ECOLOGICAL TAX REFORM:

Estimated Environmental and Employment Effects in British Columbia

by

Amy Taylor

B. Sc., Trent University, 1996

Research Project Submitted in Partial Fulfillment of the Requirements for the

Degree of Master of Resource Management

in the

School of Resource Environmental Management

SIMON FRASER UNIVERSITY

April 1999

APPROVAL

Abstract

Ecological tax reform involves implementing taxes on actions or outcome of actions which harm the environment. Although several European countries have implemented ecological tax reform, Canada has done little. This study estimates the potential impacts of ecological tax reform in British Columbia. To do this, I simulated ecological taxes on water consumption, solid waste and carbon dioxide emissions in BC.

To simulate the response to the water and solid waste taxes, I used price elasticity estimates from the literature. To simulate carbon dioxide taxes, in a way that includes energy efficiency and fuel switching responses, I used an economy-wide simulation model. Two scenarios of ecological tax reform were tested, one having much higher tax rates than the other. In both scenarios, the tax rates increase over time. Changes in water consumption, solid waste and carbon dioxide emissions, and revenue generation resulting from the taxes, were simulated in five year intervals over twenty years. The tax revenue was recycled to the provincial economy as a decrease in payroll charges. Estimates from the literature, on the responsiveness of employment levels to lower payroll charges, were used to simulate changes in employment over the same twenty years.

Although there is uncertainty associated with the methods I employed, the simulations suggest the potential to combine environment and employment policy objectives. The low tax scenario generated annual revenue greater than $1 billion in 2020 while the high tax scenario generated annual revenue greater than $2.5 billion. In response to the water tax, water consumption by each sector of the economy fell by between 15% and 35% from a business as usual scenario. Solid waste decreased by up to 50% and carbon dioxide emissions dropped by 8.5% and 15% in the low and high tax scenarios respectively. Increases in employment were approximately 4% with the low taxes and almost 9% with the high taxes. The uncertainty associated with the results was addressed through extensive sensitivity analyses and comparison of results with other studies. While the modest and gradual nature of the tax changes should

minimize secondary effects (burden on particular industrial sectors or household income shifts), the final section presents strategies to further mitigate such impacts.

Dedication

The River.

Acknowledgments

An eternity of thanks to my family.

Many thanks to my friends both in BC and at home.

Thanks to the Energy Research Group.

And of course, thanks to my boys.

Table of Contents

APPROVAL ... ii

ABSTRACT ... iii

DEDICATION ... v

ACKNOWLEDGMENTS ... vi

TABLE OF CONTENTS ... vii

LIST OF FIGURES ... ix

LIST OF TABLES ... x

1. INTRODUCTION ... 1

1.1 Market Prices Do Not Tell the Ecological Truth ... 1
1.2 Taxes and Charges Have Incentive Effects ... 2
1.3 Some Conventional Taxes/Charges May Result in Deadweight Loss To Society ... 4
1.4 Current Research and Practice ... 9
1.5 Research Questions ... 11

2. METHOD ... 12

2.1 Evaluation of Ecological Bads in British Columbia ... 12
2.2 Simulating Ecological Taxes in British Columbia ... 15
2.2.1 The Water Tax ... 20
2.2.2 The Solid Waste Tax ... 23
2.2.3 Carbon Dioxide Tax ... 25
2.2.4 Allocating the Tax Revenue ... 30

3. DATA AND PARAMETER ESTIMATES ... 35

3.1 Water Tax ... 35
3.2 Solid Waste Tax ... 39
3.3 Carbon Dioxide Tax ... 40
3.4 Employment ... 42

4. RESULTS ... 44

4.1 Ecological Tax Reform Scenarios ... 44
4.2 Tax Revenue ... 44
4.3 Water Tax ... 47
4.4 Solid Waste Tax ... 49
4.5 Carbon Dioxide Tax ... 50
4.6 Employment ... 53

5. DISCUSSION ... 54

5.1 Sensitivity Analysis ... 54
5.1.1 Elasticity of Demand for Labour ... 55
5.1.2 Own-Price Elasticity for Gasoline ... 57
5.1.3 Own-Price Elasticity for Water ... 58
5.1.4 Solid Waste Generation ... 59
5.2 Comparison of Results with Relevant Studies ... 60
5.2.1 Revenue Generation ... 60

5.2.2 Carbon Dioxide Emission Impacts *62*
5.2.3 Water Consumption Impacts *63*
5.2.4 Employment Effects *66*
5.3 ADDRESSING CONCERNS ASSOCIATED WITH ECOLOGICAL TAX REFORM 68
5.3.1 Impacts on Competitiveness *69*
5.3.2 Revenue Erosion *72*
5.3.3 Regressivity *73*
5.3.4 Loss of Safety Incentives to British Columbia Employers *74*

6. CONCLUSION AND RECOMMENDATIONS **75**

APPENDIX A: DETAILED ASSUMPTIONS USED IN THIS ANALYSIS **78**

APPENDIX B: REVENUE GENERATION. **82**

BIBLIOGRAPHY **84**

List of Figures

FIGURE 2-1. GENERAL FRAMEWORK FOR METHODS. 19
FIGURE 2-2. IMPACT OF WATER PRICE ON CANADIAN PER CAPITA WATER CONSUMPTION. 22
FIGURE 2-3. GENERAL FRAMEWORK FOR CALCULATING RESPONSE TO WATER TAX. 23
FIGURE 2-4. COMPARISON OF TWO DIMENSIONS OF MODEL TYPES USED TO ANALYSE ENERGY DEMAND; THE INTERNALISATION OF BEHAVIOUR IN MODEL EQUATIONS AND THE DEGREE OF DETAIL OF END-USES OF ENERGY. 27
FIGURE 2-5. BREAKDOWN OF CPP, EI AND WCP PAID BY BC EMPLOYERS IN 1995. 32
FIGURE 2-6. GENERAL FRAMEWORK FOR SIMULATING THE CHANGE IN EMPLOYMENT. 34
FIGURE 3-1. FREQUENCY DISTRIBUTION OF OWN-PRICE ELASTICITY FOR RESIDENTIAL WATER DEMAND FUNCTIONS (FROM VARIOUS STUDIES IN THE 1960S, 70S AND 80S). 38
FIGURE 3-2. FREQUENCY DISTRIBUTION OF OWN-PRICE ELASTICITY FOR INDUSTRIAL WATER DEMAND FUNCTIONS (FROM VARIOUS STUDIES IN THE 1960S, 70S AND 80S). 39
FIGURE 4-1. CHANGE IN WATER CONSUMPTION IN BRITISH COLUMBIA FOLLOWING THE IMPLEMENTATION OF AN ECOLOGICAL TAX ON WATER CONSUMPTION: INDUSTRIAL SECTOR. 47
FIGURE 4-2. CHANGE IN WATER CONSUMPTION IN BRITISH COLUMBIA FOLLOWING THE IMPLEMENTATION OF AN ECOLOGICAL TAX ON WATER CONSUMPTION: COMMERCIAL SECTOR. 48
FIGURE 4-3. CHANGE IN WATER CONSUMPTION IN BRITISH COLUMBIA FOLLOWING THE IMPLEMENTATION OF AN ECOLOGICAL TAX ON WATER CONSUMPTION: RESIDENTIAL SECTOR. 49
FIGURE 4-4. CHANGE IN CO_2 EMISSIONS IN BRITISH COLUMBIA FOLLOWING THE IMPLEMENTATION OF AN ECOLOGICAL TAX ON CO_2 EMISSIONS: INDUSTRIAL, COMMERCIAL AND RESIDENTIAL SECTORS COMBINED. 51
FIGURE 4-5. CHANGE IN GASOLINE CONSUMPTION IN BRITISH COLUMBIA FOLLOWING THE IMPLEMENTATION OF AN ECOLOGICAL TAX ON CO_2 EMISSIONS. 52
FIGURE 4-6. CHANGE IN DIESEL CONSUMPTION IN BRITISH COLUMBIA FOLLOWING THE IMPLEMENTATION OF AN ECOLOGICAL TAX ON CO_2 EMISSIONS. 52
FIGURE 4-7. EMPLOYMENT IN BRITISH COLUMBIA OVER TIME: BAU, TETR AND AETR. 53
FIGURE 5-1. MAKE-UP OF INDUSTRY IN BRITISH COLUMBIA. 70

List of Tables

TABLE 1-1. OVERVIEW OF ENVIRONMENTALLY-RELATED TAXES AND CHARGES IN A NUMBER OF OECD COUNTRIES AS OF 1/1/1995. 10
TABLE 2-1. THE MAGNITUDE OF A NUMBER OF ECOLOGICAL BADS THAT EXIST IN BRITISH COLUMBIA. 13
TABLE 2-2. ANALYSIS OF VARIOUS ECOLOGICAL BADS IN LIGHT OF THE STATED CRITERIA 14
TABLE 2-3. TENTATIVE ECOLOGICAL TAX REFORM, ECOLOGICAL TAX RATES OVER TIME. 17
TABLE 2-4. AMBITIOUS ECOLOGICAL TAX REFORM, ECOLOGICAL TAX RATES OVER TIME. 17
TABLE 2-5. CARBON CONTENT OF VARIOUS FUELS. TONNES OF CARBON PER UNIT OF FUEL. 25
TABLE 3-1. M^3 OF WATER CONSUMED PER DAY IN 1991 AND 1996 BY EACH SECTOR OF THE ECONOMY IN BRITISH COLUMBIA. 35
TABLE 3-2. OWN-PRICE ELASTICITY FOR WATER. VALUES FROM LITERATURE. 38
TABLE 3-3. TONNES OF SOLID WASTE GENERATED PER YEAR BY EACH SECTOR OF THE ECONOMY IN BRITISH COLUMBIA. 39
TABLE 3-4. EXPERIENCE WITH VOLUME-BASED CHARGES ON SOLID WASTE (% REDUCTION IN SOLID WASTE GENERATION).40
TABLE 3-5. FOSSIL FUEL CONSUMPTION IN 1990 AND 1995 AND FUEL PRICE IN 1995 BY SECTOR OF THE ECONOMY IN BRITISH COLUMBIA. 41
TABLE 3-6. OWN-PRICE ELASTICITY FOR MOTOR FUEL. VALUES FROM LITERATURE. 41
TABLE 4-1. TENTATIVE ECOLOGICAL TAX REFORM, ECOLOGICAL TAXES OVER TIME. 44
TABLE 4-2. AMBITIOUS ECOLOGICAL TAX REFORM, ECOLOGICAL TAXES OVER TIME. 44
TABLE 4-3. ANNUAL TAX REVENUE FROM THE ECOLOGICAL TAXES ($1995 MILLIONS). 45
TABLE 4-4. ANNUAL TAX REVENUE FOR TERT BY ECOLOGICAL TAX ($1995 MILLIONS). 46
TABLE 4-5. ANNUAL TAX REVENUE FOR AETR BY ECOLOGICAL TAX ($1995 MILLIONS). 46
TABLE 4-6. ANNUAL TAX REVENUE ($1995 MILLIONS) AND PERCENT OF TOTAL TAX REVENUE (IN BRACKETS) FOR TETR BY SECTOR OF THE ECONOMY. 46
TABLE 4-7. ANNUAL TAX REVENUE ($1995 MILLIONS) AND PERCENT OF TOTAL TAX REVENUE (IN BRACKETS) FOR AETR BY SECTOR OF THE ECONOMY. 47
TABLE 5-1. RESULTS OF SENSITIVITY ANALYSIS FOR 2020 FOR OWN-PRICE ELASTICITY FOR MOTOR FUEL 57
TABLE 5-2. RESULTS OF SENSITIVITY ANALYSIS FOR 2020 FOR OWN-PRICE ELASTICITY FOR WATER, TETR. 59
TABLE 5-3. RESULTS OF SENSITIVITY ANALYSIS FOR 2020 FOR OWN-PRICE ELASTICITY FOR WATER, AETR. 59
TABLE 5-4. SOLID WASTE GENERATION SENSITIVITY ANALYSIS, 2020. 60
TABLE 5-5. SUMMARY OF A NUMBER OF STUDIES ON THE CHANGE IN WATER CONSUMPTION FOLLOWING THE IMPLEMENTATION OF METERS AND A VOLUME-BASED RATE SCHEDULE. 65
TABLE A-1. ISTUM INDUSTRIAL GROWTH RATES. 78
TABLE A-2. ISTUM RESIDENTIAL GROWTH RATES. 78
TABLE A-3. ISTUM COMMERCIAL GROWTH RATES. 78
TABLE A-4. ISTUM FUEL PRICES, (1995 $ / GJ) INCLUDING TAXES. 79
TABLE A-5. ASSUMED FUEL TAXES. 79
TABLE A-6. BUSINESS AS USUAL ENERGY CONSUMPTION BY SECTOR. 79
TABLE A-7. BUSINESS AS USUAL MOTOR FUEL CONSUMED (LITRES). 80
TABLE A-8. BUSINESS AS USUAL PRICE PAID FOR MOTOR FUEL ($/LITRE). 80
TABLE A-9. BUSINESS AS USUAL OF SOLID WASTE GENERATED (TONNES). 80
TABLE A-10. BUSINESS AS USUAL WATER CONSUMPTION (M3). 80
TABLE A-11. BUSINESS AS USUAL PRICE PAID FOR WATER CONSUMPTION ($/M3). 80
TABLE A-12. BUSINESS AS USUAL POPULATION AND EMPLOYMENT IN BC. 81
TABLE A-13. BUSINESS AS USUAL PAYROLL CHARGES IN BC ($1995). 81
TABLE B-1. REVENUE GENERATION BY ECOLOGICAL TAX, TETR. 82
TABLE B-2. REVENUE GENERATION BY ECOLOGICAL TAX, AETR. 82
TABLE B-3. CO_2 TAX REVENUE GENERATION BY SECTOR, TETR. 82
TABLE B-4. CO_2 TAX REVENUE GENERATION BY SECTOR, AETR. 82
TABLE B-5. WATER TAX REVENUE GENERATION BY SECTOR, TETR. 82
TABLE B-6. WATER TAX REVENUE GENERATION BY SECTOR, AETR. 83
TABLE B-7. SOLID WASTE TAX REVENUE GENERATION BY SECTOR, TETR. 83

TABLE B-8. SOLID WASTE TAX REVENUE GENERATION BY SECTOR, AETR. 83

1. Introduction

Ecological tax reform (ETR) means increasing or implementing taxes on what the literature refers to as "ecological bads". Ecological bads include various actions or outcomes of actions which result in damage to the environment (for example emissions and natural resource depletion). In some cases, the introduction of ecological taxes is combined with reductions in taxes and charges on so-called "goods" or actions which are considered to be beneficial to society (for example employment). Such a tax shift may or may not be revenue neutral. The rationale for ecological tax reform is threefold: market prices do not tell the ecological truth, taxes and charges have incentive effects and some conventional taxes and charges may result in deadweight loss to society.

1.1 Market Prices Do Not Tell the Ecological Truth

There exists a discrepancy in much of today's market economy; market prices do not include ecological impacts. The full cost of environmental impacts incurred during production, consumption and disposal of a good or service is often not included in market prices. The cost of such environmental impacts, referred to by economists as negative externalities, are instead externalized, thereby being borne, not by individual consumers, but by third parties, perhaps society as a whole. Where negative externalities exist, the market price of a good or service remains artificially low. This implies that the market is not operating at the most efficient level and thus society's welfare is not maximized. As environmental degradation increases, due to continued production of goods that impact the environment, the need to rectify this market failure becomes imperative. Ecological taxes can be used to ensure that, to a certain degree, market prices, including the tax, reflect the financial and ecological costs associated with production, consumption and disposal of a good or service.

In making this argument, I do not assume that economists are capable of putting a precise dollar value on all natural resources and environmental amenities. Rather, I am suggesting that we acknowledge that environmental damage exists and that we should begin moving society toward an economic system that recognizes those damages. In this way, a policy designed to incorporate environmental externalities, through the use of taxes, would be similar to government's policy with respect to taxes on tobacco and alcohol. Taxes are levied on these goods as a proxy for the damage they cause to society without knowing exactly what the precise total damage from their consumption is.

1.2 Taxes and Charges Have Incentive Effects

Taxes and charges have incentive effects; producers and consumers move away from that which becomes relatively more expensive and toward that which becomes relatively less expensive. It is increasingly argued that "ecological taxes", by sending price signals to producers and consumers, can be an effective and economical means of reducing pollution and its harm (Peters and Bernow 1996). By shifting taxes and charges away from "goods" and towards "bads", governments can change the relative prices of factors of production to reflect the negative externalities associated with a particular good or service. For example, taxes and charges can be shifted such that materials and energy become relatively more expensive and labour, assuming it is less pollution-intensive[1], becomes relatively less expensive. Such a shift from "goods" to "bads" not only offers consumers and producers an incentive to economize on the amount of "bads" they produce, but indeed it also offers them an incentive to increase their use of "goods".

Economists use elasticity values to measure the responsiveness of quantity produced or demanded to a change in its price. The own-price elasticity indicates the change in demand or output as a result of a change in price and the elasticity of substitution measures the substitution between factors of production (capital, materials, energy and labour) as a result of a change in the relative cost of one or several of the factors. Little responsiveness to a change in price is referred to as inelastic. Significant response is referred to as elastic. The box below shows two equations for elasticity relevant to this study. The first is the own-price elasticity of pollution[2], a percentage change in the output of pollution for a percentage change in its internalized cost. The second is the elasticity of demand for labour.

$$\text{Own-price Elasticity of Pollution} = \frac{\text{Percent Change in Pollution}}{\text{Percent Change in Cost of Pollution}}$$

$$\text{Elasticity of Demand for Labour} = \frac{\text{Percent Change in Labour}}{\text{Percent Change in Price of Labour}}$$

Thus, ecological tax reform, by changing the relative price of inputs, provides a means of offering on-going incentives to producers and consumers to reduce those activities which are harmful to the environment. The Tellus Institute (1997) investigated

[1] This may not be the case in all economies.

the effect of ecological tax reform on the state of New York[3]. Their study simulated a tax of $50 per tonne of carbon dioxide (CO_2) in conjunction with decreases in broad-based taxes and charges on households and businesses. They found that such a policy would raise $10 billion in revenue per year while decreasing emissions by 18% of what would otherwise have been expected by the year 2012. They also found that employment and overall production output would increase as a result of the tax reform.

1.3 Some Conventional Taxes/Charges May Result in Deadweight Loss To Society

The current tax system primarily levies taxes and charges on factors that society seeks to encourage: income, capital formation, employment and output. The effect of these taxes and charges is to depress income, employment and sales and discourage capital formation (Ottinger and Moore 1994). The resulting loss of business, work and savings is sometimes referred to as the excess burden or deadweight loss from the tax system (Dower and Repetto 1994). Bossier and De Rous (1992) studied the marginal cost of public funds in the United States and found the deadweight loss associated with a 35% tax on labour income to be 7% of tax revenue. According to Bossier and Do Rous, therefore, the marginal cost of public funds in the U. S. is 107%, or $1.07 per dollar of revenue. This implies that government expenditure in the United States, under the current tax system, would have to be 7% more beneficial than private expenditure to result in a net welfare gain.

---

[2] Normally the demand for the pollution is not measured. Instead, the demand for the pollution-intensive good or service is used as a proxy for the demand for the pollution associated with that good or service.

[3] Note that the results of this research are limited by whatever assumptions are inherent in the model employed in the analysis.

Kneese and Schultze (1975), Mills (1978), and Baumol and Oates (1988) among others, have suggested that the current tax system would be made more economically efficient by substituting ecological taxes for taxes or charges which impose large deadweight loss on society. Where efficiency gains are made, such a tax reform results in what is referred to as a double dividend. The first dividend arises because the imposition of an ecological tax removes or reduces a negative externality from the economy. The second dividend comes from the decrease in deadweight loss to society when the ecological tax revenues are used to decrease an already existing distortionary tax or charge (Mabey and Nixon 1997). To the extent that ecological taxes are nondistortionary, therefore, ecological tax reform provides a means of reducing deadweight loss and thereby increasing total economic welfare to society. Several researchers argue that indeed this is the case.

Shackleton et al. (1993) compared results from four models of the US economy to examine how different carbon tax revenue recycling options affect GDP. They concluded that "the cost of a carbon tax may be largely and perhaps even fully offset by taking advantage of its efficiency value and using the revenues to cut existing taxes that discourage capital formation and labour supply". Terkla (1984) investigated the impact on the United States of a nationwide tax on particulates and sulphur dioxide of $192 per tonne emitted from all industrial sources. He found that such a tax would raise between $468 and $237 million, for 97% and 85% reduction in current emissions in response to the tax respectively. In addition, Terkla found that when effluent tax revenues were substituted for income tax revenues, each dollar of effluent tax revenue had a net efficiency gain of $0.35. This was due to the fact that raising the dollar through a income tax would have resulted in an additional $0.35 in deadweight loss to society. Likewise, each effluent tax dollar substituted for a capital income tax dollar had a net efficiency gain of at least $0.56. Terkla concluded that the efficiency value of the revenues raised by effluent taxes on particulates and sulfur dioxide range from $630 million to $3.05 billion if substitution for labour income taxes and from $1 to $4.87 billion if substituted for corporate income taxes.

The Tellus Institute (1997) in Boston used an input-output model to test the effects of ecological tax reform focused on carbon dioxide emissions in Minnesota. They examined the impacts of taxes of $10, $30, and $50 per ton of CO_2 on the state's energy sector and economy. They reduced social security payments and indirect business taxes such that tax revenues remained unchanged following carbon taxation. They found that a CO_2 based ecological tax reform would reduce energy demand by 3.55%, and 15% for the $10/ton and $50/ton tax cases respectively. Associated reductions in CO_2 emissions were 4.5% and 17.8% for the $10 and $50 taxes respectively. They found that employment impacts for the $10/ton tax were a 0.32% increase in 1997 to a 0.10% increase in 2012 over the base year employment for reductions in social security payments and a 0.24% increase in 1997 to a 0.07% increase in 2012 in the case of the indirect business tax. Results for the $50/ton tax were three to five times higher.

The most extensive look at ecological tax reform has been done by Ernst Ulrich von Weizsacker (von Weizsacker and Jesinghaus 1992). He argues that green taxes should be levied on environmentally important input factors such as fossil fuels, nuclear energy, water (especially water that ends as waste water) and raw materials. Equal reductions in taxes in other areas would ensure revenue neutrality and provide incentives to invest in new technologies for decreasing energy and raw material inputs.

von Weizsacker used elasticity estimates to predict the advantages from ecological tax reform. His results show less environmental damage, and so reduced repair and health costs, and increased employment as labour related taxes are reduced.

Despite this evidence, other research suggests that ecological tax reform does not necessarily decrease total deadweight loss to society. For example, Morgenstern (1996) submits that recent research on the existence of a double dividend hypothesis shows that it applies only in certain cases and not to all tax shifting in general. Indeed, when double dividend claims are subject to theoretical analysis, evidence of an increase in net welfare to society from ecological tax reform is less clear. For example, Jaccard and Montgomery (1996) point out that existing tax structures represent, to some extent, society's best efforts to allocate revenue collection for collective goods among the various actors and activities in the economy. To suggest that such allocations are distortionary implies that the analyst has a better sense of social preferences than the allocation that emerges from a democratic political process. This can be difficult to justify. Morgenstern (1996) and others point out that there are broader equilibrium feedbacks of ecological taxation, like CO_2 taxes, that could offset the direct effect of the tax. For example, if the cost of final goods increase, the demand for all inputs, including labour, will decrease. This may offset the shift toward labour among inputs. Research by Bovenberg and Goulder (1993) and Bovenberg and de Mooij (1994) lend support to this argument.

My objective is not to further the debate on the existence or lack thereof of a double dividend. My intention, instead, is to focus on the first order, or direct, effects of a shift in factor costs resulting from an ecological tax reform policy. Further research is required to assess the relative importance of any indirect adjustments that may also be triggered.

1.4 Current Research and Practice

Ecological tax reform is increasingly part of political initiatives in Europe. Sweden, Norway, Finland, Poland, the Czech Republic and the Netherlands have all introduced various forms of ecological tax reform. Switzerland and Austria are also considering proposals for reform (von Weizsacker and Jesinghaus 1992). In contrast to these governments, the Canadian government has yet to introduce such policies. The Canadian press and population at large are, to a significant degree, completely unaware of the concept. Table 1-1 is an overview of environmentally-related taxes and charges in a number of OECD (Organisation for Economic Co-operation and Development) countries (OECD 1995). Further investigation into ecological tax reform for Canada in general, and British Columbia (BC) more specifically, is needed to fully realize the potential effects of such policy initiatives.

The purpose of my research is to explore the environmental and employment effects of ecological tax reform by using a model to simulate ecological tax reform for the province of BC over a twenty year period. Results will indicate the effect of an ecological tax reform policy on government revenues, consumption or output of ecological bads and changes in employment in BC.

Table 1-1. Overview of environmentally-related taxes and charges in a number of OECD countries as of 1/1/1995.

Environmental Tax Measure	Canada	Denmark	Finland	Norway	Netherlands	Sweden
Motor Fuels						
Leaded/Unleaded		X	X	X	X	X
Diesel		X	X	X		X
Carbon/Energy		X	X	X	X	X
Sulphur				X		X
Other	X	X	X	X	X	X
Other Energy Products						
Other excise		X	X	X	X	X
Carbon/energy		X	X	X	X	X
Sulphur		X		X		X
NOx						X
Vehicle Related						
Sales/Excise/Reg.	X	X	X	X	X	X
Road/Registrat.	X	X		X	X	X
Agriculture Inputs						
Fertilizers				X		X
Pesticides		X	X	X		X
Other Goods						
Batteries		X				X
Plastic Bags		X				
Containers			X	X		
Tires	X	X				
CFCs/halons		X				
Lubricant oil			X			
Oil pollution			X	X		
Direct Tax Provisions						
Env't Invest/ Accelerated depreciation	X	X	X	X	X	
Employer-paid commuting expenses part of taxable income		X	X			X
Air Transport						
Noise charge				X	X	
Other	X			X		X
Water Charges and Other Taxes						
Water charges		X	X	X		
Sewage charges		X	X	X	X	X
Water effluent charges					X	
Waste Disposal and Management Charges						
Municipal waste	X	X	X	X	X	X
Waste disposal charge		X		X	X	
Hazardous waste			X	X		

Source: OECD 1995

1.5 Research Questions

For this study, I explore the effect that ecological tax reform in BC might have on the environment and employment in the province. Specifically, I pursue the following three questions.

- **Question 1**

How much will a package of ecological taxes affect the output of ecological bads to which they are applied?

- **Question 2**

How much revenue could BC potentially raise from introducing a package of ecological taxes?

- **Question 3**

What is the potential increase in employment from using the revenue from the package of ecological taxes to decrease the cost of labour in BC?

2. Method

The following sections describe the methods I employed for simulating ecological tax reform in BC.

2.1 Evaluation of Ecological Bads in British Columbia

Before simulating ecological tax reform in BC, I established a set of criteria for determining where the implementation of ecological taxes is appropriate. To determine what ecological taxes to simulate in BC, I used the criteria to evaluate a number of ecological bads that exist in BC. The criteria are described in the box below.

Criteria for Determining Where Ecological Taxes are Appropriate:

1. Where activities that cause environmental harm are well understood, widely practiced and well monitored.
2. Where each unit of activity contributes more or less proportionally to the overall problem.
3. Where a marginal change in the use of the good implies a beneficial effect on environmental quality.
4. Where the impact on environmental quality of the time and location of release of effluent or use of a good is not large.
5. Where there is ease of implementation and enforcement of the environmental taxes.

Table 2-1 shows the magnitude of a number of ecological bads that exist in BC. The size of some of the ecological bads are presented for the Greater Vancouver Regional District (GVRD) only, while others are presented for the whole province.

Table 2-1. The magnitude of a number of ecological bads that exist in British Columbia.

NO_x (tonnes per year in 1990, GVRD)	
Point Sources	8,811
Area Sources	3,302
Mobile Sources	41,327
Particulate Matter (tonnes per year in 1990, GVRD)	
Point Sources	11,969
Area Sources	3,343
Mobile Sources	4,188
SO_x (tonnes per year in 1990, GVRD)	
Point Sources	3,766
Area Sources	351
Mobile Sources	3,858
VOC (tonnes per year in 1990, GVRD)	
Point Sources	8,576
Area Sources	34,069
Mobile Sources	42,662
CO_2 (kilotonnes per year in 1990, BC)	
Industrial	12,800
Commercial	3,200
Residential	4,400
Transportation	18,270
Electricity	1,500
Solid Waste Generation (tonnes per year 1995, BC)	
Industrial/Commercial/Institutional	1,223,448
Residential	1,519,075
Water Consumption (m^3 consumed per day in 1995, BC)	
Industrial	210,640
Commercial	331,248
Residential	1,254,815

Sources: GVRD 1993, GVRD 1994, MELP 1995, Tate and Lacelle 1995, Bailie et al. 1998.

By analysing these ecological bads in light of the criteria which determine when environmental taxes are appropriate, I established a package of bads on which to simulate ecological taxes in BC. Table 2-2 summarizes this analysis.

Table 2-2. Analysis of various ecological bads in light of the stated criteria.

Ecological Bad	Criteria 1	Criteria 2	Criteria 3	Criteria 4	Criteria 5
NOx	YES	NO	YES	YES	YES
PM	NO	YES	YES	YES	NO
SO_2	NO	YES	YES	YES	YES
CO_2	YES	YES	YES	YES	YES
VOC	YES	NO	YES	YES	YES
Solid Waste	YES	YES	YES	YES	YES
Water Cons.	YES	YES	YES	YES	YES

The majority of nitrogen oxide (NO_x)and volatile organic compound (VOC) emissions are from automobiles (Hammond et al. 1997). Reductions in emissions from automobiles over time, as a result of emission reducing technology advances and energy efficiency improvements, implies that the relative contribution of individual cars to total emissions is highly variable. Older cars emit much more than newer cars. In other words, each unit of activity does not contribute more or less proportionally to the overall problem (Criteria 2). For taxes to be implemented directly on NO_x and VOC therefore, they would have to be levied on an individual car basis to reflect the differential contribution of the particular car to total emissions. Implementation of such a tax would be extremely difficult and expensive.

Particulate matter (PM) is created through road dust, construction, demolition, and fuel burning. It could be reduced by taxing those activities that produce the greatest amount of emissions. The problem, however, is that most sources of particulate matter are currently not well monitored (Hammond et al. 1997). Implementation, monitoring and enforcement programs would therefore be difficult and expensive (Criteria 1 and 5).

Sulfur dioxide (SO_2) is produced during petroleum extraction, petroleum processing and during fuel combustion. As such, implementing a tax on SO_2 emissions would require substantial monitoring (Criteria 1) and enforcement (Criteria 5) and could therefore prove to be cost ineffective.

Carbon Dioxide (CO_2) is emitted during fuel combustion. Like a tax on SO_2, implementing a tax directly on CO_2 emissions would require substantial monitoring and enforcement. Alternatively, a tax could be levied on the carbon content of fuels. Such a tax would be administered at the point where fuels enter the economy and thus would be relatively easy to administer, monitor and enforce (Hammond et al. 1997, Congressional Budget Office 1990). A tax on the carbon content of fuel would meet all the criteria for determining where environmental taxation is appropriate[4].

Similarly, taxes levied on a per unit basis on solid waste generation and water consumption meet all the criteria for determining when environmental taxes are appropriate.

2.2 Simulating Ecological Taxes in British Columbia

As a result of the above analysis, I simulated ecological taxes on water consumption, solid waste generation and CO_2 emissions in BC. Two scenarios for ecological tax reform were simulated and results were compared with a business-as-usual (BAU) scenario. Table 2-3 shows the price paid for each of the ecological bads in scenario 1, called tentative ecological tax reform (TETR). TETR is characterized by relatively gentle increases in tax rates over time.

Table 2-4 shows the second scenario of ecological tax reform: ambitious ecological tax reform (AETR). The tax rates in this scenario are substantially higher than

[4] Even this tax has problems however, For example, a carbon tax fails to reward those who try to capture or use the carbon dioxide emissions.

in the previous scenario. In both scenarios, the tax rates increase gradually over time so that the costs of adjusting to the ecological taxes are minimized.

Table 2-3. Tentative ecological tax reform, ecological tax rates over time.

Ecological Tax	Units	2000	2005	2010	2015	2020
CO_2 Tax	\$/tonne CO_2	7.5	15	22.5	30	37.5
Water Rate, Ind	\$/m3	0.02	0.05	0.08	0.11	0.14
Water Rate, Com	\$/m3	0.02	0.05	0.08	0.11	0.14
Water Rate, Res	\$/m3	0.03	0.06	0.10	0.15	0.25
Solid Waste Rate	\$/bag	0.50	0.63	0.75	0.88	1.00

Table 2-4. Ambitious ecological tax reform, ecological tax rates over time.

Ecological Tax	Units	2000	2005	2010	2015	2020
CO_2 Tax	\$/tonne CO_2	13.75	27.5	41.25	55	68.75
Water Rate, Ind	\$/m3	0.05	0.10	0.15	0.20	0.25
Water Rate, Com	\$/m3	0.05	0.10	0.15	0.20	0.25
Water Rate, Res	\$/m3	0.10	0.20	0.30	0.40	0.50
Solid Waste Rate	\$/bag	0.5	0.875	1.25	1.625	2.00

The tax rates in AETR for water consumption by the industrial and commercial sectors were set such that the projected increase in water prices in 2020 was approximately two times higher than that which was projected in the BAU scenario. Specifically, in the BAU scenario, prices were projected to increase by \$0.25 between 1995 and 2020. In AETR, they are projected to increase by \$0.50 between 1995 and 2020. In TETR, the increase in the projected price of water for the same sectors was \$0.40 between 1995 and 2020. For the residential sector, the projected increase in the price of water in 2020 in AETR was three times higher than that which was projected for the BAU. In other words, in the BAU scenario, prices were projected to increase in the residential sector by \$0.25 between 1995 and 2020. In the AETR, that increase is projected to be \$0.75. In TETR, the increase in the projected price of water for the same sector was \$0.50, two times higher than the BAU scenario. The rationale for the comparatively higher increase in the price of water for the residential sector reflects the relatively less responsive nature of this sector to changes in the price of water. In other words, I believed that the increase in price resulting from the ecological tax had to be relatively more onerous in the residential sector to achieve a substantial reduction in water consumption.

The tax rates for the CO_2 tax are based on taxes simulated by the Tellus Institute (1997) in their ecological tax reform studies of Minnesota and New York. They simulated CO_2 taxes which reached $30 and $50 per ton of CO_2 in 2012.

The tax rates for solid waste, simulated in this analysis, are based on experience in the Capital Regional District (CRD), BC. The CRD has a volume-based payment system for solid waste which charges an average of $1.00 per can or bag of garbage, assuming two cans of garbage per week per household[5]. This is the ecological tax rate simulated on solid waste in TETR. The volume-based rate in AETR is twice that of TETR and is closer to charges in various regions of the United States[6].

In doing this analysis, I was ultimately concerned with simulating the response of the economy, in terms of reduction in consumption of the ecological bads, to the implementation of the ecological taxes. While the way in which I simulated that response was different for each of the taxes I simulated, the general principle was the same: namely, that firms and households will conserve or switch away from an input whose relative cost increases. The magnitude of this response, or in other words, the degree of elasticity, depends on their technological options and their preferences.

Figure 2-1 shows the general framework for the method I used to simulate the effect of ecological tax reform on the ecological bads to which they are applied in BC. The ecological tax was applied to the ecological bad and both revenue

[5] Residents of the Capital Regional District are able to have one bag of garbage collected per week, at no incremental charge. Bags in excess of one are between $1.50 and $2.50 per bag.

generation and change in consumption or output of the ecological bad were simulated. This was done for each of the ecological taxes.

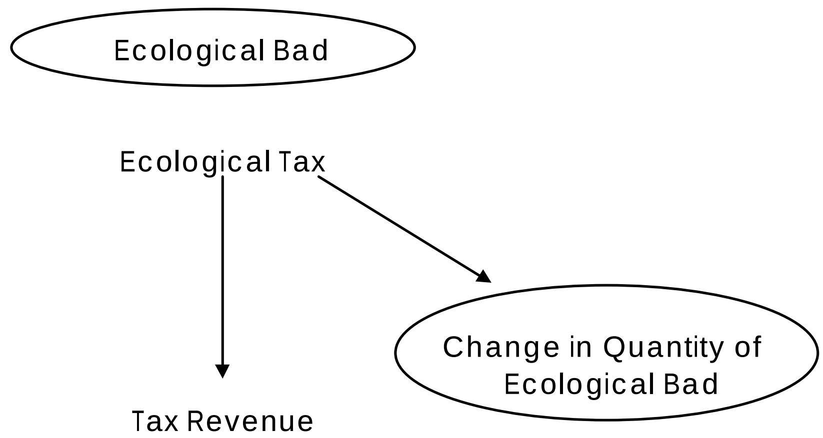


Figure 2-1. General framework for methods.

These calculations were completed at five year intervals over a twenty year period. To do this, price and quantity were projected to the year 2020 for each of the ecological bads. Calculations were completed for each sector of the economy: residential, commercial, industrial and transportation. In this analysis, I assume that all sectors of the economy know in advance what the tax rate in the future will be. Results for changes in consumption of the ecological bads were compared with a business-as-usual scenario (BAU). This allowed me to estimate change as a result of ecological tax reform in BC relative to the economy in the absence of tax reform while taking into account the natural growth in the economy over time.

Note that only the direct effects for changes in consumption/output of ecological bads of the tax reform are captured in this analysis. Clearly, indirect effects would also results from such a reform. Specifically, consumers might shift their preference for a particular good or service as a result of the tax reform. Such shifts

[6] Austin City, Texas, White Bear Lake, Minnesota and Seattle Washington levy volume-based

could induce some degree of structural change in the economy. This would be the case if, for example, a tax on solid waste induced a large shift to recycled material. Such alterations are not simulated in this analysis.

In the sections that follow, I outline the specific way in which I simulated the response to the ecological taxes for each of the ecological bads to which the taxes were applied. I begin by highlighting a number of key assumptions associated with this analysis (see box below).

Key Assumptions

1. CO_2 is emitted in fixed proportion to fossil fuel use.

2. Ecological tax reform is associated with factors which won't affect British Columbia's position nationally/internationally or that where it could we have negotiated so as to minimize such effects.

3. CO_2 coefficient for electricity is the weighted average of the carbon content of the fuels used to produce electricity in BC. This value is assumed to remain the same over time.

4. Decisions are made based on the long-run own-price elasticity for the various factors. This is legitimate because the tax rate over the twenty year period is well known by all in year one.

5. In this analysis, the elasticities are assumed to be constant throughout the range of price changes.

6. Appendix A contain additional assumptions for price and quantity of ecological bads and payroll charges over time as well as projected population increases.

2.2.1 The Water Tax

Water pricing is a very complex issue. Historically, water rates have been set such that the costs associated with delivering water to consumers were fully recovered by the municipality. According to McNeil and Tate (1991), however, a municipal water

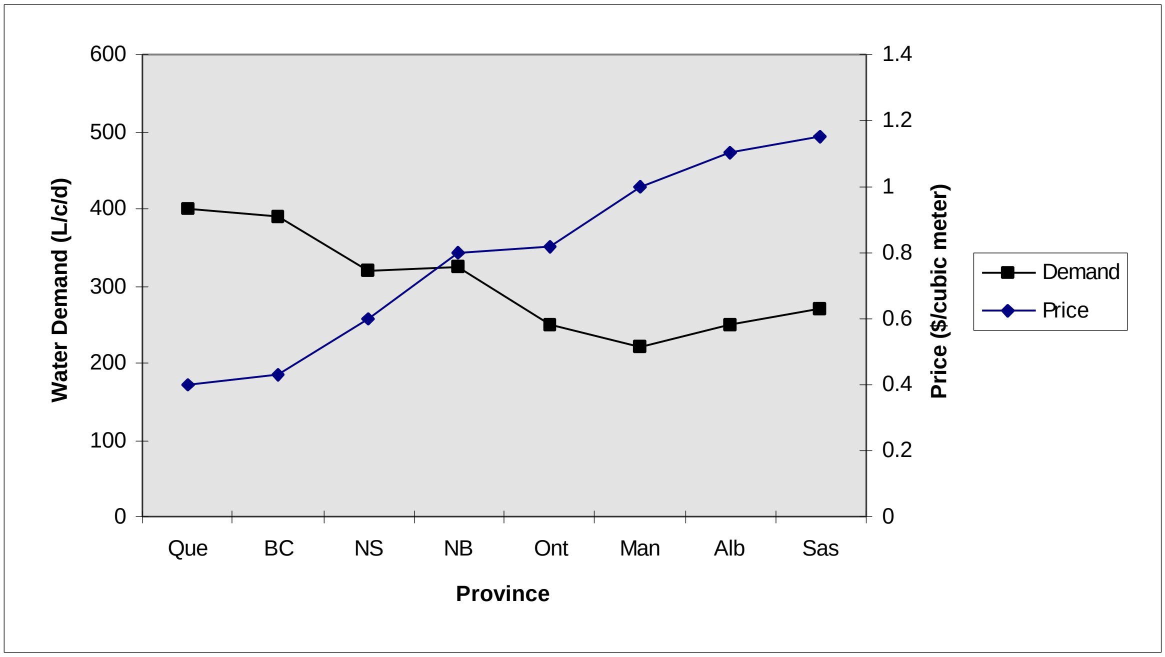
charges on solid waste in excess of $2.00 per can.

pricing policy should have two goals: full cost recovery and economic efficiency. Full cost recovery refers to setting the water rate such that all infrastructure costs, present and future, are recovered from the fees for water. Economic efficiency refers to a pricing scheme which maximizes the net value of water use to society. This implies that all costs, economic and ecological, be included in water rates. Ecological costs associated with water consumption include, among other things, loss of aquatic habitat, groundwater depletion and destruction of land through increased infrastructure development.

Tate and Lacelle (1995) surveyed the municipal water rates in Canada and found exceptionally low rates in BC[7]. Such low rates imply that the true ecological costs of water consumption in BC are not reflected in the price of water. Water consumers in BC, therefore, are not provided with an incentive to conserve water. A water pricing scheme designed to internalize both the economic and ecological costs associated with water consumption, through use of meters and volume-based water pricing, would recognize the ecological costs associated with water consumption and offer consumers an incentive to conserve.

Research has shown that both domestic and industrial water consumption is sensitive to changes in price (Grima 1972, Howe and Linaweaver 1967 , and Hanke 1978). Figure 2-2 shows the price paid for water and the amount of water demanded in each of the provinces in Canada. It suggests that an inverse relationship exists between price and demand for water in Canada. As well, it shows the low water rates in BC relative to almost every other province.

[7] Only 17% of the municipal water consumption in the province is metered.



Source: Water Plants Engineering 1994.

Figure 2-2. Impact of water price on Canadian per capita water consumption.

To simulate the effect of the ecological tax on water consumption by each sector of the economy, I applied the own-price elasticity. Figure 2-3 shows the general framework for calculating the response to the water tax. For each sector of the economy, at five year intervals over a twenty year time period, I multiply the percentage change in price, as a result of implementing the ecological tax, by the relevant own-price elasticity for water to calculate the percentage change in quantity of water demanded[8]. This allows me to calculate a new water demand for each sector of the economy. By multiplying the new demand by the water tax, I calculate the water tax revenue.

[8] I did not include agriculture water consumption in my analysis because agriculture water prices in BC are currently levied according to the number of hectares irrigated (as a proxy for water consumption) and they are amoung the highest rates in Canada (from $39 to $407 per hectare).

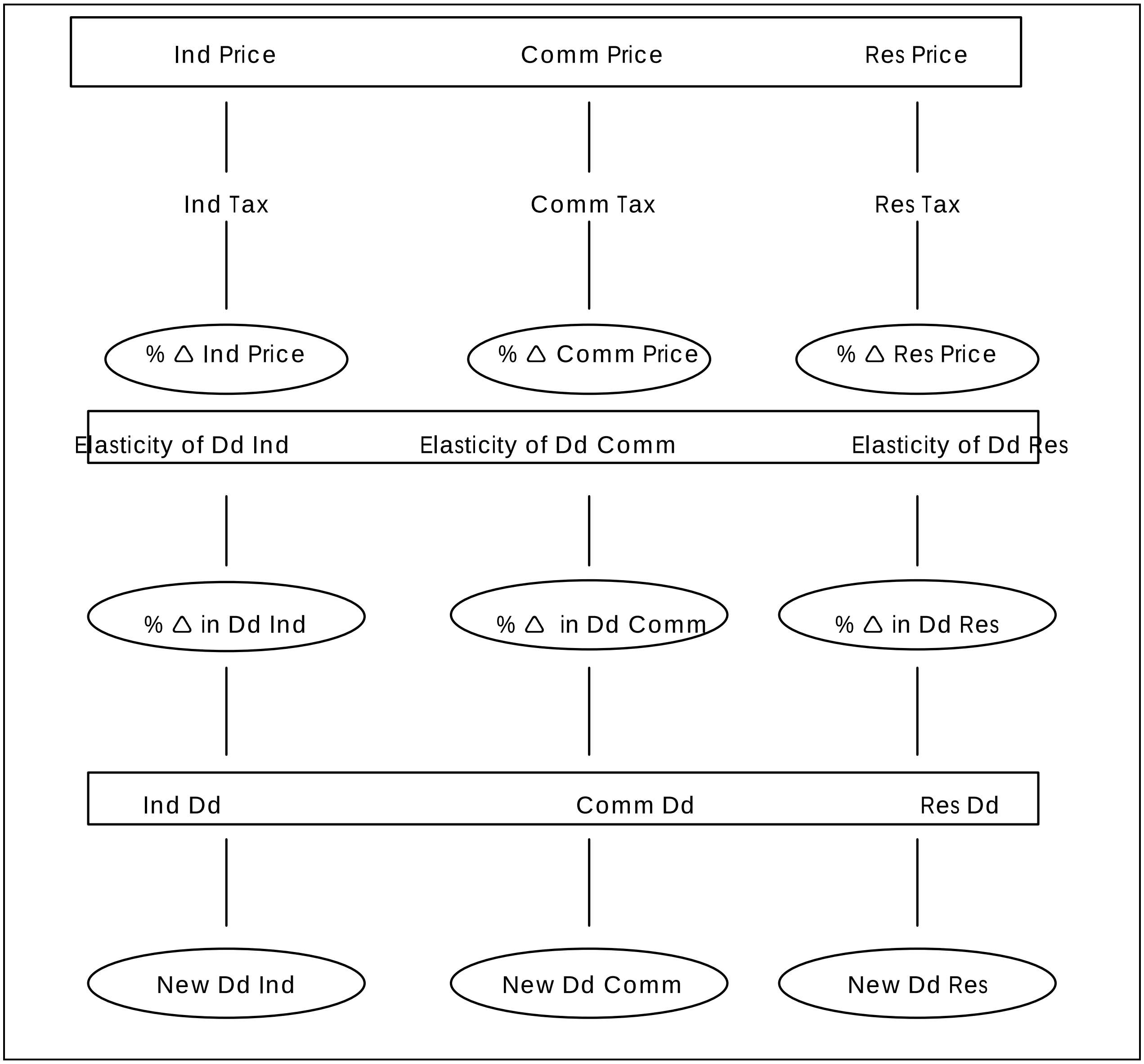


Figure 2-3. General framework for calculating response to water tax.

2.2.2 The Solid Waste Tax

Environmental impacts from solid waste generation in BC are not fully reflected in the market price of waste disposal in the province (Jenkins 1993). As a result, the incremental costs of solid waste, including externalities such as loss of habitat and soil and ground water contamination, are not borne by individuals according to the amount of solid waste they produce but instead are borne by third parties, perhaps society in BC as a whole. More appropriate pricing of the waste management systems in BC would lead to greater internalisation of externalities associated with incremental waste disposal. Such an ecological tax reform policy could involve a volume-based charge, levied on a per bag or per 32 gallon container basis, designed to internalise externalities. This would provide incentives to practice waste reduction (reuse, composting, changes in purchase habits and recycling).

Jenkins (1993) studied the economics of solid waste reduction. He began by calculating the own-price elasticity for solid waste disposal services for both the residential and commercial sectors using data from several communities in the United States. In both cases he found an inverse relationship between price and quantity demanded. He determined the own-price elasticity for solid waste disposal services to be -0.12 and -0.29 for the residential and commercial sectors respectively.

To calculate the response to ecological taxes using elasticity values, first requires calculating the percentage change in price resulting from the tax. In much of BC, however, charges on solid waste are not currently levied on the incremental volume of solid waste generated[9]. As such, the price paid per unit of garbage generated in much of BC is zero. It is therefore mathematically impossible to calculate the percentage change in price, as a result of the ecological tax, for each unit of solid waste generated. For the tax on solid waste, I was therefore not able to simulate the response of the economy using elasticity values from other relevant research. Instead, I looked at the physical effects of a number of real-life cases where volume-based charges on solid waste were implemented (in BC and elsewhere). Specifically, I

[9] In some places, weekly bag limits have been implemented which require bags exceeding that limit to be paid for individually. Such a policy was introduced in Vancouver in January

looked at how much solid waste generation in those places fell following the implementation of volume-based charges on solid waste. I used this information as a proxy for what BC can expect to happen from switching to volume-based charges throughout the province. I calculated the tax revenue from the solid waste tax according to this information at five year intervals over a twenty year time period.

2.2.3 Carbon Dioxide Tax

CO_2 emissions are the leading contributor to the build-up of greenhouse gas emissions in the atmosphere (Repetto et al. 1992). The amount of CO_2 emitted from the combustion of fuels is a direct result of the relative carbon content of the fuel. Table 2-5 shows the amount of carbon contained in various fossil fuels. A CO_2 tax levied on fossil fuels according to their respective carbon content internalizes some of the environmental costs associated with the build up of greenhouse gases in the atmosphere. At the same time, such a tax provides an incentive to reduce energy consumption, given the predominance of carbon-related energy in our economy, and to move toward fuels and sources of energy which contain less carbon.

Table 2-5. Carbon content of various fuels. Tonnes of carbon per unit of fuel.

Fossil Fuel	Tonnes of C per Unit of Fuel
Coal (Tonne)	0.605
Natural Gas (1000 m^3)	0.57
Oil (m^3)	0.83
LPG (1000 m^3)	0.42
Gasoline (litre)	0.000545
Diesel (litre)	0.000818

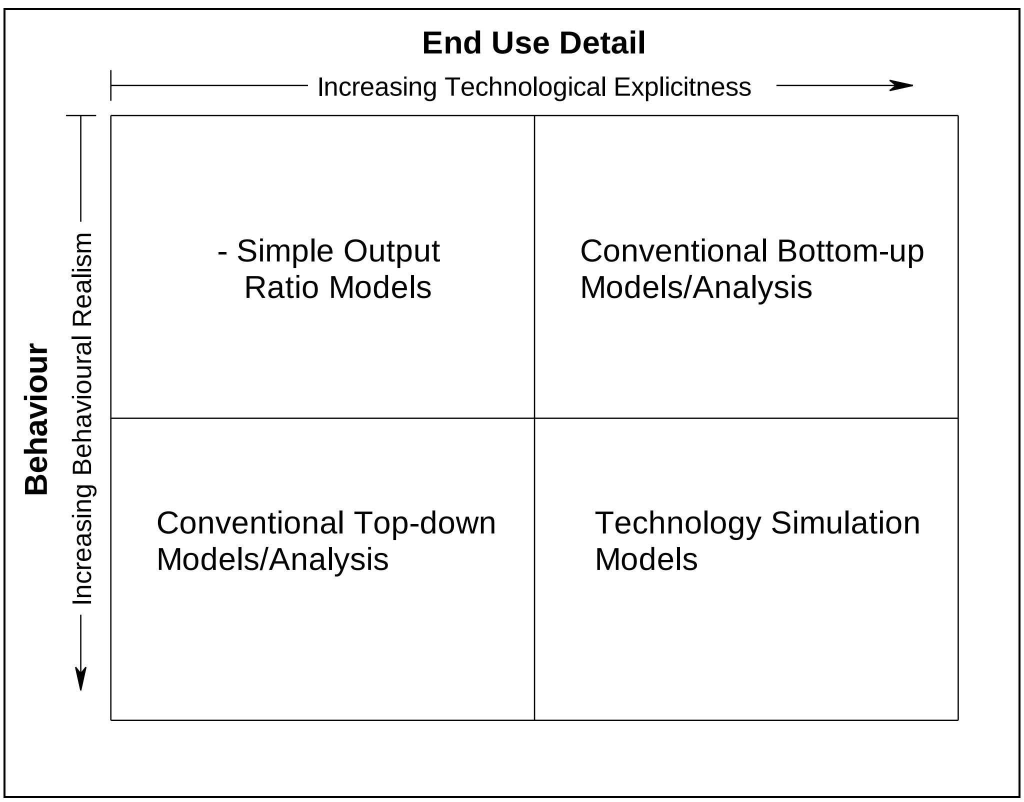
Source: adapted from Poterba 1991

While changes in water consumption and solid waste generation are relatively easy to simulate in isolation, simulating the response to the CO_2 tax is somewhat more

1999. However, the general practice has been to pay for garbage collection and disposal as part of the annual fixed property tax, resulting in a zero incremental change for waste disposal.

complicated. The reason for this is that the carbon content of energy forms varies significantly from one energy form to the next. This means that the CO_2 tax will differentially affect the price of various fuels according to the relative carbon content of the particular fuel. Thus, in the case of the CO_2 tax, both the reduction in consumption of various fuels and the fuel switching that will ensue from the implementation of the CO_2 tax must be taken into account. An energy use model which incorporates both own-price elasticities and cross-price elasticities is therefore required to simulate the CO_2 tax.

To simulate the effect of implementing a CO_2 tax in BC, I therefore used the Intra-Sectoral Technology Use Model (ISTUM) of the Energy Research Group at Simon Fraser University. Figure 2-4 characterizes model types according to their degree of technological explicitness and behavioural realism.



From Nyboer (1997)

Figure 2-4. Comparison of two dimensions of model types used to analyse energy demand; the internalisation of behaviour in model equations and the degree of detail of end-uses of energy.

ISTUM, is a technology simulation model developed in the 1980's (Jaccard and Roop 1990, Jaccard et al. 1993). In the spectrum of models shown in figure 2-4, it is considered to be both technologically-explicit and behaviourally realistic. ISTUM keeps track of the various technologies used by each sector of the economy to meet the specific service demands of that particular sector (e.g. lighting, heating, refrigeration). To do this, it simulates the timing of technology stock turn-over. Each technology has an associated decay function based on its expected life-span. When a technology reaches the end of its life-span, it is retired. New technologies then compete for the market shares made available by the retired technology and by growth in demand for the technology's service. This competition is based on the life-cycle-cost of the particular technology as well as other behavioural considerations. These behavioural parameters are based on the premise that the true costs and cost risks of a technology to a firm or household are not revealed by a strict financial analysis; real world market behaviour evidence is required to understand these costs (Bailie et al. 1998). Additional considerations include: real world cost variability, market penetration, time preferences, technology specific preferences and limitations, and tax and price effects (for a detailed description of these parameters see Bailie et al. 1998).

ISTUM is appropriate for my study for a number of reasons. First, it contains detailed information on, among other things, the CO_2 emissions associated with the use of a particular technology. Second, ISTUM simulates technology turn-over in five year intervals from 1995 to 2015, which is fairly consistent with the time frame of my study.

Third, because the imposition of a CO_2 tax differentially affects the prices of fossil fuels, it is necessary to account for not only the decrease in consumption of a particular fuel, as a result of the CO_2 tax, but also the fuel switching that ensues following the implementation of the tax. When a CO_2 tax is simulated using ISTUM, the net effect on the quantity demanded of the various fuels is measured, i.e. both own-price and cross-price elasticities are included in the analysis[10]. To assess the net social cost impact of the tax, lost tax revenue from decreased consumption of natural gas, oil and coal was subtracted from the new revenue generated from the ecological taxes.

ISTUM is broken down by sector of the economy. In this analysis, the effect of the CO_2 tax was simulated for the industrial, commercial and residential sectors using ISTUM. The industrial sector includes: chemical producers, industrial minerals, metals, mining, pulp and paper and other manufacturing (food, beverage, tobacco, rubber, plastic, leather and allied products, primary textiles, textile products, wood, furniture and fixtures, printing and publishing, fabricated metal products, transportation equipment, clothing and machinery). The commercial sector includes all institutional buildings as well as offices and all other commercial establishments.

To simulate the effect of the CO_2 tax on the motor fuel consumption, I used the own-price elasticity for motor fuel[11]. In this method, I calculated the percentage change in the price of gasoline and diesel, as a result of the CO_2 tax, according to the relative carbon content of the two fuels and used the elasticity value to calculate the ensuing change in demand. Calculations were made for changes in fuel consumption

---

[10] The fuel price elasticities implicit in ISTUM can be derived by varying fuel prices individually and measuring the subsequent change in demand.

[11] In this sense, the motor fuel ecological tax simulation method is akin to the approach for water and waste. The reason for not using ISTUM was that the ISTUM transportation model lacks

and tax revenue at five year intervals over a twenty year time frame. To assess the net social cost impact, lost tax revenue from decreased consumption of gasoline and diesel was subtracted from the new revenue generated from the ecological taxes.

the behavioural realism required of an ecological tax simulation. Current research at ERG is adding behavioural response to the transportation model.

2.2.4 Allocating the Tax Revenue

After simulating the response to the ecological taxes and the associated revenue generation, I considered several options for allocating the new tax revenue. For example, the revenue could be allocated to debt reductions, to improve or increase support services (for example hospitals and education), to decrease income tax, to decrease sales tax or to decrease the cost of labour in BC. Recognizing that increasing employment opportunities in the province is a major thrust of the provincial government, I decided to allocate the new tax revenue to decreasing the cost of labour in the province.

To determine the charge that I would reduce by the same amount as the tax revenue generated from the ecological taxes, I surveyed the various charges employers in BC are responsible for. I then chose that charge which is known, from the literature, to have the greatest dampening effect on job creation. Charges currently paid by British Columbian employers include: provincial corporate income tax, incorporation fees, registration fees, Vancouver/Victoria businesses tax, capital taxes, insurance premiums, property taxes, sales taxes and payroll taxes. Payroll taxes, more appropriately called payroll charges, in BC include Worker's Compensation premiums (WCP), Canada Pension Plan (CPP) and Employment Insurance (EI).

A survey by the Canadian Federation of Independent Business (1996) on job creation in small and medium sized businesses found that just over 50% of respondents claim they would hire additional employees if payroll charges were reduced [12]. Similarly, the Chamber of Commerce (1994), found that payroll charges ranked second, behind deficit/debt reductions, as the issue to which government should give top priority to promote employment creation in Canada. The same study found that employment insurance and worker's compensation payments were the payroll charges which most discouraged job creation across all business sizes. The results of these surveys are in agreement with studies by Beach, Lin and Picot (1995), DiMatteo and Shannon (1995), Bean, Layard and Nickell (1986) and Dahlby (1992) which all conclude that the demand for labour is impacted by the level of payroll charges required of employers. McKitrick (1997) showed that if Canada imposed a carbon tax in the year 2000 to reduce carbon emissions to 1990 levels, and used the tax revenue to finance reductions in payroll charges, consumer welfare would be unchanged and GNP would increase by 0.6% in the short-run. On the other hand, if lump-sum transfers were used to recycle the revenue, welfare and GNP would fall by 0.3% and 0.8% respectively[13].

As a result of the above research, I concluded that payroll charges would be the most appropriate charges to reduce. Figure 2-5 shows the relative portion of CPP, EI and WCP paid by employers in BC in 1995. Of these charges, only Worker's Compensation premiums are paid by British Columbian employers to the provincial government; both EI and CPP are collected by the federal government. As such, I used the revenue from the ecological taxes to finance a reduction in Worker's Compensation premiums in BC. Worker Compensation premiums are experienced-based charges that are levied on BC employers according to the number of people

---

[12] Although the results of the survey indicate that employment would increase if payroll charges were reduced, the survey tested a hypothetical situation. Concrete proof of increased employment would only be realized if the payroll charges were actually reduced.

they employ; the more people an employer hires, the more WCP paid. To simulate the effect of the decrease in payroll charges in BC, I used the elasticity of demand for labour specific to payroll charges in Canada. Figure 2-6 shows the general framework for simulating the response to the decreased payroll charges.

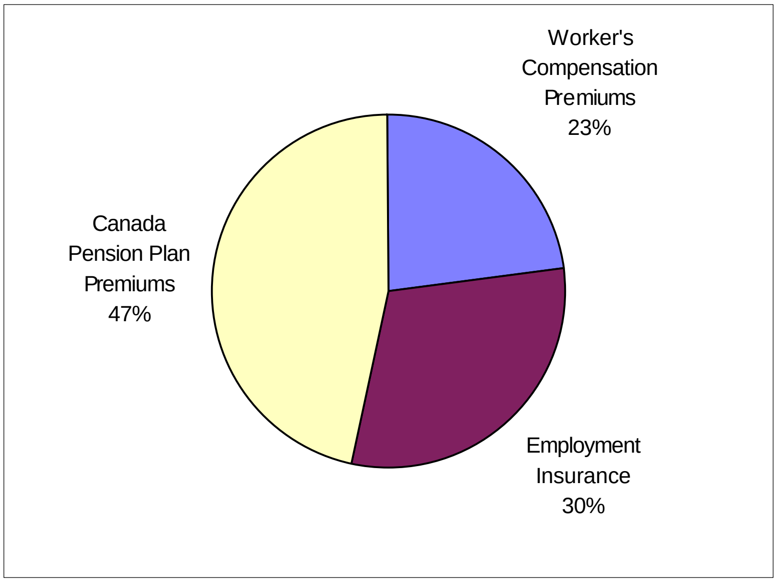


Figure 2-5. Breakdown of CPP, EI and WCP paid by BC employers in 1995.

The tax revenue from the ecological taxes is used to finance a decrease in payroll charges in BC and the percentage change in the payroll charges is calculated. The elasticity of demand for labour, specific to payroll charges, is then used to estimate the percentage change in demand for labour in BC and the new employment levels are simulated.

Note that only the direct effects of the change in the cost of labour in BC are captured in this analysis. Clearly, indirect effects would also result from such a tax reform. For example, overall effects on employment, resulting from assumptions about reductions or increases in the distortionary effects of current taxes and charges, are not

[13] According to the Technical Committee on Business Taxation (1997) the impact of payroll

included in the estimated response. Future research would clearly want to probe this issue.

charges on the demand for employees depends on the time-frame in which the response is measured and the wage rates of employees.

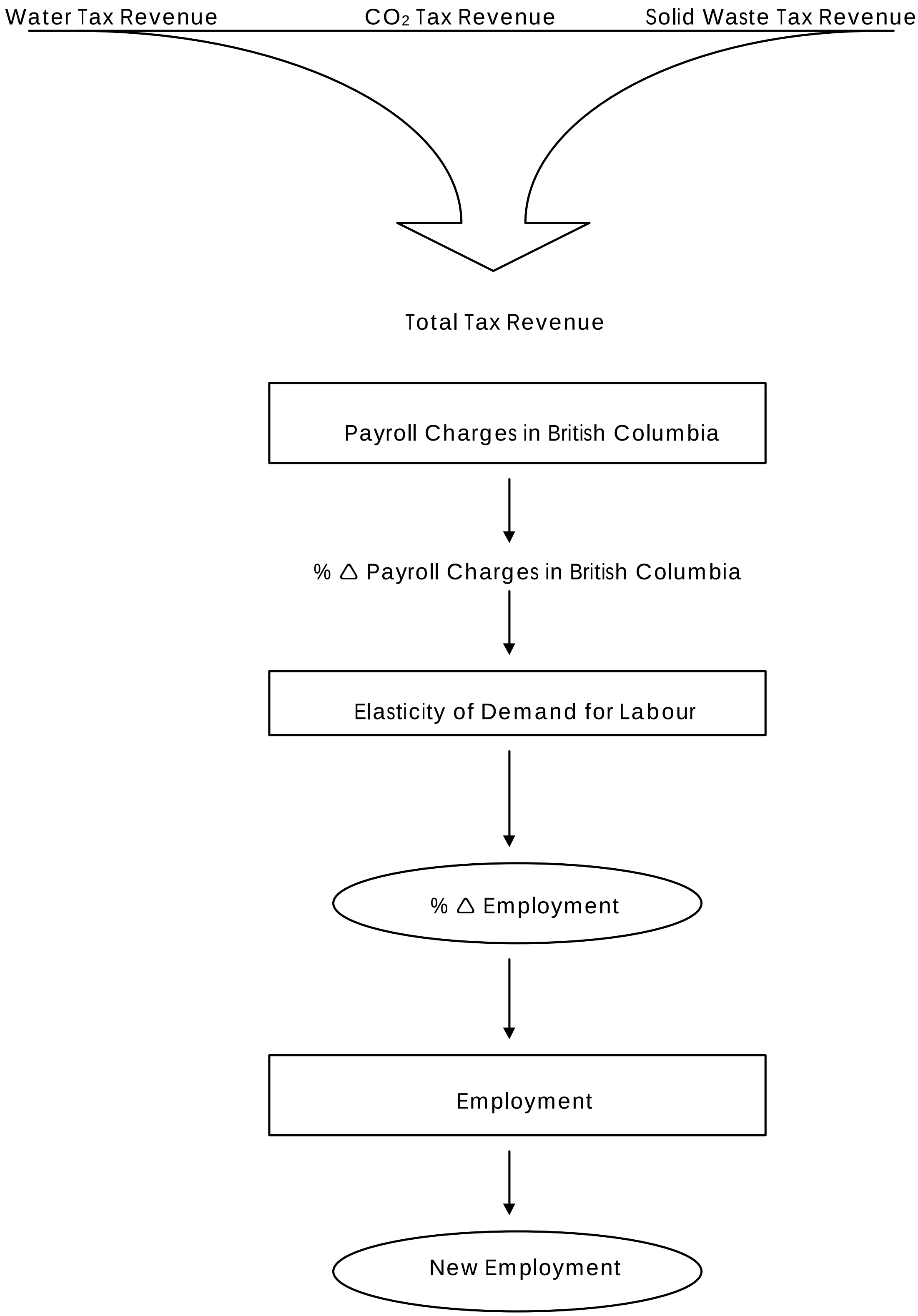


Figure 2-6. General framework for simulating the change in employment.

3. Data and Parameter Estimates

In this section, I present the details of the data used to define the business-as-usual scenario. As well, the parameter estimates required to simulate the response to the ecological taxes and changes in payroll charges are described.

3.1 Water Tax

To simulate a tax on water consumption in BC, I needed information on quantity of water consumed and water price for each sector of the economy projected to 2020. For water consumption, I used historical data from 1983, 1986, 1989, 1991, 1994 and 1996, for BC and extrapolated it, based on projected increases in population in BC, to 2020. The historical data was obtained from D. Lacelle's Municipal Water Pricing Database[14]. Table 3-1 shows m^3 of water consumption per day by the various sectors of the economy in BC for 1991 and 1996

Table 3-1. M^3 of water consumed per day in 1991 and 1996 by each sector of the economy in British Columbia.

Sector	1991	1996
Industrial	211,617	179,816
Commercial	354,411	333,206
Residential	1,157,847	1,308,096

Source: Municipal Water Pricing Database 1991, 1996

For each sector of the economy, I assumed a starting price, based on existing metering in BC, and assumed that price to be province-wide. I then assumed an increase ($0.01/year) in that price over time[15]. Price information for the industrial sector was derived from "Water Demand Management in Canada: A State-of-the-Art-Review" (Tate 1990). Price information for the residential and commercial sectors was

[14] The database is housed in the Water and Habitat Conservation Branch of Environment Canada.

derived from "Municipal Water Rates in Canada: Current Practices and Prices, 1991" (Tate and Lacelle 1995). For the industrial sector, the price of water in 1995 was assumed to be $0.18/m^3$. This value is the price paid for the first block of water by the industrial sector[16]. For the commercial sector, the price of water in 1995 was assumed to be $0.33/m^3$ of water consumed. This number is the mean price paid per m^3 of water consumed by the commercial sector in BC assuming $100m^3$ of water consumed per month. For the residential sector, the price of water in 1995 was assumed to be $0.28/m^3$ of water consumed. This number is the mean of the constant unit charges (volume-based charges) paid by the residential sector in BC[17].

To simulate the effect of the water tax on water consumption, I implemented the water tax and applied the own-price elasticity water for each sector of the economy. Table 3-2 shows several values for own-price elasticity for water by different sectors of the economy as derived in various studies. The own-price elasticity for domestic water generally falls between the range of -0.1 to -1.0, with a median of -0.25 (McNeil and Tate 1991). The studies carried out on industrial/commercial water demand have shown a wide variability in elasticity, mostly between -0.05 and -1.0. McNeil and Tate (1991) summarized the literature with respect to elasticity values for water consumption by the residential and industrial sectors of the economy (figures 3-1 and 3-2 respectively). According to their research, -0.3 is the most common elasticity value calculated for the residential sector while -0.6 is the most common value for the

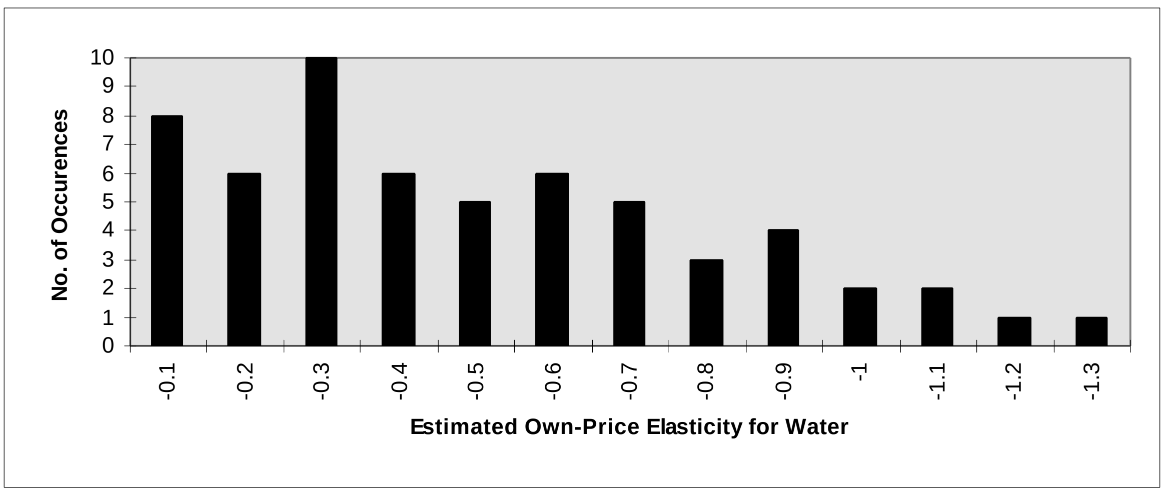
---

[15] This increase represents the increase in constant unit charges in British Columbia from 1989 to 1991 (Tate and Lacelle 1995).
[16] A block of water is a specified quantity of water which will have common charge. The second block of water may cost more or less than the first.
[17] This number represents 17% of the municipal water rates in British Columbia.

industrial sector. In keeping with this research, the values used in this analysis are, -0.3, -0.6 and -0.6 for the residential, commercial and industrial sectors respectively.

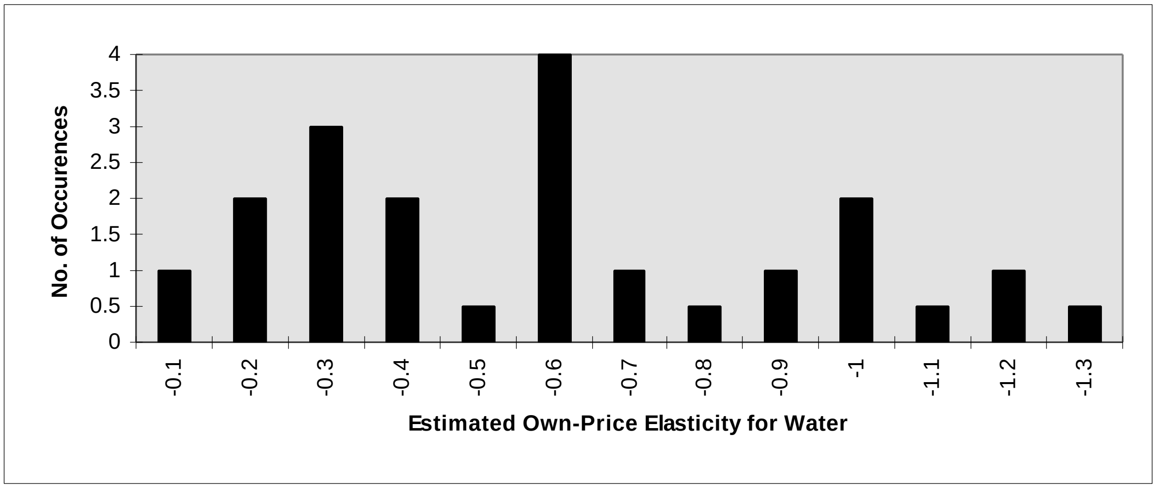
Table 3-2. Own-price elasticity for water. Values from literature.

STUDY	YEAR	COM	RES	IND	NOTES
Grima	1972		-0.93		Annual value, residential for Southern Ontario (Toronto area)
Sims	1979			-0.945	For brewers in Canada
Macerollo and Ingram	1981		-0.311		Aggregate demand for 56 Ontario municipalities
Sigurdson	1982		-0.815		For Saskatchewan and Manitoba
Sewell and Roueche	1974		-0.395		Aggregate demand for Victoria BC, median value
McNeil and Tate	1993	-0.6	-0.25	-0.6	Median values
Tellus Institute	1994	-0.5	-0.385	-0.5	
CWWA	1994		-0.2 to -0.4	-0.5 to -0.8	
Howe and Linaweaver	1967		-0.4		Aggregate demand (weighted average of domestic and sprinkling activities)
Harer and Winter			-0.254		For Ontario
Flack	1981		-0.225		
Billings and Agthe	1986		-0.27 to -0.49		For Tucson, Arizona
Jones and Morris	1984		-0.14 to -0.44		For Denver, Colorado



Source: adapted from McNeil and Tate 1991

Figure 3-1. Frequency distribution of own-price elasticity for residential water demand functions (from various studies in the 1960s, 70s and 80s).



Source: adapted from McNeil and Tate 1991.

Figure 3-2. Frequency distribution of own-price elasticity for industrial water demand functions (from various studies in the 1960s, 70s and 80s).

3.2 Solid Waste Tax

To simulate a tax on solid waste generation in BC, I needed information on quantity of solid waste generated for each sector of the economy projected to 2020. To obtain this information, I used historical data, 1990 to 1995, for BC and extrapolated it to 2020. The historical data was obtained from the "Municipal Solid Waste Reduction Data Summary Report." This report is published annually by the Municipal Waste Reduction Branch, Environmental Protection Department of the Ministry of Environment, Lands and Parks. Table 3-3 shows the tonnes of waste generated in 1990 and 1995 by each sector of the economy in BC.

Table 3-3. Tonnes of solid waste generated per year by each sector of the economy in British Columbia.

Sector	1990	1995
ICI	819,759	1,223,448
Residential	1,125,268	1,519,074

NB. ICI incorporates industrial, commercial and institutional.
Source: Municipal Solid Waste Reduction Data Summary Report , MELP 1990 to 1995

To simulate the effect of the solid waste tax, I implemented the solid waste tax and used real-life experience in various locations as a proxy for what BC can expect from implementing volume-based charges throughout the province. Table 3-4 shows the effect of implementing volume-based rate structures on solid waste generation in a number of places.

Table 3-4. Experience with volume-based charges on solid waste (% reduction in solid waste generation).

AREA	IMPACT	SOURCE
Perkasie, Pennsylvania	59 %	Skumatz, 1993
Le Center, Minnesota	60 %	Skumatz, 1993
White Bear Lake, Minnesota	22 %	Skumatz, 1993
Gloucester, Massachusetts	40 %	Skumatz, 1993
Seattle, Washington	Approximately a 70% (average of 3.5 cans per household per week to 1 can)	Scarlett, 1991
Capital Regional District, British Columbia	18-22 %	Gale et al., 1995
Denmark	10-20 %	Gale et al., 1995
Municipalities in the Netherlands	10-20 %	Gale et al., 1995
Nanaimo, British Columbia	10-15 %	Kelleher et al., 1996
Central Okanogan, British Columbia	40 %	Kelleher et al., 1996
Sydney Township, Ontario	42 %	Gale, 1996
Gananoque, Ontario	47 %	Kelleher et al., 1996
14 Cities in the United States	18-65 %	Blume, 1992
14 Cities in the United States	18-30 %	Repetto et al., 1992

From the above table, I established representative reductions in solid waste generation from the ecological tax on solid waste to be 25% and 50% reduction. I used these values to calculate the resultant tax revenue for TETR and AETR respectively.

3.3 Carbon Dioxide Tax

To simulate a tax on CO_2 emissions in BC, I needed information on both the quantity of fossil fuels consumed and the price paid for fossil fuels by each sector of the economy in BC projected to 2020. With the exception of gasoline and diesel, this information was obtained from J. Nyboer (1997). Gasoline and diesel consumption information was obtained from Statistics Canada's "Refined Petroleum Products" annual report. Gasoline and diesel price information was obtained from "Energy Statistics Handbook". Table 3-5 shows the amount of fossil fuels consumed and the prices paid for each by sector of the economy in BC.

Table 3-5. Fossil fuel consumption in 1990 and 1995 and fuel price in 1995 by sector of the economy in British Columbia.

Sector	Units	1990	1995	$/GJ (95)
Industrial				
Coal	Tonnes	127,450	100,403	2.51
Nat gas	1000 m^3	3,103,803	2,992,644	1.42
Oil	m^3	868,330	1,141,223	3.98
Commercial				5.09
Nat gas	1000 m^3	1,242,509	1,205,001	3.23
Oil	m^3	109,954	112,109	11.29
LPG	1000 m^3	151,195	162,446	
Residential				
Nat gas	1000 m^3	1,659,185	1,571,076	5.36
Oil	m^3	265,796	1,946,33	10.55
Transportation				
Gasoline	1000 L	3,589,823	4,163,178	17.20
Diesel	1000 L	971,853	1,336,298	14.09

Source: J Nyboer 1997, Statistics Canada: Energy Statistics Handbook 1990-95.

To simulate the effect of the CO_2 tax on gasoline and diesel consumption in the transportation sector, I implemented the CO_2 tax and applied the own-price elasticity for motor fuel. Table 3-6 shows several values for own-price elasticity for motor fuel which have been derived in various studies.

Table 3-6. Own-price elasticity for motor fuel. Values from literature.

STUDY	YEAR	VALUE	NOTES
Fuss	1977	-1.56	Ontario
Hale	1979	-0.2 to -0.25	Western Canada
Houthakker et al.	1974	-0.24	
Ramsey, Rasche and Allen	1975	-0.7	
Fuss and Waverman	1975	-0.22 to -0.45	
Adams, Graham and Griffin	1974	-0.92	Analysis included evidence from 20 countries
Pindyck	1979	-1.3	Analysis included evidence form 10 countries
Bohi	1981	-0.36 to -0.77	Summary from literature
Bohi	1981	-0.7	Bohi's own estimate
Eskeland	1996	-0.8	

In this analysis, I used Hale's lower estimate of -0.2. I chose this value for two reasons: first, it was calculated for western Canada; and second, it is the most conservative estimate for the own-price elasticity for motor fuel. As such, using it minimizes the chance of overestimating the response of the transportation sector to the CO_2 tax.

3.4 Employment

To simulate the effect of decreasing the cost of labour in BC, I needed data on employment levels in the province projected to 2020. To obtain this information, I used the "British Columbia Population Forecast 1994-2021" published by British Columbia Statistics, Ministry of Government Services in 1994. Specifically, projected employment levels for BC in this analysis are based on two pieces of information, first, the projected population, 15 years and older, in BC to 2020 as predicted by British Columbia Statistics in the above mentioned report, and second, the ratio of that population in 1995 to the number employed in BC in 1995. For example, British Columbia Statistics predicts that the population, 15 years and older in BC in 2020 will be 4,774,800. In 1995, the ratio of the population, 15 years and older to the number employed was 0.5978. Therefore, the predicted employment level for BC in 2020 is 2,854,835 (4,774,800*0.5978) [18].

As well, I needed data on payroll charges paid by British Columbian employers projected to 2020. To obtain this information, I extended the trend in payroll charges from historical data (1986-1997) to 2020. Data on Worker's Compensation premiums came from the "Workers Compensation Annual Report." I obtained data on Canada Pension Plan and Employment Insurance from Statistics Canada.

[18] This assumes no change in labour force participation rates over time.

To simulate the effect of the decreased cost of labour in BC, I used the elasticity of demand for labour, specific to payroll charges in Canada. Numerous studies have been done on the impact of payroll charges on employment in Canada. Beach, Lin and Picot (1995) estimate the long-run labour demand elasticity in Canada to be approximately -0.3. Bean, Layard and Nickel (1986) estimate -0.2. DiMatteo and Shannon (1995) estimate -0.32[19]. To minimize the potential for overestimating the response to the decrease in the cost of employment in BC, I chose the most conservative estimate for the elasticity of demand for labour, specific to payroll charges in Canada, that of Bean et al. (1986).

[19] These studies estimated the response to changes in payroll charges using historical information in which payroll charges have increased over time. Economists do not know if the elasticity is symmetric between a price increase and a price decrease because payroll charges have never been lowered.

4. Results

The following sections present the results of this study. First, the two scenarios for ecological tax reform are shown. Second, revenue generation from the ecological taxes is presented. Third, for each of the ecological taxes, the ensuing change in quantity demanded is shown. Finally, changes in employment in BC from the lower payroll charges are shown.

4.1 Ecological Tax Reform Scenarios

Table 4-1 shows the price paid for each of the ecological bads in the TETR scenario. Table 4-2 shows the second scenario of ecological tax reform.

Table 4-1. Tentative ecological tax reform, ecological taxes over time.

Ecological Tax	Units	2000	2005	2010	2015	2020
CO_2 Tax	\$/tonne CO_2	7.5	15	22.5	30	37.5
Water Rate, Res	\$/m3	0.03	0.06	0.10	0.15	0.25
Water Rate, Com	\$/m3	0.02	0.05	0.08	0.11	0.14
Water Rate, Ind	\$/m3	0.02	0.05	0.08	0.11	0.14
Solid Waste Rate	\$/bag	0.50	0.63	0.75	0.88	1.00

Table 4-2. Ambitious ecological tax reform, ecological taxes over time.

Ecological Tax	Units	2000	2005	2010	2015	2020
CO_2 Tax	\$/tonne CO_2	13.75	27.5	41.25	55	68.75
Water Rate, Res	\$/m3	0.10	0.20	0.30	0.40	0.50
Water Rate, Com	\$/m3	0.05	0.10	0.15	0.20	0.25
Water Rate, Ind	\$/m3	0.05	0.10	0.15	0.20	0.25
Solid Waste Rate	\$/bag	0.5	0.875	1.25	1.625	2.00

4.2 Tax Revenue

Table 4-3 shows the total tax revenue generated for each of the scenarios of ecological tax reform. These results indicate the potential to raise significant tax revenue in BC through ecological taxes. Revenue generation in 2020 in the AETR scenario is approximately twice that of the TETR scenario.

Table 4-3. Annual tax revenue from the ecological taxes ($1995 millions).

Year	TETR	AETR
2000	$ 301	$ 484
2005	$ 490	$ 919
2010	$ 805	$ 1,492
2015	$ 1,166	$ 2,278
2020	$ 1,338	$ 2,698

Tables 4-4 and 4-5 show the breakdown of revenue between the ecological taxes. In both scenarios, the majority of the tax revenues come from the CO_2 tax. In TETR, 52% of the CO_2 tax revenue in 2020 comes from the industrial sector with the commercial, residential and transportation sectors accounting for 7%, 13% and 29% respectively. In AETR, the industrial sector accounts for 45% of CO_2 tax revenue in 2020 with the commercial, residential and transportation sectors accounting for 6%, 11% and 39% respectively.

The results indicate that the revenue generation from the water taxes is relatively insignificant. This revenue is calculated only on the increase in water rates above those projected in the BAU scenario. As I described in the data section of this report, to develop the BAU scenario, for each sector of the economy, I assumed a starting price, based on existing metering in BC, and assumed that price to be province-wide. I then assumed an increase ($0.01/year) in that price over time. If this were currently the case in BC, the province would already be receiving significant revenue from volume-based pricing in the province; up to $1.3 million in 2020. The tax revenue calculation does not include the revenue the province would receive from moving to that base price level . Rather it assumes that the province is already receiving that amount of revenue and thus, the revenue described in this analysis would be in addition to that which it already receives.

Table 4-4. Annual tax revenue for TERT by ecological tax ($1995 millions).

Year	CO_2	Water	Solid Waste	Total
2000	$ 189	$ 0.05	$ 112	$ 301
2005	$ 381	$ 0.10	$ 109	$ 490
2010	$ 700	$ 0.15	$ 105	$ 805
2015	$ 1,068	$ 0.20	$ 98	$ 1,166
2020	$ 1,255	$ 0.31	$ 83	$ 1,338

Table 4-5. Annual tax revenue for AETR by ecological tax ($1995 millions).

Year	CO_2	Water	Solid Waste	Total
2000	$ 377	$ 0.10	$ 106	$ 484
2005	$ 784	$ 0.25	$ 135	$ 919
2010	$ 1,348	$ 0.35	$ 144	$ 1,492
2015	$ 2,142	$ 0.43	$ 136	$ 2,278
2020	$ 2,587	$ 0.51	$ 110	$ 2,698

Tables 4-6 and 4-7 show the breakdown of tax revenue between the sectors of the economy. Revenues from the industrial sector make up the largest percentage of total tax revenue[20]. Not surprisingly, the majority of the revenue raised from the industrial sector comes from the CO_2 tax. Appendix B contains results for revenue generation disaggregated between the ecological taxes and the sectors of the economy.

Table 4-6. Annual tax revenue ($1995 millions) and percent of total tax revenue (in brackets) for TETR by sector of the economy**.**

Year	Industrial		Commercial		Residential		Transportation		Total
2000	$ 122	(42)	$ 12	(4)	$7 8	(26)	$ 84	(28)	$ 301
2005	$ 205	(41)	$ 25	(5)	$ 101	(21)	$ 159	(33)	$ 490
2010	$ 381	(48)	$ 51	(6)	$ 148	(18)	$ 225	(28)	$ 805
2015	$ 592	(51)	$ 76	(7)	$ 205	(18)	$ 293	(24)	$ 1,166
2020	$ 666	(49)	$ 88	(7)	$ 227	(17)	$ 357	(27)	$ 1,338

[20] Industrial revenue includes revenue generation from the commercial sector from the solid waste tax as data on solid waste generation was only disaggregated between the residential sector and these two sectors combined.

Table 4-7. Annual tax revenue ($1995 millions) and percent of total tax revenue (in brackets) for AETR by sector of the economy.

Year	Industrial		Commercial		Residential		Transportation		Total
2000	$ 188	(39)	$ 24	(5)	$ 96	(20)	$ 176	(36)	$ 484
2005	$ 361	(39)	$ 49	(5)	$ 156	(18)	$ 353	(38)	$ 919
2010	$ 630	(42)	$ 88	(6)	$ 234	(16)	$ 540	(36)	$ 1,492
2015	$ 1039	(46)	$ 139	(6)	$ 344	(15)	$ 756	(33)	$ 2,278
2020	$ 1,168	(43)	$ 160	(6)	$ 379	(14)	$ 991	(37)	$ 2,698

4.3 Water Tax

Figures 4-1, 4-2 and 4-3 show water consumption by the industrial, commercial and residential sectors respectively. In each figure, the drop in water consumption is shown as percent change from the business-as-usual (BAU) scenario. TETR results in a 19% reduction in water consumption by the industrial sector in the year 2020, while AETR results in a 35% reduction in water demand by the industrial sector in the same year.

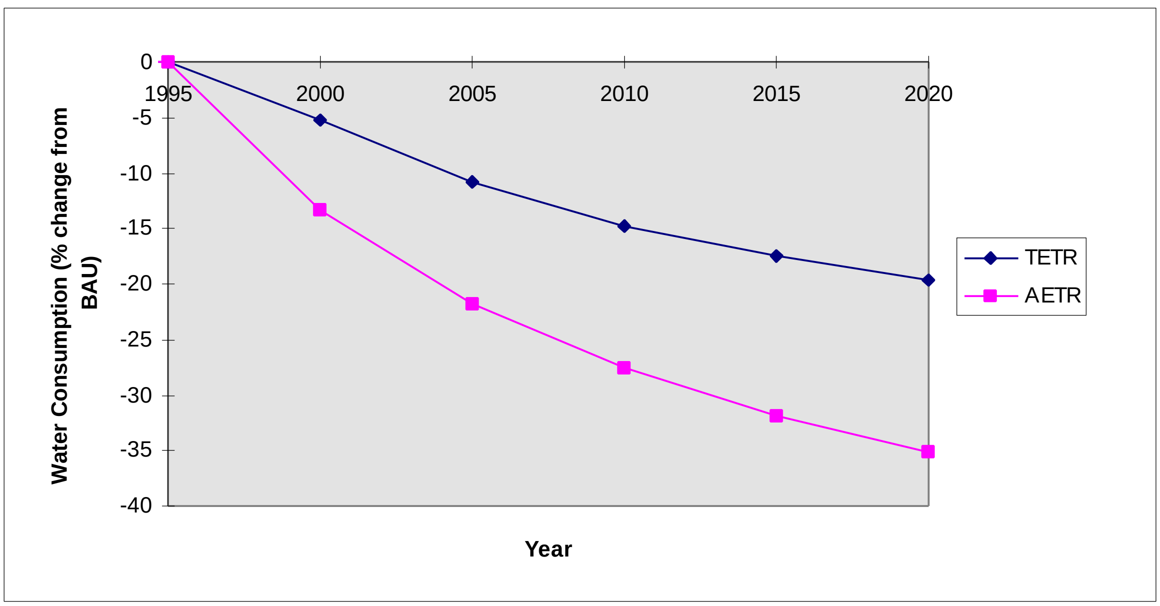


Figure 4-1. Change in water consumption in British Columbia following the implementation of an ecological tax on water consumption: industrial sector.

In the commercial sector, TETR results in a 15% drop in water demand in the year 2020, while AETR results in a 25% drop in water demand in 2020.

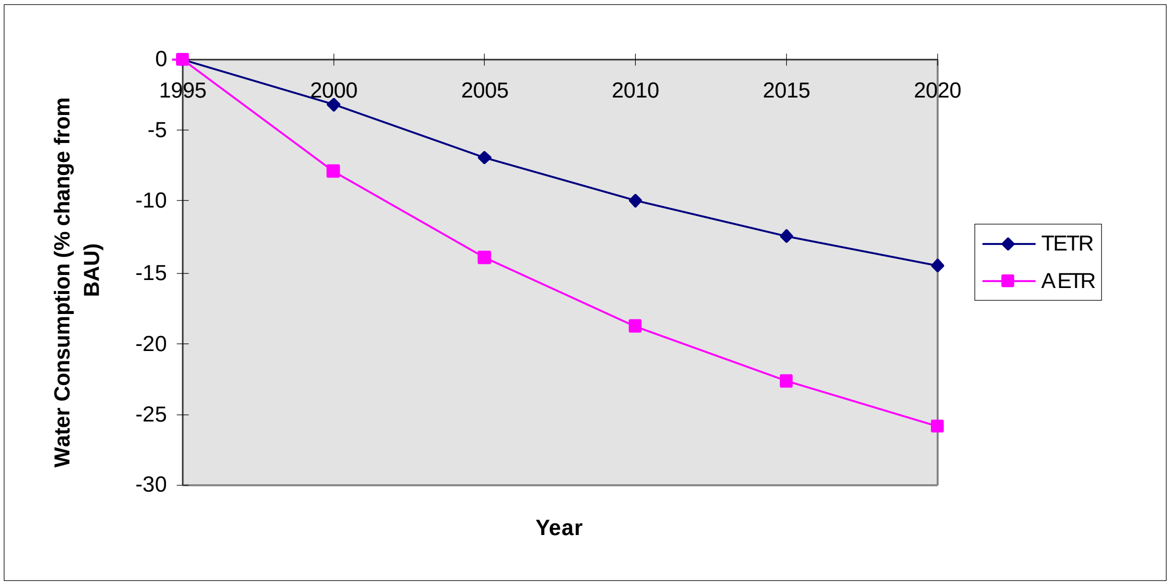


Figure 4-2. Change in water consumption in British Columbia following the implementation of an ecological tax on water consumption: commercial sector.

In the residential sector, TETR results in a drop in water demand of 14% from the BAU in 2020, while AETR results in a drop in water demand of 28% in the same year.

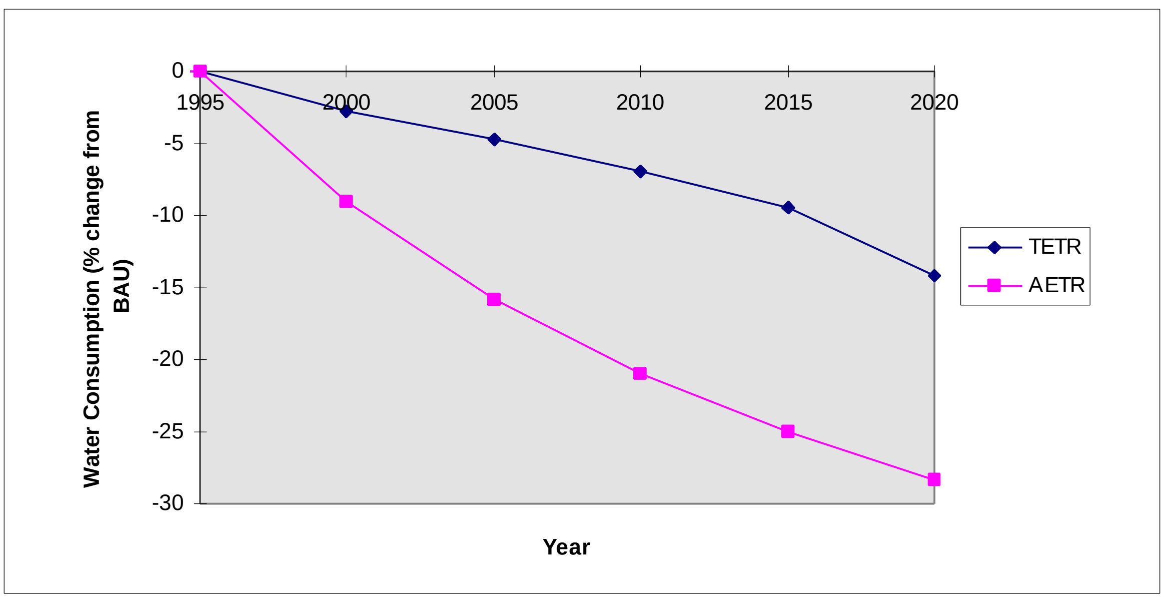


Figure 4-3. Change in water consumption in British Columbia following the implementation of an ecological tax on water consumption: residential sector**.**

Although the residential sector is the least responsive to the imposition of the tax, it is the greatest source of revenue generation from the water tax. This is not particularly surprising as the residential sector is responsible for the majority of water consumption in BC (72% of provincial consumption in 1995).

4.4 Solid Waste Tax

Experience in the Capital Regional District suggest that user-pay waste management systems in BC are capable of substantially decreasing the amount of waste going to landfill. Victoria saw a 19% reduction in solid waste generation in the first year following implementation of user pay rising to a 22% reduction by the second year (Gale et al. 1995). Similarly, Nanaimo, BC saw a 10-15% reduction in solid waste generation and the Central Okanogan, BC realized a 40% reduction in solid waste generation following the introduction of volume-based pricing. According to Skumatz (1993), "[c]ommunities that implement variable rates in conjunction with recycling programs have routinely reported between 25% and 45% reduction in tonnage going to the disposal facility"[21]. In TETR, I calculate revenue generation from ecological taxes on solid waste with a 25% reduction in solid waste generation by 2020 in the province. In AETR, with its higher ecological taxes, I calculate revenue generation from ecological taxes on solid waste with a 50% reduction in solid waste generation by 2020 in the province[22]. In both scenarios, the residential sector is responsible for the majority

---

[21] Skumatz, Lisa. 1993. Variable Rates for Municipal Solid Waste: Implementation, Experience, Economics and Legislation. Los Angeles, CA: The Reason Foundation.

[22] I have not accounted for the possibility of illegal dumping as a result of the ecological tax on solid waste generation. Future research may want to look to experience in other regions for ways to minimize the potential for illegal dumping in BC.

of the revenue generation from this tax. This is not particularly surprising since the residential sector is responsible for the majority of solid waste generation (55% of provincial generation in 1995) in the province. The sensitivity analyses in section 5-1 assesses how responsive revenue generation and therefore job creation is to the assumed reductions in solid waste.

4.5 Carbon Dioxide Tax

Figure 4-4, shows the expected decrease in CO_2 emissions from the industrial, commercial and residential sectors combined following the implementation of an ecological tax on CO_2 emissions. As the figure shows, TETR results in a reduction in CO_2 emissions of almost 3% from the 2020 BAU scenario while AETR results in a reduction of approximately 5% in 2020. In TETR, approximately 96% of the reduction in CO_2 emissions comes from the industrial sector, with 3% of the emissions reduction from the commercial sector and the remaining 1% from the residential sector. In AETR, the industrial sector is responsible for 94% of the emissions reduction with the remaining 6% split evenly between the commercial and residential sectors.

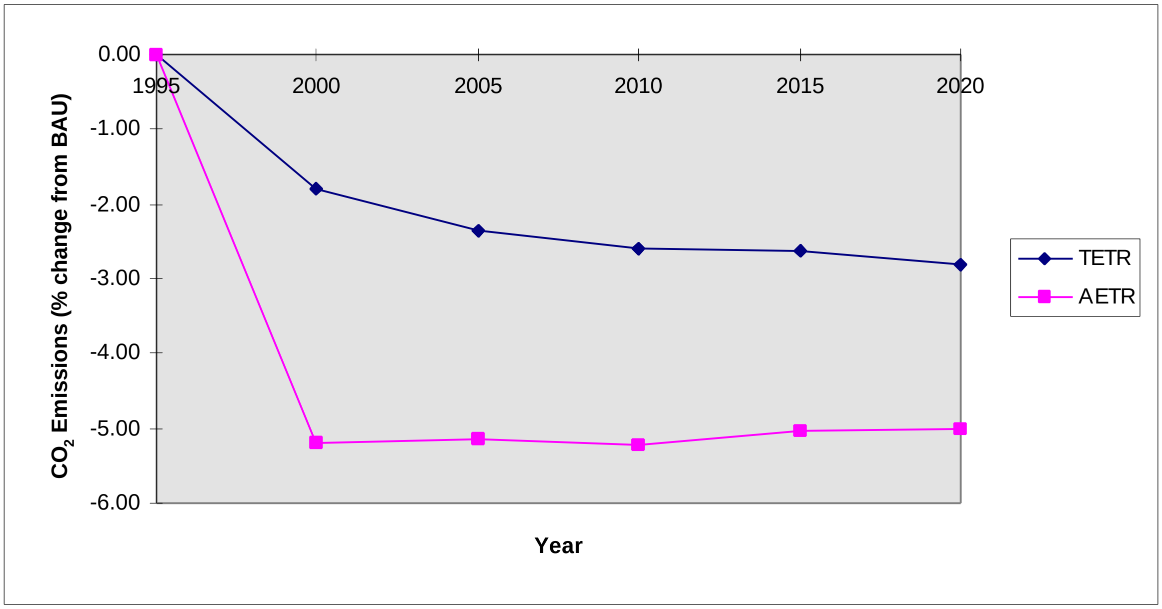


Figure 4-4. Change in CO_2 emissions in British Columbia following the implementation of an ecological tax on CO_2 emissions: industrial, commercial and residential sectors combined.

Figures 4-5 and 4-6 show the change in consumption of gasoline and diesel respectively, following the implementation of the CO_2 tax. The results indicate that the demand for diesel is more responsive to the tax on CO_2 emissions than the demand for gasoline. This result is not surprising. The tax would cause the price of diesel to increase relatively more than the price of gasoline because diesel has a relatively greater carbon content than gasoline. This implies that the percentage change in price of diesel would be greater than the percentage change in the price of gasoline. At the same own-price elasticity, therefore, the quantity demanded of diesel would fall more than that of gasoline.

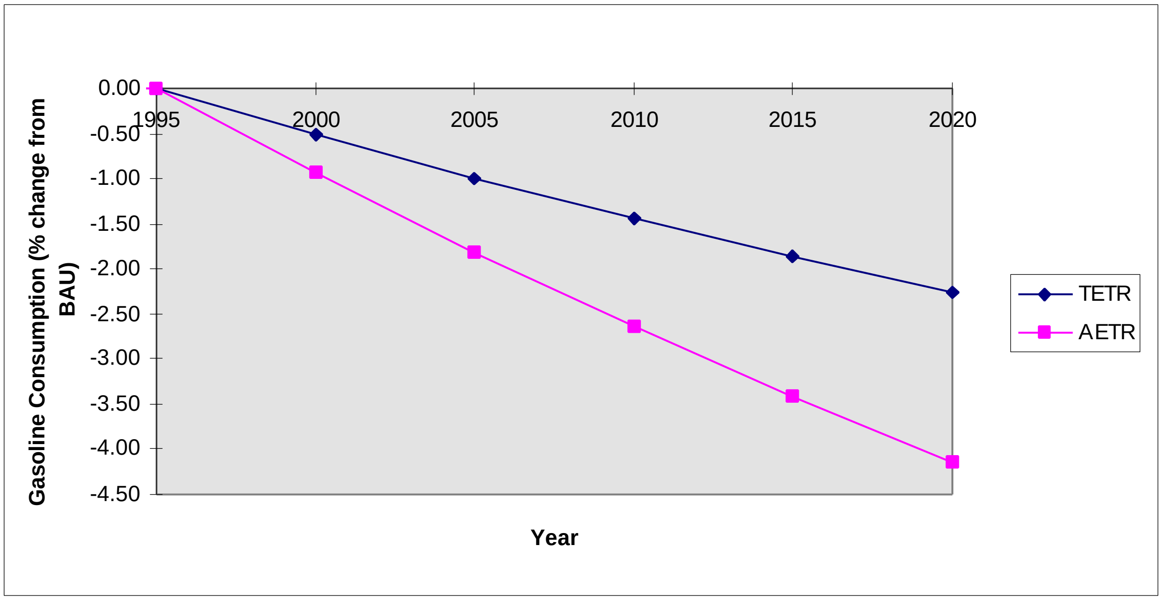


Figure 4-5. Change in gasoline consumption in British Columbia following the implementation of an ecological tax on CO_2 emissions.

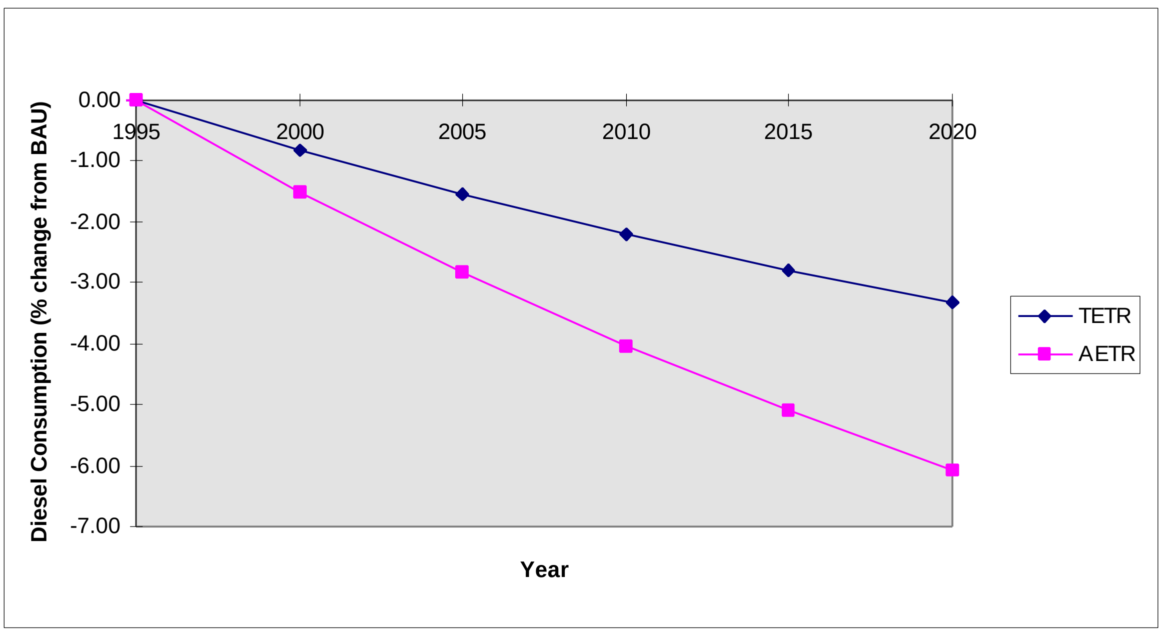


Figure 4-6. Change in diesel consumption in British Columbia following the implementation of an ecological tax on CO_2 emissions.

Total emission reductions from the CO_2 tax (industrial, commercial, residential and transportation) are 8.57% in TETR and 15.21% in AETR, in both scenarios, approximately two thirds of the total reduction in CO_2 emissions comes from the transportation sector. Because the majority of BC's CO_2 emissions originate from the transportation sector (60% of provincial emissions in 1995), these results are significant. The revenue generation from the transportation sector is less than that which is generated from the industrial sector. This is due to the small carbon content of gasoline and diesel compared to that of coal or oil.

4.6 Employment

Figure 4-7 shows employment in BC under each of the scenarios. TETR increases employment by approximately 126,000 jobs, a 4.41% increase from the BAU scenario in 2020, while AETR increases employment by approximately 254,000 jobs, an 8.9% increase from the BAU scenario in 2020.

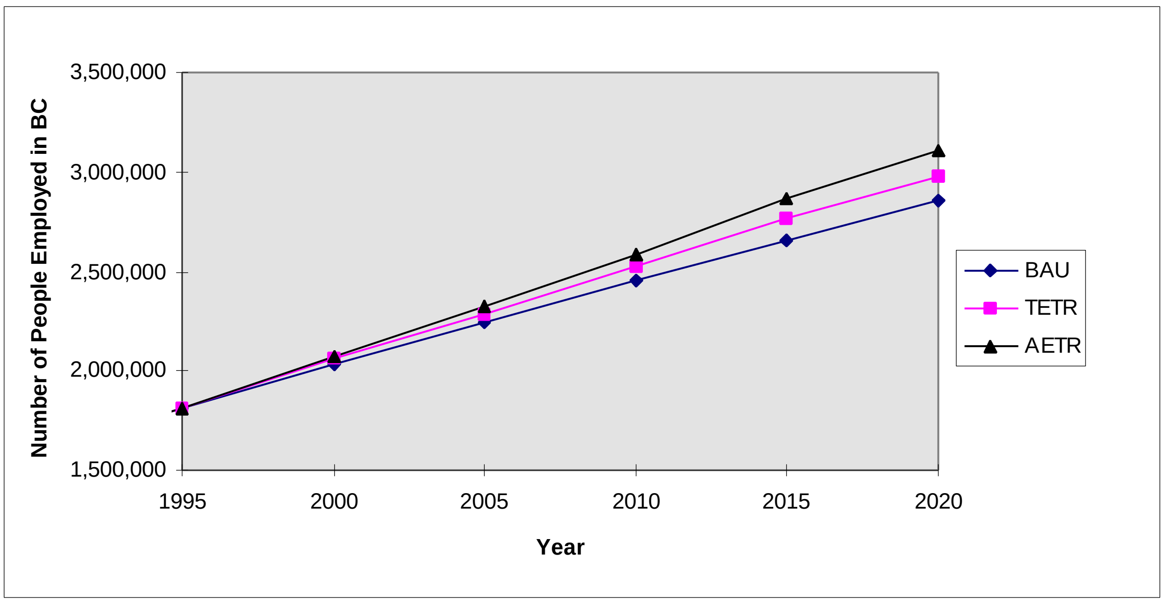


Figure 4-7. Employment in British Columbia over time: BAU, TETR and AETR.

5. Discussion

The results of this study indicate significant potential to influence consumer behaviour, generate revenue and create employment opportunities in BC. Despite these benefits, two key issues should be addressed. The first is uncertainty in the results. To address this issue I conducted sensitivity analyses on a number of uncertain parameters in my analysis and I compared the results of this study with those generated in several other key studies. The second issue concerns various shortcomings of ecological tax reform in BC, including impacts on competition and low-income households. In the sections that follow, the sensitivity analysis, comparison with other studies and addressing concerns of ecological tax reform are presented.

5.1 Sensitivity Analysis

There are several sources of uncertainty in this analysis. First, there is uncertainty in the elasticity values used to simulate the response to the ecological taxes. Most of the literature on the own-price elasticity values for fuel, water and labour gives a wide range of values. As a result, there is uncertainty involved when characterizing that range with a specific number. As well, elasticity values estimated for BC are virtually nonexistent. As a consequence, the elasticity values used in the analysis are presented in a general sense only. To determine the extent to which my results are sensitive to assumptions about elasticity values, I conducted sensitivity analyses in which I varied the elasticity values for labour, motor fuel and water to test what impact that variation had on the consumption of ecological bads, revenue generation and employment.

As well, there is uncertainty in this analysis with respect to the response to the tax on solid waste generation. I chose representative reductions in solid waste generation of 25% and 50% following the implementation of the two levels of volume-based ecological taxes on solid waste generation in BC. In TETR, I assume a 25% reduction in solid waste generation while in AETR, with its higher charge, I assume a 50% reduction. The final amount of reduction will depend not only on the volume-based ecological tax, but also on the implementation of advanced programs for recycling, composting and education. To determine the impact of this uncertainty on my results, I tested the effect of changes in these assumptions on revenue generation and employment.

5.1.1 Elasticity of Demand for Labour

As noted above, numerous studies have been done on the impact of payroll charges on employment in Canada (Beach et al. 1995, Bean et al. 1986, DiMatteo and Shannon 1995). These studies indicate that the elasticity of demand for labour is somewhere between -0.2 and -0.32. Although these studies disagree as to the extent of the impact of payroll charges on employment, they all agree that payroll charges in Canada have an impact on employment. To test the sensitivity of the results to the value of elasticity of demand for labour used in this analysis, I simulated the increase in employment resulting from elasticity values of both -0.15 and -0.45. In the TETR scenario, the increase in employment at an elasticity of demand for labour of -0.15 was 3.31% while at -0.45 it was 9.93%. This is a difference of approximately 189,000 jobs. In the AETR scenario, the increase in employment at an elasticity of demand for labour of -0.15 was 6.76% while at -0.45 it was 20.0%. This is a difference of approximately

381,000 jobs. The above analyses indicates that indeed, the results are sensitive to the assumed elasticity of demand for labour with respect to payroll charges.

5.1.2 Own-Price Elasticity for Gasoline

A number of studies have estimated the own-price elasticity for motor fuel. The range of estimates from these studies is relatively wide (-0.2 to -1.56) (See table 3-6 for details). The value used in this analysis comes from Hale, 1979. To test the sensitivity of the results to the value of own-price elasticity for motor fuel, I simulated the change in demand for gasoline and diesel, revenue generation and employment resulting from a range of elasticity values for motor fuel (-0.1 to -1.56). As table 5-1 indicates, the change in quantity demanded of gasoline and diesel and hence revenue generation from the transportation sector are sensitive to the chosen own-price elasticity value. In TETR, the reduction in quantity demanded of gasoline and diesel in 2020 varies with the changes in elasticity values from 1.24% to 17.62% and 1.82% to 25.85% respectively. In AETR these ranges are from 2.27% to 32.31% for gasoline and 3.34% to 47.39% for diesel. Obviously, the change in demand for both gasoline and diesel is highly sensitive to the own-price elasticity value. In contrast to this, change in employment is relatively insensitive to the own-price elasticity for motor fuel value. In TETR, for example, increase in employment in 2020 only varies from 4.47% to 3.66%.

Table 5-1. Results of sensitivity analysis for 2020 for own-price elasticity for motor fuel.

Scenario	Elasticity	Revenue from Transportation Sector ($1995 millions)	Total Revenue Generation ($1995 millions)	Change in Employ-ment	Change in Quantity Demanded Gasoline	Change in Quantity Demanded Diesel
TETR	-0.2	$ 357	$ 1,338	+4.41%	-2.26%	-3.31%
TETR	-0.1	$ 3720	$ 1,369	+4.47%	-1.24%	-1.82%
TETR	-1.56	$ 99	$ 1,126	+3.66%	-17.62%	-25.85%
AETR	-0.2	$ 991	$ 2,698	+8.90%	-4.14%	-6.07%
AETR	-0.1	$ 1,045	$ 2,707	+9.10%	-2.27%	-3.34%
AETR	-1.56	$ 180	$ 1,842	+6.22%	-32.31%	-47.39%

5.1.3 Own-Price Elasticity for Water

A number of studies have estimated the own-price elasticity for water. The results of these studies reveal a fairly wide range of elasticity values (-0.1 to -1.3) (See figures 3-1 and 3-2 for details). The values used in this analysis are -0.3, -0.6 and -0.6 for the residential, commercial and industrial sectors respectively (McNeil and Tate 1993). To test the sensitivity of the results to these own-price elasticity values, I simulated the change in demand for water, revenue generation and ensuing change in employment resulting from a range of elasticity values for water (-0.1 to -1.3) for each sector of the economy. Tables 5-2 and 5-3 present the results of this sensitivity analysis for scenarios 1 and 2 respectively. As table 5-2 indicates, the change in quantity demanded of water, and hence revenue generation from the water tax, are sensitive to the own-price elasticity value. In TETR, the reduction in quantity demanded of water in 2020 varies from 3.29% to 42.72%, 2.41% to 31.38% and 4.72% to 61.32% for each of the industrial, commercial and residential sectors respectively. In AETR, reductions in 2020 show similar patterns although more extreme, with water demand actually being eliminated in the case of the residential sector. In contrast to this, the ensuing change in employment is completely insensitive to the own-price elasticity for water. This is true for all sectors of the economy in both scenarios.

Table 5-2. Results of sensitivity analysis for 2020 for own-price elasticity for water, TETR.

Sector	Elasticity Value	Revenue from Water Tax ($1995 millions)	Total Revenue Generation ($1995 millions)	Change in Employ-ment	Change in Quantity Demanded Water
Industrial	-0.6	$ 0.31	$ 1,338	+4.41%	-19.72%
Industrial	-0.1	$ 0.32	$ 1,338	+4.41%	-3.29%
Industrial	-1.3	$ 0.31	$ 1,338	+4.41%	-42.72%
Commercial	-0.6	$ 0.31	$ 1,338	+4.41%	-14.48%
Commercial	-0.1	$ 0.32	$ 1,338	+4.41%	-2.41%
Commercial	-1.3	$ 0.30	$ 1,338	+4.41%	-31.38%
Residential	-0.3	$ 0.31	$ 1,338	+4.41%	-14.15%
Residential	-0.1	$ 0.34	$ 1,338	+4.41%	-4.72%
Residential	-1.3	$ 0.17	$ 1,338	+4.41%	-61.32%

Table 5-3. Results of sensitivity analysis for 2020 for own-price elasticity for water, AETR.

Sector	Elasticity Value	Revenue from Water Tax ($1995 millions)	Total Revenue Generation ($1995 millions)	Change in Employ-ment	Change in Quantity Demanded Water
Industrial	-0.6	$ 0.51	$ 2,698	+8.90%	-35.21%
Industrial	-0.1	$ 0.52	$ 2,698	+8.90%	-5.87%
Industrial	-1.3	$ 0.49	$ 2,698	+8.90%	-76.29%
Commercial	-0.6	$ 0.51	$ 2,698	+8.90%	-14.48%
Commercial	-0.1	$ 0.53	$ 2,698	+8.90%	-4.31%
Commercial	-1.3	$ 0.49	$ 2,698	+8.90%	-56.03%
Residential	-0.3	$ 0.51	$ 2,698	+8.90%	-14.15%
Residential	-0.1	$ 0.60	$ 2,698	+8.90%	-9.43%
Residential	-1.3	$-0.05	$ 2,698	+8.90%	-122.64%

5.1.4 Solid Waste Generation

Table 5-4 shows the results of the sensitivity analysis with respect to assumptions about reductions in solid waste generation following the implementation of an ecological tax on solid waste generation in BC. For each scenario, I tested a range of reduction in solid waste; 10% more and 10% less than that which was tested in the original analysis. I used this information to simulate the ensuing change in revenue generation and employment. In TETR, for a 20% difference in solid waste reduction, (-15% to -35%), there was a 23% change in revenue generation ($94 million to $72 million). In AETR, for the same 20% difference in solid waste reduction, there was a 33% change in revenue generation ($132 million to $88 million). The ensuing change in employment over the range of solid waste reduction in each of the scenarios is relatively small; a difference of 0.07% in TETR and 0.14% in AETR.

Table 5-4. Solid waste generation sensitivity analysis, 2020.

Scenario	Reduction in Waste, 2020	Revenue from Solid Waste Tax ($1995 millions)	Total Revenue Generation ($1995 millions)	Change in Employment
TETR	-15%	$ 94	$ 1,349	+4.45 %
TETR	-25%	$ 83	$ 1,338	+4.41%
TETR	-35%	$ 72	$ 1,327	+4.38%
AETR	-40%	$ 132	$ 2,720	+8.97%
AETR	-50%	$ 110	$ 2,698	+8.90%
AETR	-60%	$ 88	$ 2,698	+8.83%

5.2 Comparison of Results with Relevant Studies

In addition to conducting sensitivity analyses to discern some level of confidence in my results, I reviewed a number of relevant studies for the purpose of comparison with my own results. I did this for revenue generation, reduction in CO_2 emissions, reduction in water consumption and employment effects. Each of these comparisons are described in the sections that follow.

5.2.1 Revenue Generation

The results of this analysis indicate a significant potential to raise revenue from ecological taxes in BC. This is especially true for the CO_2 tax. For example, revenue generation from the CO_2 tax in TETR is $1.2 billion ($1995) in 2020 while AETR, in the same year, generates $2.6 billion ($1995) revenue. The Tellus Institute (1997) tested the effect of a $30 CO_2 tax on the state of New York. They found that potential revenue in 2012 from the tax was $6.8 billion ($1992). In a similar study for the state of Minnesota, the

Tellus Institute (1997) estimated that a \$50 CO_2 tax would raise \$5.8 billion (\$1992) in 2012.

Comparison of the New York and Minnesota results with those of BC indicates, that the potential revenue generation in both New York and Minnesota is larger than that in BC. The difference in CO_2 emissions between the two states and BC probably accounts for this discrepancy. In 1992, CO_2 emissions in New York state were approximately 219 megatonnes. CO_2 emissions in BC two years later constituted only 20% of the emission level of New York. Similarly, tax revenue generation in BC in 2020 from the CO_2 tax in TETR constitutes only 18% of that which is generated in New York state in 2012. CO_2 emissions in BC in 1994 constitute 57% of the emissions in Minnesota in 1992 while revenue generation in BC from the CO_2 tax in 2020 in AETR constitutes 45 % of that which is generated in Minnesota in 2012. Variations in the tax rates employed in the analyses may account for the remaining differences, e.g. a tax of \$30 used by the Tellus Institute versus a tax of \$37.50 in this analysis.

Durning, (1998) estimated that a \$10 CO_2 tax in BC would generate \$271 million in one year. In TETR of this study, a CO_2 tax of \$7.50 results in revenue generation of \$188 million (\$1995) while a CO_2 tax of \$15 generates revenue of \$380 million (\$1995). In AETR, a CO_2 tax of \$13.75 generates \$377 million (\$1995) in tax revenue. Extrapolating these results to a \$10 CO_2 tax, for the purpose of comparison with Durning, yields revenue of approximately \$250 million (\$1995) in TETR and \$274 million (\$1995) in AETR. Relatively speaking therefore, the results for revenue generation in BC are not inconsistent with those of either the Tellus Institute or Durning.

5.2.2 Carbon Dioxide Emission Impacts

The Tellus Institute (1997) predicted that a CO_2 tax in the state of New York would cause CO_2 emissions to fall by 14% in 2012 with a \$30 CO_2 tax and by 21% with a \$50 CO_2 tax. For the state of Minnesota, the Tellus Institute predicted a drop in emissions of 4.5% with a \$10 CO_2 tax and 17.8% with a \$50 CO_2 tax. The Congressional Budget Office (CBO) (1990) used three models of the United States economy to test the impact of a CO_2 tax in the US. At a per ton CO_2 tax of approximately \$27 (\$100 carbon tax), introduced in 1988, reductions in emissions ranged from 8% to 36% in the year 2000 compared with baseline levels. Manne and Richels (1990) predicted emissions reductions of 20% in 2100 from a CO_2 tax introduced in 1990 that peaked at approximately \$109 and ended at \$68 (equal to \$400 and \$250 carbon tax respectively). Burniaux et al. (1992) predicted emission reductions of 20% in 2025 with a North American CO_2 tax of \$57 introduced in 1990 (Boero et al. 1991). The results for CO_2 emission reductions for BC (approximately 8% and 15% reduction in 2020 from all sectors in TETR and AETR respectively) are relatively smaller than those for the studies described above.

A number of factors could account for these differences. First, differences in the type of model employed to estimate the change in emissions following the implementation of the CO_2 tax. The Tellus Institute used an input-output model to test the effect of the tax on New York and Minnesota. The Congressional Budget Office used a simulation model, an econometric model and a general equilibrium model to discern their results. Manne and Richels and Burniaux et al. used general equilibrium models. Reductions in CO_2 emissions following the implementation of a CO_2 tax can be attributed to reductions in consumption of fossil fuels, switching from fuels which are high in carbon content to fuels which are relatively lower in carbon content and purchasing more efficient technologies. Different types of models assume different responses to CO_2 emission taxes. For example, they contain varying assumptions with respect to changes in demand for various fuels, substitution between fuels and the introduction of new, more efficient technologies. Reductions in CO_2 emissions estimated by the Congressional Budget Office using the simulation model are most appropriately compared to those of this study. Using a simulation model, the Congressional Budget Office estimated an 8% reduction in CO_2 emissions in the United States from a CO_2 tax of approximately $27. TETR of this study realized a 8.57% (industrial, commercial, residential and transportation combined) reduction in CO_2 emissions following the implementation of a CO_2 tax of $37.50 in BC.

As well, differences in consumption of fossil fuels and sources of electricity (coal, oil, natural gas, hydro) in the regions (New York, Minnesota and BC) could account for the discrepancy between studies. British Columbia is unique in this regard. Virtually all electricity in the province comes from hydropower. Research in the United States consistently shows that one half of US CO_2 reduction will come from fuel switching in electricity generation. This is clearly not possible in BC.

5.2.3 Water Consumption Impacts

In each of the scenarios tested, water consumption fell following the implementation of a water tax in BC. For the industrial sector, the decrease in consumption from the BAU was 19% and 35% in 2020 for scenarios 1 and 2 respectively. For the commercial sector, the decrease after 20 years was 21% and 36% from the BAU for scenarios 1 and 2 respectively. Finally, for the residential sector, consumption fell by 15% and 25% after 20 years from the BAU for scenarios 1 and 2 respectively. These changes are consistent with experience elsewhere in North America.

Kello (1970) found that water use in the unmetered, fixed charge districts of Calgary was approximately double that in Edmonton, a fully metered municipality in which prices are volume dependent. Consumption in Boulder Colorado fell 38% following the implementation of metering (Grima 1972). Hopkins found the increase in water use from metered to unmetered consumption to be 51% on an average day use and 140% on the maximum day use (Grima 1972). The Engineering Department of the Borough of Etobicoke found that unmetered customers consumed 45% more water than metered customers living in streets of comparable assessment value (Grima 1972). In 1994, the city of Vernon introduced an increasing block volume-based rate schedule. Since then, Vernon has realized a 34% drop in water consumption (Jackson personal communication). Kerr et al. (1993) studied the difference in water consumption in metered versus unmetered communities in the Kelowna area. Results from six communities showed that unmetered water use exceeded metered water use by as much as 38%. Within the Greater Vancouver Regional District, the only two municipalities to fully meter single family connections are the city of Langely and the University Endowment Lands. In 1995, these municipalities had the lowest per capita daily consumption (GVRD 1997). According to McNeil and Tate (1991), overall, metering combined with water charges based on usage may lead to a 30% to 50% drop in demand. Table 5-5 summarizes a number of studies which show the decrease in water consumption following in the implementation of meters and a volume-based rate schedule. It is clear that the results of this study are consistent, although perhaps somewhat conservative, with the majority of the experience in other places. The final amount of reduction will depend not only on the installation of meters but the rate schedule employed in the location. For example, the relatively smaller reduction in water consumption in St. Catherines and Peterborough is probably the result of a less than aggressive rate schedule. In other words, it is necessary for the rate schedule to provide sufficient incentive to reduce consumption; meters on their own are not enough.

Table 5-5. Summary of a number of studies on the change in water consumption following the implementation of meters and a volume-based rate schedule.

Area	**Impact**	**Source**
Western US	Unmetered areas have over 50% higher water use than metered ones on average	Linaweaver, Geyer and Wolff (1967)
Etobicoke, Ont.	Unmetered areas have 45% higher water use than metered areas of comparable assessment	Grima (1972)
St Catherines, Ont.	11% drop immediately following metering but use rebounded because prices were low	Pitblado (1967)
Boulder, Colo.	34-37% drop in water use following meter installation	Hanke and Flack (1968)
Alberta	10-25% drop in water use following meter installation	Associated Services Ltd. (1984)
Peterborough, Ont.	10% reduction in water use predicted following meter installation	Peterborough Water Department (1984)
California, Central Valley	Household water use reduced up to 55% following meter installation; usage averaged 30% less in metered than in unmetered cities	Minton, Murdock and William (1979)
Denver, Col	Metered customers use 50% of the volume of unmetered customers	Griffith (1982)
Calgary, Alta.	Unmetered water use 46% greater than use in metered residences	Mitchell (1984)
Calgary, Alta.	Unmetered water use 65% greater than use in metered residences	Shipman (1978)
Dallas, Texas	43% drop in water demand following meter installation	Shipman (1978)
Gotherberg, Sweden	Per capita use in unmetered apartments 50% higher than in metered single family residences	Shipman (1978)
York County, Pa.	Substantial increases in industrial waste treatment charges led to reductions in water use in the 30-50% range.	Sharpe (1980)

Vernon, BC	Has seen a 34% drop in water consumption since implementing a rate schedule with prices that increase with consumption.	Jackson, 1998
Kelowna, BC	Results from 6 communities in this area showed that unmetered water use exceeded metered water use by as much as 38%.	Kerr et al, 1993

Source: Adapted from McNeil and Tate 1991

5.2.4 Employment Effects

The results of this analysis indicate that ecological tax reform can be used to influence consumer behaviour and generate significant revenue for the provincial government. Furthermore, when that revenue is used to finance a reduction in payroll charges in the province, increases in employment levels can be realized. Several other studies have measured increases in employment from the reduction of payroll charges/social security payments.

DRI/McGraw-Hill (1994) tested the effect of an ecological tax reform for the European Commission that included new taxes on energy, transportation and water, combined with a reduction in employers' payroll charges. As a result on the reform, they predicted employment increases of 2.2 million by the year 2010. Majocchi (1993) tested the effect of ecological tax reform in Germany, Italy, the United Kingdom and France. Tax revenue from carbon and/or energy taxes was used to decease employer's social insurance contributions. Resultant increases in employment were 0.79% in Germany and Italy, 0.56% in United Kingdom and 0.44% in France. The Institute of Empirical Economic Research (1997) tested the effect of a fossil fuel tax in Germany with decreases in social security payments by employers and found a 25% decrease in CO_2 emissions and 1.5 million jobs from 1990 to 2001. The Tellus Institute tested the effect of both a $10 and a $50 CO_2 tax in Minnesota with equivalent reductions in social security payments. In the case of the $10 tax, they estimate an increase of 8,790 jobs in 1997, and 2,722 jobs in 2012. With the $50 CO_2 tax, they estimate 35,484 new jobs in Minnesota in 1997 and an increase of 19,171 jobs in 2012[23].

Results of this study indicate increases in employment in 2020 of 4.41% in TETR and 8.90% in AETR. Comparing the results of this study with those described above, reveals that expected employment increases in BC are relatively larger than those predicted in studies of other regions. There may be a number of reasons for this apparent discrepancy. First, as the sensitivity analysis highlighted, the increase in employment in BC following ecological tax reform is very sensitive to the value of elasticity of demand for labour employed in this analysis. To the extent that the elasticity of demand specific to BC varies from the value used in this analysis, vastly different results for changes in employment could be realized. Furthermore, the elasticity values for water and motor fuel employed in this analysis are relatively conservative. I chose such values so as not to overestimate the reduction in consumption of ecological bads following ecological tax reform in BC. Because changes in employment were somewhat sensitive to the value used for the own-price elasticity for motor fuel, in employing a conservative estimate for its own-price elasticity, I may be overestimating revenue generation from the transportation sector and thus over estimating job creation in BC. If I had chosen elasticity values at the other end of the spectrum, I would have run the risk of overestimating the response to the ecological taxes, in terms of reduced consumption and output of ecological bads. In that case I could have underestimated tax revenue and therefore underestimated

[23] The CO_2 tax simulated by the Tellus Institute does not increase over time.

job creation in the province. Using a higher value of own-price elasticity and/or a lower value for elasticity of demand for labour, with respect to payroll charges, may have yielded results closer to those realized in other studies.

Second, the increases in employment shown in figure 4-7 are not net increases. They estimate only the addition of jobs created by the lower payroll charges and not the possible loss of jobs associated with the implementation of any of the ecological taxes. To the extent that such taxes increase the production costs of some businesses in BC, some employers may be forced to reduce the number of workers they employ. Measuring net changes in employment may have yielded results similar to those predicted by DRI/McGraw-Hill, Majocchi, The Institute of Empirical Economic Research and the Tellus Institute.

Third, the amount of revenue raised by the imposition of the ecological taxes exceeds that which is projected to be collected by the provincial government in Workers' Compensation premiums. Unless the tax revenue from the ecological taxes in excess of that which is required to reduce Workers' Compensation premiums is transferred to the federal government, and then used to finance further reductions in payroll charges in BC, increases in employment will be limited to those that result strictly from decreased Workers' Compensation premiums.

5.3 Addressing concerns associated with ecological tax reform

There are a number of concerns associated with implementing ecological tax reform in BC. First, there are concerns about the impact of ecological taxes on the competitiveness of BC's businesses. Second, to the extent that ecological taxes are successful in providing an incentive to move away from ecological bads, the tax base in BC will be eroded. Third, there are concerns about the impact of such taxes on low-income earners. Finally, because the Workers' Compensation system in BC provides an incentive to BC employers to ensure a safe workplace for employees, there is concern that reducing or eliminating such taxes in the province will lead to a lower level of workplace safety in the province. Each of these concerns will be addressed in the sections that follow.

5.3.1 Impacts on Competitiveness

As with almost any tax reform, there will be winners and losers as a result of ecological tax reform in BC. Whether an industry is a winner or loser following ecological tax reform in BC will depend on the impact of the ecological taxes relative to the reductions in payroll charges. In some cases, the reduction in payroll charges may offset or exceed the increased costs from the ecological taxes. Where the reduction in payroll charges exceeds the amount paid in ecological taxes, industries will realize a competitive advantage as a result of ecological tax reform. In general, industry that is manufacture-based will be more likely to suffer as a result of ecological tax reform while industry that is service-based is more likely to benefit. Presumably, the energy, water and solid waste costs of the service-based sector are lower than its labour costs. Therefore, implementing ecological taxes on CO_2 emissions, water and solid waste with accompanying decreases in payroll charges should leave the service-based sector better-off than before the tax reform. Dower and Zimmerman (1992) reviewed a number of studies which tested the effect of a carbon tax with tax reductions. They summarized that in four out of the five studies they considered, tax reductions resulted in a projected GNP that either stayed the same or increased, relative to what it would have been without the tax reform. According to Dower and Zimmerman (1992) those industries which stand to benefit the most from ecological tax reform include communications, information services, financial services, medicine and other high technology industries. Figure 5-1 shows the make-up of industry in BC. The white portion of the circle represents the service-based sector of the province while the grey portion represents the manufacture-based sector (manufacturing, construction and primary industries and utilities). In BC, 72% of the province's economic output originates in the service-based sector. In 1995, the service-based sector employed 1,348,000 people, three out of every four workers in the province (Ministry of Finance and Corporate Relations 1996).

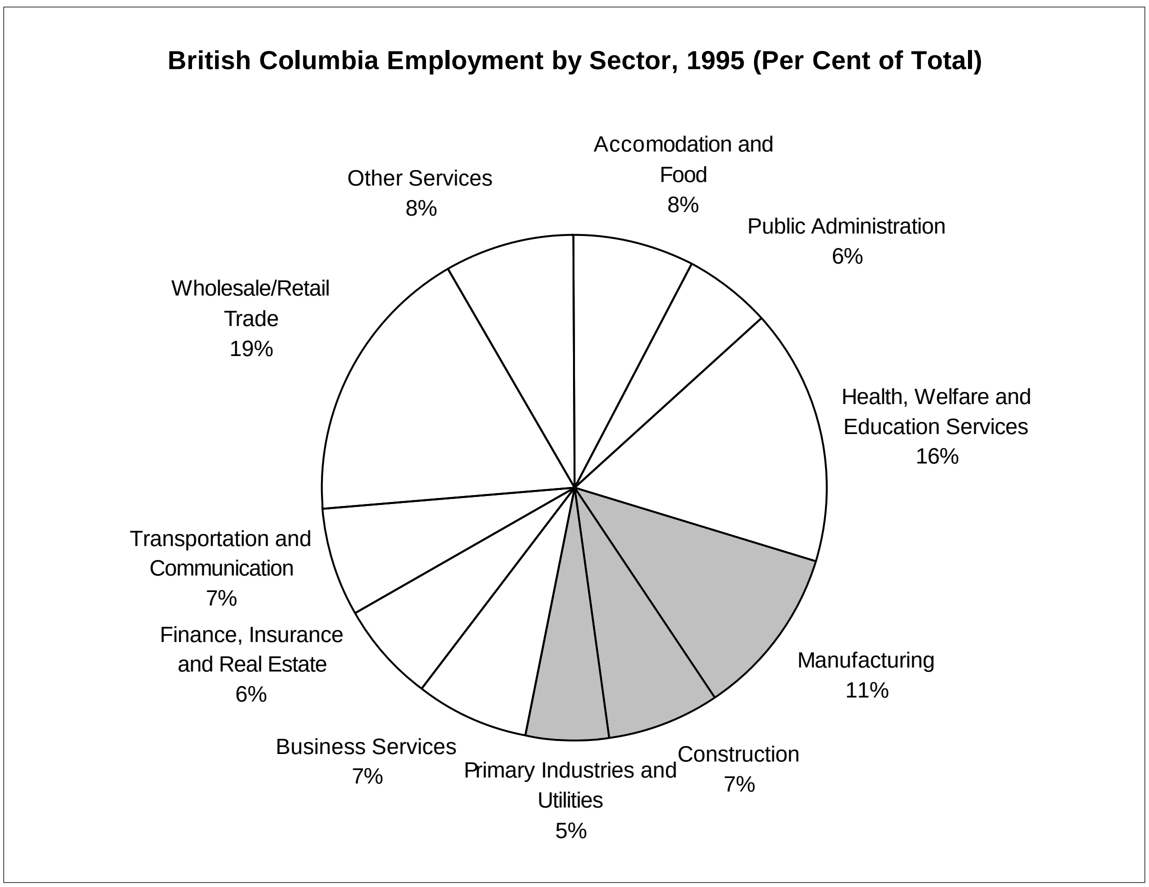


Figure 5-1. Make-up of industry in British Columbia.

As I stated above, in general, industry that is manufacture-based will be more likely to suffer as a result of ecological tax reform. It is important to note, however, that in both TETR and AETR over 40% of the total ecological tax revenue is collected from the industrial sector in 2020. This is more than any other sector. To the extent that the commercial sector is comprised also of firms (as opposed to public institutions like schools and hospitals) an additional 7% of the total ecological tax revenue is collected from firms in 2020. Yet all of the ecological tax revenue is returned to firms. This means that the ecological tax/payroll charge policy of this study results in a net transfer of funds from households to firms. Thus, even heavy industry firms that use a considerable amount of energy and water, while needing to dispose of a lot of waste, could see a fall in their costs of production depending on the relative importance of labour costs and the payroll charge reduction. Labour intensive firms will of course account for most of the employment increasing response.

For those industries that suffer as a result of ecological tax reform in BC, there are ways to mitigate competitiveness impacts. One such means is tax exemptions. The worst polluting industries could be awarded a partial or full exemption from the ecological taxes[24]. The carbon taxes in Denmark, Finland, the Netherlands, Norway and Sweden exempt or partially exempt their most energy intensive industries (European Environment Agency 1996). In some cases, this exemption is conditional upon investment by the industry in clean technologies. Although exemptions may be desirable from a political or welfare perspective, from an environmental perspective, they are less satisfying.

---

[24] Pulp and paper, mining, chemical producers and industrial mineral production account for approximately 50% of the CO_2 emissions from the industrial sector in BC. Exempting them from the tax would thus cut revenue generation from this tax from the industrial sector in half.

A second means of addressing competitiveness concerns is border tax adjustments. This would involve a country/province levying environmental tariffs on imports such that the domestic ecological tax is neutralized. Also, exports would receive a rebate at the border to maintain competitiveness in markets abroad. Tax free thresholds can also be used to minimize potential impacts on competition. Tax free thresholds require that an initial level of consumption of the ecological bad is not taxed. Beyond the threshold level, taxes increase with consumption. Such thresholds are particularly appropriate in the case of a water tax for example, because a certain amount of water consumption is considered to be a necessity. Setubal in Portugal has a water tax with such a tax free threshold (European Environment Agency 1996). Finally, impacts on competition can be completely eliminated if ecological taxes are introduced around the world. This would require complete international harmonization of ecological taxes.

5.3.2 Revenue Erosion

As well as concerns about the impact on the competitiveness of businesses in BC, concerns may arise from the potential for revenue erosion as producers and consumers respond to the ecological taxes and over time environmental damage in BC is reduced. To the extent that the ecological taxes are successful in reducing pollution, the tax base will be eroded. In the case of this study, although consumption of ecological bads fell following the implementation of the ecological taxes, in general the increase in the tax rates more than offset the decrease in consumption of ecological bads. The only exception to this was the solid waste tax. In both scenarios, revenue generation from the solid waste tax increased then fell as solid waste generation in BC was reduced over time. Revenue generation from the other ecological taxes more than offset this revenue erosion. In cases where revenue erosion was not offset by increases in tax rates, other tax options, preferably nondistorting taxes on additional ecological bads could be introduced.

5.3.3 Regressivity

Taxes are considered regressive when they impact low-income earners disproportionately more than high-income earners. Expenditure on energy, water and solid waste disposal by low-income earners is disproportionately higher than by high-income earners. The ecological taxes proposed in this study would thus be regressive (Lipsey et al. 1991). Any proposal for ecological tax reform in BC could include programs to compensate those adversely affected by the taxes. A good example of a carbon tax that protects low-income earners is the Dutch Small Energy Users Tax (European Environment Agency 1996). With this tax, revenue is returned to businesses and households according to their respective tax payments. For businesses, tax revenue is mainly returned through reductions in employers' non-wage labour costs and corporation taxes. For households, (and also for businesses) a tax free threshold of energy use has been established. In addition, households get income tax relief such that an average energy user in each of 4 income groups will be made no worse off from the tax (obviously high users are hurt and low users are better off). There are several other options for protecting against regressivity. These include: increasing social security and other transfer payments to low-income households (Poterba 1991); phasing the tax shift in gradually and predictably over a number of years to help ensure an orderly, low-cost transition (Bernow et al. 1998); expanding public transportation and simultaneously increasing the cost of air travel and heavy automobiles (von Weizsacker and Jesinghaus 1992); and introducing programs for insulating low-income earner's homes.

5.3.4 Loss of Safety Incentives to British Columbia Employers

Workers' Compensation premiums by BC employers are determined by two factors. First, employers pay relative to the number of employers he/she employs. Second, rates are set according to the number of claims an employer has made, such that an employer that has had several employees injured at work will pay relatively more than employers with no past claims. In this way, the payment system offers on-going incentive to employers to provide safe workplaces for employees. To the extent that Workers' Compensation premiums in BC are reduced, employers will have less incentive to provide safe workplaces for employees. Depending on the amount of revenue generated by the ecological taxes, this concern could very well be realized. To maintain an incentive structure to BC employers, a system of fines could be established whereby employers with poor safety records are fined for resultant damages. The system of fines could be graduated such that fines increase with the number of claims made by a particular employer. By doing so, employers who provide safe workplaces are no worse off, in fact they would be better off, than before the reform because of the reduced Workers' Compensation premiums but those employers who do not provide safe workplaces are penalized. Fines would have to be sufficient enough that it is cheaper for employers to pay for safe workplaces than it is to pay the fine.

6. Conclusion and Recommendations

Ecological tax reform involves implementing or increasing taxes on ecological bads. Several European countries have made small tax adjustments toward ecological tax reform as a means of influencing consumer behaviour, raising government revenues and increasing employment opportunities. The purpose of this study is to estimate the potential impacts of ecological tax reform in BC. To do this, I simulated ecological taxes on water consumption, solid waste generation and CO_2 emissions in the province. I simulated the change in consumption of ecological bads and revenue generation resulting from each of the taxes. I used the tax revenue to finance a decrease in payroll charges in the province and I simulated the ensuing change in employment. The results indicate substantial decreases in ecological bads and significant revenue generation. Changes in employment, although they appear significant, are limited by a number of factors discussed in the sensitivity analysis section of this report. In this conclusion, I distinguish between the two scenarios of ecological tax reform tested in this analysis. As well, I highlight a number of limitations of this study. In each case, I describe what additional research is needed to improve such an analysis. I close by making several recommendations with respect to implementing ecological tax reform in BC.

Two scenarios of ecological tax reform were tested in this analysis. Each of the scenarios reflects a different policy orientation of government. In AETR, ecological tax rates and therefore, reductions in ecological bads, are significantly higher than in TETR. As such, AETR is be more desirable from an environmental point of view. AETR moves society to an economy in which negative externalities constitute a more significant proportion of the market price of ecological bads. In doing so, AETR provides significant price signals to households and businesses thereby offering substantial incentive to decrease consumption of the ecological bads. TETR, on the other hand, because the tax rates are relatively less onerous, is more desirable from a political acceptability point of view. This is true because first, the smaller reduction in ecological bads implies that government revenues are more stable over time, and, second, the relatively lower tax rates would be easier to sell to those inherently opposed to ecological taxes.

There are a number of limitations associated with this analysis. For example, larger macroeconomic impacts are not dealt with. This analysis does not include measurements of changes in GDP as a result of ecological tax reform in BC. Future research in this area could include macroeconomic links between ecological bads and overall productivity in the province. As well, although I have simulated the increase in employment expected from a decrease in payroll charges, I have not drawn conclusions about where those employment opportunities might occur. Additional research could attempt to discern exactly what types of employment opportunities are most hindered by payroll charges.

A policy for ecological tax reform in BC should take note of the number of concerns associated with its implementation as described in this study. I conclude by making several recommendations with respect to these concerns:

1. Ecological taxes should be known well in advance and implemented gradually over a ten to twenty year period. This allows businesses and households to take advantage of technology turn-over, thus minimizing costs associated with the transition to ecological taxes.

2. At the time the ecological taxes are implemented, the tax revenue should be used to finance tax reductions in existing less desirable taxes.
3. Any policy for ecological tax reform should include measures to offset both competitive effects and regressivity on businesses and households respectively. A number of options for such measures have been discussed in this report.

Appendix A: Detailed Assumptions Used in this Analysis

Table A-1. ISTUM Industrial Growth Rates.

Subsector	Average Annual Growth			
	1995-2000	2000-2005	2005-2010	2010-2015
Pulp and Paper	0.80%	2.14%	2.04%	1.85%
Chemical	2.79%	2.57%	2.76%	2.85%
Smelting and Refining	3.06%	3.48%	3.30%	3.26%
Mining Industry	1.65%	1.42%	1.00%	1.35%
Cement	0.59%	2.63%	3.01%	3.47%
Other Manufacturing	3.34%	2.26%	2.43%	2.67%

Source: NRCan pers. com.

Table A-2. ISTUM Residential Growth Rates.

Housing Stock/ Households	5 Year Average Growth			
	1995-2000	2000-2005	2005-2010	2010-2015
Total Households	24.24%	21.16%	21.52%	55.46%
Total Housing Stock	24.9%	21.74%	22.14%	57.04%
Single Detached	11.78%	9.86%	9.64%	23.54%
Single Attached	1.52%	1.22%	1.14%	3.02%
Apartments	10.88%	10%	10.66%	28.76%
Mobile Homes	0.08%	0.08%	0.08%	0.14%

Source: NRCan pers. com.

Table A-3. ISTUM Commercial Growth Rates.

Region	Average Annual Growth *Floor Space (m^2)*			
	1995-2000	2000-2005	2005-2010	2010-2015
Commercial	2.41%	2.49%	1.97%	1.66%

Source: NRCan pers. com.

Table A-4. ISTUM Fuel Prices, (1995 $ / GJ) including taxes.

Fuel Type by Sector		Year 2000	2005	2010
Industrial	Natural Gas	1.67	1.73	1.79
	Electricity	10.50	10.50	10.50
	Light Fuel Oil	10.26	10.17	10.13
	Heavy Fuel Oil	3.62	3.55	3.52
	Coal	2.46	2.40	2.36
	LPG	10.98	10.68	10.68
	Diesel Fuel Oil	14.48	14.23	14.08
Commercial	Natural Gas	5.38	5.45	5.53
	Electricity	14.16	14.16	14.16
	Light Fuel Oil	10.26	10.17	10.13
	LPG	10.98	10.68	10.50
Residential	Natural Gas	5.69	5.77	5.85
	Electricity	19.52	19.52	19.52
	Light Fuel Oil	10.98	10.88	10.84

Table A-5. Assumed Fuel Taxes.

Region	Electricity ($/GJ)	Natural Gas ($/GJ)	Resid Oil ($/GJ)	Coal ($/GJ)
Industrial	0.69	0.12	0.45	0.15
Commercial	1.74	0.68	1.24	0.00
Residential	1.28	0.38	0.71	0.00

Note: includes federal GST and provincial taxes where applicable

Region	Gasoline ($/GJ)	Diesel ($/GJ)
Transportation	5.85	5.89

Note: Represents the difference between before tax and after tax prices.

Table A-6. Business as Usual Energy Consumption by Sector.

Sector	Electricity (GJ)	Natural Gas (GJ)	RPP (GJ)	Coal (GJ)	Other (GJ)	Total (GJ)
Industrial	97,972,628	301,596,713	11,503,162	2,998,821	46,865,744	460,937,068
Commercial	87,441,930	43,907,837	9,784,673	0	1,040,156	142,174,596
Residential	68,243,767	77,108,687	4,857,151	0	9,422,626	151,127,013
Electricity	0	83,400	12,700	0	255,900	352,000

Table A-7. Business as Usual Motor Fuel Consumed (litres).

	1995	2000	2005	2010	2015	2020
Gasoline	4,163,178,830	4,586,840,176	4,925,769,253	5,010,501,522	5,278,820,375	5,541,490,410
Diesel	1,336,298,862	1,384,385,374	1,424,879,279	1,495,743,612	1,591,916,636	1,695,682,267

Table A-8. Business as Usual Price Paid for Motor Fuel ($/litre).

	1995	2000	2005	2010	2015	2020
Gasoline	0.593	0.59	0.61	0.62	0.64	0.66
Diesel	0.521	0.55	0.59	0.61	0.65	0.68

Table A-9. Business as Usual of Solid Waste Generated (tonnes).

Sector	1995	2000	2005	2010	2015	2020
ICI	1,223,448	1,200,000	1,000,000	800,000	600,000	300,000
Residential	1,519,074	1,259,913	1,242,831	1,279,543	1,301,522	1,321,470

Table A-10. Business as Usual Water Consumption (m3).

	1995	2000	2005	2010	2015	2020
Industrial	179,816	193,518	209,080	224,340	236,928	254,818
Commercial	333,206	358,596	387,434	415,711	439,037	472,188
Residential	1,308,096	1,407,773	1,520,983	1,631,994	1,723,565	1,853,708

Table A-11. Business as Usual Price Paid for Water Consumption ($/m3).

Sector	1995	2000	2005	2010	2015	2020
Industrial	0.18	0.23	0.28	0.33	0.38	0.43
Commercial	0.33	0.38	0.43	0.48	0.53	0.58
Residential	0.28	0.33	0.38	0.43	0.48	0.53

Table A-12. Business as Usual Population and Employment in BC.

Year	Population 15 yrs and over	Number Employed
1990	2636900	1576592
1995	3029300	1811207
2000	3397900	2031591
2005	3752900	2243845
2010	4101900	2452510
2015	4442700	2656273
2020	4774800	2854835

Table A-13. Business as Usual Payroll Charges in BC ($1995).

Year	1995	2000	2005	2010	2015	2020
Amount	4,263,624,182	5,100,000,000	6,200,000,000	730,00,00,000	835,00,00,000	940,000,000

Appendix B: Revenue Generation.

Table B-1. Revenue Generation by Ecological Tax, TETR.

Year	CO_2	Water	SW
2000	63%	0.02%	37%
2005	78%	0.02%	22%
2010	87%	0.02%	13%
2015	92%	0.02%	8%
2020	94%	0.02%	6%

Table B-2. Revenue Generation by Ecological Tax, AETR.

Year	CO_2	Water	SW
2000	78%	0.03%	22%
2005	85%	0.03%	15%
2010	90%	0.02%	10%
2015	94%	0.02%	6%
2020	96%	0.02%	4%

Table B-3. CO_2 Tax Revenue Generation by Sector, TETR.

Year	Industrial	Commercial	Residential	Transportation
2000	38%	7%	11%	45%
2005	41%	7%	11%	42%
2010	49%	8%	12%	32%
2015	53%	7%	13%	27%
2020	52%	7%	13%	28%

Table B-4. CO_2 Tax Revenue Generation by Sector, AETR.

Year	Industrial	Commercial	Residential	Transportation
2000	36%	7%	11%	47%
2005	38%	6%	10%	45%
2010	43%	8%	11%	40%
2015	47%	7%	12%	35%
2020	44%	6%	11%	38%

Table B-5. Water Tax Revenue Generation by Sector, TETR.

Year	Industrial	Commercial	Residential
2000	7%	13%	79%
2005	8%	16%	76%
2010	8%	15%	77%
2015	7%	14%	79%
2020	6%	12%	82%

Table B-6. Water Tax Revenue Generation by Sector, AETR.

Year	Industrial	Commercial	Residential
2000	5%	11%	84%
2005	5%	11%	84%
2010	5%	11%	84%
2015	5%	11%	84%
2020	5%	11%	84%

Table B-7. Solid Waste Tax Revenue Generation by Sector, TETR.

Year	Ind/Comm	Residential
2000	49%	51%
2005	45%	55%
2010	38%	62%
2015	32%	68%
2020	19%	81%

Table B-8. Solid Waste Tax Revenue Generation by Sector, AETR.

Year	Ind/Comm	Residential
2000	49%	51%
2005	45%	55%
2010	38%	62%
2015	32%	68%
2020	19%	81%

Bibliography

Adams, F. G., H. Graham, and J. M. Griffin. 1974. Demand Elasticities for Gasoline: Another View. Philadelphia, Pa: University of Pennsylvania, Economic Research Division.

Associated Services Ltd. 1980. Water metering: cost effectiveness for Alberta. Edmonton: Alberta Environment.

Bailie, Alison, Bryn Sadownik, Amy Taylor, Mallika Nanduri, Rose Murphy, John Nyboer, Mark Jaccard and Andrew Pape. 1998. Cost Curve Estimations for Reducing CO_2 Emissions in Canada: An Analysis by Province and Sector. Burnaby, BC: The Energy Research Group.

Baumol, William and Walleye Oates. 1988. The Theory of Environmental Policy. New York: Cambridge University Press.

Beach, Charles, Zhengxi Lin and Garnett Picot. 1995. The Employer Payroll Tax in Canada and Its Effects on the Demand for Labour. Paper presented at Queens University.

Bean, Richard Layard and Stephen Nickel. 1986. In Baron, Joni. 1996. Payroll Taxation and Employment: a Literature Survey. Ottawa: Industry Canada.

Bernow, Steve, Robert Costanza, Herman Daly, Ralph DeGennaro, Dawn Erlandson, Deeohn Ferris, Paul Hawken, J. Andrew Hoerner, Jill Lancelot, Thomas Marx, Douglas Roodman, Irene Peters, David Roodman, Claudine Scheider, Priya Shyamsundar and John Woodwell. Ecological Tax Reform, *BioScience, March 1998, pp. 193.*

Billings and Agthe. 1986. Dynamic Models of Residential Water Demand. *Land Economics, Vol. 62, No. 1, pp. 26.*

Bird, Richard and Jack Mintz. 1992. Taxation to 2000 and Beyond. Toronto: Canadian Tax Foundation.

Blume, David. 1992. Under What Conditions Should Cities Adopt Volume-Based Pricing for Residential Solid Waste Collection? Duke University Memo Study.

Bohi, Douglas. 1981. Analyzing Demand Behavior A Study of Energy Elasticities. Baltimore: John Hopkins University Press.

Boero, Gianna, Rosemary Clarke and Alan Winters. 1991. The Macroeconomic Consequences of Controlling Greenhouse Gases: A Survey. London: University of Birmingham, Department of Economics.

Bossier, F. and R. De Rous. 1992. Economic Effects of a Carbon Tax in Belgium, *Energy Economics, January 1992, pp. 33-41*

Bovenberg, A. Lars and Rudd de Mooij. 1994. Environmental levies and distorting taxations, *American Economic Review, Vol. 84, pp. 1085.*

Bovenberg, A. Lars and L. Goulder. 1994. Cost of environmentally motivated taxes in the presence of other taxes: general equilibrium analysis. Paper presented at the International Workshop on Environmental Taxation, Revenue Recycling and Unemployment, Milan.

Burniaux, J. M., J. P. Martin, G. Nicoletti and J. Oliveira-Martins. 1992. GREEN: A Multi-sector, Multi-regions General Equilibrium Model for Quantifying the Costs of Curbing CO_2 Emissions: A Technical Manual, OECD Working Paper No. 1167. Paris: OECD.

Canadian Chamber of Commerce. 1994. Summary of the Key Findings of the Aim for a Million Project and Recommendations for Actions. Toronto: Canadian Chamber of Commerce.

Canadian Federation of Independent Business. 1995. On Hire Ground. Moncton, NB: Canadian Federation of Independent Business.

Canadian Water and Wastewater Association (CWWA). 1997. Primer on Setting Municipal Water and Wastewater Rates. CWWA.

Congressional Budget Office (CBO). 1990. Carbon Charges as a Response to Global Warming: The Effects of Taxing Fossil Fuels. Washington: CBO.

Dahlby, Bev. 1992. Taxation and Social Insurance. In Bird, Richard and Jack Mintz, ed., Taxation to 2000 and Beyond. Toronto: Canadian Tax Foundation.

DiMatteo, Livio and Michael Shannon. 1995. Payroll Taxation in Canada: An Overview, *Canadian Business Economics, Summer.*

Dower, Roger and Robert Repetto. 1994. Green Fees and the Need for Fiscal Restructuring: Opportunities and Challenges, *Pace Environmental Review Vol. 12, No. 1, pp. 161.*

Dower, Roger and Mary Beth Zimmerman. 1992. The Right Climate for Carbon Taxes: Creating Economic Incentives to Protect the Atmosphere. Washington, DC: World Resources Institute.

DRI/McGraw-Hill. 1994. The Potential Benefits of Integration of Environmental and Economic Policies: An Incentive-Based Approach to Policy Integration. Report prepared for the European Commission Directorate-General for Environment, Nuclear Safety, and Civil Protection. Norwell, MA: Kluwer Academic Publishers Group.

Durning, Alan. 1998. Tax Shift. Seattle, WA: Northwest Environment Watch.

Durning, Alan. 1996. This Place on Earth: Home and the Practice of Permanence. Seattle, WA: Northwest Environmental Watch.

European Environment Agency (EEA). 1996. Environmental Taxes Implementation and Environmental Effectiveness. Copenhagen: EEA.

Eskeland. 1996. Taxing bads by taxing goods: pollution control with presumptive charges. Washington, DC: World Bank.

Field, Barry. 1994. Environmental Economics. United Sates of America: McGraw-Hill Inc.

Flack, E. J. 1981. Residential water conservation. *Journal of Water Resour. Plan. Manage. Division, Vol. 107, No. 1, pp. 85.*

Fuss, Melvyn. 1977. The Demand for Energy in Canadian Manufacturing. *Journal of Econometrics, Vol. 5, pp. 89.*

Fuss, Melvyn and L. Waverman. 1975. The Demand for Energy in Canada. Confidential Report for the Department of Energy, Mines and Resources.

Gale, Robert. 1996. Case Studies: USER FEES. Municipalities Can Charge for Waste Management. http://www.web.net/ecoeco/cs-user.html.

Gale, Robert, Stephan Barg and Alexandra Gillies. 1995. Green Budget Reform An International Casebook of Leading Practices. Winnipeg: International Institute for Sustainable Development.

Greater Vancouver Regional District (GVRD). 1997. Water-Study Summary and Water Supply Plan. The GVRD Comprehensive Regional Water Supply Study. Burnaby: GVRD.

GVRD. 1994. Let's Clear the Air: GVRD Air Quality Management Plan Working Paper. Fine Particulate and Visibility. Burnaby: GVRD.

GVRD. 1993. Lets Clear the Air: GVRD Air Quality Management Plan Stage 2 Report. Priority Emission Reduction Measures. Appendix C Motor Vehicle Emissions. Burnaby: GVRD.

Griffith, F. P. 1982. Policing demand through pricing. *Journal of American Water Works Association Vol. 74, No. 6, pp. 269.*

Grima, A. 1972. Residential Water Demand for Water: Alternative Choices for Management. Toronto: University of Toronto Press.

Hale, Robert. 1970. Estimating the Demand for Motor Vehicle Gasoline in Western Canada. A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Masters of Arts, Department of Economics, Simon Fraser University.

Hammond, Jeff, Stephen DeCanio, Peggy Duxbury, Alan Sanstad, Christopher Stinson. 1997. Tax Waste Not Work. San Francisco: Redefining Progress.

Hanke, S. 1978. A Method for Integrating Engineering and Economic Planning, *Journal AWWA, Vol. 70, No. 9, pp. 487.*

Hanke, S. H. and J. E. Flack. 1968. The effects of metering on urban water. *Journal of American Water Works Association Vol. 60, No. 12, pp. 1359.*

Houthakker, H. S., P. K. Verleger and D. P. Sheeham. 1974. Dynamic Demand Analyses for Gasoline and Residential Electricity. *American Journal of Agriculture and Economics, Vol. 56, No. 2.*

Howe, C. and F. Linaweaver. 1967. The Impacts of Price on Residential Water Demand and Its Relation to System Design and Price Structure, *Water Resources Research Vol. 3, No. 1, pp. 12.*

Institute for Empirical Economic Research. 1997. What is the Cost of a Reduction in CO_2 Emissions? Osnabruck: University of Osnabruck.

Jaccard, Mark and J. Roop. 1990. The ISTUM-PC Model: Trial Application to the B.C. Pulp and Paper Industry, *Energy Economics, Vol. 12, No. 3, pp. 185.*

Jaccard, Mark, John Nyboer and Allan Fogwill. 1993. How Big is the Electricity Conservation Potential in Industry? *The Energy Journal, Vol. 14, No. 2, pp. 139.*

Jaccard, Mark and David Montgomery. 1996. Cost of reducing greenhouse gas emissions in the USA and Canada, *Energy Policy, Vol. 24, No. 10/11, pp. 889.*

Jackson, Eric. May 1998. Personal Communication. City of Vernon.

Jenkins, Robin. 1993. The Economics of Solid Waste Reduction. Vermont: Edward Elgar Publishing Limited.

Jones, C and J. Morris. 1984. Instrumental price estimates and residential water demand. *Water Resources Res., Vol . 20, No. 2, pp. 197.*

Kelleher, Maria, Alex Hogan and Janet Robins. 1996. User Pay The status of "pay-as-you-throw" systems in Canada. *Solid Waste Management, Oct/Nov., pp. 12.*

Kellow, R. L. 1970. A study of water use in single dwelling residences in the city of Calgary, Alberta. Edmonton: University of Alberta.

Kerr Wood Leidel Gore and Storrie Inc. 1993. Summary Report on Residential Water Metering.

Kneese, Alan and Charles Shultz. 1975. Pollution, Prices and Public Policy. Washington: Brookings Institute.

Linaweaver, F. P. Jr., J. C. Geyer and J. B. Wolff. 1967. A study of residential Water use. Washington, DC: GPO

Lipsey, Richard, Douglas Purvis, Peter Steiner. 1991. Microeconomics, Seventh Canadian Edition. New York, NY: Haper Collins Publishers.

Mabey, Nick, James Nixon. 1997. Are Environmental Taxes a Free Lunch? Issues in Modelling the Macroeconomic Effects of Carbon Taxes, *Energy Economics, Vol. 19, pp. 29.*

Majocchi, Albert. 1996. Green Fiscal Reform and Employment: A Survey, *Environmental Resource Economics Vol. 8, pp. 375.*

Majocchi, A. 1994. The Employment Effects of Eco-Taxes: A Review of Empirical Models and Results. Paris: OECD.

Macerollo, C. and M. Ingram. 1981. The Value of Water in the Grand River Basin: An Estimate of the Demand for Water in Ontario. *Canadian Water Resources Journal, Vol. 6, No. 1.*

McKitrick, Ross. 1997. Double Dividend Environmental Taxation and Canadian Carbon Emissions Control. *Canadian Public Policy, Vol. XXIII, No. 4, pp. 417.*

McNeil, Roger and Donald Tate. 1991. Guidelines for Municipal Water Pricing. Ottawa: Environment Canada.

Mills, Edwin S. 1978. The Economics of Environmental Quality. New York, NY: Norton.

Ministry of Finance and Corporate Relations. 1996. British Columbia Financial and Economic Review. Victoria: Crown Publications.

Minton, G., R. Murdock and R. William. 1979. Developing a conservation program tailored to area needs. *Journal of American Water Works Association, Vol. 71, No. 9, pp. 486.*

Mitchell, B. 1984. The value of water as a commodity. *Canadian Water Resources Journal, Vol. 9, No. 2, pp. 30.*

Morgenstern, Richard. 1996. Environmental Taxes: Is There a Double Dividend? *Environment, Vol. 38, No. 3, pp. 16.*

Nyboer, John. 1997. Simulating Evolution of Technology: An Aid to Energy Policy Analysis. A Case Study of Strategies to Control Greenhouse Gases in Canada. Thesis Submitted for the Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy. Burnaby: Simon Fraser University.

Organization for Economic Cooperation and Development (OECD). 1995. Environmental Taxes in OECD Countries. France: OECD.

Ottinger, Richard and William Moore. 1994. The Case for State Pollution Taxes, *Pace Environmental Review, Vol. 12, No. 1, pp. 103.*

Parry, Ian. 1995. Pollution taxes and revenue recycling, *Journal of Environmental Economics and Management, Vol. 29, pp. 64.*

Peterborough Water Department. 1984. Metering of residential customers. Peterborough.

Peters, Irene and Steve Bernow. 1996. Ecological Tax Reform: A Case Study of Carbon Taxes in New York, *Energy Report, Vol. 4, No. 2.*

Pitblado, J. R. 1967. The effects of metering on domestic water-the city of St. Catherines. Toronto: University of Toronto.

Pindyck, Robert. 1979. The Characteristics of the Demand for Energy. In I. C. Sawhill, ed., Energy Conservation and Public Policy. Englewood Cliffs, NJ: Prentice-Hall.

Pitblado, J. R. 1967. The effects of metering on domestic water-the city of St. Catherines. Toronto: University of Toronto.

Poterba, James. 1991. Tax Policy to Combat Global Warming: On Designing a Carbon Tax. In Dornbusch, Rudiger and James Poterba ed., Global Warming: Economic Policy Responses. Cambridge: MIT Press.

Ramsey, J. B., R. Rasche and B. Allen. 1975. An Analysis of the Private and Commercial Demand for Gasoline. *Review of Economics and Statistics, Vol. 57, No. 4, pp. 502.*

Repetto, Robert, Roger Dower, Robin Jenkins and Jacqueline Geoghegan. 1992. Green Fees: How a Tax Shift Can Work for the Environment and the Economy. Washington DC: World Resources Institute.

Robert Kaufman. 1992. The Efficiency Value of Carbon Tax Revenues. Washington, DC: Environmental Protection Agency.

Sewell, W. R. D. and L. Roueche. 1974. Peak Load Pricing and Urban Water Management. *Natural Resources Journal, Vol. 13.*

Shackleton, Robert, Michael Shelby, Alex Cristofaro, Roger Brinner, Joyce Yanchar, Lawrence Goulder, Dale Jorgenson, Peter Wilcoxen, Peter Pauly. 1992. The Efficiency Value of Carbon Tax Revenues.

Sharpe, W. E. 1980. Why consider water conservation? In Water conservation strategies: AWWA management resources book. Denver: AWWA.

Shipman, H. 1978. Water metering practices. *Aqua Vol. 2, pp. 2*.

Sigurdson, D. G. 1982. Consumer Surplus from Public Water Works. *Canadian Journal of Agricultural Economics, Vol. 30, No. 3, pp. 359*.

Sims, W. A. 1979. The Response of Firms to Pollution Charges. *Canadian Journal of Economics, Vol. XII, No. 1.*

Skumatz, Lisa. 1993. Variable Rates for Municipal Solid Waste: Implementation, Experience, Economics and Legislation. Los Angeles, CA: The Reason Foundation.

Tate, Donald and David Lacelle. 1995. Municipal Water Rates in Canada: Current Practices and Prices, 1991. Ottawa: Environment Canada.

Technical Committee on Business Taxation. 1998. Report of the Technical Committee on Business Taxation. Ottawa: Department of Finance.

Tellus Institute. 1997. Carbon Taxes with Tax Reductions in Minnesota. Boston: Tellus Institute.

Tellus Institute. 1997. Ecological Tax Reform: Carbon Taxes with Tax Reductions in New York. Boston: Tellus Institute.

Tellus Institute. 1994. An Evaluation of Kentucky-American Water Company's Long Range Planning. Boston: Tellus Institute.

Terkla, David. 1984. The Efficiency Value of Effluent Tax Revenues, *Journal of Environmental Economics and Management Vol. 11, pp. 107*.

von Weizsacker, Ernst and Jochen Jesinghaus. 1992. Ecological Tax Reform. London: Zed Books Ltd.