266	-7.4649	0.1266	-7.4649
L4	--	--	0.1091	-3.9519	0.1091	-3.9519
L5	--	--	6.1551	3.1329	6.1551	3.1329
L6	--	--	2.3675	-0.9658	2.3675	-0.9658
ELF	--	--	3.8956	0.0000	3.8956	0.0000
NEP	--	--	--	--	80.3694	108.6443
Economy-Wide	1.4936	1.5745	1.5052	0.4462	1.5052	0.4462

4.4 Summary

Regional environmental data were integrated with the FMF hybrid conventional SAM to create an environmentally extended SAM. The green adjustments to conventional product measures demonstrate the overestimation of product found in conventional measures. Green NNP is calculated from the environmentally extended SAM. This initial value can be used as the baseline for tracking economic and environmental sustainability over time.

Finally, conventional and environmentally extended CGE models were constructed for the study region. The conventional CGE models were used to demonstrate the variation that exists between the SAM (i.e., I-O based models) and the more flexible CGE models. The economy-wide output impacts estimated from the CGE models are generally smaller or more moderate than the estimates obtained from the SAM models. Although the environmentally extended CGE models do not contain environmental feedback to production or utility, the unidirectional economic impacts on the environmental variables provide an indication of changes to environmental quality. However, due to data constraints, only a small degree of environmental effects are captured.

5 Summary, Limitations, and Recommendations

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. An examination of the implicit assumptions underlying these models puts the validity of these models in question. Although conventional CGE models represent an improvement over these I-O techniques, they are still lacking with respect to the treatment of natural resources 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.

This report demonstrates that the consideration of environmental variables leads to a potentially more appropriate or less biased measure of regional product. The environmentally adjusted measure of NNP provides local decision-makers with a baseline value for comparing economic and environmental sustainability in the future. However, this measure should be used with caution due to the lack of environmental data for the region and over time.

Examinations of the case study scenario results demonstrate several implications for the FMF region. An exogenous decrease in forestry sector land use results in a reduction of overall output from the region but leads to an increase in regional household income. 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 is response to exogenous economic shocks. Both the decrease of land use in forestry and an increase of visitor activity result in environmental degradation due to decreased carbon sequestration in forestry and increasing vehicle emissions from visitors. Conversely, the closing of a coalmine results in a strong positive effect on the quality of the environment as measured in this report by carbon emissions.

A comparison of the model results based on various approaches demonstrates that the CGE approach produces more moderate and/or potentially less biased results compared to those of the I-O models. However, if the economy of the FMF is similar in structure to the short-run models, the I-O based hybrid conventional SAM model provides a reasonably similar estimate to that of the short-run CGE model except in the case of land use policies. Finally, the CGE approach offers the most promise for the inclusion of environmental adjustments including non-market values.

Despite the improvements this study represents over the current common practice, there are still many limitations. 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.

The CGE models specified in this report are similar to I-O models in that no substitution is allowed between intermediate inputs and primary factors and it is assumed that intermediate inputs are used in fixed proportions. The models do not necessarily need to impose these restrictions depending on the issues that are under investigation. Cobb-Douglas functional forms are also used for both production and utility functions. These features are retained for the sake of simplicity and for the purpose of comparing the CGE and I-O results. However, the CGE framework allows the use of more flexible functional forms. For example, constant elasticity of substitution (CES) functions are frequently used in the development of CGE models.

In this report, a preliminary environmentally extended CGE model of the FMF economy was constructed that identifies environmental quality impacts resulting from economic changes. 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.

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7 Appendix A

7.1 A Hybrid Environmentally Extended SAM of the FMF 1995 (Millions of Dollars)

Table 17

	Forestry	Mining	CPNG	Wood	Visitor	ROE	l	k	d	b	h1	h2	h3	Env	g	kf	row	Total
Forestry	5.9	0.2	0.0	0.0	0.7	3.5	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.1	20.4	375.3	406.3
Mining	0.2	2.8	11.4	0.0	6.2	14.4	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	50.2	408.7	494.1
CPNG	3.5	6.1	1.3	0.5	2.5	1.8	0.0	0.0	0.0	0.0	0.2	0.3	0.3	0.0	0.0	38.0	156.7	211.1
Wood	17.9	0.1	0.0	2.7	0.7	0.5	0.0	0.0	0.0	0.0	0.2	0.4	0.6	0.0	0.4	10.7	64.1	98.4
Visitor	0.0	0.0	0.0	0.0	38.8	27.8	0.0	0.0	0.0	0.0	1.3	2.1	3.1	0.0	0.5	11.1	231.2	316.1
ROE	22.9	27.1	16.4	6.3	25.8	25.4	0.0	0.0	0.0	0.0	29.3	38.9	56.1	0.0	11.6	8.7	2.1	270.5
L	91.0	104.3	24.9	14.4	69.7	36.9	0.0	0.0	0.0	0.0	2.1	3.2	3.4	0.0	54.0	0.0	0.1	404.0
K	74.5	55.5	42.2	5.4	34.6	32.0	0.0	0.0	0.0	0.0	0.3	0.4	0.5	0.0	8.5	0.0	0.0	253.7
D	6.9	13.9	15.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	36.3
B	0.0	0.0	0.0	0.0	0.0	0.0	0.0	145.2	0.0	0.0	0.1	0.2	0.2	0.0	38.7	0.0	0.0	184.5
H1	0.0	0.0	0.0	0.0	0.0	0.0	35.3	14.0	0.0	0.5	0.0	0.0	0.0	-0.1	22.6	0.0	1.3	73.6
H2	0.0	0.0	0.0	0.0	0.0	0.0	105.9	20.8	0.0	0.2	0.0	0.0	0.0	-0.1	14.4	0.0	-0.8	140.5
H3	0.0	0.0	0.0	0.0	0.0	0.0	211.9	22.9	1.6	0.1	0.0	0.0	0.0	-0.2	3.7	0.0	-10.5	229.5
Env	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	1.1	1.9	0.0	0.0	5.8	0.0	9.6
G	4.0	5.3	7.5	0.6	4.6	3.3	0.0	36.2	34.7	18.9	7.2	34.3	57.7	0.0	0.7	2.1	-24.4	192.8
KF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.3	-0.6	24.0	32.6	9.9	8.5	0.0	-14.1	185.6
ROW	179.5	278.8	92.0	68.5	132.4	124.9	50.8	14.6	0.0	39.5	32.6	35.5	73.0	0.0	29.1	38.6	0.0	1189.8
Total	406.3	494.1	211.1	98.4	316.1	270.5	404.0	253.7	36.3	184.5	73.6	140.5	229.5	9.6	192.8	185.6	1189.8	