DISSERTATION

A COMPUTABLE GENERAL EQUILIBRIUM ANALYSIS OF AGGREGATES MATERIALS RECYCLING AND WASTE DISPOSAL POLICY ALTERNATIVES

Submitted by

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In partial fulfillment of the requirements

for the Degree of Doctor of Philosophy

Colorado State University

Fort Collins, Colorado

Summer 2009

COLORADO STATE UNIVERSITY

July 1, 2009

WE HERBY RECOMMEND THAT THE DISSERTAITON PREPARED UNDER OUR SUPERVISION BY MICHAEL DENE MILLER ENTITLED A COMPUTABLE GENERAL EQUILIBRIUM ANALYSIS OF AGGREGATES MATERIALS RECYCLING AND WASTE DISPOSAL POLICY ALTERNATIVES BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY.

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ABSTRACT OF DISSERTATION

A COMPUTABLE GENERAL EQUILIBRIUM ANALYSIS OF AGGREGATES MATERIALS RECYCLING AND WASTE DISPOSAL ALTERNATIVES

The work presented in this dissertation is intended to provide community leaders insights into possible aggregates material disposal and recycling policy alternatives. In this work four main policy alternatives are examined – a tax on landfill deposits, a subsidy for the purchase of recycled aggregates materials, a requirement that all industries in the community increase their consumption of recycled aggregates, and a requirement that the top five producers of aggregates waste supply greater amounts of materials to recycling facilities. The scenarios reported include "base case" situations and sensitivity analysis. For the sensitivity analysis, there are changes in the levels of taxation, subsidy, required use of the recycled materials, and required supply waste to be recycled. Additionally, the percentage of materials being sent to landfill and the percentage of materials being recycled is adjusted in order to measure the impacts of the tax and subsidy on communities with differing levels of recycling already in place. Two other policy alternatives are also analyzed and briefly discussed: 1) The model is allowed to respond to changes in the prices of intermediate goods; and 2) Tax and subsidy rates are changed simultaneously.

This dissertation finds that, as a result of the limited economic impact of the aggregates materials industry (compared to the local economy in total), landfill deposit taxes and materials purchase subsidies have little impact on the community's economic well being. However, due to the rather "painless" nature of these policies,

implementation of these policies do not preclude their use in laying the groundwork for other, more impactful solid waste material disposal approaches. The implementation of the two regulatory policy alternatives has significant positive impacts throughout the economy, but carries with them greater unknown liabilities that are beyond the scope of this dissertation.

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Acknowledgements

It would not have been possible for me to complete this task without the help, love and guidance of numerous people. It is to them that I dedicate this dissertation.

To begin with, I would like to thank all of my committee members: Dr. Stephen Davies, Dr. Harvey Cutler, Dr. Dana Hoag, Dr. Dawn Thilmany, and Dr. Martin Shields. In particular, I wish to express my sincere gratitude to Professor Stephen Davies for his patience, understanding, and contribution to this dissertation. I am especially grateful to Professor Harvey Cutler, the unwavering optimist. There is no way I can ever thank him enough for all he has done for me. His constant support and friendship in good times and bad times have made completion of this dissertation possible. I am certain that I would not have gotten this far without his guidance. Harvey, you have made a difference in my life.

I further wish to thank Dr. Deborah Shields. She has been my mentor and my friend. Working with her has been an extremely rewarding experience – one that has taught me how to be a true professional.

This work could not have been accomplished without the encouragement of my parents, Creed and Patricia Miller. Thank you for all you have given me. They are no better people in this world. I also need to mention my two children, Matthew and Charlotte. They are the joys of my life and a reason to be a better person.

Finally, to my wife Karina, who makes everything possible. There is nothing that we cannot accomplish together. I love you and am forever grateful for all you do for me. Thank you for showing me the wonders of Oz.

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Chapter One: Introduction

1.0 Background

Natural aggregates, which mainly consist of crushed stone and sand and gravel, is among the most abundant of natural resources and is a major basic raw material used by construction, agriculture, and industries employing complex chemical and metallurgical processes (USGS, 1999). Despite a low value per volume of commodity produced, natural aggregates is the second most valuable non-fuel mineral commodity in the world and is a major contributor to and an indicator of the economic well-being of nations (Drew, et al., 2002).

Aggregates are the main ingredients in the production of asphalt for roads, as well as concrete and cement used in buildings. Aggregates make up about 87% of Portland cement concrete and about 95% asphaltic concrete. Portland cement is the generic term for the type of cement used in virtually all concrete employed in buildings and most infrastructures (except roads and streets). Asphaltic concrete is the main material used in construction and repair of roads in the United States. Of the approximate 2.3 million miles of paved roads in the US, 94% are surfaced with asphalt, including 65% of the interstate system (Pit and Quarry, 2002). Paint, paper, plastics, and glass also require aggregates in the form of sand, gravel, and crushed stone. Aggregates are also important ingredients in agriculture, medicine, and household products and are also being used more and more to protect our environment. Soil erosion-control programs, water purification, and reduction of sulfur dioxide emissions generated by electric power plants are just a few examples where aggregates are used.

In many instances recycled aggregates are able to replace natural aggregates, and as such, may make it possible to extend the life of natural resources and reduce environmental damage at construction sites and disposal facilities. As an example, recycled aggregates can be used for road base, sub-base, and the shoulder of roads and streets. Recyclables can also be used in gravel roads as surfacing, as a base for building foundations, and as fill for utility trenches. However, the physical properties of recycled aggregates materials often limit the uses of the material as a main component in structural situations. In particular, the amount of recycled aggregates used in the construction of buildings structures and road surfaces is restricted due to changed characteristics (the loss of strength) in the recycling procedures. Recycled aggregates are most likely to be used in more highly urbanized areas, where construction of buildings and other infrastructure have created a greater demand for aggregates, and where there are few nearby sources of natural aggregates, debris disposal costs are relatively high, and the replacement of old structures have increased the quantities of available construction materials.

1.1 Policy Options

Recognizing that there is an inextricable inter-dependency between our economy and our environment, with both having an impact on our communities and our way of life, decision-makers at all levels of government and in the private sector seek policies that lead to extending the life of existing resources. These policies must support the development of a thriving and competitive economy, where finite resources are used prudently and where they are compatible with a cleaner and protected environment that includes the natural, social, cultural and historic environment of a community. As such, there are on-going searches for ways to promote the use of secondary (recycled and re-used) aggregate materials in a manner that is both friendly to the environment and cost efficient. Several policy options that encourage the increased use of recycled aggregates will be explored in this dissertation. Those options are:

- Disposal taxes implemented for those entities that deposit aggregate materials in local landfills. These "user pay" taxes are charged for failure to conserve resources and adding expenses to the community. In this dissertation the income generated by the tax flows into the Sales Tax sector of government. Implementation of this type of tax policy produces very small net economic costs or benefits to the community, generally with small losses to community household incomes and small gains to tax revenue collections.
- Recycled materials purchase subsidies may be used to encourage the demand for recycled material. The subsidy is modeled as a sales tax "rebate" in this work, in which a percentage of the cost is rebated, with the funds coming from community sales tax revenues. This policy is used to decrease the private costs to recycled materials users and thereby increase the social benefits to the municipality. As may be expected, implementing a subsidy in this manner produces results contrary to those generated by implementing a tax. With higher levels of subsidy, the analyzed elements of the economy generally produce positive net changes. However, as with the tax on waste disposal, these changes are fairly small.
- This dissertation also presents simulations involving changes in regulations. There are two types of regulatory policies that are modeled here. The first type

requires users to increase the amount of recycled materials utilized in their production processes. The second type of regulation requires that the top five producers of waste aggregates materials increase the supply of materials made available for recycling (and therefore not sent to local landfills). In both cases, the changes to the economy are much greater than under the tax and subsidy scenarios, but the regulatory changes do not include the increased administrative and other costs associated with these programs.

1.2 Outline of Study

Chapter Two of this dissertation provides the motivation for the role of local government control of an aggregates conservation program in the city of Fort Collins. The chapter details the pecuniary and

Chapter Three of this dissertation presents a review of the literature emphasizing the econometric, input-output, and CGE models that have been employed in recycling literature. This literature review will feature net economic benefit determinations and comparisons between alternative waste management policies for the encouragement of recycling and the discouragement of solid waste landfilling. The literature will highlight recycling at the industrial, municipal and household levels.

Chapter Four details the construction of the CGE model used in this dissertation and the theory upon which the model is built. Chapter Five outlines the data requirements for the model, the sources of data used in the model, and how the data is utilized in the study. This section additionally highlights any manipulations and/or reconciliations used to format the data to the Social Accounting Matrix (SAM). The individual components of the SAM are discussed in detail in Chapter Four, with special attention paid to the interactions between the sectors in the matrix. Finally, the calibration of the CGE to the base year SAM will be explained in this chapter.

Chapter Six presents the results of simulations performed. The first set of simulations are used to compare the results of increasing landfill disposal taxes on selected economic indicators for the community, including household incomes, tax revenues collected, wages, employment, and domestic supply. These indicators are analyzed at varying levels of community recycling intensity. In the subsequent section, I simulate changes in the economic output in the community that results from sales tax funded recycled material use subsidy. The third section of the chapter produces the results from the regulatory policy changes. Overall, the simulations are performed in order to measure the effectiveness of upstream and downstream waste reduction policies on community well being and to determine how policy changes affect the substitution of recycled aggregates for virgin materials and further alters the demand for landfill services.

Chapter Seven summarizes the construction and performance of the model. The discussion will include limitations and potential misuses of the model. Lastly, areas of improvement to the model and additional areas of research using CGE analysis for recycling issues will be briefly discussed.

Chapter Two: Rationale and Motivation

2.0 Introduction

Aggregates materials are high volume, low-value products and as such pose special problems for community policymakers. In particular, the production of aggregates involves large scale quarrying operations that create disamenities (unsightly views, noise, etc) and environmental costs for the community. Additionally, the disposal of the aggregates waste into landfills takes up considerable space and increases the potential long term costs for maintenance and landfill relocation operations. Therefore, finding ways to conserve the materials can potentially be an important element in increasing community economic and social well-being.

While it is generally accepted that conservation of these or most any resources is a good idea, there are often profound differences of opinion about many aspects of the conservation process. Chief among these questions are:

- Which entity/entities (if any) should provide the service and to what degree should these efforts be implemented?

- Assuming there is a decision to take an active approach and implement conservation efforts, what is the preferred policy to be used to encourage conservation?

The answers to these questions provide the motivation and reasoning for the position of this dissertation - that there is a significant role to be played by government in the development of the aggregates waste and recycling markets in Fort Collins, Colorado.

2.1 Who Should Provide the Service and How Much Should be Provided?

This portion of the chapter develops the argument that, for the city of Fort Collins at this time, the structure of the market and the existence of substantial externalities make it necessary that any major aggregates conservation program include government incentives and/or disincentives. The additional position of this dissertation is that until the industry is able to grow significantly there will continue to be, at most, a limited role for private concerns.

2.1.1 Cost Structure and Resource Availability

One rationale for the intervention of local government is that the present cost structure associated with the development of a viable aggregates conservation and recycling operation does not exist for a private concern in a market the size of Fort Collins.

A significant barrier associated with the development of a privately controlled aggregates material recycling program is that the size of operation necessary for a private enterprise to be profitable is much larger than is currently possible in the community. Wilburn and Goonan (1998) performed material flow analysis for three different sized aggregates operations in the Denver, Colorado area. The authors found that due to economies of scale characteristics, smaller aggregates recycling operations (operational capacity up to 110,000 tons of aggregates per year) were likely to *lose* approximately $72,000[1] a year (1996 dollars), while medium and large facilities (253,000 tons per year

[1] Amount is based on 12% DCFROR

and 312,000 tons per year, respectively) were "money makers". The total costs for the smaller facility were composed of capital costs ($895,000 or $8.13/ton) and total operating costs ($647,900 or $5.89/ton). The total operating costs consist of variable operating costs (equipment, labor, fuel, supplies, permits and fees), recovery of capital, and fixed costs (overhead). On the revenue side, the authors include tipping fee credits of $1.10/ton and $5.23/ton for the average market price of recycled aggregates for a 60:40 mix of asphalt and concrete.

In a waste composition study of the Larimer County landfill, Mid-Atlantic Solid Waste Consultants estimated that, for 2006, 10,644 tons of drywall, asphalt roofing, and block/brick/stone materials were brought to the landfill from construction sites, commercial, residential, and self haul sources (2007). These items make up majority of aggregates-based materials deposited in the landfill by private concerns. Additionally, the city of Fort Collins produced slightly more than 16,000 tons of concrete and asphalt materials from their operations (mainly street and road maintenance and construction). While the recycling facility discussed in the article is small (110,000 tons), it exceeds the combined amount of aggregates material produced by the city of Fort Collins and the material deposited into the Larimer County landfill by a significant amount. So why should the city be involved in a market where losses appear inevitable? The answer lies in what the study does not consider.

A private recycling operation would need to purchase the waste material from other concerns (i.e. city sources and construction firms) before re-processing and selling the materials. A major advantage for the city is the vertical integration afforded by the possession of a majority of the material that could potentially be recycled. Robinson, Menzie, and Hyun (2004, p. 291) find that incentives to private virgin aggregates producers for the inclusion of recycled aggregates activities include cost reductions through "linked" operations. The same holds true for the city, where the availability of a "free" resource from the Streets Department (recyclable concrete and asphalt materials from demolished roads) produces significant cost savings. While the city would still need to purchase materials from private concerns in the community, the "free" resource already in its possession provides an advantage over private firms. Additionally, the community would avoid the costs associated with the disposal of the aggregates waste (tipping fees, etc) in the present and delay some future costs for landfill expansion and/or relocation.

The Wilburn and Goonan article also only addresses the market-based benefits and cost, while the non-market benefits that accrue to the community from limiting the disamenities associated with quarry activities are not considered. Inclusion of these non-market elements would further enhance the potential "profitability" of the operation and increase the community social welfare, as well as lead to greater recycling activity. However, these non-market benefits do not show up directly on a balance sheet, and are therefore, likely to be ignored by a private operator.

2.1.2 Externalities

The discussion in the previous section of the chapter argues that, under the existing circumstances, it is more economically feasible for a community the size of Fort Collins to operate its own aggregates recycling facility rather than have a private firm do so. However, due to the existence of externalities, an argument can be made that even if the operation is run by a private firm, there is still a significant role for government to play. This portion of the chapter more closely addresses these external costs and benefits that are present in the market.

The work also argues that through the use of it's "coercive" powers (i.e. taxation, regulation, and subsidy issuance), government may be able to modify individual behaviors and address externality issues in order to bring about a socially optimal solution for the community. This is something private entities are less likely to be able to do and provides an additional rationale for government intervention in the market.

It can be argued that market decisions, including those about resource conservation, are best made when the markets are allowed to operate with limited government interference. This approach allows for the most efficient amount of recycling and waste diversion, as it uses profit-maximization as a guideline and creates the greatest total surplus (consumer plus producer surpluses). According to proponents of this position, this approach does not eliminate the market for recycled goods and services, but rather constrains unnecessary and costly government restrictions on the market. By allowing the decisions to be based on the prevailing market conditions, the industry can grow as the desires and needs of the consumer dictate (i.e. when the disamenities associated with quarry and disposal activities and the advantages produced by using recycled materials redirect consumer behaviors) and the abilities of the producers to provide the good or service at a competitive price increases.

Proponents of government intervention argue that the private profit-maximization approach does not fully account for the negative externalities created in the production process. They maintain that private producers, without government intervention, do not consider the external costs to society and will *over-produce* the product or service. The failure to internalize the negative externality results in diminished social well-being.

Figure 2-1 shows that over-production occurs when the external costs of waste disposal in the community are ignored (not internalized). In this figure, the private profit-maximizing quantity of landfill deposits produced (Q_p) are greater than the socially optimal production that occurs when the external costs are included (Q_s). The amount of overproduction is equal to the distance from Q_p to Q_s. In order to account for the external costs imposed on the community from producing additional (aggregates) deposits into the landfill, it is important to increase the costs of these deposits from P_p to P_s.

Figure 2-1: Over-production with a negative externality

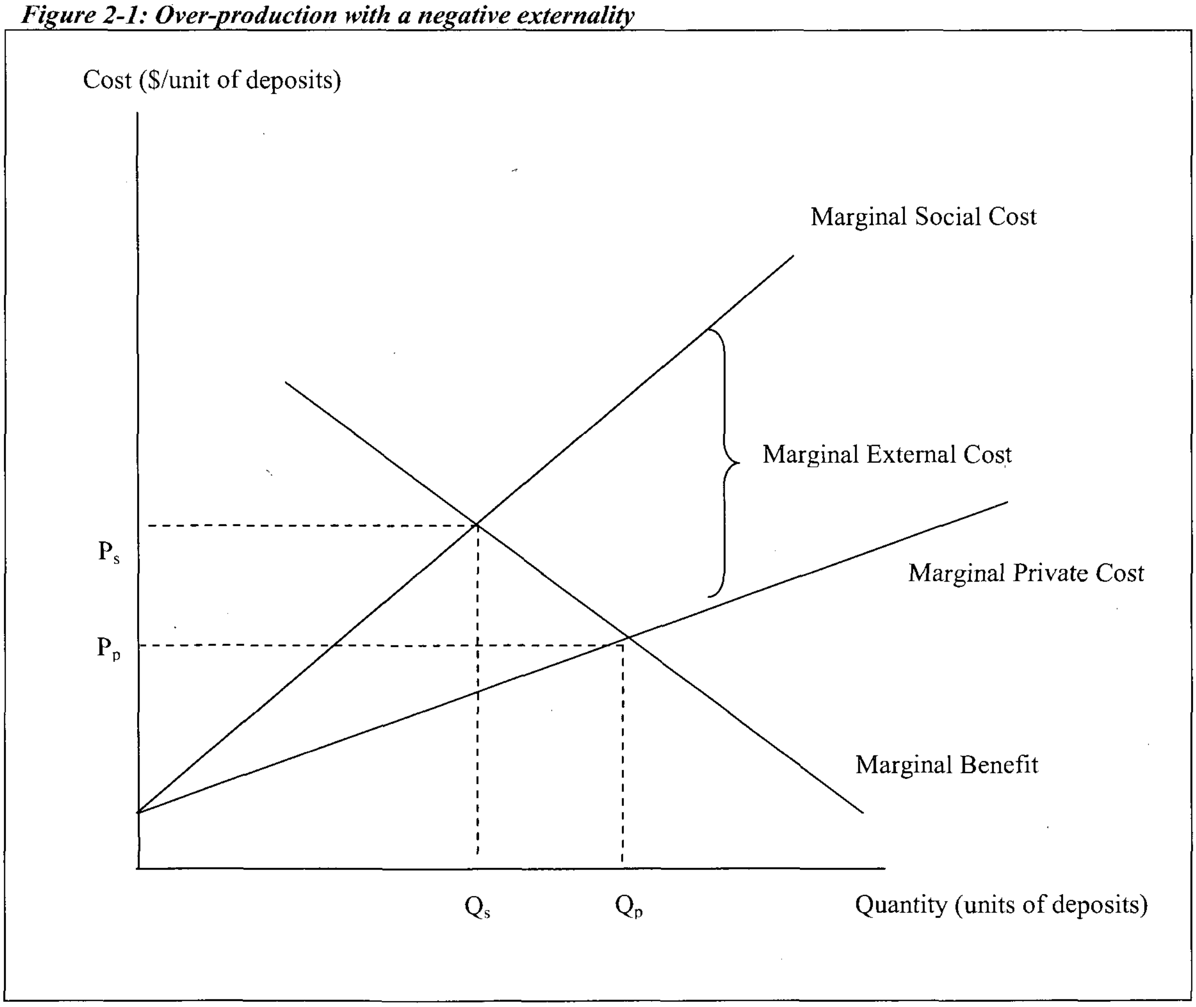
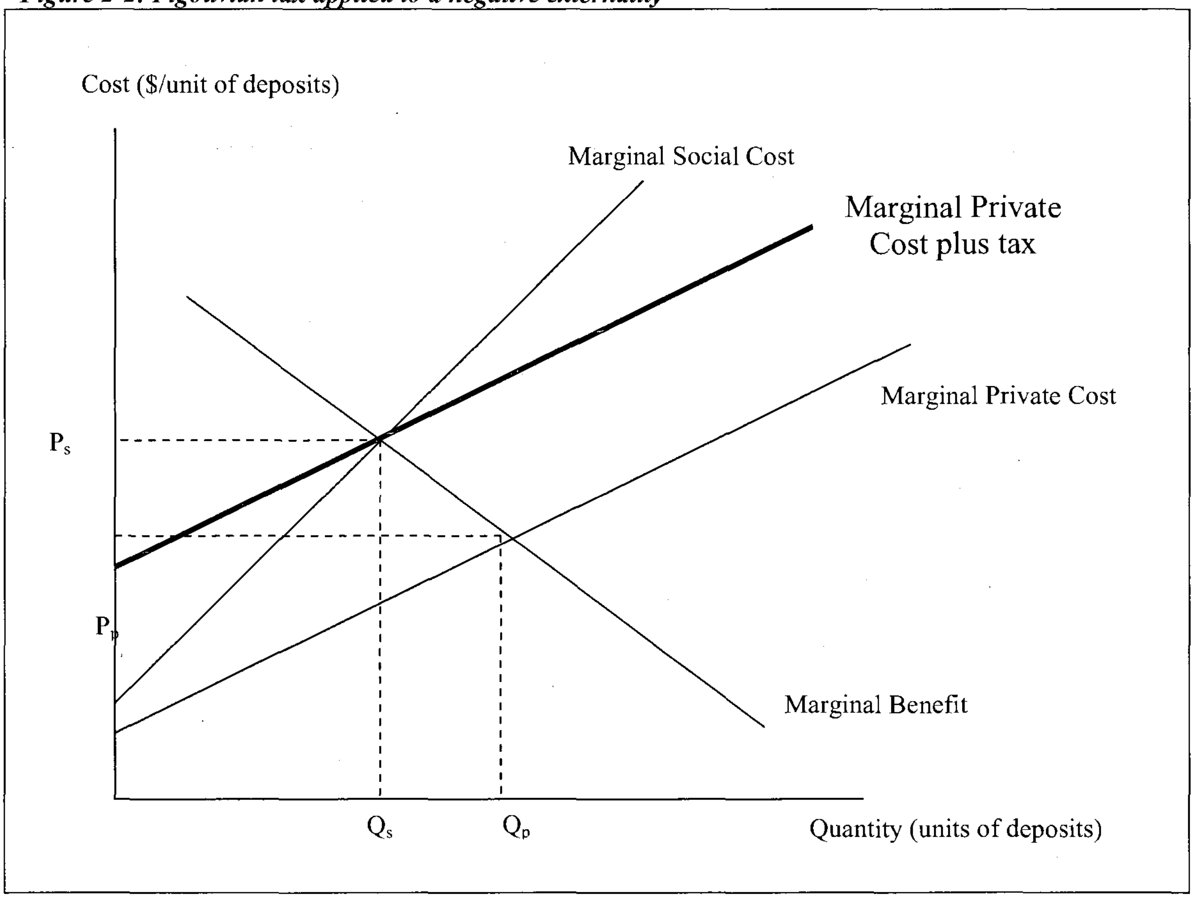


Figure 2-2 illustrates what happens when one form of government intervention (a Pigouvian tax on the disposal of aggregates) is implemented. With a Pigouvian tax, the tax is set equal to the marginal external costs at the socially optimal point of production. In this case, the tax on deposits elevates the price of disposal, leading to a reduction in the amount of deposits. A reduction of deposits into the local landfill would most likely result from corresponding reductions in the amount of aggregates waste created in the production process or from finding alternative means of disposal of the waste.

Figure 2-2: Pigouvian tax applied to a negative externality



While some waste reduction may be achieved through the use of alternative materials in the construction process (unlikely as the material characteristics and low cost of aggregates makes it attractive), the majority of the reduction will need to come from alternative disposal approaches. Alternative disposal may take several different forms (legal and illegal), but additional contributions into the recycling process would most certainly occur. The increased supply of recycled materials would then lead to lower prices for recycled aggregates and lead to greater use of these materials, helping to develop the recycled aggregates market further.

Providing a disincentive for depositing aggregates waste materials into the landfill is just one tool that may be available to the government, but not to private concerns. Another tool that can be used is to use incentives, such as a subsidy, to increase the consumption of a *positive* externality.

As displayed in Figure 2-3, in general, when a positive externality is produced, consumers will *under-use* the good in question (the socially optimal level of use (Q_s) is greater than the private optimal level of use (Q_p)). Therefore, some method of increasing demand would need to be found. However, without some form of financial support, increased demand for this product results in a corresponding price increase. This discourages additional use of the good and leaves society short of the optimal use level. As a result, some form of support is needed to defray the costs of using the good and increase consumption of the material to the point of where the optimal social benefit is achieved. This dissertation uses a government issued subsidy on the purchase of recycled materials to accomplish this consumer price reduction. Figure 2-4 shows the amount of subsidy needed to achieve the socially optimal level of use and the final price (P_f) to consumers for the product. The subsidy leads to an increase in the demand for recycled aggregates, and in turn, encourages the development of a larger recycled aggregates market and fewer deposits into the local landfill.

Figure 2-3: Under-use with positive externality

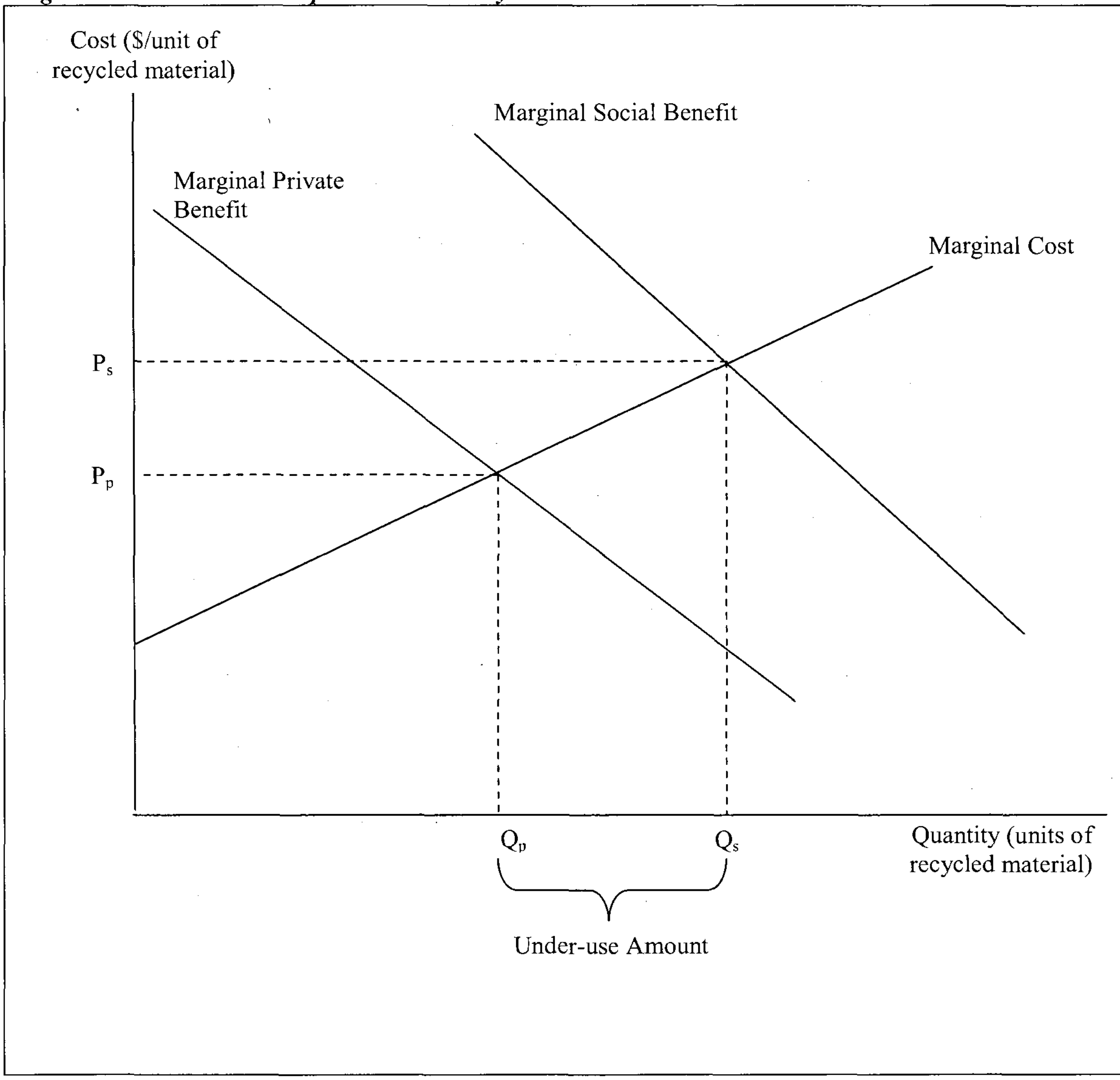
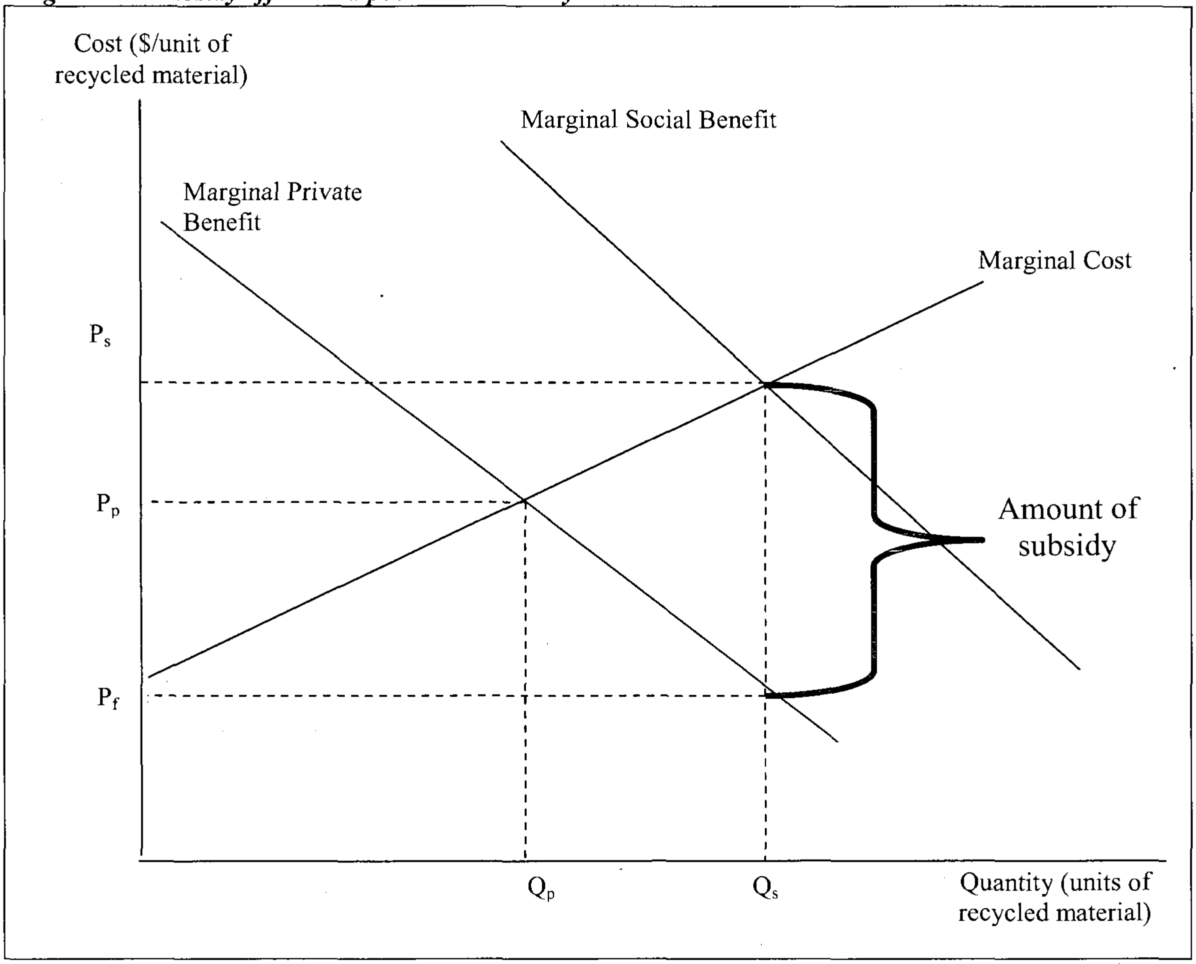


Figure 2-4: Subsidy effect on a positive externality



For the reasons presented in the preceding sections – money, resources, power, and economies of scale – the local government is the proper entity to administer a recycling program at this time. Providing that the industry is able to grow significantly there may be a time when private concerns may be able to become active in the industry.

2.2 Rationale for Model Use

One of several tools that decision makers use to compare the consequences of alternative policies is the Computable General Equilibrium (CGE) model. However, CGE modeling has rarely been used in recycling program analysis and, to my knowledge, has never been used for examination of the viability of aggregates recycling in communities. This CGE model of Fort Collins, Colorado is used to analyze the net benefits of implementing a larger aggregates recycling program for the city and to determine the most efficient manner to finance the program – a tax on landfill deposits, a subsidy for use of recycled aggregates materials, mandatory increased use of recycled materials, and mandatory increased supply of recyclable materials. The information gained from the simulations can then be used by community decision-makers to determine whether such a recycling program is worthy of consideration.

Chapter Three: Review of Related Research

3.0 Introduction

The literature on Computable General Equilibrium modeling and its use in the recycling of solid waste materials is very limited at this time. With aggregate materials specifically, there is little existing English-language CGE published literature on the efficacy of encouraging the use of recycled aggregate materials and no known existing CGE literature that specifically addresses the use of disposal taxes, material subsidies, or combinations of the two in order to encourage the use of recycled aggregates. Therefore, this dissertation will focus on the incentives to recycle solid waste materials in general, highlighting the existing literature that is most closely related to the topics of interest for this dissertation, regardless of the modeling technique employed.

I begin this review by briefly discussing the two predominant modeling techniques used in the literature on solid waste recycling - the econometric forecasting model and the fixed price input-output model. Within the econometric modeling section of this chapter there are synopses of the research that investigate the net benefits (*Cost-Benefit Analysis (CBA)*) of solid waste disposal programs. After the *CBA* review, an examination of a variety of disposal programs attempted and whether these programs are successful in reducing the amount of materials sent to landfills (and increasing material recycling). Included in this section is discussion on disposal taxes and user fees and output tax/return subsidies (*Disposal-Refund Systems*).

Following the econometric modeling literature, the paper addresses the material developed using *Fixed Price Input-Output (I-O)* techniques. I-O techniques are considered the "backbone" of the more involved CGE modeling. This portion of the chapter addresses some of the same issues as the econometric work, in particular, the net benefits and efficacy of implementing specific solid waste recycling (reduced landfilling) policies. However, the I-O models are able to capture the direct, indirect, and induced effects of policy changes on economic and social well being. Additionally, articles are discussed in which the I-O framework is used to perform *Life Cycle Analysis (LCA), Waste Input-Output (WIO) Analysis, and Waste Input-Output Linear Programming (WIO-LP) Analysis.*

I follow those sections with a discussion of the pertinent articles that use CGE techniques. There is less research that utilizes the CGE framework; however, the existing work cited investigates many of the same issues contained in this dissertation, in particular price incentive policies, economic well being, and environmental implications. The chapter concludes with a comparison of the econometric forecasting and I-O approaches with CGE modeling and a brief discussion on the justification for this research.

3.1 Econometric Models

Econometrics, the branch of economics that applies statistical methods to the empirical study of economic theories and relationships by combining statistically estimated parameters with exogenous economic trends, is the most widely used prominent modeling technique for solid waste and resource research. Econometric models can be used to estimate the responses of an economy due to exogenous changes to a sector of that economy. For example, in solid waste and recycling research, econometric modeling techniques have been applied to a variety of imposed policy approaches that attempt to measure the economic benefits and costs of recycling. In line with this dissertation, the majority of literature cited in this section presents the econometric analysis of the various tax, subsidy, and regulatory policies used to encourage greater recycling of solid waste materials at the consumer (mainly household) level.

While the majority of the work addresses the policies that are used to encourage greater use of recycled solid waste (therefore limiting disposal problems and provide source reduction), in order for most firms and municipalities to adopt these policies they must be economically feasible. This is where my discussion begins.

3.1.1 Cost – Benefit Analysis

In an effort to determine the net benefits (or costs) of recycling aggregate materials **Hsiao, Huang, Yu, and Wernick (2002)** use information and data gathered through material flow analysis to develop an iterative, dynamic model of waste concrete from construction and demolition (C&D) operations to disposal in Taiwan. Material flow involves the economic evaluation of materials from the beginning of a project to the completion, including disposal. Due to land mass limitations and other factors, the disposal of C&D wastes (including aggregates-based products such as concrete and cement) are of increasing concern in Taiwan. Therefore increasing the recycling rates of these materials is seen as one way to conserve precious, highly-valued space, while doing significantly less environmental damage.

Hsiao, et al begin by estimating the amount of construction and demolition waste material generated from the waste generation per unit area of activity (construction and demolition) and the floor area for the activity. Next, by employing MINITAB software and using the annual data for floor area constructed the authors estimate future trends in building. The data for floor area demolished was available for only one year, so estimates of future demolition amounts are done by developing a "demolition ratio". The ratio is a function of the construction activity for a given year, a projected timeline for the structure, and a previous amount of unit area of demolition. Using a timeline of 28 years a demolition ratio of 15.33% is established. Applying the ratio to the estimated future building enables the authors to have a working amount of demolition material created. Hsiao, et al next establishes a recycling target for given years and area geographic area in Taiwan by utilizing the carrying capacity ratio (defined as the weight of generated waste concrete to the remaining regional landfill capacity). The target ratio is determined using the following equations:

If $0 \leq CR \leq 1$, the recycling rate (RT) is $CR^2 * 100\%$

If $1 < CR$, the recycling rate is 100%

The final step performed by the authors is the calculations of economic benefits of recycling C&D waste. They do this by comparing the projected costs of recycling to the costs of not recycling in each area of the nation by applying:

(Total costs of transporting the waste concrete to the treatment site) + (Direct costs of using natural aggregate materials) – (Total costs of recycling and reusing the waste concrete)

Based on these calculations the authors determine that recycling C&D materials at a recycling rate of 32.5% would generate a net economic benefit of US$3.5 million and a 100% recycling rate would produce a net benefit of over US$11.7 million.

The work of Hsiao, et al builds on earlier materials flow analysis; in particular on the study performed by **Wilburn and Goonan (1997)**. Utilizing data from the Denver, Colorado area, the authors perform a net present value analysis (12% DCFROR) for small, medium, and large fixed site recyclers of aggregate materials (aggregates recycling capabilities of 110,000 tons, 253,000 tons, and 312,000 tons per year, respectively). The analysis finds positive outcomes (returns) for employing medium ($631,000) and large ($901,000) aggregates recycling firms, but negative returns for the small recycler (-$72,000). The authors determine that recycled aggregates (RCA) can compete well with natural aggregates for some uses; however, these operations need to overcome risks associated with availability, pricing, and quality of recycled material. In particular, the "high capital requirements, inadequate public support, and quality problems or perceptions can also make it difficult for a recycler to compete effectively". Wilburn and Goonan further determine that the growing "urbanization" of our society offers increasing opportunities for industry growth as landfills and quarrying operations compete for increasingly expensive land. While analyzing the varied uses of materials flow analysis, **Kelly (1998)** extends the materials flow discussion of Wilburn and Goonan on the economic and environmental feasibility of utilizing a substitute material (recycled aggregates) instead of virgin materials for specified construction purposes. Utilizing crushed cement (the recycled substitute for virgin aggregates) as an example, Kelly is able to show how the use of materials flow analysis can alter the material composition of the end item. In this case, crushed cement is found to be economically feasible for use as road base, bituminous concrete, and cement concrete, as long as on-site crushing operations are installed. On-site operations decrease transportation costs and limit availability/accessibility problems. However, the physical property limitations of crushed cement means that the composition of the materials used in bituminous and cement concrete production must be "adapted". Bituminous concrete must have greater absorption capabilities than road base, and as such the recycled cement would need to be augmented with additional virgin material. Due to "finishability and workability" characteristics, cement concrete generally needs to have greater amounts of fine material (sand) in the mix than is provided by the RCA. As a result, the costs associated with production increase and may limit the use of recycled materials.

Kwak, Yoo, and Kim (2004) present a cost-benefit analysis of a policy developed by the Korean government to recycle waste agricultural film (WAF). Recognizing that existing landfills are quickly reaching capacity and that securing new land is difficult due to local opposition and that disposal by incineration has costs, emission, and hazardous waste problems of its own, the government launched a search for viable alternatives. Financed through an income tax, the "programme of enhancement of recycling the WAF" (PRWAF), is intended to reduce the land pressures of developing new landfill sites and also limit the environmental damage done by waste disposal. Kwak, et al, use a contingent valuation method (a dichotomous choice person-to-person survey) and maximum likelihood analysis in order to measure two issues within the program:

1) the net benefits of implementing the program

2) the degree to which the Korean people would be supportive of the program

Overall, the authors find the total economic benefits to the people of Korea for such a program would be between US$11.02 million and US$13.60 million annually for five years with the implementation of the PRWAF. Additionally, the survey finds that Koreans would be willing to pay between US$3.6 and US$4.40 per household per year to support a recycling program that reduces the use of landfills.

While most research is been concerned with the demand side of the municipal solid waste services, **Callan and Thomas (2001)** present a study of the cost structure of the services from the supply side of the market. The authors produced a multi-product cost function, employing a seemingly unrelated regression (SUR) to analyze two separate components of the solid waste system – disposal and recycling. Callan and Thomas find that by jointly offering waste disposal and recycling services a municipality can save approximately 5% over the costs of providing these services separately.

3.1.2 Disposal Policies

In the last several years there has been a significant amount of research performed on the most efficient policies to be used to encourage the use of recycled materials and to discourage the use of landfills. While there is no available literature that specifically addresses recycling policies for aggregate materials from an economic incentive/disincentive point of view, there is a significant amount on solid wastes in general. Therefore, I mention several works where economic incentives or disincentives are used to encourage resource reduction. In particular, I cite articles that address taxes on virgin materials, taxes and user fees on disposal (including unit pricing and advance disposal fees), subsidies for the use of recycled materials, output tax/recycling subsidy combinations, and recycled content standards.

Taxes on virgin materials are taxes on the use of material inputs and are based on the implied disposal costs for those materials. These "upstream" taxes are imposed on the producer and not the consumer and are intended to integrate resource conservation part of the production process. A disposal tax is one that is levied for the final cost of depositing waste (most often in a landfill) and is generally assessed in the form of "flat" taxes/fees or user fees. Flat taxes/fees call for a set charge for waste disposal regardless of the amount produced. These are most prevalent in communities where garbage collection is provided by the government and is paid for through property or utility taxes. In these circumstances, the marginal cost of disposing additional waste is zero and therefore, there is no incentive to reduce waste output and the policy leads to an overproduction of garbage (Fullerton, 2005; Fullerton and Kinnaman, 1996). User fees (unit pricing) are charges based on the amount of waste material disposed and they are usually determined on a weight, volume, or per container (bag) method. While this policy leads to reduction in landfill deposits, there is also evidence that it also leads to increased incidents of illegal disposal activities (dumping, burning, etc). Aggregate material disposal based on a user fee policy is analyzed in the results section of this dissertation. Advance disposal fees, a type of user fee, assesses a charge on the final product and is determined by the implied disposal cost for the associated packaging.

A second area of investigation in this dissertation is analysis of the impacts of a subsidy on the use of recycled material and a tax on waste disposal activities (landfilling). Subsidies are given to encourage or discourage an activity. In cases where the goal is to encourage recycling (reducing the dependence on virgin materials and landfills), a subsidy serves as a "reward" for using recyclable or recycled materials. However, due to the rewards for recycling, there is a disincentive to reduce consumption and this policy may instead result in an increase in the use of landfills.

A combination output tax/recycling subsidy is one in which generally a deposit is placed on material purchased and then refunded when the material (or its packaging) is returned. The goal of the policy is to incorporate the best of a tax policy with the best of the recycling subsidy policy, while mitigating the negative characteristics of each. In the case of waste reduction/recycling increase, the user fee is intended to encourage a reduction in the use of landfills, while the subsidy is meant to encourage alternative, legal means of disposal. The most common form of this policy, the deposit/refund system (DRS), is used most notably for beverage and plastic containers. Since aggregate material products are high volume-low value, heterogeneous products, establishing a subsidy for the return of waste aggregates is difficult. This dissertation therefore examines a different type of recycling subsidy component. In here, the recycling subsidy will be given in the form of a subsidized price on the purchase of recycled aggregate materials products.

A final policy approach is the use of recycled content standards, in which items produced for consumption are required to contain a specified minimum percentage of recycled material as part of the input.

3.1.2.1 Disposal Taxes and User Fees

Disposal taxes are costs for disposal of solid wastes and are paid for by the consumer. Along with property taxes as a means of payment, the most utilized form of the disposal tax is the user fee. User fees are a staple of many waste reduction and recycling promotion policies. These fees are intended to reflect the full social cost of waste disposal and are mainly amount-based or volume-based taxes. The most common types of fees are rely upon the number of containers used (i.e. per-unit tax programs) and the size of garbage container utilized (a proxy for the volume of waste disposed). The majority of literature discussed here and on disposal taxes/user fees overall concerns the disposal habits of household consumers. This differs from the analysis in this dissertation where the consumer is a larger entity (generally a municipality or firm) that uses the aggregates in the production of infrastructure (roads, bridges, buildings, etc). However, the actions of the larger entities may be influenced in much the same manner as the household unit and, as such, that literature will be discussed thoroughly. But I begin with a firm–related paper.

Conrad (1998) developed a partial equilibrium model that combines three elements of source reduction - waste prevention, waste recycling, and waste disposal - into one model as he compares the outcomes of applying taxes on *new scrap* waste disposal to taxes on the use of virgin materials. Conrad's paper differs from the work presented in this dissertation in the respect that he models an "upstream" tax – one that is applied to material that does not leave the processing plant, while I model a tax on the disposal of used materials – a "downstream" tax.

In addition to the combined three-element (waste prevention, waste recycling, and waste disposal) model presented, the major contribution of the article is the inclusion of waste as a by-product of either the end item production process and/or the recycling process. In other words, the author recognizes that, regardless of the process, there will be some waste created during a production process. He models that waste as part of a multi-product output. One output is the "original" product (with waste as a by-product), while the second output utilizes the original waste to create a "side-product" (with some additional waste remaining).

The author models a production process where waste is produced as a by-product of the operation. However, Conrad adds to the model by including a variable "e", which represents the "effort" taken to reduce waste at the production facility – noting that this "effort" entails additional (maybe significant) labor costs. This is represents the waste reduction element of production. The "effort" is modeled by adding variables for labor and labor cost (L and PL), while simultaneously decreasing the net waste to be disposed. The model is presented as a cost minimization process where labor costs, material costs, and disposal costs are constrained subject to the amount of labor, materials, and "effort" available. The benefit accrued through this process is due to the increased availability of material that can be re-introduced into the production of a side good (or sometimes added back into the manufacturing process for the original good) and the reduction in waste and disposal costs.

The waste recycling element of the process is handled next with amount of recyclable waste represented as a function of the gross amount of waste available and the percentage of waste that can be recycled (β). In total, the costs of recycling the scrap material are composed of costs for labor and gross materials, labor and other costs of recycling, and the cost of disposal of the remaining waste. Benefits are derived from not having to purchase additional materials for the secondary production process.

The final element (waste disposal) that makes Conrad's paper unique is the inclusion of a dual cost function that incorporates the two previously discussed elements in the model. For ease of analysis, this element is presented as a profit-maximization approach (as opposed to the cost minimization approach for the first two elements). By utilizing the dual cost function approach on this open industrial cycle model, the author reaches several conclusions. Of greatest interest to this dissertation is that:

- Both a tax on waste disposal and a tax on virgin material use produce greater recycling and waste reduction, but the tax on virgin materials has a larger impact on each
- Output losses are greater with the tax on waste disposal
- If producers of the waste do not bear the full cost of disposal there will be a bias toward the use of virgin materials
- A tax on virgin materials produces an awareness of waste issues at the beginning of the production process and thus reduces overall waste

As mentioned earlier, the majority of the studies performed involved individual household consumers and municipalities, but are appropriate for inclusion in this dissertation because of the common disposal issues involved.

Ferrara and Missios (2005) use ordered probit analysis of surveys from 1,409 single family households in twelve communities across Ontario, Canada to analyze the effectiveness of a variety of economic (unit pricing, free unit provisions, unit limits, recycling frequency, and mandatory recycling programs) and household characteristics on the efforts to encourage increased recycling of household waste. In this model, the unit pricing scheme is based upon a bag-tag program, in which households must purchase stickers to be placed on each standard size garbage bag (usually 32 gallons) before the garbage will be collected. Free unit provision programs are "bag-tag" programs in which a set number of bags are collected for free. The consumer is charged for any number of bags in excess of the free units. Under this policy, the marginal cost of disposal is zero for the free units, but is greater than zero for the "non-free" disposal. Unit (bag) limits set constraints on how much waste is collected and theoretically should increase recycling. Recycling frequency is a proxy for recycling subsidies and should further encourage recycling activities.

The authors looked at seven different materials (estimating seven different ordered probit regressions) found in the homes - newspaper, glass, plastic, aluminum, tin/steel cans, cardboard, and toxic chemicals. Ferrara and Missios conclude that user fees (bag-tag program) and mandatory recycling programs are the most effective policy instruments in increasing recycling intensity, finding the coefficients on the marginal price of waste disposal significant for all but one product (glass for the mandatory program and toxic chemicals for the user fee approach). Toxic chemicals are not subject to a user fee policy. Other applicable conclusions include a more frequent recycling collection cycle (a recycling subsidy) increased the amount of recycling for glass, aluminum, and toxic chemicals (coefficients positive and significant), but the provision of free units and limiting the amount of garbage collected (bag limits) discourage recycling for all materials.

Further evidence of the success of user fee programs in reducing waste material (and increasing recycling) is found by **Fullerton and Kinnaman (1996)**. In this study, the authors conducted a survey of 75 individual households in Charlottesville, Virginia in order to measure the demand for the collection of solid waste when the city government imposed a $0.80 per 32-gallon bag ($0.40 per 16-gallon bag) cost on garbage collection. There would be no cost for collecting recyclables. The authors find that increasing the price of disposal through increasing the price of each bag collected leads to a decrease in the weight of garbage by 14% and a decrease in the volume of garbage collected (measured by the number of bags/cans utilized) by approximately 37%. The discrepancy in the reduction of weight and the decrease in bags collected may reflect the "stomping" syndrome, where people compress trash in order to use fewer bags/cans. The authors also find evidence of illegal dumping, concluding that slightly over 5% of the households disposed of some waste illegally (dumping, burning, etc.). In order to conclude that illegal dumping existed, it was necessary to determine that:

1) The survey instrument included a question on method of garbage reduction. One of the options was "other". This needed to be checked.
2) During the weekly measurement of waste collected the amount of garbage collected had to fall to zero for four consecutive weeks.

Fullerton and Kinnaman also perform a "quick" cost-benefit analysis of the community's user fee program. The results indicate that the administrative costs of the program are greater than the benefits gained form the policy. Therefore, if costs and benefits were the only criterion for maintaining the program, the program should be eliminated. However, decisions also involve political, social, and environmental pressures which may sway the conclusions.

Callan and Thomas (1997) provide another measure of the effectiveness of a user fee in producing increasing levels of household recycling. The authors use annual *aggregated* data (not *individual* household data as utilized by Ferrara and Missios) on recycling and socio-economic characteristics in Massachusetts in order to estimate the effectiveness of eleven individual determinants and seven combination determinants. Six of the individual variables represent state and local government waste disposal policies, while the rest are socio-economic factors. This ability to evaluate the impacts of the user fees, individually and in combination with other factors, on recycling efforts is the major contribution of the work. The authors regress these variables on a measure for recycling intensity, the "ratio of MSW (municipal solid waste) recycled or composted to tons of MSW generated".

Unit pricing (user fees) is the only purely cost variable included in the study, with unit pricing being evaluated individually and also paired with two other policy variables - availability of curbside recycling availability and the availability of a materials recycling facility. Employing OLS estimation techniques, the authors find that a policy that institutes a user fee program for household solid waste disposal leads to a 6.6% increase in recycling efforts. Furthermore, if the user fee policy is combined with a curbside recycling program, recycling intensity increases by an additional 5.5% (a total increase of 12.1%) and if a materials recycling facility is available in the town, the recycling rate increases an additional 1.1% (7.7% in total).

The determination of increased recycling due to increased disposal costs is also found by **Hong and Adams (1999)**. In this work, the authors analyze the impacts of a block pricing program on waste disposal and recycling habits in Portland, Oregon. Block pricing is a unit fee program, but is different from the per-bag system in that with block pricing a household contracts for a given *volume* of service from the waste disposal provider. In Portland the consumer chooses from various sized carts (trash cans) and trash pick-up interval – the larger the cart and the more frequent the pick-up, the higher the fee. Consumers consider several factors when deciding the level of service to purchase, including the anticipated amount of waste created, the amount of recycling to be performed, and the opportunity for illegal waste disposal. The authors find that increases in the price differential for purchasing a larger volume of service (a larger cart), has only a small impact on the amount of non-recyclable goods collected (significant at the 10% level), but has a larger impact on the increase in the amount of recyclables collected (significant at the 5% level). The result of the effectiveness of a user fee program is corroborated by other work performed by Hong (alone and with collaboration). **Hong, Adams, and Love (1993)**, also using household data from Portland, Oregon, found that an increase in the user fee for garbage collection negatively affects the volume of non-recyclable garbage produced and positively affects the amount of recyclable garbage produced. Furthermore, the responsiveness of the change in renewables to the change in collection price is greater than is the responsiveness of non-renewables to the price change. **Hong (1999)** finds that in Korean households a unit price (price-per-bag) has a significant impact on recycling rates.

Not all research has found a significant correlation between increased user fees (per bag fee) and increased recycling efforts though. As mentioned earlier, Fullerton and Kinnaman (1996) find that a user fee program had a positive impact on recycling, increasing the weight of recycling collected by 16%. However, in a later work, **Kinnaman and Fullerton (2000)** determine that increases in the disposal costs have a negligible effect on household recycling activities. The authors use data aggregated from

114 communities with user fees and 845 communities without user fees (some with curbside recycling programs and some without curbside recycling to determine both the demand for garbage and the demand for recycling services as the unit price of garbage collection is changed. This model, different from others on the subject, allows for endogenous changes in the price of collection and other policy options. The model determines the maximum utility of households as a function of consumption (c), garbage collected (g), recycled material collected (r), illegal disposal (b), and a set of demographic characteristics (ά), subject to income, consumption amounts, and the prices of the different disposal options. The authors use a Probit model to calculate the marginal effects of having a free curbside collection policy, finding that the probability of having free curbside collection decreases in communities with existing deposit-refund systems and with each additional person in the household. The probability increases with increasing levels of education, greater residential spatial density, and higher tipping fees at the landfills. Other variables, most notably state provision of economic incentives, state purchasing of recycled materials, and mandated recycling quotas are not found to have statistically significant effects.

Whether or not to implement a price per bag user fee is determined by the communities based on cost-benefit trade-offs of having such program. On one hand, having the fee likely produces greater income and covers some of the disposal costs, while reducing the landfill demand. However, incorporating a user fee is also likely to encourage greater illegal disposal of waste material. The price per bag cost is therefore determined by the communities and is assumed to provide the greatest return. The authors incorporate the observed optimal cost of a per bag price into a Tobit model.

Among the results generated, Kinnaman and Fullerton find that increasing levels of education is the only demographic independent variable that has a significant and positive impact on the price of unit fee. Increasing levels of income have a negative effect on the price of each bag of garbage collected. No other demographic variables have a significant impact on the price per bag of waste collected. Other variables estimated, including yardwaste bans, increased tipping fees, and the time needed to implement recycling quotas have positive and significant impacts on the price of the price per bag program. Implementing a required quota program has a significant and negative impact on the price of the per bag policy.

The final portion of the paper is devoted to OLS analysis of the effects of implementing a price per bag policy. In this model the total amount of waste and recycling amounts are regressed on twelve demographic and policy variables. he authors find that a $1 per bag increase in collection costs results in a 412 pound-per-person per-year reduction in garbage generated, but only a 30 pound-per-person per-year increase in recycled materials. The "disappearance" of 382 pounds of waste per person per year may result from source reduction, including composting, burning, and illegal dumping.

Other notable studies that failed to find a significant positive correlation between unit pricing and increased recycling intensity include **Martinez (2004)**, **Jenkins, Martinez, Palmer, and Podolosky (2003)**, and **Reschovsky and Stone (1994)**. Martinez takes household-level data from twenty MSAs across the United States as he analyzes the impacts of curbside recycling and unit pricing as means to encourage additional recycling. Employing ordered Logit regression analysis on five materials (glass containers, aluminum, plastic bottles, yard waste, and newspaper), Martinez argues that implementing curbside recycling programs increases recycling intensity, but the effectiveness of unit pricing is "unclear". The author finds that for three (newspaper, aluminum, and yardwaste) of the five materials analyzed, increasing the per-unit cost of disposal decreased recycling efforts, while the other two materials (glass bottles and plastic bottles) showed increases in recycling intensity. However, none of the outputs were statistically significant. Martinez hypothesizes three possible reasons for this "non-impact":

1) The relatively high average income-households surveyed (approximately $40,000) may not be affected by the estimated $1.91 average cost of disposal.
2) Households may be disposing of material in other manners (i.e. illegal dumping and burning) than garbage pick-up and recycling.
3) The surveyed households are part of a subscription can programs, which provide a weaker incentive to recycle than other pricing systems, such as bag-tag programs.

Much of the material presented by Martinez grew out of the work performed by Jenkins, et al (of which Martinez was second author). For the earlier work, the authors use maximum likelihood estimation in an ordered Logit model to investigate the impact of unit pricing (as well as curbside recycling availability and demographic characteristics) on recycling habits of over 1000 middle and upper income households in twenty MSA around the United States. As with the Martinez dissertation, the authors utilized household-level data collected data on five separate materials – newspaper, glass bottles, aluminum, plastic bottles, and yard waste – with the analysis showing that increases in the per unit disposal price for garbage does not significantly increase recycling efforts. The authors do find however that convenience of recycling (curbside over drop-off) and the length of existence of the recycling programs have significant and positive impacts on recycling program intensity.

Reschovsky and Stone reach similar conclusions. In their work, the authors surveyed 1422 households in the Tompkins County, New York area about their recycling habits involving six different materials – newspaper, glass, plastic, cardboard, metal and compost. They found that while curbside recycling programs, in conjunction with a user fee program, increased recycling rates by 27% to 58% (depending on the material), user fees alone have little impact on the recycling intensity of the community.

3.1.2.2 Output Tax/Return Subsidy (Deposit Refund Systems)

An output tax/return subsidy has generally been found to be the most efficient policy for waste reduction as it provides incentives for recycling, while avoiding much of the illegal disposal problems (Calcott and Walls, 2005; Sigman, 1995; Fullerton and Kinnaman, 1995; and Dinan, 1993). As mentioned earlier, the most prominent of this type of policy is the deposit-refund system (DRS). With a DRS a container for a product is purchased as part of the product (think soda bottle and soda) and when the container is returned for recycling or re-use, a portion of the original payment is refunded to the consumer. If the material is not returned then the deposit is retained and is, in essence, a tax on disposed material. Glass bottles and certain types of plastic containers are the most prominently featured in these operations.

Calcott and Walls (2005) evaluate a deposit-refund system as part of their analysis of two recycling program options – a curbside collection option where there is no payment for returned materials and a "reverse vending machine" or drop-off option where payment is received upon return of the waste. A "no recycle" policy and implementation of regulations (mandatory prices received for recycled materials) are also evaluated in the paper. Calcott and Walls present a model where outcome is determined in a constrained optimal environment and in which the degree of recyclability is determined by the cost associated with recycling the material. In this model the authors incorporate four stages of the product life cycle (extraction, production, consumption, and removal (disposal or recycling)) with two different resources (material and "non-material") as they focus on the distortions to the recycling and "Design for Environment" (DfE) markets created by transaction costs. "Design for Environment" is the idea is that manufacturers are responsible for producing goods that use materials that are more suited for recycling and in return for the "improved" product design, producers receive compensation incentives.

The model assumes a steady state where all recyclable material created is used by manufacturers in the production process. The model also assumes that there are no market distortions due to taxes and that the products manufactured have varying amounts of recyclable materials. The latter assumption guarantees that some products will be recycled and others will be landfilled. The model further assumes that firms have heterogeneous cost functions, but that the presence of diseconomies of scale prohibits firms from growing large enough to gain market power.

Through their model, Calcott and Walls reach four conclusions;

1) Regulation is generally unnecessary and may produce inefficiencies that are not present if the market is left alone.

2) Deposit-refund systems can operate successfully even when curbside recycling is provided. The markets created by the DRS provide incentives for Design for Environment operations.

3) Producers should bear the social costs of disposal and therefore should not be able to keep unclaimed profits from unreturned waste material.

4) The combination of a DRS along with a small disposal fee helps produce a constrained optimal output. The disposal fee must be set equal to the social cost of disposal minus the difference between recycling costs and extraction costs for virgin materials.

Sometimes the administrative costs of providing a deposit-refund system are prohibitive and therefore make the program impractical. Such is the assumption of **Dinan (1993)**. Whereas Calcott and Walls evaluate DRS for general household waste disposal, Dinan concentrates on the analysis of products that make up significant portions of the waste disposal total (old newspapers - ONP) and those waste materials that have high social marginal costs (batteries). Using these two materials the author compares the efficiency of a disposal tax/re-use subsidy to a tax on virgin materials as a method to reduce the amount of waste material generated in households (source reduction). The author models three different scenarios for disposal – resource use under the socially optimal solution, resource use under a virgin material tax, and resource use under a combination disposal tax and reuse subsidy. He determines that the tax on virgin materials is not an efficient way to persuade consumers to reduce waste disposal at landfills, finding instead that the tax does not encourage the use of recycled goods in products where virgin materials are not originally used and may actually lead to increases in material deposited in landfills. Dinan argues instead for a combination of the disposal tax and a subsidy for the re-use of materials, as long as the tax is set equal to the future deposit costs and the subsidy is set to the current cost of disposal. This is consistent with one of the approaches used in this dissertation - the implementation of a combined tax on aggregate materials deposited in a landfill with a subsidy for the use/purchase of recycled materials.

By introducing distance elements and pick-up frequency variables **Ferrara (2003)** presents a slightly different conclusion in her analysis of the user fee and deposit-refund (DRS) approaches. The author presents a model for waste disposal in which utility is maximized given variables for consumption of goods (with varying amounts of waste), leisure time, waste accumulation on property (disutility), and the total amount of waste in the landfill (disutility). The function is subject to constraints based on time available for leisure, recycling efforts, and dumping waste materials. Additional restrictions are based on household income, the subsidy for recycling material and the cost of disposing waste. Ferrara finds that an optimal waste management policy for waste disposal can be developed based on a distance-from-landfill related consumption tax and recycling subsidy. The author determines that the further away a household is from the landfill, the greater the amount of waste it produces, the less it recycles, and the more it illegally disposes. As a result, Ferrara determines that households that live further from the landfill would pay a greater consumption tax and receive a lower recycling subsidy for their waste. However, the author recognizes that the developed policy is unlikely to be adopted as people are not going to accept a policy that penalizes those living a further distance from the landfill. As an alternative policy (which also provides a socially optimal output), Ferrara suggest a policy based on the frequency of pick-ups. Under this scenario, homes that live closer to the landfill (and are therefore more subject to the disamenities of the landfill) would have material to be recycled picked up more frequently than those who live further away, but would also have their non-recyclables picked up less frequently. The increased frequency of recyclables pickup serves as a "subsidy" for recycling and the decreased frequency of garbage pickup is an output tax. The policy includes a uniform consumption tax and a uniform recycling subsidy throughout the community, regardless of proximity to the landfill.

Palmer, Sigman, and Walls (1997) develop a partial equilibrium model for solid waste generation in order to assess the cost effectiveness of three policies (Deposit-Refund Systems, Advance Disposal Fees, and Recycling Subsidies) intended to reduce solid waste disposal and encourage recycling. The authors use data on five different waste materials (paper, glass, plastics, aluminum, and steel) to determine an "intervention" price – the price necessary to be paid in order to reach specified levels of waste reduction. The model uses three different equations - a "mass balance" equation and two market clearing equations (one for recyclable goods and one for recycled scrap material) - along with elasticities developed in previous literature and price and quantity data to determine the intervention price for overall waste reduction, as well as for identical levels of waste reductions for each material. The mass balance equation has the amount of waste disposed net of the quantity of a good consumed and the amount of the good recycled (W = Q – R). Illegal disposal of waste material is not considered in this model. The authors then combine the mass balance equation with the two market clearing equations produces an equation for waste disposal, where the amount of waste disposal is a function of recycling rates and the prices of recyclable and non-recyclable goods. Adjustments to the equations are made to incorporate the three policy options, previously determined elasticities, and prices and quantities for the intermediate goods evaluated. With this information, Palmer, et al is able to determine the costs of reducing a specific amount of waste material taken to the landfill (or other legal operations).

As presented in the model, the three policies are directed at firms (producers), not households (consumers). Therefore the producers pay the deposits under the DRS option and pay the disposal fees under the ADF option. The refund generated under the DRS option is paid to the end item possessor of the product. As pointed out in the article, for example, if the producer manufactures aluminum cans in the soda industry, they would pay the deposit when they purchase the aluminum sheets, but the person who sells the can to the recycler gets the refund. The same principal applies to the recycling subsidy – the person/firm that returns the material for recycling receives the subsidy. This arrangement produces an advantage for the DRS as it creates incentives to both recycle (refund to consumers) and reduce waste (avoid deposit/tax for producers). With ADF and subsidy programs only one side of the argument is addressed.

Results from the model indicate that overall, in the absence of high administrative costs, the deposit/refund system achieves the goals at the lowest cost, with a 10% reduction costing $45/ton, while the cost for the ADF program is $85/ton and the cost for the recycling subsidy is $98/ton. The paper also concludes that reducing waste for some materials is easier than with others and therefore identical reduction targets for all materials are inefficient. Using the least cost method (deposit/refund) the marginal cost of reducing every waste component by 10% would be $70/ton (compared to the $45/ton for an overall 10% reduction). Finally, using price and quantity data from 1990, the authors determine that a 7.5% reduction in waste would have been efficient under the deposit/refund system.

The Palmer, et al article complements other studies performed by Palmer and Walls (Palmer and Walls (1999), Palmer and Walls (1997), and Palmer and Walls (1994)). The 1997 paper compares the deposit/refund approach to a recycled content approach in an effort to determine which policy generates the optimal amount of landfilled waste (and thus, the optimal level of recycling). The study first models the socially optimal levels of waste in a perfectly competitive market. Both producer and consumer behavior are represented in the model, with production output modeled as a function of virgin material use, recycled material use, and labor. Additionally, a production residual is incorporated into the model which allows for the production of waste materials. All prices (output, virgin material inputs, recycled materials, labor, and disposal of waste residuals) are taken as a given. Consumer behavior is modeled using an inverse market demand function. The socially optimal levels of virgin material use, recycled material use, labor, and residuals produced, and consumption are then determined by "maximizing net social surplus subject to a mass balance equation".

A component for deposit/refund is added by incorporating a tax on outputs and a subsidy for recycling (the refund portion) and then profits are maximized with producers choosing the desired (profit-maximizing) levels of virgin material use, recycled material use, and labor. Recycled content is modeled by introducing a term in which a percentage of the material inputs are from recycled materials (β). The socially optimal outcome cannot be achieved by β alone. In order to do determine the socially optimal outcome, the authors include variables that represent a tax on output and a tax on labor. From here the firm's profits are maximized by finding the level output tax and labor tax that result in a socially optimal solution (with respect to recycling use and labor). The recycled content standard has several shortcomings, including the economic and political problems when additional taxes are implemented. Additionally, determining the appropriate level of taxation is difficult to achieve. Comparing the recycled content results to those of the deposit/refund, Palmer and Walls conclude that the deposit/refund program provides a superior approach as the levels of deposit and refund are relatively easy to set and achieving the socially optimal levels of waste disposal, input usage, and production levels does not involve the imposition of additional taxes and/or subsidies.

In the 1999 article, the authors examine the possible effectiveness of different policy tools on Extended Product Responsibility (EPR) programs. EPR "embodies the notion that agents along a product chain should share responsibility for life-cycle environmental impacts of a product, including those associated with ultimate disposal". EPR usually focuses on "take-back" programs, in which manufacturers are required to take back end of life materials and then dispose of the material. Palmer and Walls determine that, when compared to the take-back approach, a combination upstream product tax and recycling subsidy provide a less costly, more efficient method of disposal and increases recycling rates. As with traditional Pigouvian taxes, the combination policy tool encourages waste reduction and input substitution, but does so without providing the incentives for illegal disposal that Pigouvian taxes do. The 1994 Palmer and Walls article compares DRS programs to taxes on virgin materials and finds that the virgin materials tax is likely to result in greater negative impacts on the overall economy and is more difficult to administer. The authors also determine that households are more likely to accept programs that encourage the "cleaning up" of the environment and, as such, are more likely to support recycling subsidies that are part of the DRS program. (Fullerton and Raub, 2004)

Sigman (1995) examines another deposit/refund policy intended to advance the recycling of a specific product (lead - particularly from automobile batteries) and therefore reduce the environmental damage from their disposal. The author compares the results from a tax on virgin materials, a subsidy for recycled material production, a deposit-refund program, and a recycled content standards program.

By applying a virgin materials tax on lead the author determines that the tax imposes costs to both the primary producer and consumer in excess of the revenues generated from lead sales; however, the price increase is not passed on to the recycled lead consumer. The deposit-refund system, as developed by Sigman, imposes costs to the non-recycling consumer in the same manner as does the virgin material tax. The only difference is the manner in which money is returned to the consumer. With the virgin material tax, the return is generated from higher prices paid for used batteries, while under the DRS the money is refunded through a direct payment when the battery is returned. The subsidy for recycling lead is a direct transfer to users of lead-based products from those outside the lead market. The subsidy results in net lower prices for the lead products. As recycled and non-recycled lead are modeled as perfect substitutes for each other, the price of recycled product will be equal to the price of the non-recycled product for consumers. The result of the lower price is that consumption of these lead products increases, possibly making for a worse disposal situation. Implementing a revenue neutral recycled content standard that allows for permit trading produces a decline in the producer price of lead; however, the effect on the price paid by consumers is determined by the recovery rate elasticity (ε_r) and the secondary supply elasticity (ε_v). If $\varepsilon_r > \varepsilon_v$, the consumer price increases; otherwise the price declines. Therefore, the consumers may or may not purchase more lead-based products such as batteries.

OLS analysis by the author finds that the recycling of lead from batteries and other lead-based products is responsive to changes in prices and that achieving desired disposal rates is most cheaply done by imposing either a virgin materials tax or a deposit–refund system. (Recall that the costs to consumers are the same for the two policies – only the method of monetary return is different) The recycling subsidy is the most expensive program since it decreases the price of lead and leads to further consumption.

Other articles of interest include the work done by **Marco Percoco (2004)**, in which he compares the possible outcomes of four policy alternatives - unit pricing (weight or volume based), virgin materials tax, deposit-refund system (DRS), and recycled content standards programs – on the ability to achieve the socially optimum outcome in Italy. Percoco finds that both unit pricing and DRS can achieve a socially optimal outcome, but as found by several others, the DRS may be preferable since the unit pricing systems may provide incentives for illegal disposal. The recycled content standard is the least preferred option since would involve additional taxes and that unless firms have the same production function (as modeled by Percoco), they would need to have different required levels of recycled material use in order to reach a socially optimal output.

The majority of the literature concerns combination output tax/return subsidy policies in which the tax and the subsidy are connected, such as when the packaging material must be returned before a refund is granted (a type of DRS). However, this is not the only tax-refund scheme investigated. The process presented in **Fullerton and Wolverton (2002)** involves a disconnected relationship, where the recycling subsidy is not dependent on returning the packaging, nor is the tax paid upon purchase of the material. In this work the authors use a general equilibrium model to examine a two part presumptive tax and environmental subsidy policy, where the tax and subsidy are not directly linked. In this study, the authors implement a "presumptive" tax on production, which is intended to reduce production and consumption. A "presumptive" tax is one in which the presumption is that the material will be thrown away and not reused in any manner. The tax is coupled with an environmental subsidy that is applied to all non-waste inputs and is given only when "clean" technology is used or part of the good is recycled. The subsidy makes the waste materials relatively more expensive and therefore should result in lower waste per unit of output. The main advantage of this program is that "both parts apply to market transactions with invoices to ensure compliance".

Fullerton and Wolverton demonstrate that their "two-part instrument" produces identical results to those from a properly applied Pigouvian tax on waste. However, as also noted by numerous other authors, the Pigouvian approach has problems that render it impractical. The authors conclude that a Pigouvian tax is not feasible, since many forms of waste are not measurable (emissions from tailpipes) or it is easier to cheat or both. The authors also conclude that even where a Pigouvian tax is feasible, it has higher social and administrative costs and enforcement is difficult. There is also a political appeal to consider. With the "two instrument" policy, the tax is not generally applied to the consumer or producer, but is reflected more in the market structure and the opportunity for a refund is a popular characteristic. Other advantages of the two-instrument program include 1) the two parts of the program do not have to apply to the same side of the market – the consumer may be eligible for the refund and the firm can pay the tax; 2) the tax and subsidy do not have to be equal and; 3) the tax and subsidy can apply to different materials.

Most of the work in the field finds that an output tax/return subsidy (deposit-refund system) is the most efficient policy for reducing solid waste and encouraging recycling. However, this is not the universal position. In their paper, Dewees and Hare (1998) evaluate three separate policies – subsidization of recycling, a mandatory deposit-refund system, and source reduction through conversion to more "recycle-friendly" materials in an effort to determine the most efficient approach to reduce packaging waste and lengthen the life of landfills. An example of source conversion is the use of aluminum cans instead of glass soft drink bottles. There are four materials evaluated in the paper - glass, steel, aluminum, and plastic.

Dewees and Hare find that the costs of running a deposit-refund system for the materials is high, citing studies where the costs of collection and processing range from 3.9¢ to 4.9¢ for refillable soda bottles and from 3.3¢ to 6¢ per container for beer bottles. Additional cited studies on the California DRS finds a profit can be made with a deposit-refund program for aluminum containers, but per container losses occurred for glass and plastic (PET) products (2.2¢ and 7.7¢, respectively).

The authors find that a lower cost alternative to a DRS program may be policy in which a packaging fee may be used to subsidize recycling. This fee would be paid by producers and might be considered fair in light of the incurred disposal costs on municipalities, while producers and industries profit from the product consumption. However, the authors suggest that recycling most containers, especially glass, has generally not been accepted by the public. Therefore, the authors believe that emphasis should be placed on source reduction, where success in Canada has been demonstrated in several markets. As an example, the authors present data from the Ontario, Canada area in which conversion from glass to aluminum in soft drink packaging resulted in significant declines in packaging (by weight). Specifically the weight of packaging for soft drinks fell from 218 grams per liter of beverage consumed to 19 grams per liter consumed between 1972 and 1995. This occurred despite dramatic increases in the amount of beverages consumed and recycling averages of only 35% to 50% of beverage containers sold and the end result is less landfilled material (by weight).

Other econometric work of importance on output tax/return subsidies include that performed by **Eichner (2003)**, in which he performs a partial equilibrium analysis of a consumptive good from "birth to grave" - that is, as the good is "produced, consumed, recycled, and finally landfilled". In this model the producers and household consumers operate in a perfectly competitive market place, while the recycling firms are in an imperfectly competitive industry (as carried out under the German "green dot" program). The author examines the impacts of an output tax on the consumptive good and subsidies on the recycled material and on recycling services concluding that the deposit-refund outcomes are unlikely to be implemented due to political (tax) and practical reasons.

However, he determines that the combination of a tax on the end good, a subsidy on the use on recycled material, and a subsidy on the use of recycling services produce an efficient outcome that does not run afoul of the political situations.

A different approach is utilized by Highfill and McAsey (2001 and 1997) and Huhtala (1997) in four separate papers, with each of these papers utilizing optimal control models. **Highfill and McAsey (2001)** use a dynamic optimal control model in which income is allowed to grow over time to measure municipal landfilling and recycling trade-offs. Recycling is seen as a backstop waste disposal technology to landfilling. In this model the municipality has an exogenous stream of income that is divided between consumption and waste disposal expenses. The authors conclude that municipalities with high levels of income should participate in recycling programs, while low income municipalities should exhaust existing small landfills, but not large landfills. The paper also concludes that once recycling begins it will continue for the life of the planning period. The two other papers that address the landfilling-recycling trade-offs with dynamic or optimal control modeling are **Highfill and McAsey (1997)** and **Huhtala (1997).** The first paper concludes that a municipality that recycles will always recycle and recycling will always increase, while landfilling will decline. The **Huhtala (1997)** paper develops an optimal control model that "accounts for the physical costs of recycling, the social costs of landfilling, and consumers' environmental preferences". Using this model and waste disposal data, the author determines that recycling rates of 50% are economically and environmentally feasible.

3.2 Fixed Price Input-Output (I-O)

Input-Output (I-O) models, originally developed by Wassily Leontief, often form the "backbone" for general equilibrium models (CGE included), so it is necessary to provide some background on the technique. As defined by Berck and Hoffmann (2002), I-O models are "highly disaggregated, fixed-price, fixed-coefficient, demand-driven, economy-wide simulation models that can be used in economic projections for industry, government, and household economic activities". I-O is modeled so that the interdependence of an economy's various productive sectors is observed by viewing the product of each industry, both as a commodity for consumption and as a factor in the production of itself and other goods. As implied above, and expressed by Hefner (1997), the basic idea of I-O models is that the outputs of some industries are the inputs of others, creating an inter-industry flow of activity throughout the economy. This flow of activity is most often displayed in a matrix. The columns in the matrix represent the input requirements generated by one unit of output on all producers and are used to capture the direct, indirect, and induced effects of demand for the good. Direct and indirect effects capture the impacts of changes in final demand. Induced effects are those income or employment effects that are triggered by household consumption expenditures. In other words, induced effects capture the "additional expenditures resulting from increased earnings of local residents as a result of the increase in final demand".

Closely aligned with the material in this dissertation is the work of **Duchin and Lange (1998)**, where they look at recycling one resource – plastics. Noting that the use of plastics in industry continues to grow and that plastics have the lowest recycling rate among the major municipal solid waste materials (in part due to deteriorating physical properties of recycled plastics), the authors utilize a 90-sector database with eight different categories of plastic in an investigation into the conditions under which industrial plastics recycling will increase and pressures on landfill space will be reduced. One data adjustment that had to be made in was for the differences in reporting units for different factors – i.e. some inputs are reported in monetary units, while others (such as petroleum) are reported in physical units (gallons, tons, etc.). Conversions are performed by adding a separate row outside the I-O matrix where the physical elements are quantified.

Duchin and Lange produce two scenarios - a baseline scenario where the industry recycling environment remains status quo (much greater use of virgin materials) and one with estimates of the amount of recycled plastics the main industrial users can be expected to absorb. After identifying the possible sources of recyclable plastics, Duchin and Lange report the results of the scenarios. Under the baseline scheme the use of plastics is expected to increase by 47%, with limited use of recycled plastic materials and therefore greater reliance on virgin plastics. With the recycling scenarios, the total amount of plastic used is expected to be approximately the same as in the baseline scenario; however, the use of virgin plastic is expected to decline by 11%.

Kagawa, Inamura, and Moriguchi (2004) present a multi-regional input-output analysis of waste disposal patterns in which they discuss the impact that disposal policies from different regions in Japan have on other regions in the country. Using data collected by the local Japanese governments, the authors combine a multi-regional physical I-O model (material measured in tons) with a multi-regional monetary I-O model (measurements in yen) for a 69 sector industrial waste and 42 sector commodity sector economy to determine the intra- and inter-regional flow of material waste between nine regions in Japan. The model demonstrates that the inter-regional effects of waste disposal can be significant, with one case showing the household consumption and disposal habits of the Kanto region having a greater impact on waste disposal operations in the Shikoku region than did the disposal behavior of Shikoku residents have on their own local operations.

A previous merger of the physical and monetary I-O models was presented by **Kagawa, Inamura, and Moriguchi (2002)**. In this study, the authors develop a process that merges physical I-O modeling techniques with monetary I-O techniques in an effort to estimate the "intermediate requirements embodied in the final disposal" (landfilling, incineration, and recycling) of the wastes produced by households and industries. The ability to estimate the final disposal value within the framework of the model is the main accomplishment of the paper. The merged techniques process is a "hybrid input-output model with non-marketable joint production" (final goods and services and scraps and wastes) to develop invisible factor multipliers. One of the main conclusions finds that when scrap and waste requirements are presented in terms of the "invisible" multipliers the results can be interpreted to show that when recycling is encouraged (and therefore other forms of disposal are discouraged simultaneously) the end result is a decrease in the demand for recyclable materials as an intermediate good.

Creason and Podolsky (2001) use I-O techniques, with data from 42 state-level models, to estimate the direct, indirect, and induced economic impacts of recycling programs for newspaper, glass, and aluminum products. The waste and recycling data are collected from municipalities around the nation and then aggregated into state-level data sets. Since recycling is not an activity captured in national I-O matrices, the authors produce another I-O sector by incorporating the net revenues from three independent sectors – landfills and collection, program administration, and processing.

For direct economic effects of municipal recycling programs, the authors find positive revenues created for each of the 42 states analyzed, with totals ranging from a low of $83 per ton recycled (Rhode Island) to a high of $977 per ton recycled (Arkansas). Net indirect and induced effects are also positive for the states.

The authors conclude that while recycling increases the costs of waste management, spin-offs to other industries creates positive economic impacts, with increases in economic output and employment in almost every state (Montana showed a net impact of zero jobs created). As a result of the spin-off activities there is a small net positive effect on state economies.

The Creason and Podolsky article builds on the earlier I-O work by **Butterfield and Kubursi (1993)** and **Klein and Robison (1993)**, in which the economic impacts of recycling waste are investigated. Contrary to the Creason and Podolsky article, Butterfield and Kubursi show employment losses in Canada (Ontario) result as a consequence of increased recycling initiatives in Canada and the United States. The authors find that the negative impacts are greater as a result of US initiatives because of the ability of the Canadian economy to substitute job losses in the primary industries with increases in employment in the recycling sector. Klein and Robison use cost data (*Pollution Abatement Costs and Expenditures (PACE)*) for manufacturing industries in 1977, 1982, and 1985 to compute the direct and indirect costs of waste disposal (proxies for incentives to reduce solid waste). The values reported in the article show a trend toward increasing disposal costs per dollar of output from 1977-1985, with the trend continuing through 1988 (non-reported values). Cement is "housed" in the materials intensive industry sector, which is one of the higher disposal cost sectors. The total disposal costs for cement in 1985 were over 0.5 cents per dollar of output. The authors conclude that the rising disposal costs present firms with incentives to reduce the amount of solid waste they send to landfills and that this results in the development of new technologies and increased emphasis on recycling.

Life cycle analysis (LCA) is a cradle-to-grave examination of the environmental and economic effects of a product at every stage of its existence, from production to disposal and beyond. As stated by **Duchin and Levine (2006)**, "the LCA community has created a significant body of best-practice methods and shared data and increasingly incorporates their analyses within input-output models of entire economies to capture that portion of the impact that would otherwise be overlooked". As an example of the work performed, **Pan and Kraines (2001)** utilize an input-output framework to examine two different aspects of the life cycle of analysis – impact avoidance (pollution abatement) and end-of-life waste material reduction (resource recycling). However, this LCA model (and others like it) does not specifically address the waste creation-disposal flow processes. That was the case until 2002 when **Nakamura and Kondo** developed waste input-output (WIO) analysis. Waste input-output analysis is a hybrid LCA process in which there is a mutual dependence between the flow of goods and solid waste. As developed by Nakamura and Kondo, WIO is an extension to the Leontief environmental input-output (EIO) model that includes an engineering process model of solid waste disposal in order to include the specific input-output relationships of waste treatment – i.e. that they are significantly affected by the level and composition of waste feedstock.

In their work, Nakamura and Kondo aim to determine the optimal methods of waste management in order to lessen the dependency on landfills, while also limiting environmental damage. The authors begin by developing two WIO tables of estimates for Japan – one that has the estimates for the flow of inter-industry goods and a second that has the estimates for the flow of waste. The tables are then combined to produce a square matrix that can be used for the IO calculations. Results of the model indicate that Japan could reduce its CO_2 emissions by concentrating waste incineration (a major method of waste disposal in Japan) into a few, large facilities. Increased sorting of materials (i.e. plastics) and then recycling or incinerating them would lessen the dependency on landfills also.

Several other WIO papers merit mentioning here. **Kondo and Nakamura (2005)** present a decision analytic extension of the WIO model that includes aspects of linear programming. The model, known as the Waste Input-Output Linear Programming (WIO-LP), extends the original model by incorporating the ability to select and analyze a set of feasible waste management technologies and strategies through use of linear programming techniques. In this paper the authors minimize the environmental load (impacts) of each management strategy, subject to the technologies available for each scenario and the flows of goods and services.

Kondo and Nakamura apply the model to an eighty sector data set of the 1995 Japanese economy which includes five alternative waste treatment technologies and two alternative recycling technologies (blast furnace and recovered/recycled materials). The authors employ the model to identify the waste management and recycling strategy so that the "eco-efficiency maximizing frontier" (or "environmental impact minimization frontier") can be quantitatively determined and plotted. Any waste management strategy that lies on a frontier produces the best available eco-efficiency level, while moving to the northeast portion of the graph increases the best available level of eco-efficiency. Any strategy lying inside the frontier would be deemed inefficient and any strategy on the outside is deemed infeasible (unattainable).

Other WIO papers which have implications for the subject matter includes those produced by **Kagawa (2005)** and **Nakamura and Kondo (2006)**. Kagawa (2005) incorporates income distribution, household consumption, and household waste production in order to create a "household-endogenized" WIO model where the "hidden money" flow from household waste disposal behavior is analyzed. Using this method the author finds that waste disposal activities (combined industrial and household) in Japan produced 0.1% of the GDP output in 1995, with household disposal services contributing almost 1.5 times more to the GDP than did industrial waste collection and treatment.

Nakamura and Kondo developed the WIO life cycle cost (LCC) analysis model to analyze the environmental and economic impacts of disposing of a specific set of products - electrical home appliances when they at the end of their life cycle. Life cycle cost varies from life cycle analysis in that LCC is an analysis of the amount of money necessary to own, operate, and maintain a product over its useful life and in this case includes the cost of disposal, while LCA is an "assessment of a product's full environmental costs, from raw material to final disposal, in terms of consumption of resources, energy and waste". Three end of life scenarios were considered – 1) landfilling; 2) intensive recycling; and 3) intensive recycling with "Design for Disassembly (DfD)". DfD is the is a disassembly process in which disassembly of products is carefully planned and carried out in a manner that doubles the efficiency of disassembly and can raise the purity of some recovered material up to the virgin level (some types of plastics). The authors find that from an LCA position intensive recycling of electrical appliances is the most costly form of disposal (landfilling is the least expensive), but the recycling costs can be significantly reduced by implementing DfD and by implementing a carbon tax.

3.3 The CGE Literature

The research that most closely relates to the work presented in this dissertation was performed by **Okushima and Yamashita (2005)**. The authors develop a multi-sector applied CGE model of waste management issues in Japan in which price substitution effects are evaluated after the implementation of a nationwide industrial waste tax. The model, ODIN-WR, allows for the consideration of price substitution effects between primary and secondary (recycled) goods.

The ODIN-WR model developed for the research provides a detailed description of the production and consumption structures of the economy, as well as the interdependence between elements of the economy. The authors explain that the ODIN-WR model adopts capital-energy separation as the model structure as opposed to most other CGE models (such as the one developed for this dissertation) which use a value-added structure in the framework. The Okushima and Yamashita model is comprised of 21 industrial sectors and four energy sectors that include primary and secondary goods for seven different sectors (agriculture, mining, food paper and pulp, ceramic, stone and clay, iron and steel, and non-ferrous metals). The primary and secondary materials sectors compete with and substitute for each other. In addition to the 21 production and four energy sectors, the model also has sectors dedicated to households, government, and investment. Data for the model was obtained from the use of input-output tables from the Japanese government (Management and Coordination Agency), as well as from the Discharge and Disposal Situation of Industrial Waste (Ministry of Health and Welfare). Due to variations in the manner in which statistics on waste generation and disposal are reported the authors needed to estimate the amounts of recycling and final disposal by industry and item.

The price incentive policy (waste tax/recycling subsidy) examined in the paper is devised to be a tax on the producers of waste and to provide a subsidy for the receivers of the waste (recyclers). The policy is efficient as both the tax and the subsidy are assessed in proportion to the amount of waste created/accepted. Furthermore, the tax is limited to reduce final waste disposal by no more than 10%. If a greater waste reduction is targeted, the tax would need to be increased, and so would the price of the primary goods. The resulting increase in price would also lead to increased production costs for the secondary industries. If the production costs to the secondary producers end up exceeding the revenues, the secondary industry would shut down, resulting in a failure of the model.

The authors next address the elasticity of substitution, noting that as the elasticity increases the easier becomes the price substitution between primary and secondary goods. Using figures from existing literature, Okushima and Yamashita run simulations with the elasticity of substitution established at 0.3 and a tax of 1,200 yen. The simulation yields a reduction of industrial waste of 65 million tons – 6% of the business-as-usual (BaU) reference case. Through the proposed policy the authors find that:

- Industries that discharge a lot of waste per unit of production are hurt by the waste tax policy
- Industries that are in a highly competitive situation with secondary (recycled) goods are also hurt by the policy
- Industries that use large amounts of recycled materials (such as aggregates) in production benefit form the policy

The authors conclude that the price incentive policy can produce an efficient reduction in final waste disposal, believing that the policy stimulates the growth of secondary industries while doing little damage to the primary industries.

Thiele (1999) and **Wiebelt (2001)** provide static CGE models used to investigate the possible implications of environmental policies for the South African mining sector. Thiele includes a hazardous waste recycling sector as one of twelve production sectors distinguished in the economy, with eight (including recycling) involved in the extraction and production of energy and mineral resources. The other four production categories are agriculture, other manufacturing, construction, and services. Additionally, considerations are included for factors of production (capital and labor), household racial composition (black and other), government consumption, and imports/export activities. The author finds that for this model to be effective it must allow for substitution between primary and intermediate goods and services, but there is no reason to have a bias toward either of those resources. Thiele concludes that due to the large impact of the mining industry on the South African economy, using CGE analysis can be an important and effective tool when assessing the implications of environmental and trade policy changes on energy and mining operations.

Wiebelt builds on Thiele's work, employing the same data in his analysis of the long- and short-run impacts on the South African mining industries (an the overall economy) as a result of improved hazardous waste management. In particular, the model incorporates an environmental tax on hazardous waste created through mining activities. This is an important consideration as mining operations account for approximately 90% of the industrial hazardous waste created in the country.

Improved hazardous waste management is modeled as an environmental tax on the waste stream created from the mining operations. Implementing the tax leads to an increase in domestic production costs, increasing the relative price of domestic mineral commodities vis-à-vis imported commodities. Further substitution effects will lead to an increase in domestic manufacturing reliance on these imported commodities and therefore a decline in the *initial* domestic demand for South African mineral commodities.

In addition to the impacts of the tax on the mining industry, there are repercussions for the overall economy as well. According to the model, there should be an increase in the demand for fabricated metal and machinery and construction. This will create an increase in the demand for labor in those markets. The costs of intermediate inputs to some sectors (petroleum and coal based products) will increase and result in a contraction in those sectors. In the labor market, the impact of the environmental tax on wages would be a decline of 0.4% overall, with the wages for black workers declining by

0.5%. This is because black labor is concentrated in the mining sectors and these are the sectors that would be most negatively affected. Other impacts due to the hazardous waste tax would be the creation of a balance of trade deficit, since higher export prices for South African goods result in a decline in the foreign demand for the nation's products, and currency depreciation.

Other CGE-related papers involve welfare implications as the result of implementing emissions (carbon dioxide and sulfur dioxide) taxes. **André, Cardenete, and Velázquez (2003)** and **Bye (2000)** find that when properly applied these environmental taxes can produce "double dividends" – reduce pollution emissions and replace distorting (income or payroll) taxes. André, et al finds that reducing payroll taxes when environmental taxes are increased leads to higher levels of employment, but reducing income taxes do not lead to this employment dividend. However, the authors find that when income taxes are reduced emissions are reduced by a larger amount than when payroll taxes are reduced. Bye uses an intertemporal CGE framework and finds evidence that a "double dividend" can be achieved when a 700 Norwegian Krone (about $US100) CO_2 tax is introduced and used to replace distorting payroll taxes. Bye's results indicate that given the tax on emissions, total welfare increases by 0.12% and CO_2 emissions are reduced by 13.5%. Total welfare is "measured as total discounted utility ignoring the environmental effect". Other supporting work on environmental tax reforms includes studies by **Kumbaroğlu (2003)** and **Timilsina** and **Shresha (2002)**. Kumbaroğlu uses an "energy-economy-environmental" CGE model to examine the impacts of increased environmental (NO_X) taxes on economic performance. This model differs from the two previously mentioned in that Kumbaroğlu allows for public consumption of the tax revenues rather than as a replacement for distorting income and payroll taxes. However, the model still produces "double dividends", this time as a reduction of polluting emissions and less reliance on imported fuels (petroleum mainly). The NO_X tax will most affect industries that use petroleum and as such will lead to substitution away from these industries and toward industries that use less petroleum and are therefore less reliant on foreign industries. Therefore, domestic economic development is speeded up.

Timilsina and Shresha employ a static CGE model consider the economic and environmental impacts of two separate revenue recycling policies on national well-being when a carbon tax is introduced. The revenue from increased environmental tax could be re-distributed in two manners: 1) recycle the tax as a lump-sum payment to households; and 2) reduce income tax rates. The authors find that introducing the environmental tax leads to decreases in CO_2, NO_X and SO_2 emissions, while also increasing national exports. The authors find that a US$10 per ton tax reduces CO_2, NO_X and SO_2 emissions by 5%, 8%, and 4%, respectively. By increasing the tax to US$40 per ton a higher per ton the reductions are approximately tripled. This is true under either revenue recycling tool. However, the (negative) impact on the economy is less when the environmental tax is used to replace the (distorting) income tax than when recycled in lump-sum form. There are several other papers of interest that discuss utilizing carbon (environmental) taxes as a replacement for other taxes. Two of the more recent articles are Rodriguez (2002), Bosquet (2000), and Bovenberg and Goulder (1995). Although not discussed in this dissertation, they make significant contributions to the field.

3.4 Comparisons of Econometric, Input-Output and CGE Models

The choice of modeling tools used to analyze regional economic issues includes econometric forecasting models, fixed price Input-Output (I-O) multi-sector models, and Computable General Equilibrium (CGE) models. Berck and Hoffmann (2002) point out that econometric models are criticized for relying on forecasts of national trends as exogenous input variables and restrictive treatment of relations as for example, revenues equal to expenditures, which limit the applicability of theoretically consistent results. The reliance on national trends within these models generally renders them less suited to examination of the influence of public policies on disaggregated industries or regional welfare effects. Time series econometric modeling methods are generally limited to a significantly smaller number of sectors, but do allow for direct estimation of long term relationships, of adjustments, and of standard error of the estimates. Additionally, time series modeling requires data from the variables over many time periods (years) in order to produce acceptable estimates, while fixed-price I-O and CGE models create multipliers from a single time period (year).

Fixed-price I-O models (including Social Accounting Matrices or SAMs), generally provide more consistent representations of economic structure. These approaches are similar to general equilibrium models; however, the assumptions of fixed price models tend to be more restrictive. Fixed price-models have difficulty in the analysis of supply side relationships, since they are generally designed to study demand side impacts of policy changes, this limits their use in taxation/revenue policy analysis. Fixed price I-O models incorporate a complete accounting of factor payments which, unlike econometric models, does allow analysis of general welfare issues such as policy impacts on household income distribution.

CGE models build on I-O models, by strengthening the theoretical basis of modeling and thus enable examination of a wider set of policy issues. The basis of a CGE model incorporates factor and commodity substitution into the structure of production and demand in a manner consistent with modern neo-classical economic theory. A CGE model consists fundamentally of a system of equations, representing the clearing of factor and commodity markets resulting from the optimizing behavior of economic agents and institutions. Endogenous prices adjust until factor and commodity market equilibrium conditions are satisfied, consistent with endogenous factor incomes. After calibration, or reproduction of, base year data, the system can simulate economic response to changes in policy variables relative to that base year.

In comparison with fixed-price I-O and econometric models, CGE models are more suited to addressing the implications on efficiency and equity of alternative public policies as the underlying assumptions are much more tenable and the results more tractable. The flexibility of various CGE specifications accommodates a wide range of policy variables and adjustment periods. The use of relative factor prices and allowing factor substitution generates a more accurate treatment of the impact of government policies on factor markets and on the distribution of income among households. As added benefit, if factor endowments are assumed fixed, the relative efficiency of regional factor utilization can also be compared within the CGE framework.

3.5 Conclusion and Contribution to the Field

Although there are several models used in the analysis of resource waste reduction, there are three modeling forms that dominate the research – econometric models, input-output models, and CGE analyses. While each technique has been found to be appropriate for research on this subject, Byers (1999) points out that CGE analysis brings the advantages of "sound economic theory, constrained factor and commodity supply relationships, relative factor prices, and commodity substitution in production and consumption" that may be partially missing from the other techniques.

This literature review provides justification for the use of CGE modeling to investigate the nature and benefits of resource recycling issues in a small city environment. Additionally, the literature indicates a need to develop new models that can address the issues pertaining to waste management alternatives and policy applications. One of the attractions of the CGE model is that it is designed to produce solutions to introduced alternative assumptions, and therefore, it is appropriate for use when considering the impacts of policy alternatives, such as implementing taxes and subsidies. The contribution of this dissertation to the field of study is the incorporation of CGE modeling into the local waste management decision-making process, highlighting the need for analysis of recycling options, including the optimal method of financing the options. CGE modeling techniques have been used rarely in the investigation of solid waste management issues and never at the local level or when specifically modeling aggregates material. This dissertation not only addresses that issue, but opens up several other avenues of research as the techniques developed here can be applied to a variety of waste management problems.

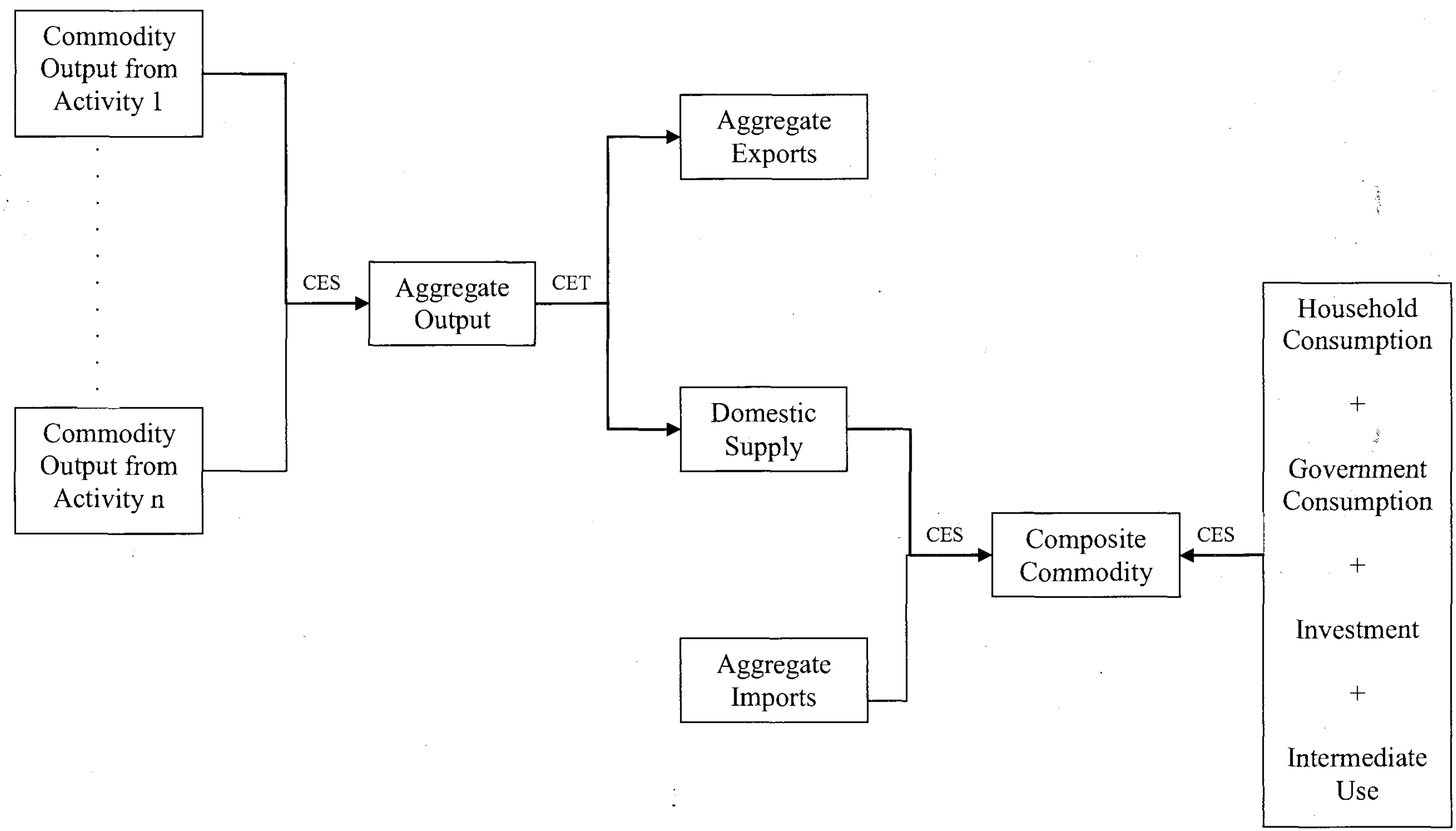
Chapter Four: The Computable General Equilibrium Model

4.0 Introduction

The Computable General Equilibrium model used in this dissertation is intended to capture the market processes of a small city (Fort Collins, Colorado) when aggregates waste disposal policy changes are considered. The model presented here is an extension of the computable general equilibrium model developed by Cutler and Davies, which itself was based on the work of **Berck, Golan, and Smith** (1997). In this incarnation, there are additional sectors developed for the provision of landfill services and a recycled aggregates goods market. Furthermore, the model includes provisions for variable intermediate good prices, which allows for input substitution between virgin materials and recycled aggregate materials based on relative material price changes.

The data are gathered and presented in a Social Accounting Matrix (discussed in depth in Chapter 5) before being captured by the CGE modeling software (GAMS). Included in the software are the equations which link the elements of the SAM and produce market clearing results. These equations cover activities in eight separate components of the model (production, household consumption, government actions, trade, investment, factor supply, migration, and model closure). Within the components there are equations for prices, quantities, income, expenditures, and equilibria. The following sections of this chapter will briefly discuss each of these sets of equations.

Figure 4-1: Flow Diagram for the CGE Model



Source: Lofgren, et. al., 2002

Figure 4-1 is a flow diagram for the model, with the eight activities housed within the sections of the diagram. CES (constant elasticity of substitution) and CET (constant elasticity of transformation) are defined and discussed in the forthcoming pages.

4.1 The CGE Model Equations

As mentioned above there are equations for eight separate components represented in the model. For each of the equations, the algebraic and corresponding GAMs code expressions are provided and discussed. The algebraic notation utilized taken from Schwarm (2002). The set, parameter, and variable notations are shown and defined in Appendix A.

4.1.1 Producer Equations

In all, there are twenty-two producing sectors in the model, including one sector for landfill services and one for recycled aggregate materials. A representative profit-maximizing (cost-minimizing) firm is modeled.

The firm produces outputs by taking a combination of the primary factors of production (labor, land, and capital) and intermediate goods supplied from both domestic and "foreign" firms (Figure 4-2). The majority of these outputs are then sold to individuals and firms for domestic consumption, with the remaining amount exported outside the region (ROW).

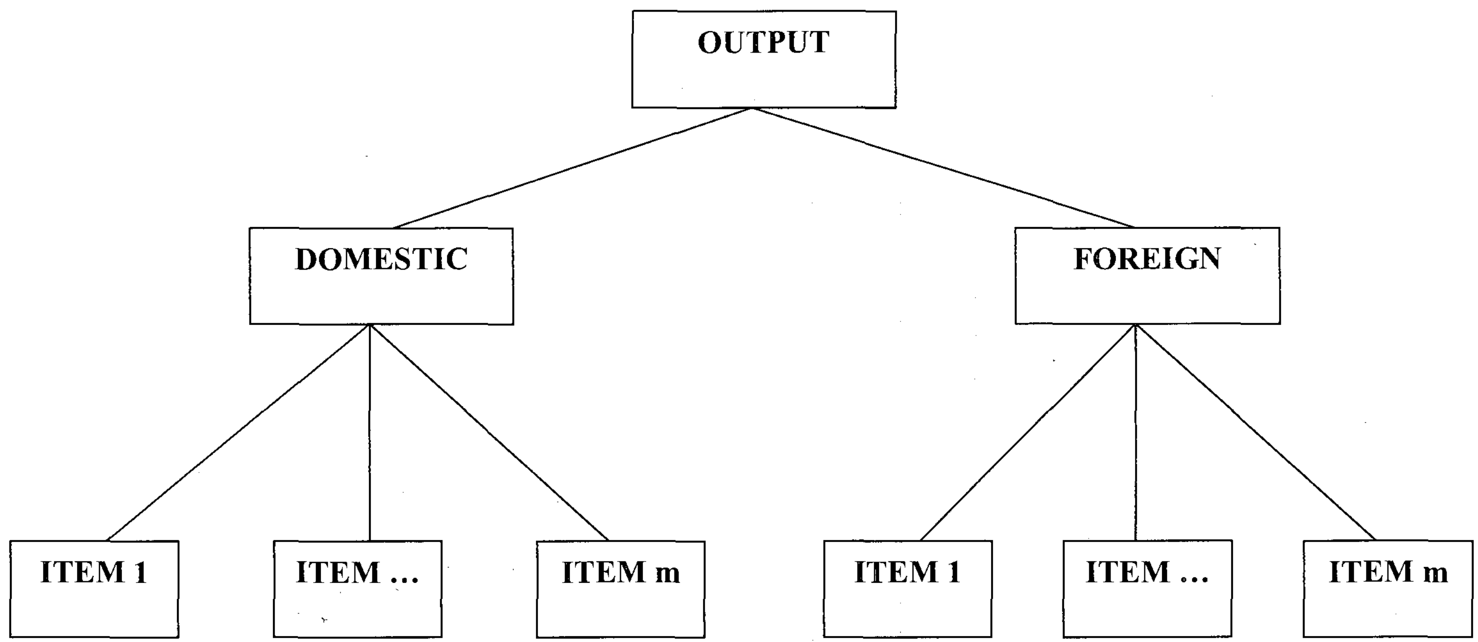
The production function is modeled as a two-stage process. The first stage combines the factors of production components with intermediate inputs in a Leontief production function. The Leontief function, a special case of Constant Elasticity of Substitution (CES), employs the inputs in fixed proportions, with no substitution, so the exponents of the function represent the proportion of each input used in the production process. Labor and capital are perfectly mobile in the domestic markets, but only labor can move freely into the foreign markets. Land is not allowed to be transferred from one sector to the other, be it domestically or foreign.

The second stage employs a Cobb-Douglas production function (another special case of CES) using Armington elasticities. Armington elasticities provide for the "degree of substitution in demand between similar products produced in different [regions]" (Lofgren, et. al., 2002). Therefore, Armington elasticities determine the degree of substitution between domestic and imported goods, and allow domestically produced and imported goods from the same industry to enter into the process as imperfect substitutes for each other.

As previously implied, firms may maximize profits by selling to both domestic and export markets. The decision as to which market to sell their output is determined by the Constant Elasticity of Transformation (CET). The CET represents the imperfect substitution possibilities between selling in the two markets.

Within the producer sectors there are five sets of equations discussed here. Those equations are for value added conditions, the production function, intermediate demand, factor demand, and factor outflow.

Figure 4-2: Nested Tree Structure for Production



Source: Lofgren, et. al., 2002

Value Added

Value added equations represent net price of the good created from the contributions of labor, land, and capital. As expressed in this model, the value added price for a good is the market price minus the costs of intermediate inputs and indirect taxes (sales and excise taxes).

$$p_i^{va} = p_i^d - \sum_{j \in J} \alpha_{ji} p_j \left(1 + \sum_{g \in GS} \tau_{gj}\right) \qquad (4.1a)$$

```
PVA(I) =E= PD(I) - SUM(J, AD(J,I) * P(J)
        * (1 + SUM(GS, TAUQ(GS,J))) )
```
(4.1b)

Production Function

The production function is a composed of the production function scale (δ_i) and the product of the factors demanded by each sector $\left({}^{d}_{fi}\right)$. α_i is the factor share proportion for each industry and ρ_i is the substitution exponent, which determines the degree of substitutability between factors.

$$q_i = \delta_i \prod \text{[illegible]} \qquad (4.2a)$$

```
DS(I) =E= DELTA(I)*PROD(F$ALPHA(F,I),FD(F,I)**ALPHA(F,I))
```
(4.2b)

The firm determines the profit-maximizing level of production by choosing the optimal amount of input from each factor. In the case of this model, the optimal level of input from each factor is determined by utilizing equation 4.2b and its first order conditions (calculated by differentiating the equation with respect to quantity produced). So, the value of the marginal product (VMP) is set equal to the price of the factor. This is the first order condition and is expressed as:

$$R_{F,I} * RA_F * (1 + \sum_{GF} TAUFX_{GF,F,I}) * FD_{F,I} = PVA_I * DS_I * ALPHA_{F,I} \quad (4.2c)$$

Intermediate Goods Demand

The intermediate goods demand equation is a function of the base intermediate demand amount, change in aggregate prices, sales and excise taxes, and the ratio of present supply to base domestic supply amounts. "γ" represents the cross-price elasticities between goods.

$$v = \bar{v} \prod_{i \in I} \left[\frac{pi' \left(1 + \sum_{g \in GS} \tau_i \right)}{pi' \left(1 + \sum_{g \in GS} \tau_i \right)} \right]^{0.1\lambda} \left(\frac{ds}{ds} \right) \quad (4.3a)$$

```
V(I) =E= V0(I)* (PROD(J, ( ( P(J)  * ( 1 + SUM(GS, TAUC(GS,J)) ) )
      / ( P0(J) * ( 1 + SUM(GS, TAUQ(GS,J)))) ) )
      ** (LAMBDA(J,I)*0.1) ) ) * ( DS(I) / DS0(I))**(1.0)
```

(4.3b)

Factor Demand

An assumption of the model is that the average rental/wage rates for the primary factors are the same regardless of the sector in which the factor is employed; however, the model does allow for differences in the returns across the sectors by multiplying an economy-wide scalar for the rental rate of the factors (ra_{fi}) by a sectoral rental rate value (r_f). The economy-wide scalar (ra_{fi}) is allowed to vary for land and capital returns, producing differentiated rates of return, but is held constant for labor calculations. With labor, the different wage rates are gathered from ES-202 and unemployment sources. This information is included in the Social Accounting Matrix (SAM) from which most of the CGE data are drawn. Whether the result of allowing the sectoral rental rate to vary or gathering the differentiated data from exogenous sources, the combined terms act to "measure the extent to which the sectoral marginal revenue product of the factor deviates from the average return across the economy" (Robinson, et. al., 1999). The term $\left(1+\sum_{i \in IG} \tau_{fig}^{x}\right)$ handles the taxes from the use of the factors (u_{fi}^{d}).

The right hand side of equation 4.4a produces the factor price – the value added price across production sectors (p_i^{va}) times the domestic supply of goods (q_i) times the factor share exponent of the good (α_f). Equation 4.4b is the equivalent GAMS expression for the factor demand.

$$r_{fi}\, ra_f \left(1+\sum_{i \in IG} \tau_{fig}^{x}\right) u_{fi}^{d} = p_i^{va} q_i \alpha_{fi} \quad \forall f \in F, i \in I \tag{4.4a}$$

```
R(F,I) * RA(F) * ( 1 + SUM(GF,TAUFX(GF,F,I) ) ) * FD(F,I)
=E= PVA(I) * DS(I) * ALPHA(F,I);
```

(4.4b)

Factor Incomes:

Factor income is simply the income generated by the three factors of production in this model. Equation 4.5a presents the income when all factors are combined (aggregated) for all private and public sectors. To calculate the income, the sum of the sectoral factor rates for each private and public sector and the sum of the economy-wide scalar for the rental rate of the factors for each sector are multiplied together. That result is then multiplied by the amount of each factor demanded to yield the result.

$$y_f = \left(\sum_{i \in IG} r_{fi} ra_f \right) u_{fi}^{d} \quad \forall f \in F \tag{4.5a}$$

Equations 4.5b – 4.5d are the GAMS code equations for the non-aggregated factor incomes.

```
Y(L) =E= SUM(IG, R(L,IG) * RA(L) * FD(L,IG))
```
(4.5b)

```
Y('KAP') =E= SUM(IG, R('KAP',IG) * RA('KAP') * FD('KAP',IG))
```
(4.5c)

```
Y('LAND')=E=SUM(IG,R('LAND',IG)*RA('LAND') * FD('LAND',IG))
```
(4.5d)

Factor Income Outflow

Factor income outflow is the portion of the factor income that is sent outside the local economy. Equation 4.6a shows the aggregated amount of factor income exported outside the community. Equations 4.6b and 4.6c, respectively, are the GAMS equations for the disaggregated income that was derived from land and capital assets taken outside of the local economy.

$$yx_f = \delta y_f \qquad (4.6a)$$

$$LNFOR(LA) = E = LFOR(LA)*Y(LA) \qquad (4.6b)$$

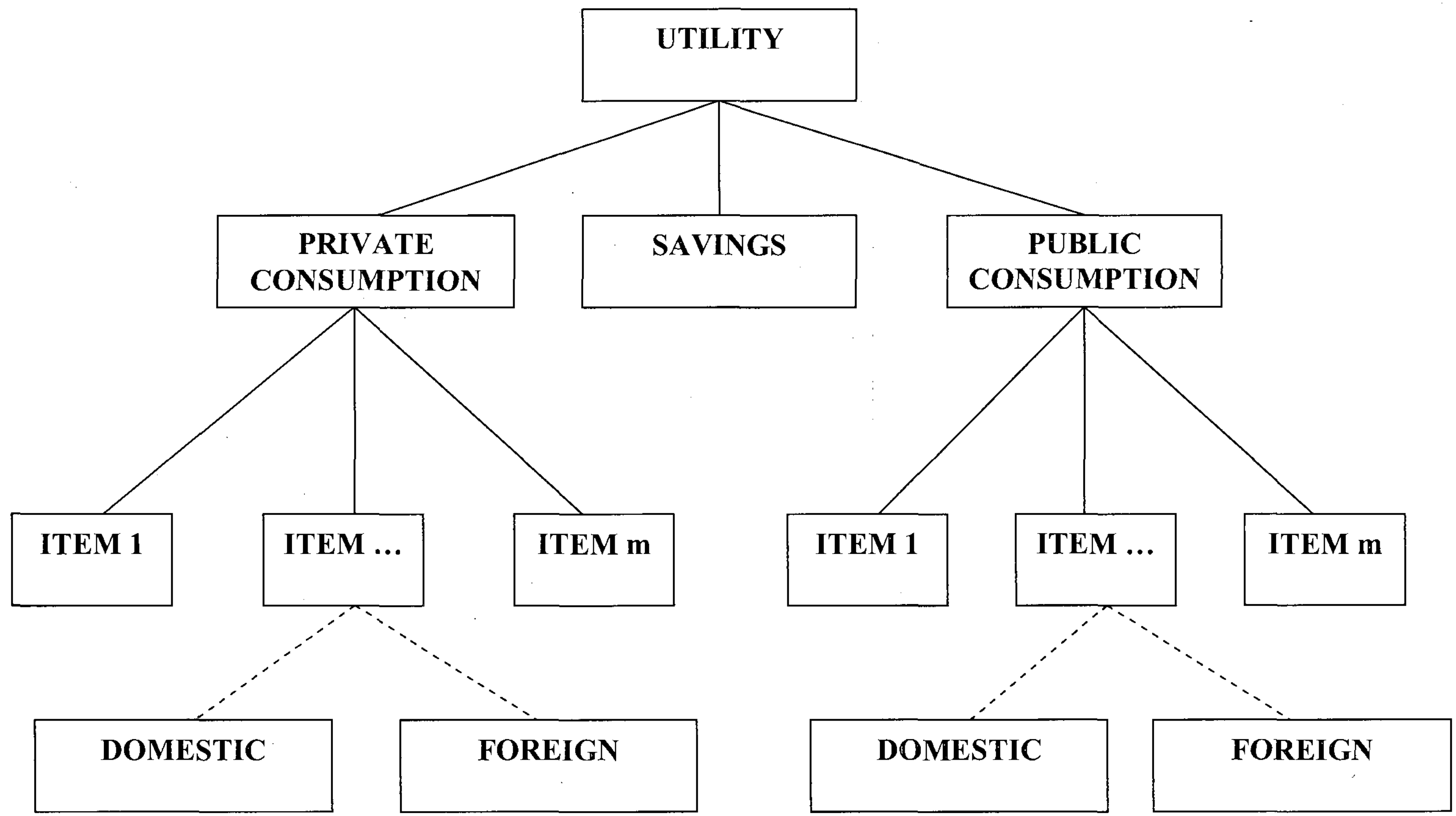
$$KPFOR(K) = E = KFOR(K)*Y(K) \qquad (4.6c)$$

4.1.2 Household Equations

Each of the six income-delineated household categories receives income from returns on labor (wages) and rents from land and capital owned and government transfer payments. The households make payments for final (composite) goods and services supplied by private industry, housing, savings/investments, and taxes paid to all levels of government. Subtracting the payments from the revenues generates the household budget constraint. Aggregating under a constant elasticity of substitution (CES) function, households maximize utility subject to the aforementioned budget constraint. Figure 4-3 is a nested tree structure for the workings of households as they maximize utility by distributing their wealth between purchases of composite goods and services from the private sectors, the public sectors, and the savings sector.

Within the household portion of the model there are equations representing the consumer price indices, gross household incomes, disposable household incomes, private consumption, and household savings.

Figure 4-3: Nested Tree Structure for Final Demand



Source: Lofgren, et. al., 2002

Consumer Price Indices

The consumer price index (CPI) is used as the numeraire price index and thus insures that "factor returns and household income measure real returns in terms of welfare". (Lofgren, et. al., 2002)

CPI is calculated by dividing the sum of aggregate prices from private (household) consumption in the scenario by the reference value of aggregate prices from private consumption (equal to 1). Continuing to utilize the notation of Schwarm (mentioned earlier), the algebraic expression is displayed as:

$$p_h = \frac{\sum_{i \in I} p_i (1 + \sum_{g \in GS} \tau^c_{gi}) c_{ih}}{\sum_{i \in I} \bar{p}_i (1 + \sum_{g \in GS} \tau^q_{gi}) c_{ih}} \quad (4.7a)$$

where p_h is the calculated CPI, p_i is the aggregate price for goods and services demanded, $\bar{p}_i$ is the reference aggregate price (set to1), τ^c_{gi} is the consumption sales tax rate, τ^q_{gi} is the reference consumption sales tax rate, and c_{ih} is private (consumer) expenditures.

As expressed in the GAMS code for this model, the equation for CPI is:

```
CPI(H)   E = SUM(I, P(I) * ( 1 + SUM(GS, TAUC(GS,I) ) ) * CH(I,H) )
           / SUM(I, P0(I) * ( 1 + SUM(GS, TAUQ(GS,I) ) ) * CH(I,H) )
```
(4.7b)

Gross Household Income

Gross household income is total amount of income earned by all households in the city, accounting for the wages leaving the community from those commuting into town and wages earned from those commuting out of town for work, as well as the income generated by other factors (land and capital). Algebraically, this can be expressed as:

$$y_h = \sum_{f \in F} \frac{\omega_{hf}\,\alpha_h^w}{\sum_{h \in H} \omega_{hf}\,\alpha_h^w} y_f \,(1 - \sum_{g \in GF} \tau_{gf}^h) \quad \forall h \in H \qquad (4.8a)$$

in which y_h is gross household income, y_f is total income from all factors (including the net commuting income, land, and capital), and τ_{gf}^h are the factor taxes generated.

In GAMS, this is modeled as:

```
Y(H) =E= SUM(L, A(H,L) * HW(H) / SUM(H1, A(H1,L) * HW(H1) ) *
(Y(L) + (CMIWAGE(L) * CMI(L))) * (1 - SUM(G, TAUFL(G,L)))) +
A(H,'COMMO1')*CMOWAGE('L1')*CMO('L1') +
A(H,'COMMO2')*CMOWAGE('L2')*CMO('L2') +
A(H,'COMMO3')*CMOWAGE('L3')*CMO('L3') +
SUM(LA, A(H,LA) * HW(H) / SUM(H1, A(H1,LA)* HW(H1)) *
(Y(LA)+ LNFOR(LA) ) * ( 1 - SUM(G, TAUFLA(G,LA) ) ) ) +
SUM(K, A(H,K) * HW(H) /SUM(H1,A(H1,K) * HW(H1)) *
(Y(K) + KPFOR(K)) * (1 - SUM (G, TAUFK(G,K) ) ) )
```

(4.8b)

<u>Household Disposable Income</u>

Disposable income is simply the gross household income (from labor, land, and capital) plus private retirement and government transfer payments minus the personal income and other taxes.

$$y_d^h = y_h + \sum_{h \in H} y_h^m \alpha_h^n + \sum_{g \in G} w_{hg} \alpha_h^n - \sum_{g \in GI} t_{gh} \omega_h - \sum_{g \in G} \tau_{gh}^h \omega_h \quad \forall h \in H \qquad (4.9a)$$

in which y_d^h is the disposable (after tax) income, y_h is the gross income, w_{hg} are transfer payments, t_{gh} and τ_{gh}^h are taxes paid by households.

In the GAMS notation used in this model the expression is written as

```
YD(H) = E = Y(H) + (PRIVRET(H) * HH(H)) - SUM(G, TP(H,G) * HH(H))
        - SUM(GI, PIT(GI,H) * HH(H)) - SUM(G, TAUH(G,H) * HH(H))
```
(4.9b)

Private Consumption

Private consumption is a function of several factors, the first of which is adjusted real household incomes, $\bar{c}_{ih}\left(\frac{y_h^d}{\bar{y}_h^d} \div \frac{p_h}{\bar{p}_h}\right)^{\beta_{ih}}$ (original consumption ($\bar{c}_{ih}$) multiplied by disposable household incomes $\left(\frac{y_h^d}{\bar{y}_h^d}\right)$ and divided by the CPI$\left(\frac{p_h}{\bar{p}_h}\right)$). The product of the last two terms is raised to the value of the income elasticity of demand, which is unitary in this model. The next portion is composed of the product of the ratios of changes (relative changes) in aggregate prices from each industry sector (including taxes)$\left[pi'\left(1+\sum_{g\in GS}\tau_{gi'}^{c}\right) \div \overline{pi}'\left(1+\sum_{g\in GS}\tau_{gi'}^{q}\right)\right]^{\lambda i'i}$, where "λ" represents the cross-price elasticities between goods (set equal to -1). As a result, if an increase in real disposable income is greater than the changes in aggregate prices, private consumption increases.

Taken together, the algebraic equation (equation 4.10a) is written as:

$$c_{ih} = \bar{c}_{ih} \left(\frac{y_h^d}{\bar{y}_h^d} / \frac{p_h}{\bar{p}_h} \right)^{\beta_{ih}} \prod_{j \in J} \left[\frac{p_j \left(1 + \sum_{g \in GS} \tau_{gj} \right)}{\bar{p}_j \left(1 + \sum_{g \in GS} \tau_{gj} \right)} \right]^{\lambda_{ji}} \qquad (4.10a)$$

Using GAMS notation the expression is

```
CH(I,H) =E= CH0(I,H)* ( ( YD(H) / YD0(H) ) / ( CPI(H) / CPI0(H) ) )
        ** BETA(I,H) * PROD(J, ( ( P(J)
        * ( 1 + SUM(GS, TAUC(GS,J) ) ) )
        / ( P0(J)* ( 1 + SUM(GS, TAUQ(GS,J) ) ) ) )
       ** (LAMBDA (J,I)*1) )
```

(4.10b)

Household Savings

The final equation for households is the determination of savings. Household savings are simply modeled as the difference between disposable income and the consumption expenditures and taxes.

$$s_h = y_h^d - \sum_i c_{ih} p_i \left(1 + \sum_{g \in GS} \tau_{gi} \right) \qquad (4.11a)$$

Here s_h is the household savings and other terms are previously defined. Equation 4.11a presents the corresponding GAMS code for the household savings function.

```
S(H)=E= YD(H) - SUM(I, P(I) * CH(I,H) * ( 1 + SUM(GS, TAUC(GS,I) ) ));
```

(4.11b)

4.1.3 Government Equations

All of the government income was determined exogenously and was calculated by examining the city's *Comprehensive Annual Financial Report (CAFR)*, county financial and assessor's data, as well as state and federal financial records (including unemployment insurance and ES-202 data).

<u>Government Income</u>

Government income is derived from several sources including:

- Sales and excise taxes on intermediate goods, imports and exports, household consumption, government consumption, and investments
- Taxes on factor payments
- Taxes on transfer payments (social security, etc)
- Income taxes and property taxes
- Intergovernmental transfers (state and federal grants, etc.)

$$
\begin{aligned}
y_g = & \sum_{i \in I} \tau^{s}_{gvi} v_i p_i + \sum_{i \in I} t^{e}_{g} e_i p^{d}_{i} + \sum_{i \in I} \tau^{m}_{gi} m_i p^{w}_{i} + \sum_{i \in I} \sum_{h \in H} \tau^{s}_{ghi} c_{ih} p_i + \sum_{i \in I} \tau^{s}_{gni} c_{in} p_i \\
& + \sum_{i \in I} \sum_{g' \in G} \tau^{s}_{gg'i} c_{ig'} p_i + \sum_{i \in I} \sum_{f \in F} \tau^{s}_{gf} r_{fi} \, ra_f \, u^{d}_{fi} + \sum_{g' \in G} \sum_{f \in F} \tau^{s}_{gf} r_{fg'} \, ra_f \, u^{d}_{fg'} \\
& + \sum_{f \in F} \tau^{f}_{gf} y_f + \sum_{h \in H} \tau^{h}_{hg} a_h + \sum_{h \in H} \tau^{h}_{ghi} a^{w}_{h} + \sum_{g' \in GX} b_{gg'} \qquad \forall g \in g
\end{aligned}
\tag{4.12a}
$$

The CGE notation for the sources of government income is displayed in equation 4.12b.

```
Y(GX) =E= SUM(I, TAUV(GX,I) * V(I) * P(I) )
         + SUM(I, TAUX(GX,I)* CX(I) * PD(I))
         + SUM(I, TAUM(GX,I) * M(I)*PWM0(I))
         + SUM((H,I), TAUC(GX,I) * CH(I,H) * P(I) )
         + SUM(I, TAUN(GX,I) * CN(I) * P(I) )
         + SUM((GN,I), TAUG(GX,I) * CG(I,GN) * P(I) )
         + SUM((F,I), TAUFX(GX,F,I) * RA(F) * R(F,I)
         * FD(F,I) )
         + SUM((F,GN), TAUFX(GX,F,GN) * RA(F)
         * R(F,GN) * FD(F,GN) )
         + SUM(L, TAUFH(GX,L) * (Y(L) + CMIWAGE(L)
         *CMI(L)))
         + SUM(K, TAUFH(GX,K) * (Y(K)) )
         + SUM(LA, TAUFH(GX,LA) * (Y(LA)) )
         + SUM(H, PIT(GX,H) * HH(H) )
         + SUM(H, TAUH(GX,H) * HH(H) )
         + SUM(GX1, IGT(GX,GX1))
```
(4.12b)

<u>Government Endogenous Purchases of Goods and Services</u>

The government demand of final goods and services (left side of the equation) is determined by adding the government income generated from taxes collected (y_g) and the net intergovernmental transfers, $\sum_{g'\in G} b_{gg'} - \sum_{g'\in G} b_{g'g}$ (in minus out). The sector specific expenditures are generated using IMPLAN determined fixed shares (α_{ig}).

$$p_i\left(1+\sum_{g\in GS}\tau_{ig}^{g}\right)c_{ig}=\alpha_{ig}\left(y_g+\sum_{g'\in G}b_{gg'}-\sum_{g'\in G}b_{g'g}\right)\quad \forall i\in I,\ g\in GN \tag{4.13a}$$

The same equation expressed in GAMS code is:

```
P(I) * ( 1 + SUM(GS, TAUG(GS,I) ) ) * CG(I,GN) =E=
AG(I,GN) * (Y(GN)+ GVFOR(GN))
```
(4.13b)

Government Endogenous Rental of Factors

In addition to the purchase of final goods and services, government must also pay for the provision of labor, land, and capital. On the left side of equation 4.13a, we find the sector specific expenditures for the primary factors, where u^d_{fg} is the factor demanded and r_{af} and r_{fg} determine the shares of each factor purchased. The right hand side of the equation is the government income, as was described in the previous section.

$$u^d_{fg}\, r_{af}\, r_{fg} = \alpha_{fg}\left(y_g + \sum_{g' \in G} b_{gg'} - \sum_{g' \in G} b_{g'g} \right) \quad \forall i \in I,\ g \in GN \tag{4.14a}$$

The GAMS code for equation 4.14a is seen in equation 4.14b.

```
FD(F,GN) * R(F,GN) * RA(F)*( 1 + SUM(GF, TAUFX(GF,F,GN))) = E =
AG(F,GN) * (Y(GN)+ GVFOR(GN))
```
(4.14b)

Government Savings

Government savings, as displayed in equation 4.15a, are calculated by subtracting the total government expenditures (final goods and services and factor costs) from the total amount of tax revenues received. The expenditures include the taxes on consumptive goods and factors of production, as well as the net intergovernmental transfers. Equation 4.15b provides the GAMS code for the calculation.

$$s_g = y_g - \sum_{i \in GS} c_{ig}\, p_i \left(1 + \sum_{g' \in GS} \tau^c_{ig'} \right) - \sum_{f \in F} u^d_{fg}\, r_{af}\, r_{fg} \left(1 + \sum_{g' \in GF} \tau^x_{fg'} \right) - \sum_{h \in H} w_{hg}\, a^n_{hg} + \sum_{g' \in G} b_{gg'} - \sum_{g' \in G} b_{g'g} \tag{4.15a}$$

```
S(GN)    E = (Y(GN) – GVFOR(GN)) - SUM(I, CG(I,GN) * P(I)
            * (1 + SUM(GS, TAUG(GS,I) ) ) ) - SUM(F, FD(F,GN)
            * R(F,GN) * RA(F) * (1 – SUM(GF, TAUFX(GF,F,GN))))
```

(4.15b)

4.1.4 Trade Equations

Individuals, firms, and governments that operate outside the community, but have economic/financial associations with sectors of the city are designated as the "rest of the world" (ROW) in this model. The model assumes an open economy relationship between the sectors within the city and the ROW sector and it is the interactions between these elements that produce export and import relationships.

<u>Export Demand</u>

The demand in the rest of the world for domestically produced goods (exports) is based on the domestic and world price relationship (taxes included). As modeled here, the demand for locally produced products rise as the ROW produced goods become relatively more expensive. In expression 4.16a, p_i^d is the term for domestic price and $\bar{p}_i^w$ is the given world price. Export elasticities (η^e) are taken from IMPLAN and are exogenously introduced, with the manufacturing sector having a greater elasticity than the other sectors, indicating that manufacturing products are more sensitive to relative price changes. Equation 4.16b is the GAMS representation of the algebraic equation 4.16a.

$$e_i = \bar{e}_i \left[\left(p_i^d \sum_{g \in GK} 1 + \tau_{gi} \right) \div \left(\bar{p}_i^w \sum_{g \in GK} 1 + \tau_{gi} \right) \right]^{\eta} \qquad (4.16a)$$

```
CX(I) =E= CX0(I)*( (PD(I)*(1+SUM(GK,TAUX(GK,I))))
   /(PW0(I)*(1+SUM(GK,TAUQ(GK,I))))) **(ETAE(I)*1.02)
```

(4.16b)

Domestic Shares of Domestic Demand

Equations 4.17a and 4.17b show the proportion of the domestic demand that is provided by domestic producers – the rest of which is provided by suppliers outside the city. As with the export demand, the percentage of locally produced goods that are consumed by local consumers is determined by the ratio of domestic and world prices (import taxes included). In this case, a relatively higher domestic price will result in a lower amount of domestically produced goods consumed locally.

$$d_i = \bar{d}_i \left(p_i^d \div p_i^w \div \left(1 + \sum_{g \in G} \tau_{gi}^m \right) \right)^{\eta^d} \qquad (4.17a)$$

```
D(I) =E= D0(I) * ( PD(I) / PWM0(I)
   /(1+SUM(GK,TAUM(GK,I)))) ** ETAD(I)
```

(4.17b)

Import Demand

Import demand is calculated by determining the percentage of domestic consumption that is not supplied by domestic producers and multiplying that by the total domestic demand (See equations 4.18a and 4.18b for the algebraic and GAMS coded equations.)

$$m_i = (1 - d_i) x_i \qquad (4.18a)$$

M(I) =E= (1 - D(I)) * DD(I) (4.18b)

Aggregate Domestic Price Paid by Purchasers

Aggregated (average) prices are those paid by producers for the purchase of intermediate goods. These prices are determined by the multiplying the share of goods consumed domestically by the domestic price and adding that to the share of imported goods, at world prices (including total import taxes). Equation 4.19b is the GAMS equivalent for algebraic equation 4.19a.

$$p_i = d p_i^d + (1 - d_i) \bar{p}_i^w \left(1 + \sum_{g \in G} \tau_{gi}^m \right) \quad (4.19a)$$

P(I) =E= D(I) * PD(I) + (1 - D(I))
 * PWM0(I)*(1+SUM(GK,TAUM(GK,I))) (4.19b)

Net Capital Inflow

Net capital inflow is determined by subtracting the total value of exports from the total value of imported resources. In equation 4.20a, $\sum_{i \in I} m_i \bar{p}_i$ represents the import value, while the total export value is determined by adding together (for all sectors) the value for the purchase of exports ($\sum_{i \in I} e_i p_i^d$), retirement funds leaving the community ($\sum_{h \in H} y_h^m a_h^n$), land and capital payments made to factor owners outside the city and government outflows ($\sum_{f \in F} y_f^m$), and the net wages taken out of the city - wages from those commuting out – wages from those commuting in – ($\sum_{l \in L} Exwage * \overline{CMO} - \sum_{l \in L} - r_l \overline{CMI_l}$).

$$z = \sum_{i \in I} m_i p_i - \sum_{i \in I} e_i p_i^d - \sum_{h \in H} y_h^w a_h^w - \sum_{f \in F} y_f^w - \sum_{l \in L} Exwage_l * \overline{CMO} - \sum_{l \in L} r_l \overline{CMI} \tag{4.20a}$$

```
NKI = E = SUM(I, M(I) * PWM0(I) ) - SUM(I, CX(I) * PD(I) )
     - SUM(H, PRIVRET(H)*HH(H)) - SUM(LA, LNFOR(LA))
     - SUM(K, KPFOR(K)) - SUM(G, GVFOR(G))
     - SUM(L,CMOWAGE(L)*CMO(L)) - SUM(L,CMIWAGE(L)
     * CMI(L))
```
(4.20b)

4.1.5 Investment Equations

Gross Investment by Sector of Destination

Equations 4.21a (algebraic) and 4.21b (GAMS) capture the calculations for the purchase of factors as inputs into the production process. In this model, as the return to capital $\left(\frac{r_{k,i}}{\bar{r}_{k,i}}\right)$ increases and/or the domestic supply of the factors $\left(\frac{u_i^d}{\bar{u}_i^d}\right)^{\eta_i^k}$ increases, vis-à-vis initial levels, the investment increases. As pointed out by Schwarm, payments to capital are based on the costs of maintenance for the capital, which in turn, are based on an assumed 10% depreciation rate. The initial level of investment is determined by "applying [the depreciation rate] to rates of return". The investment determination is reached on a sector-by-sector basis.

$$n_i^k = \bar{n}_i^k \left(\frac{r_{k,i}}{\bar{r}_{k,i}}\right)^{\eta^k} * \left(\frac{u_i^d}{\bar{u}_i^d}\right)^{\eta_i^k} \tag{4.21a}$$

```
N(K,I) =E= N0(K,I)*( R(K,I)/R0(K,I)) ** ETAIX(K,I)
  *(DS(I) / DS0(I))**(ETAIX(K,I)*2.0)
```

(4.21b)

Gross Investment by Sector of Source

Where gross investment by sector of *destination* captures the expenditures for goods and factors in the production process, gross investment by sector of *source* details the demand for one sector's output by other sectors. The demand for each sector's output is determined as a "fixed share" of the total output demand from all sectors multiplied by any new capital investment ($\beta_{ii'} n_i^k$). The shares are taken from the CAPCOM, a capital coefficient matrix. The matrix is developed from information obtained from the Larimer County Assessor's Office.

$$p_i \left(1 + \sum_{g \in GS} \tau_{gi}^{n} \right) c_i^{n} = \sum_{i' \in I} \sum_{k \in K} \beta_{ii'} n_{i'}^{k}$$

(4.22a)

```
P(I)*( 1 + SUM(GS, TAUN(GS,I) ) ) * CN(I) =E=
SUM(IG, B(I,IG)* (SUM(K, N(K,IG)) ) )
```

(4.22b)

Capital Stock

The level of capital stock present in the economy is determined by taking the initial amount of stock less the depreciated capital plus the new capital investment. Capital stock is assumed to depreciate by 10%.

$$u_{K,t}^{i} = \bar{u}_{K,t}^{i} (1 - \delta) + n_i^{k}$$

(4.23a)

$KS(K,IG) = E = KS0(K,IG) * (1 - DEPR) + N(K,IG)$ (4.23b)

4.1.6 Factor Supply Equations

Labor Supply

The supply of labor is expressed as a rate (equation 4.24a) – the percentage of households in the community in which one or more individuals is employed. The total labor supply change is calculated by determining the effects of changes in real wages $\left(\frac{r_l^a}{\bar{r}_l^a}\right) / \left(\frac{p_h}{\bar{p}_h}\right)$ in the local economy, the changes in primary factor demand when adjusted for household income changes when commuting in is incorporated $(\sum_{Z,L} u_{z,l}^d / \left(\sum_H a_h^w * \varepsilon\right) + CMI$, the changes in commuting out when the relative changes to external wages and internal wages are considered $\left(\sum_L \frac{Exwage}{r_l^a}\right) * CMO / \left(\sum_H a_h^w * \varepsilon\right) + CMI$, and the changes in real household transfer payments $\sum_{g \in G} \frac{W_{h'g}}{p_h} / \sum_{g \in G} \frac{\overline{W}_{h'g}}{\bar{p}_h}$. Elasticicties are reflective of the responsiveness of labor supply to changes in the average wage (η_h^{LS}) and of household responsiveness to changes in transfer payments (η_h^w). The new level of labor supply is determined by multiplying the initial level of labor supply by these outcomes.

$$\frac{a_H}{a_{H0}} = \frac{a}{\bar{a}} \left[\frac{\sum \left(\frac{[illegible]}{\bar{p}} \right)}{\left(\frac{p_H}{\bar{p}_H} \right)} \right] \left[\frac{\sum a}{\left(\sum a_i * z_i \right) + CMI} \right] \left[\sum \frac{Exwage}{ra} \right] \left[\frac{CMO}{\sum a_i * z_i + CMI} \right] \left[\frac{\sum \frac{[illegible]}{p}}{\sum \frac{[illegible]}{\bar{p}}} \right]$$

(4.24a)

```
HW(H)/HH(H) =E= HW0(H)/HH0(H)* ((SUM(L, RA(L) / RA0(L))/3)
        /(CPI(H) /CPI0(H)) * (SUM((Z,L), FD(L,Z))
        /(SUM(H1, HW(H1) * SUM(L, JOBCOR(H1,L)))
        + SUM(L,CMI(L)) )) - SUM(L,EXWGE2(L)/RA(L))
        /3*(SUM(L, CMO(L)) /(SUM(H1, HW(H1)
        * SUM(L,JOBCOR(H1,L)))+ SUM(L,CMI(L)))))
        ** (ETARA(H)*1)* (SUM(G, TP(H,G)/CPI(H))
        /SUM(G, TP(H,G) /CPI0(H) ))** ETAPT(H)
```

(4.24b)

<u>Commuting Out</u>

Commuting out is a measure of workers residing in Fort Collins, but working elsewhere. Equation 4.25a provides the algebraic relationships that govern whether or not individuals commute outside the city for work. Commuting out is a function of the effect of external wages (*Exwage*$_L$) relative to the rate of return on labor within the city. As the external wage becomes higher relative to the internally offered wage (return on labor), there will be increased commuting out.

$$CMO = \overline{CMO}\left(\frac{Exwage_L}{ra_L}\right)^{\eta^{L}_{cmo}}$$

(4.25a)

Equations 4.25b, 4.25c, and 4.25d represent the GAMS notation for the three different wage group categories. *ECOMO* is the elasticity of labor supply for "out-commuters". This elasticity is lower for category 'L1' than it is for 'L2' and 'L3', signifying the decreased sensitivity to changes in wages offered outside the community for lower wage earners. This is due to the effect on travel costs (gas, wear-and-tear, etc.) associated with commuting. When wages are lower ('L1'), these additional travel costs make up a larger percentage of the wages and may preclude the making the commute. For example, if someone in the 'L1' category is earning $10,000 per year a 10% higher wage may not cover the extra costs of getting to and from the job. However, if the individual is originally making $50,000 per year, the additional $5,000 in income is more likely to be enough to entice someone to commute.

```
CMO('L1')=E= CMO0('L1')* (((EXWGE1('L1') / RA('L1') ))** ECOMO('L1'));   (4.25b)
```

```
CMO('L2')=E=CMO0('L2')* (((EXWGE1('L2') / RA('L2') ))** ECOMO('L2'));   (4.25c)
```

```
CMO('L3')=E= CMO0('L3')* (((EXWGE1('L3') / RA('L3') ))** ECOMO('L3'));   (4.25d)
```

<u>Commuting In</u>

Commuting in is organized in a similar manner to commuting out. However, as seen in equation 4.26a, a higher relative wage offered by employers inside the city (ra_L) attracts workers from outside the city. Once again, the lower wage earners are less likely to commute in based on the net negative economic impacts of the commute. Equations 4.26b – 4.26d are the GAMS code specifications for commuting for the three wage levels.

$$CMI = \overline{CMI}\left(\frac{ra}{Exwage}\right)^{\frac{1}{\varepsilon_{cmi}}} \quad (4.26a)$$

```
CMI('L1')   E = CMI0('L1')* ((( RA('L1')
            /(SUM( H, CPI(H))/6)/EXWGE2('L1') ))
            ** ECOMI('L1'))
```
(4.26b)

```
CMI('L2')   E = CMI0('L2')* (((RA('L2')
            /(SUM( H, CPI(H))/6)/EXWGE2('L2') ))
            ** ECOMI('L2'))
```
(4.26c)

```
CMI('L3')   E = CMI0('L3')* (((RA('L3')
            /(SUM( H, CPI(H))/6)/EXWGE2('L3') ))
            ** ECOMI('L3'));
```
(4.26d)

4.1.7 Migration Equations

Population

The community's population is a function of the current population ($\overline{a}_h$), the natural rate of population growth (π), and net migration. Net migration (in-migration minus out-migration) is determined as a function of changes in real per household disposable incomes (nominal change in disposable income adjusted by the change in CPI) and employment opportunities for household members migrating into or out of the community.

$$a_h = \bar{a}_h \pi_h + \bar{a}^{in}_h \left(\frac{\bar{a}_h p_h y^d_h}{a_h p_h \bar{y}^d_h} \right)^{\eta^{yd}} \left(\frac{a^n_h \bar{a}_h}{a_h \bar{a}^n_h} \right)^{\eta} - \bar{a}^{out}_h \left(\frac{a_h p_h y^d_h}{\bar{a}_h p_h y^d_h} \right)^{\eta^{yd}} \left(\frac{a_h \bar{a}^n_h}{a^n_h \bar{a}_h} \right)^{\eta} \quad \forall h \in H \tag{4.27a}$$

```
HH(H) =E= HH0(H) * NRPG(H) + MI0(H) * ( ( YD(H) / HH(H) )
          / ( YD0(H) / HH0(H) ) / ( CPI(H) / CPI0(H) ))**(ETAYD(H)*1.0)
          * (( HN(H) / HH(H) ) / ( HN0(H) / HH0(H) ) ) ** ETAU(H)
          - MO0(H) * ( ( YD0(H) / HH0(H)) / (YD(H) / HH(H))
          / ( CPI0(H) / CPI(H) ) ) ** ETAYD(H) * ( ( HN0(H) / HH0(H))
          / ( HN(H) / HH(H) ) ) ** ETAU(H)
```

(4.27b)

<u>Non-Working Households</u>

Non-working households are calculated by subtracting the number of working households from the total number of households in the city. Non-working households consist of those with no regularly employed individuals in the home, including students, retirees, and those on government subsistence programs. Equations 4.28a and 4.28b provide the notation for the algebraic and GAMS code equations, respectively.

$$a^n_h = a_h - a^w_h \tag{4.28a}$$

```
HN(H) =E= HH(H) - HW(H)
```

(4.28b)

4.1.8 Model Closure Equations

As this (and every other) CGE model includes more variables than there are solvable equations several of the variables are exogenously incorporated. These exogenous variables serve to constrain the model simulations and are represented in closure equations. In the model presented here, I have designated closure equations for personal income, factor markets, goods markets, and domestic demand.

As described by Mbabazi (2002), there are several different macroeconomic closure rule structures - the most common of these being Classical/Neoclassical in structure. While the majority of the closure rules presented here adheres to this approach there are portions that do not take this form. Schwarm points out elements of the closure rules implemented in his work use a Keynesian approach. Te same can be said for this dissertation also. In particular, a Neoclassical approach would force savings to equal investment and would not include unemployment in the equation sets. This model partially incorporates the Keynesian method, in which neither of these restrictions is enforced, and therefore a "hybrid" approach is utilized.

<u>Personal Income</u>

As seen in equation 4.29a the personal income is calculated by adding the household incomes from the prime factors (land, labor, and capital), government transfer payments, and private retirement.

$$q = \sum_{h \in H} y_h + \sum_{h \in H} \sum_{g \in G} w_{h,g} a_h^{n} + \sum_{h \in H} y_h^{m} a_h^{n} \qquad (4.29a)$$

```
SPI =E= SUM(H, Y(H)) + SUM((H,G), TP(H,G) * HH(H))
           + SUM(H, PRIVRET(H) * HH(H))
```
(4.29b)

Labor Market Clearing

Labor, as with each of the primary factors, must clear – the supply of the factor must equal the demand for the factor. The supply of labor (left hand side) is given by adding the number of local residents employed in the community to the number of individuals commuting into the community. The term a_h^w is the total number of working households in the community. ε, the "JOBCOR" statistic (calculated in the SAM), serves as the conversion factor between the numbers of households to the number workers. Therefore, $a_h^w * \varepsilon$ produces the number of local residents employed in the city on a household basis. The numbers of workers in each household category are then combined to produce the total number of local workers employed in local businesses. CMI is the number of workers commuting into the community. Adding these two elements together produces the total labor supply. The demand for labor is determined by subtracting the number of workers commuting out of the community from the number of available laborers in the city (summing all industry labor demands). These values are given on a sector-by-sector basis and then summed.

$$\sum_{h \in H} a_h^w * \varepsilon + CMI = \sum_{z \in Z} a_{l,z}^{f} + CMO_l \qquad (4.30a)$$

$$SUM(H, HW(H) * JOBCOR(H,L)) + CMI(L) =E= SUM(Z, FD(L,Z)) + CMO(L) \qquad (4.30b)$$

Capital Market Clearing

As with the labor market, the capital market clears when the total supply of capital (left hand side) is equal to the total demand for capital (right hand side). The capital clearing equation has the market clearing on a sector-by-sector basis (as with labor and land). Equation 4.31b is the GAMS equivalent of the algebraic equation 4.31a.

$$u^s_{K,i} = u^d_{K,i} \tag{4.31a}$$

$$KS(K,IG) =E= FD(K,IG) \tag{4.31b}$$

Land Market Clearing

The final primary factor (land) operates in the same manner as capital and labor, with the supply and demand equating and determined on a sector-by-sector basis.

$$u^s_{LA,i} = u^d_{LA,i} \tag{4.32a}$$

$$LAS(LA,IG) =E= FD(LA,IG) \tag{4.32b}$$

Goods Market Clearing

The goods market clearing closure equation forces the domestic supply to be equal to the domestic demand for the output plus the net exports (exports – imports).

$$q = x + e - m \tag{4.33a}$$

$$DS(I) =E= DD(I) + CX(I) - M(I) \tag{4.33b}$$

Definition of Domestic Demand

The final closure equation presented in this model is for the demand for domestically produced goods and services. As modeled here, the domestic demand is composed of the demand for intermediate goods by firms, private (household) consumption, public (government) consumption, and foreign consumption (exports).

$$x_i = v_i + \sum_{h \in H} c_{ih} + \sum_{g \in G} c_{ig} + c_i^n \qquad (4.34a)$$

DD(I) =E= V(I) + SUM(H, CH(I,H)) + SUM(G, CG(I,G)) + CN(I) (4.34b)

Chapter Five: Data and the Social Accounting Matrix

5.0 Introduction

The first portion of this chapter is intended to describe the data used to construct the elements of the CGE model and provide sources of data. The data collected defines the behavior of fifty-eight separate accounts, representing the revenues and expenditures of industry (producers), factors of production (land, labor, and capital), households, and governmental entities. Gathering the data entailed utilizing information from numerous sources in both the private and public sectors. These sources will be discussed in the sections below.

The second portion of this chapter will include a description of the Social Accounting Matrix (SAM). The SAM is essential in the management of the data. Through the SAM the data is organized and arranged for further use by the modeling software (GAMS).

5.1 Geographical Dimensions of the Study

The data compiled for this paper are for Fort Collins, Colorado, a smaller-sized city with a population of about 120,000 inhabitants (118,652 in the 2000 census). The calculations in this work are originally based on data from the 1990 census, which have been updated to include 1998 estimates. Fort Collins is the county seat and the largest city in Larimer County, with the city having over one-quarter of the total county population. The city is located along the Front Range corridor about seventy miles to the north of Denver and forty miles south of Cheyenne, Wyoming.

5.2 Employment and Wages Data

Employment and wage data are used to produce information for the three labor groups in the model, as well as for Social Security and tax contributions. For the majority of workers in the city, these data are available from two sources collected by the Colorado Department of Labor and Employment (CDLE) – the Covered Employment and Wages (ES-202) program and the state Unemployment Insurance (UI) program. The ES-202 program summarizes quarterly employment and wage data provided by the state employment agencies (the CDLE in Colorado) for workers covered by State unemployment insurance. The ES-202 program provides industry-level employment and wage data at the national, state, and county levels. The program covers almost all privately employed non-agricultural workers. Wage and employment information for approximately 47% of agricultural workers are also covered under this program (BLS, 1997). In addition to the data collected under the ES-202 program, the state UI records are used to help track employees and their wages. Each private sector employed individual is assigned an identification number that matches the individual to the employer paying his or her wages. By combining the information gleaned from these two sources, the values to be inputted into the model are derived.

As indicated above, not all employees are covered by the ES-202 and UI programs. Public employees, who do not contribute to Social Security, self-employed individuals, and the majority of agricultural workers make up the largest percentage of these workers. For public employees, the data is gathered from public records, such as school district audits and city Comprehensive Annual Financial Reports (CAFR). Employment for other individuals not covered by public records is estimated using existing data sources. **Table 5-1** presents the summary employment and wage data for Fort Collins. These data show that over one-quarter of the employees earn less than $5,000 annually, most of who are part-time workers, including students and semi-retired persons. These eight labor categories are later aggregated into three groups for use in the SAM, with L1-L3 making up the lowest category, L4-L6 composing the middle income category, and L7-L8 composing the highest income category in the city.

Table 5-1: Employment and Wage Statistics (1998)

Labor Category ↓	# of Employees	% of Employees	Total Annual Wages (Million $)	Average Annual Wage ($)
Less than $5000 (L1)	16,856	25.45%	44.28	2,627
$5,000 - $9,999 (L2)	9,368	14.14%	67.90	7,248
$10,000 - $19,999 (L3)	11,729	17.71%	173.46	14,789
$20,000 - $29,999 (L4)	10,417	15.73%	255.39	24,517
$30,000 - $39,999 (L5)	6,361	9.60%	219.41	34,493
$40,000 - $49,999 (L6)	4,112	6.21%	182.74	44,440
$50,000 - $69,999 (L7)	3,912	5.91%	229.18	58,584
$70,000 and Greater (L8)	3,482	5.26%	344.80	99,024
Total	66,237		1,516.90	

5.3 Household Data

In this model, there are six household divisions (HH1-HH6) encompassing a total of 40,119 households for the city. As displayed in **Table 5-2**, the household divisions are based on income, with almost half of all households in categories HH5 and HH6. Households are comprised of full-time, part-time, and unemployed individuals. **Table 5-3** presents the number and percentage of total households, non-working households, and working households. Over one-half of all non-working households are in category HH6 (income greater than $70,000). This is because non-working households include retirees, in addition to students and those unemployed. Each of the households makes expenditures for the consumption of goods and services provided by the production (industry) sectors, household services (HS1-HS4), and taxes. HH5 and HH6 contribute to savings and investments. On the income side, the households receive payments for labor (3 sectors), as well as returns on land and capital ownership.

Table 5-2: Household sectors by income (1998)

HH Sectors↓	Income Level	Total # of Households	% of Households
HH1	Less than $10,000	3,525	8.70%
HH2	$10,000 - $19,999	5,249	12.96%
HH3	$20,000 - $39,999	9,061	22.36%
HH4	$40,000 - $49,999	3,011	7.43%
HH5	$50,000 - $69,999	8,681	21.43%
HH6	$70,000 or Greater	10,990	27.12%
Total		40,517	100.00%

Table 5-3: Total, Non-Working, and Working Households (1998)

	Total Households		Non-Working Households		Working Households	
HH Sectors↓	# of Households	% of Households	# of Households	% of Households	# of Households	% of Households
HH1	3,525	8.70%	61	2.17%	3,464	9.19%
HH2	5,249	12.96%	174	6.18%	5,075	13.46%
HH3	9,061	22.36%	255	9.05%	8,806	23.36%
HH4	3,011	7.43%	214	7.60%	2,797	7.42%
HH5	8,681	21.43%	567	20.13%	8,114	21.52%
HH6	10,990	27.12%	1,546	54.88%	9,444	25.05%
Total	40,517	100.00%	2,817	100.00%	37,700	100.00%

Two data sources were used in the estimation of expenditures on goods and services in the community. IMPLAN is an input-output (IO) modeling system capable of estimating up to 528 sectors for any region consisting of one or more counties. In this dissertation, IMPLAN is used to provide estimates of household spending patterns, as well as producing estimates of expenditures by industry sectors. Coupled with the IMPLAN data is survey data made available through the U.S. Bureau of Labor Statistics (BLS). The survey provides a continuous flow of information on the buying habits of American consumer and consists of two separate surveys:

- A quarterly "Interview Survey" in which each consumer unit in the sample is interviewed every three months over a 15-month period. This portion of the survey is intended to collect data on major items of expense, household characteristics, and income;
- Sample consumer units complete a "Diary Survey" as part of the Consumer Expenditure Survey (CES). In this survey participants are asked to maintain expense records, or diaries, on all purchases made each day for two consecutive one-week periods. The unit of analysis for the CES is the consumer unit, consisting of all members of a particular housing unit who are related by blood, marriage, adoption, or some other legal arrangement.

In addition to expenditures made for goods and services, households also spend on housing services, mostly consisting of mortgage and rental payments. These values show up under the HS1-HS4 categories. HS1 corresponds to residences valued at less than $120,000; HS2 has values between $120,000 and $200,000; and HS3 residences are for homes valued at greater than $200,000. HS4 residences are reserved for multi-unit housing, such as apartment buildings. The breakdown of the number of households in each housing services sector is presented in **Table 5-4**. The office of the Larimer County Assessor provides the housing data. Looking at the SAM for this model, we see that those individuals that fall into HH1 income levels are spending only on HS4, while those with household incomes in the HH6 range (over $70,000) live in homes that fall into sectors HS3 and HS4 only.

Table 5-4: Households per Housing Services Sector (1998)

		Households per Housing Sector Division				
HH Sector ↓	People per Household	<120,000 (HS1)	121K-200K (HS2)	>200K (HS3)	Multi (HS4)	Total
0k-9,999	1.75	0	0	0	3,525	3,525
10K-19,999	2.30	404	0	0	4,845	5,249
20K-39,999	2.60	3,377	0	0	5,684	9,061
40K-49,999	2.90	2,682	0	0	329	3,011
50K-69,999	3.10	4,020	4,661	0	0	8,681
70K+	3.00	0	8,546	2,444	0	10,990
Total		10,483	13,207	2,444	14,383	40,517

A third component of household expenditures is savings/investment. Household data are difficult to determine in most instances. Therefore, the model solves for this endogenously and treats savings as the difference between income received and amount spent by the households. Only positive savings are allowed and only household sectors HH5 and HH6 have any savings.

A final expenditure is for taxes. Households pay federal and state personal income taxes, county property taxes, and a variety of local services and amenities.

Federal and state taxes are identified as USPIT and are found by analyzing the federal and state tax records. Data for the property taxes (CNPRP) collected are available through the Larimer County Assessor's office. The tax revenues for/from local services and amenities are grouped together as CYORV. The data on these expenditures are found in the analysis of city financial records.

Household income comes from several different sources. These include wages from labor (3 sectors), returns from investments in land and capital, remittances from retirement plans and investments, and government transfers (mainly social security and "welfare"). The labor income provides the majority of the revenues and these values are developed from data received from ES-202 and UI records. Income generated by the land and capital is produced from the information available at the Larimer County Assessor's office, while the government transfers to individuals are found in federal and state databases.

5.4 Capital and Land Data

Capital stock and land, along with labor, are the necessary inputs into the production process. In this model, the land component of the model is actually the composed of three separate categories of land – commercial land, residential land, and undeveloped land. Capital stock is comprised of K1 - the value of buildings that firms use to produce output (i.e. factories and farms) and K2 - the machinery and equipment used by businesses and individuals (i.e. computers, tractors, and assembly line machinery). **Table 5-5** shows the amount of land and labor used in each industrial (productive) and housing services sectors of the Fort Collins economy. With 5,216 acres, land usage is dominated by the agricultural production (AGPRO) sector, while over half the capital investment belongs to the manufacturing (31%) and computer manufacturing sectors (21%). Estimates of the capital stock values were produced from information obtained from the Larimer County Assessor's Office. Information on land, including the value, acreage, and zoning, were also obtained from the Assessor's office. In addition to the income generated to businesses from capital and land, residences also gain additional wealth through the returns from these sectors. The county assessor's office maintains records on the values from the land and structures on the land that are owned by individuals.

Table 5-5: Land and Capital Usage by Industrial and Housing Sector (1998)

	Land		Capital	
Sector ↓	Land Usage (# of Acres)	% of Land Used	Capital Usage (Million $)	% of Capital Used
AGPRO	5216	43.03%	13.44	0.18%
AGSER	5	0.04%	15.00	0.20%
CONST	43	0.35%	156.37	2.04%
MINNG	76	0.62%	408.51	5.33%
RECYC	37	0.31%	204.25	2.67%
AGPRS	30	0.25%	295.43	3.86%
MANUF	233	1.92%	2,409.85	31.45%
CMANF	146	1.20%	1,596.20	20.83%
COMMU	14	0.11%	52.43	0.68%
ELECT	3	0.02%	37.48	0.49%
WATER	3	0.03%	15.21	0.20%
RETAL	130	1.07%	260.09	3.39%
FIRE	22	0.18%	119.32	1.56%
LODGE	11	0.09%	26.91	0.35%
EATING	16	0.13%	173.40	2.26%
LWSER	136	1.13%	336.40	4.39%
HGSER	52	0.43%	259.19	3.38%
TRUTL	20	0.16%	28.55	0.37%
WHOLE	151	1.25%	83.89	1.09%
ELE2	74	0.61%	35.90	0.47%
UNIJC	402	3.31%	11.22	0.15%
DK	45	0.37%	119.63	1.56%
HS1	1584	13.06%	247.50	3.23%
HS2	2,662	21.96%	434.10	5.66%
HS3	910	7.50%	102.92	1.34%
HS4	104	0.86%	220.33	2.88%
Total	12,122	100.00%	7,663.54	100.00%

5.5 City and County Data

The information gathered for the city and county portions of the dissertation are developed from financial and personnel departments within the city and county. Local city government sectors incorporated into the model include Police, Fire, Parks and Recreation, Transportation, and Administration. As with the private sector, the government sectors make expenditures for goods and services, labor, and Social Security contributions. The data for these transactions are readily available through city and county databases, with much of the information available in the city Comprehensive Annual Financial Report (CAFR) and the audited financial records for the county. For the Poudre R1 school district, the expenditures are found in the district's audited statements. Financial data from Colorado State University came from state and university financial records and are easily obtained.

Revenues for the governmental sectors are generated through taxes. The model implemented here uses a general fund (CYGF) as a way of transferring the collected taxes from their original sources to pay for the city sectors previously mentioned (Police, Fire, etc). The largest sources for the funds are sales taxes, household payments for city services (CYORV), use taxes, and property taxes. Property tax records are available through the Larimer County Assessor, while records of the other taxes can be found in the city databases.

5.6 Aggregates, Recycling, and Landfilling Data

Data on the costs and benefits of the aggregates industry operations are available through a variety of sources, including the United States Geological Survey (USGS), Larimer County, and the city of Fort Collins. Data on the value and quantity of virgin aggregates materials use is provided at the district level by the USGS Mineral Information Team. Larimer County (and therefore Fort Collins) lies in Colorado District 2 along with Weld and Morgan counties. Using city and county populations as a basis for the distribution of the materials, Fort Collins is estimated to acquire/use approximately one-quarter of the materials produced for District 2. Confidentiality concerns prohibit the disclosure of data below the district level.

The city of Fort Collins, through the Street Department, runs an aggregates recycling facility, where old material is processed for re-use. Larry Schneider, Fort Collins City Streets Superintendent, was very helpful in providing revenue and cost data for the manufacturing and selling of the recycled aggregates. Cost information for the Larimer County landfill use was also necessary for the calculations. This information is accessible by contacting the county landfill office.

Not included in the analysis performed in this dissertation are the costs of transportation to the recycling facility. However, it is assumed that the costs of transportation to the recycling facility are offset by the gains from not having to take the waste materials to the landfill and pay the other associated expenses (tipping fees, etc).

5.7 The Social Accounting Matrix (SAM)

The SAM is a double entry accounting system that allows the data to be organized in a manner so that it can be extracted and used by the GAMS software, which in turn produces the reported results. **Figure 5-1** provides an example of the theoretical framework of the SAM.

Figure 5-1: The Social Accounting Matrix

		Expenditures						
		Production/ Commodities (1)	Factors – Labor (2)	Factors– Land and Capital (3)	Households (4)	Governments (5)	Rest of World (6)	Total (7)
Receipts	Production/ Commodities (1)	Intermediate Demand ($3151 mil)			Household Demand ($2533 mi)	Government Demand ($430 mil)	Exports ($3814 mil)	Total Production Revenues
	Factor - Labor (2)	Value Added for Labor ($1387 mil)				Government Payments for Labor ($130 mil)	Value of Labor Exported out of Fort Collins ($419 mil)	Total Factor Income for Labor
	Factors – Land and Capital (3)	Value Added for Land and Capital ($890 mil)						Total Factor Income for Land and Capital
	Households (4)		Distribution of Value Added for Labor ($891 mil)	Distribution of Value Added for Land and Capital ($560 mil)	Savings ($244 mil)	Transfer Payments to Households ($56 mil)	Foreign Transfers and Savings ($846 mil)	Total Household Income
	Governments (5)	State, Local, and Federal Taxes ($245 mil)	Social Security ($106 mil)		Household Taxes ($261 mil)	Inter-governmental Transfers ($87 mil)	Foreign Transfers and Savings ($26 mil)	Total Governmental Revenues
	Rest of World (6)	Imports ($4255 mill)						Total Imports
	Total (7)	Total Production Expenditures	Total Labor Expenditures	Total Land and Capital Expenditures	Total Household Expenditures	Total Government Expenditures	Total Exports	City GCP

A SAM provides a static picture of the economy at a given point in time. The SAM in the table above records the monetary flows into and out of six designated components, or segments, within the economy (not including the total columns). The columns of the SAM are intended to record the expenditures one sector pays to another for goods and services, while the rows record the receipts of payments for those goods and services. Therefore, whenever any transaction is made the amount of that transaction appears at the intersection of the participating sector. In order for a SAM to be considered balanced, the total amount of funds received in each sector must be equal to the total amount of expenditures paid out by the corresponding sector. As an example, the column amount from the "Mining" sector must be equal to the row amount from the "Mining" sector. This must be true for all sectors and for the total of all sectors.

The Production/Commodities component of the SAM (henceforth referred to as the Production sector and designated as row and column (1)) presents the purchases of intermediate and final goods in the product markets. This portion of the model is in effect an input-output table. There are twenty-six sectors within this component, including sectors for agriculture, construction, manufacturing, mining, utilities, and finance, among others. Of special significance to us is that the Production component also includes the aggregates recycling sector. Each sector may pay for goods and services received from any of the Production sectors (including itself). The sectors also pay for factors of production (land, labor, and capital), transfers to social security, local, state and federal taxes, and for any imported goods or services. On the other side of the ledger, the individual production sectors receive income from other Production sectors (including themselves), households (including investments), state and local government activities, and from those agents outside of the economy (exports). The construction and finance, insurance, and real estate (FIRE) industries also receive payment for the goods and services they provide to the Housing Services components of the economy. For this dissertation, Housing Services are considered as sectors in the Production component.

The aggregates recycling sectors (DN and DK) are included in the Production component of the SAM. DN is a transfer mechanism in which recyclable (waste) aggregates materials produced by the other sectors (exclusive of DK) in the Production component are collected. These waste materials are then taken by the DK sector, which reprocesses and sells the recycled materials to other sectors within the Production, Household, and Government groups. While DN and DK are developed as separate industries within the SAM, they actually are two components of the same aggregates recycling industry – one component required to collect the materials and the other to process and market the finished, recycled materials to other sectors.

The factors of production are labor (column and row (2)), and land and capital (column and row (3)). These are the value added components of the economy. In this SAM, there are three sectors for labor, one for land, and one for capital. Each factor of production produces income for the six household sectors. Salaries and wages from the labor sectors provide the majority of income to the households, while returns from land and capital add to the household income. Additionally, the three categories of labor make payments into the social security trust fund. All three of the factors receive payments from each of the Production sectors, including payments from the housing services sectors to land and capital. The state and local government sectors provide wages (labor), but do not own land or capital so they do not provide payment to those factors.

As mentioned earlier in the chapter, the Households component (columns and rows (4)) is divided into six groups based upon income, with households earning between $0 and $9,999 in HH1, $10,000 and $19,999 in HH2, $20,000 and $39,999 in HH3, $40,000 and $49,999 in HH4, $50,000 and $69,999 in HH5, and $70,000 or more in HH6. These households pay for the commodities produced by the Production sectors, as well as to the savings component of the Household groups. The groups further contribute to government tax revenues at the federal, state, and local levels, while receiving income from labor salaries and wages, returns on land and capital, and transfers of social security benefits.

The Household groups also include two sectors dedicated to commuting into and out of Fort Collins for work. These sectors attempt to capture the impacts of commuting on the six household groups. The "commuting in" component is comprised of individuals working in the city, but living outside Fort Collins, while the "commuting out" portion represents those who work outside the city and bring income back into the community.

Taxes are also paid by the Households groups. Taxes are transfers of funds from one entity (individuals or businesses) to other entities (governments). Social security taxes are paid by all employers in the private and public sectors and by each of the three labor groups (USSOCL1-USSOCL3). Social security taxes are paid out to the individual household occupants and to STFED operations.

Private personal income taxes come from the wages earned in the six Households sectors. An additional sector is included for a variety of other federal taxes (FEDTX). These taxes are collected from almost all sectors and distributed to other state and federal agencies for use. Other taxes are paid by employers (private and public) and by the households. These include property taxes, sales taxes charged by the City of Fort Collins for almost all retail goods, and use taxes charged to firms by the City of Fort Collins for purchases of intermediate goods that originate outside the city. City sales taxes are received from the retail, eating, lodging, low services, and utilities production services. A "catchall" sector that combines all other local taxes is called "other revenue" (CYORV) and includes items such as fines and fees.

Revenues received by the Households sectors come from a variety of sources. As noted earlier, the largest portion of income for the households comes from the factors of production. The households also receive funds from their investments, transfers from the government (Social Security, welfare, etc), and for remittances originating outside of the city.

The Government sectors (columns and rows (5)) make payments for the goods and services they purchase from the Production sector businesses. They also make payments for labor (wages) and a variety of transfers, both to the private sector and to other elements in the government. The majority of the local government operations are financed through taxes that are collected and pooled into the city general fund. These funds are then redistributed to the various government agencies (police, fire, parks and recreation, etc.).

A sector designated as Rest of World (columns and rows (6)) is the part of the economy where imports and exports are introduced. When the economy imports goods and services, money leaves the economy and when goods or services are exported additional money is introduced into the economy. All of the Production sectors import goods and services, while goods and services are exported from all of the Production sectors except housing services. Additionally, labor is exported (commuting out) and there are transfers from both the Households sector and the Government sector to entities outside of the city.

The SAM is the final "resting place" for the data before it is extracted by the CGE software. However, the data must often be transformed before ever getting to the SAM. This activity occurs in the "side" worksheets. For this SAM there are twelve separate "side" worksheets where the data initially enters the process. Some of these worksheets, like the Import-Export sheet, feed directly to the SAM, while others export the data to other worksheets for additional processing before being sent to the SAM.

Chapter Six: Model Results

6.0 Introduction

The intent of this chapter is to report the results of simulations that have been performed in an attempt to evaluate the effectiveness of implementing/maintaining an aggregates recycling program in a small city. The policy alternatives evaluated in this chapter include a tax on depositing aggregates materials waste in a landfill, a subsidy for the purchase of recycled aggregates materials, a regulation requiring that industry in the city increase the amount of recycled aggregates used, and a regulation that requires specified industries to increase their provision of waste that can be recycled.

For the landfill tax and recycled materials purchase subsidy, the model is used to explore the net benefits when the availability of materials varies due to changes in the recycling rate/landfill deposit mix and changes in the levels of taxation and subsidy. Mix, as used in this dissertation, refers to the percentage of material being recycled versus the percentage of material being directed to the local landfill. As an example, a simulation that includes a 50%-mix would have 50% of all waste aggregates material being recycled and send 25% of the material to the landfill when the tax/subsidy is applied. For both the landfill tax and recycled materials purchase subsidy, an "original" (current) mix (approximately 21% of aggregate waste materials being recycled), a 25% mix, and a 50% mix are simulated. The original mix represents an estimation of the current level of waste aggregates recycling in Fort Collins.

In addition to the tax and subsidy scenarios, two different regulatory policy changes (mandatory increased use of recycled material and mandatory increased provision of recyclable material) are analyzed. For the increased use of recycled materials, simulations are run in which each of the productive sectors is required to grow their use of recycled aggregates by designated percentages. In order to perform these simulations, the domestic input-output coefficients (AD coefficients) of the CGE model are adjusted to produce a "transfer" of source material from the mining (quarrying) sector to the recycling sector. In other words, changes are made that result in decreasing amounts of the virgin materials utilized and increasing amounts of recycled materials used by the other productive sectors in the economy.

For the second mandatory change in regulatory policy the top five producing sectors (construction, agricultural processing, manufacturing, low services, and high services) of possible recyclable aggregates materials are required to increase their supply of these materials by specified percentages. For these scenarios I produce changes to the CGE program that diverts material away from the landfill and directs it to the recycled materials sector. This task is performed by adjusting the AD coefficients on those top 5 producers of recyclable materials in the same manner used for the increased consumption. However, in this instance, the effort is directed toward increasing the supply of recyclable materials directly instead of increasing the demand for the recycled materials. For this regulatory change increased costs are incurred, as the affected sectors are required to sort and prepare the materials for recycling. The costs of sorting and preparing are largely borne as increased labor costs. Due to the lack of detailed information on these additional labor costs the approach taken here is to decrease labor productivity to the point that a "break-even" condition is achieved. The reduced labor productivity is achieved by introducing the variable "TT" into the GAMS (CGE) code. In the simulations performed here, breaking even means that the sum of the changes in domestic supply of all sectors equals zero (or near zero) when the labor productivity of the five major producers decreases.

The remainder of this chapter presents the simulation results and conclusions drawn from these simulations. "Base case" scenarios for each of the four policy changes (landfill tax, materials purchase subsidy, increased consumption of recyclable materials, and increased provision of recyclable materials) are presented first. This portion is followed by a sensitivity analysis section, in which levels of taxation and subsidy are increased and recycling-landfilling mixes are changed. For the regulatory changes, the AD coefficients and "TT" variables are adjusted to increase the percentages of material consumed or supplied in the individual sectors, while maintaining a "break-even" condition.

6.1 Simulation Results

In this section I present the results of simulations for policies intended to encourage additional aggregates recycling and discourage the use of landfilling as a method of disposal. As previously mentioned, "base case" simulations are analyzed first, followed by the sensitivity analyses.

6.1.1 Base Case Simulation Results

For the landfill tax, the "base case" consists of the original mix and a 5% tax increase on landfill deposits, while the purchase subsidy "base case" is composed of the original mix and a 5% return on the purchase of recycled aggregates materials. The revenues derived from the landfill tax flow into the Sales Tax component of the model. Modeled in a similar manner, the subsidy for the purchase of recycled aggregates materials is drawn from the Sales Tax component. The 5% tax and subsidy increases are chosen because smaller increases produce essentially no change in economic conditions. With that said, even at the 5% levels, the tax and subsidy changes have little economic impact. For the regulatory changes, the "base case" scenarios involve 5% increases in the consumption and production of recycled materials (brought about by the AD changes). With the increased supply regulation it is also necessary to adjust the "TT" variable to produce the "break-even" condition for the increased production of materials. The "base case" analysis includes three sections, with the first section evaluating changes in household incomes, tax revenues, employment and wages, and domestic supply. These results are presented in **Table 6-1**. The second section takes a closer look at the changes in household income, with analysis of the distribution of the changes between six household categories (HH1-HH6). These results are presented in **Table 6-2**. A third section summarizes the results of the "base case" and highlights the strengths and weaknesses of each approach.

6.1.1.1 Household Incomes, Tax Revenues, and Domestic Supply

<u>Landfill Tax and Material Purchase Subsidy Results</u>

Cursory looks at the landfill tax and materials purchase subsidy scenarios show very small economic impacts on the community when the policies are implemented. However, based on the results, some behavioral responses may be inferred. **(Table 6-1)**

Under the increased tax plan, local tax revenues increase, while household incomes decline. As previously mentioned, revenues from the landfill tax increases flow to the city sales tax coffers. The increased sales tax revenues are significantly greater than the declines in the revenues to the other local tax categories - county property taxes (CNPRP), city use taxes (CYUSE), and all other tax revenues (CYORV). These tax revenue declines are most likely due to small losses in employment and a reduction in the number of working households in the city. A fifth local tax (CYNVT) is unchanged. The net result is positive tax revenues. Household incomes, as expected, fall with the increased landfill tax. The additional costs of doing business lead to lower employment levels and a decline in the number of households in the city. Overall, the additional income flowing to sales tax revenues offset the declines in household incomes, creating positive net revenues (HH Income + Tax Revenues) for the community and a net gain in households and workers.

Table 6-1: Base Case Changes Due to Implementation of a Materials Landfill Tax, a Materials Purchase Subsidy, an Increased Materials Use Regulation, and an Increased Materials Supply Regulation

	Landfill Tax	Purchase Subsidy	Increased Materials Use	Increased Materials Supply
HH Income	-$0.95 million	$0.20 million	$3.46 million	$0.57 million
Tax Revenues	$0.72 million	-$0.17 million	$0.14 million	$0.28 million
Net Revenues	$0.23 million	$0.03 million	$3.60 million	$0.85 million
Total Households (#)	-10	2	52	97
Employment (#)	-28	7	162	315
Wages (%)				
W1	-0.000425	0.000118	0.3026	0.3992
W2	-0.000044	0.000021	0.0543	0.1608
W3	-0.000056	-0.000003	-0.0016	0.1362
Domestic Supply	-$2.53 million	$0.60 million	$21.91million	---

When the results of a materials purchase subsidy are analyzed, the outcomes are predictably contrary to those presented with the landfill tax – i.e. household incomes are positive, tax revenues are negative, and net revenues are negative. In this case, the subsidy is financed by general sales tax collections, producing losses in sales tax revenues. Three of the other four tax collection sectors produce small increases, but are insufficient to overcome the declines in the sales tax revenues, thereby producing negative net tax revenues. CYNVT is unchanged. On the household income side, the subsidy lowers costs for the (mostly commercial) purchase of recycled aggregates. These lower costs produce additional profits, resulting in small gains in household income. When combined, the losses in tax revenues collected are greater than the gains in household incomes, producing negative net revenues for the community.

Aggregates are a high-volume, low-value product, and as such, the change in net revenues created from either the increased disposal tax or the recycled materials purchase subsidy is small. As a result, the changes in employment, wages, and the total number of households in the city are also small under either policy change. The changes in domestic supply for the individual sectors or for all sectors combined, while not insignificant, are likewise small with either option. Under the materials purchase subsidy scenarios, domestic supply shows small gains.

Despite the small impact from either of these policies, there is one possibly significant finding that does result from these simulations. With the landfill tax there is a positive change in the supply of recycling services (DK) and a decline in landfill services (LF) – both of these are goals of the policy. With the subsidy, there is also an increase in the provision of recycling services, but also an increase in the landfill services provided, a condition that is contrary to the stated goals of the policy.

Regulatory Changes Results

When the policy involves regulatory (mandatory) changes in business operations, the results are significantly different from the tax and subsidy approaches. Unlike the previous scenarios in which the changes (both positive and negative) are very small, there are large gains with the regulatory policy changes. This is due to several reasons; chief among them are cost reductions from securing less expensive material inputs and the creation of new jobs.

Referring back to **Table 6-1**, changes in both household incomes and tax receipts are positive when a mandatory 5% increase in the consumption of recycled materials ("base case") is simulated. The increase in household incomes is due in large part to the increased demand for labor and resulting higher wages as production increases. The increases are more pronounced among the lower wage groups, with almost two-thirds of the employment gain (105 jobs) flowing to those in the lowest labor category. The wage growth is also greatest in the lower category, with the increase (0.3%) in wage category *W1* almost five times larger than the percentage increase for those in the middle wage category, *W2*. This is an indication that the policy change impacts lower-income households the most.

Much of the gains are created as a product of lower costs and higher output. By substituting a less expensive input (recycled aggregates for virgin aggregates) businesses are able to generate larger output, creating new jobs and/or better paying jobs in the community. Led by significant increases in sales tax revenues (over $105,000) created by greater economic activity in the community, the total tax revenues also increase. Together, these outcomes produce significant gains in net revenues (taxes + household incomes) in the city ($3.6 million).

Domestic supply impacts (increase of $22 million) are larger than with either the subsidy or tax options (original mix, 50% disposal tax excepted). With domestic supply, eighteen of the twenty-seven sectors evaluated showed positive changes, while eight of the remaining nine sectors produced relatively small declines in supply (less than $200,000 lost). Three sectors, DK ($9.8 million), Construction ($6.6 million), and Low Services ($2.6 million), produced the majority of the increase. An interesting development occurs when looking at the Mining sector. Despite a decline in the domestic demand for virgin aggregates materials (due to the increased recycled material use requirement), the supply in the sector actually increases by $225,000. This is precipitated by a decline in prices received by the producers, which leads to a $230,000 increase in exports.

The second mandatory change (and overall, the fourth policy initiative) evaluated is designed to require the top five producers of possibly recyclable aggregates materials (construction, agricultural processing, manufacturing, low services, and high services) to increase their supply of these materials. For this scenario it was necessary make changes to the CGE program that diverted material away from the landfill and direct it to the recycled material sector. This is performed by adjusting the AD coefficients of the top 5 producers of recyclable materials to reflect a 5% increase in the materials supplied for recycling (and away from landfill deposits). A significant portion of the expense of redirecting the waste material from the landfill requires an increased amount of labor to sort the waste material into that which can be recycled and that which cannot be recycled. Under this scenario the goal is to reach a "break-even" condition, where "break-even", as previously defined, involves having the total domestic supply for all productive sectors sum to (near) zero. Please refer back to page 2 in the Introduction portion of this chapter for further details.

While the positive changes in household incomes are significantly smaller than they are with the increased mandatory use regulation (approximately 1/6th the size), the changes are still much larger than those experienced with either the tax or subsidy changes. As with the mandatory use regulation, the increase in household incomes is driven by two main components: (1) increased employment and (2) increased wages.

There are 315 new jobs created when this simulation is performed, with 185 of those jobs (almost 59%) created in the lowest labor category (*L1*). This is appropriate as the material sorting positions are considered low skill, low wage jobs. However, employment grows in all three labor groups (*L1, L2,* and *L3*). Wage growth is also greatest among those in the lower wage group (*W1*) increasing nearly 0.4% (followed by growth for *W2* at 0.16% and *W3* at 0.14%). Each of these reflects the upward pressure on wages as the productive sectors search for employees and business expands.

Under this scenario, tax revenues increase by a larger amount (over $275,000) than in any of the other scenarios, with each of the tax sectors producing positive changes. The greatest impact is in the property tax sector, where increased employment (and therefore an increased number of households in the city) drives up property values and correspondingly property tax collections. Increased property tax collections account for over 88% of the total tax revenue increases. When taken together, the changes in household income and the changes in tax revenues produce the second largest net revenue impact on the city (about 1/4th of the increased materials use scenario).

As previously mentioned, for a "break-even" condition to exist in this model, changes to domestic supply from all sectors must sum to zero. So, while the community-wide supply impact is neutral, the impacts on the individual sectors are not. All of the five sectors that are forced to increase their supply of recyclable material show increases in domestic supply. Although the firms in these sectors are forced to hire more workers and thus increase the costs of doing business, the majority of these workers are low wage. When this is coupled with lower total disposal costs (less material sent to landfill) and higher prices for their (formerly) waste material, increased supplies are possible. All other non-housing service sectors experience declines in supply.

This policy produces a couple of desired outcomes that others fail to produce - a decline in the supply of and demand for mining (quarrying) and landfill services.

6.1.1.2 Household Income Distributions

These analyses are performed using the base case (original mix) data for each possible policy. Close analysis of changes in household incomes yields similar distributional effects between three of the four scenarios, with only the mandatory increased supply of recyclable materials having appreciable differences.

For the landfill tax scenario, while the losses in household incomes are small overall, the almost half of those losses occur in the HH6 (45.0%) (**Table 6-2**). Categories HH5 (19.9%) and HH3 (19.8%) account for the majority of the remaining losses. As previously determined, household incomes decline because the tax on depositing aggregate materials in a landfill adds to the cost of "doing business", which in turn, results in smaller profits. However, this effect is very small, and business owners and operators are not forced to reduce production by significant amounts. As such, payrolls are only slightly impacted. The owners and operators absorb much of the losses in revenues and see slightly smaller incomes, thus affecting incomes in the highest income groups (HH6 and HH5). The rest of the decline in incomes results from the small drops in employment in the community. The group that experiences the greatest drop in employment (and thus income) is HH3. With the exception of HH1, there are more households that fall into HH3 than any other category. As such, employees from the HH3 category are most likely to show the largest cumulative losses at this level of taxation. The least affected group would be those in HH1. Although this is the group with the largest number of employees, they are mainly students and other part-time workers earning less than $5000 per year, so the impact on them would be small. In total, the greater burden for this tax falls to those in the upper half of the income brackets (HH4-HH6), accounting for over 70% of the income losses.

Table 6-2: Distribution of Household Income Changes by Household Category for the Base Cases

	Landfill Tax		**Purchase Subsidy**		**Increased Materials Use**		**Increased Materials Supply**	
Category	**Change Amount ($ Mil)**	**Percent of Change***	**Change Amount ($ Mil)**	**Percent of Change***	**Change Amount ($ Mil)**	**Percent of Change***	**Change Amount ($ Mil)**	**Percent of Change***
HH1	-0.020139	2.12%	0.004715	2.4%	0.10779	3.1%	0.09965	17.6%
HH2	-0.073448	7.74%	0.018337	9.4%	0.43741	12.6%	0.11349	20.1%
HH3	-0.188244	19.83%	0.040797	20.9%	0.82053	23.7%	0.56233	99.4%
HH4	-0.051636	5.44%	0.01041	5.3%	0.17027	4.9%	-0.06701	-11.8%
HH5	-0.188717	19.88%	0.040777	20.9%	0.68069	19.7%	0.06324	11.2%
HH6	-0.427120	44.99%	0.079967	41.0%	1.24214	35.9%	-0.20611	-36.4%
Total	-0.949305	100.0%	0.195003	99.9%	3.45883	99.9%	0.56559	100.1%

* Percent of Change Columns may not sum to 100% due to rounding factors

Similar distributions are seen when the subsidy is examined, with the greatest income gain occurring with those households in category HH6 (41.0%). Members of HH6 represent the majority of the owners/operators of businesses and much of any additional economic profit/income would be expected to fall to these individuals. Along with HH6 members, household income categories HH3 and HH5 (each with 20.9% of the income increase) benefit the most from the subsidy. Overall, the upper-middle to upper income households (HH4-HH6) end up with a larger share of the household income gains (67.3% versus 32.7%) with this simulation.

With few exceptions, a similar distribution pattern also exists when a mandatory increased use of recycled materials policy is implemented (regulatory policy #1). As mentioned in an earlier portion of this chapter, when the policy is instituted there are large gains in total household incomes (almost $3.5 million). Once again, as with the subsidy, the greatest benefits fall to those in HH6, HH3 and HH5. However, in this instance, those in categories HH6 and HH5 receive a smaller percentage of the benefits, while HH3 members increase their percentage of the total income change (up 23.7%). Since a significant portion of category HH6 is composed of the owners/operators of the local businesses, it should be expected that they would claim the largest share of these gains and, as in the previous instances, HH3, with the largest percentage of *fulltime* workers, has the next highest percentage of income gains. As a result of the increases in income for HH6, the top three household categories (HH4-HH6), with over 60% of the total gains, have a larger share of the changes than under the subsidy simulation (gains) or tax simulation (loss).

Due to income losses in two household income categories (HH4 and HH6), the distribution under the increased material supply scenario (regulation #2) is much different from the other three scenarios. Almost all (99.4%) of all the *net* gains in income are received by HH3 members. However, three other household categories (HH1, HH2, and HH5) enjoy gains in income of between 11% and 20%. Overall, due in large part to employment gains in the low skill, low wage areas, the lower income households (HH1-HH3) experience significant percentage gains in income, while the upper income households (HH4-HH6) produce net declines in household income. This indicates that the policy tends to benefit lower income households, while having a negative impact on the higher income residents.

6.1.1.3 Summary of the "Base Case" Scenarios

Considering the four "base case" policy options analyzed so far in this chapter a few trends can be discerned. First, neither the landfill tax nor the materials purchase subsidy options have any major economic impact on the community, with losses or gains being minimal. The landfill tax, while producing net revenue (HH Income + Tax Revenues Collected) increases, has the political liability of being a tax. Additionally, changes in employment, the number of households, and domestic supply are all negative. The subsidy produces the opposite result, with positive changes in household incomes, employment, the number of households, and domestic supply and negative changes (declines) in tax revenues. Another difference between these two policies lies in the area of how well they address the goals – to encourage the use of recycled materials and to thereby discourage the use of landfill services. While neither policy has a significant impact on these goals, sector analysis of the domestic supply and demand outcomes show that the tax increase discourages both the use of landfill services and the use of recycling services. However, it also needs to be pointed out that while the supply of landfill services decline, the decline is not offset by the increase in recycling activities. As a result, it can be concluded that consumers may find alternative methods of disposal – possibly including illegal disposal (dumping). The use of a subsidy leads to small increases in the supply of landfill services recycling activities, with the landfill use increasing by a larger amount. This indicates that the introduction of this program may lead to increased use of landfills – a result opposite the desired outcome.

While the gains and losses from these two programs are small, they should not completely be dismissed as options, especially if there are plans to increase recycling programs in the future. Implementing a recycling program that incorporates either the landfill tax or the materials purchasing subsidy may have positive "spillover" effects for the community. In other words, recycling one type of product may lead to an awareness of recycling in general and make acceptance of other recycling programs easier to come by – especially when the program appears relatively "painless".

The two regulatory policy changes have potentially larger benefits, but also larger possible negatives. For the implementation of a policy that would require an increase in the use of recycled aggregates materials (regulation #1), there are increases in all measured areas of consideration (household incomes, tax revenues, domestic supply). Additionally, there is a significant increase in the supply of recycling services, while there is also a decline in the supply of landfill services. Both of these are stated goals of the policies. With the second regulatory change, the requirement that the top five suppliers of recyclable materials increase their provision of the materials, gains in all measured areas of consideration are also positive and significant. This policy does a better job of reducing the supply of landfill services.

When comparing the regulatory changes to the tax and subsidy options, there appears to be significant economic advantages to implementing either of the regulations.

However, in both regulatory cases, there several factors that would engender opposition from the public and some local officials. A few (but not all) of these factors are:

- Additional administrative and monitoring costs to the local government
  - Local governments could incur significant additional costs in record keeping and monitoring of activities that could greatly reduce the benefits of either of these options. Among the additional requirements would be the development of a monitoring system and staffing the agency tasked with the duties. It is unlikely that self-reporting by businesses would be a sufficient method of monitoring.
- Resistance to mandatory (forced) actions
  - While self-reporting reliability is one facet of the problem, a greater difficulty could be the "I dare you" approach. Individuals and businesses do not like being told how to perform their day-to-day activities. Without the cooperation of a substantial percentage of the community, the venture is likely to fail – or, at the least, add to the costs of implementing the policies.
- Market development
  - While some of the industry sectors may be able to more easily meet their needs with the recycled materials, others will find increased uses more difficult to come by. Due to characteristic changes that occur during the recycling processes, there are limits to the uses of the materials at this time. For instance, recycled aggregates can be useful as road base, but not for the road surface and while the recycled materials can be used in

building construction, they cannot be used in building foundation work. As such, there would be a need to develop additional markets for the materials beyond the present uses.

- Facility development
  - There may also be a need to develop more processing facilities in addition to developing more uses of the materials. At this time the city of Fort Collins has converted some of the land originally designated for aggregates recycling to other measures, but could expand the processing load if needed as the number of markets increase.

The next portion of this chapter will present sensitivity analyses performed on these options.

6.1.2 Sensitivity Analysis

Sensitivity analysis is performed on each of the four possible policy changes simulated for the "base cases". For the landfill tax and the materials purchase subsidy, the analyses include increasing the tax rate, the subsidy rate, and the "mix" rate (percentage of material that is being recycled when the tax or subsidy is implemented). Additionally, analysis is performed in which the input coefficients are allowed to vary in response to price changes. In its current form, these coefficients are "fixed". Further analysis of the regulatory policy changes is also performed. With the mandatory recycled material use regulation the percentage of required material use is increased to 10% and 20%, while the recyclable material provision requirement is increased to 10% and 20% for the five top potential supply firms.

6.1.2.1 Landfill Tax and Materials Purchase Subsidy

The sensitivity analyses are performed by combining increases in "mix" rates (up to 25% and 50%) with increases in the tax or subsidy rates (up to 25% and 50% also). The results of changes in household incomes, tax revenues generated, and employment can be seen in **Table 6-3** for the landfill tax changes, while the subsidy change results are shown in **Table 6-4**. Additional results are presented in the Appendix C.

In both cases (landfill tax and materials use subsidy), there is little change from the base case results, regardless of mix or tax/subsidy change. For the landfill tax (**Table 6-3**), household incomes fall and tax revenues increase as the tax rate increases. Predictably, under all scenarios job losses grow as the tax rate increases. However, job losses decline as the "mix" rate increases. This may indicate that recycling activities result in greater job growth than would be attained by continuing/expanding the landfill sector.

Table 6-3: Changes Due to Implementation of Different Landfill Tax Rates at Varying Levels of Recycling Rates

	Original Recycling Mix*	**25% Recycling Mix**	**50% Recycling Mix**
5% Tax Rate			
HH Income		-$0.6 million	-$0.3 million
Tax Revenues		$0.5 million	$0.2 million
Employment (#)		-18	-9
25% Tax Rate			
HH Income	-$4.7 million	-$3.1. million	-$1.6. million
Tax Revenues	$3.6 million	$2.4 million	$1.2 million
Employment (#)	-134	-85	-40
50% Tax Rate			
HH Income	-$9.3 million	-$6.1 million	-$3.2 million
Tax Revenues	$7.2 million	$4.8 million	$2.4 million
Employment (#)	-269	-175	-86

* The Original Recycling Mix and 5% landfill tax rate were reported as the Base Case scenario and are therefore not included in this table

Under the aggregates materials purchase subsidy scenarios, the household incomes rise and the tax collections (always negative) fall as the subsidy increases. However, the "mix" rate appears to have little impact on the income or tax revenues created. Additionally, employment increases as the subsidy rate increases, but changes little when the "mix" rate increases. Taken together, as with the landfill tax, these changes provide a small net increase on community economic well-being.

Table 6-4: Changes Due to Implementation of Different Materials Purchase Subsidy Rates at Varying Levels of Recycling Rates

	Original Recycling Mix*	**25% Recycling Mix**	**50% Recycling Mix**
5% Subsidy Rate			
HH Income		$0.195 million	$0.196 million
Tax Revenues		-$0.168 million	-$0.169 million
Employment (#)		7	13
25% Subsidy Rate			
HH Income	$0.979 million	$0.982 million	$0.983 million
Tax Revenues	-$0.844 million	-$0.845 million	-$0.846 million
Employment (#)	33	39	39
50% Subsidy Rate			
HH Income	$1.972 million	$1.973 million	$1.975 million
Tax Revenues	-$1.695 million	-$1.695 million	-$1.696 million
Employment (#)	66	66	72

* The Original Recycling Mix and 5% materials purchase subsidy rate were reported as the Base Case scenario and are therefore not included in this table

6.1.2.2 Regulation Changes

The first portion of this chapter includes the results of the base case simulations in which regulatory policy changes are made. These simulations model 1) mandatory increases in the use of recycled aggregates materials; and 2) mandatory increases in the provision of recyclable waste aggregates materials by the top five aggregates waste producing sectors (construction, agricultural processing, manufacturing, low services, and high services). This portion of the chapter reports the results of the sensitivity analysis on these two policy approaches. This analysis is somewhat greater in scope than that performed for the tax and subsidy changes due to the greater potential impact of these regulatory modifications.

Mandatory Use Increase Sensitivity Analysis:

The first regulation discussed is a requirement that all productive sectors increase their consumption (use) of recycled aggregates materials. The base case simulated increasing the consumption rate by 5%, while this sensitivity analysis increases that rate to 10% and 20%. For the base case operations, it is necessary to adjust the input-output coefficients (AD coefficients) of the CGE model so that 5% of the virgin materials used are replaced by 5% of recycled aggregates in the production process. For this sensitivity analysis, those percentages are increased to 10% and 20%, respectively.

Referring to **Table 6-5**, changes in household incomes and tax receipts are both positive and increasing as the consumption of recycled materials increases. Household incomes increase by 46% over the base case change at the 10% increased consumption level and 145% over the base case change at the 20% increased consumption change. As the continued use of a less expensive material (recycled aggregates) grows, so do industry outputs, which leads to job growth and higher wages in the community.

Tax revenues also increase as the recycled material use grows. While the growth in tax revenues as a percentage of the total amount of taxes collected is small (0.17% for the 10% increased use and 0.38% for the 20% increased use scenarios), if additional costs are not significant it may provide another source of positive revenue for the city. As with the base case, the majority of the tax increase is the result of larger sales tax collections.

However, unlike the base case scenario, property tax collections are positive (Appendix C).

Total domestic supply output increases as the recycled materials use increases. The increase in supply with the 20% increase ($59.1 million) accounts for approximately 1.1% of the "pre-regulation" change ($5.6 billion). As with the base case, the change in the supply of landfill services is negative, indicating that this policy change leads to lower usage of the landfill and possibly increases the "life" of the landfill, reducing the eventual cost to the city. However, as a result of the increased economic activity throughout the city, when compared to the base case, the decline in landfill services supply is smaller as the use requirement increases.

Table 6-5: Sensitivity Analysis for Changes Due to Mandatory Increases in the Consumption of Recycled Aggregates Materials

	10%		20%	
	Change in Output *	Change from Base Case**	Change in Output*	Change from Base Case**
HH Income	$5.04 million	45.7%	$8.46 million	144.5%
Tax Revenues	$0.32 million	128.6%	$0.73 million	421.4%
Total Households	65	25.0%	93	78.7%
Changes in Employment	203	25.3%	294	81.5%
Changes in Wages				
W1	0.0038%	---	0.0055%	---
W2	0.0008%	---	0.0015%	---
W3	0.0001%	---	0.0004%	---
Domestic Supply	$33.97 million	55.0%	$59.05 million	169.5%

* Output changes represent the total (overall) change.
** Change from Base Case represents change from the base case simulations and is not an total (overall) change.

Mandatory Production Increase Sensitivity Analysis:

The second mandatory change in regulatory policy discussed in the dissertation is a requirement that the top five producers of possible recyclable aggregates materials (construction, agricultural processing, manufacturing, low services, and high services) increase their supply of these materials. The base case scenario for this policy change calls for the five top producers to increase their supply of recyclable aggregates waste by 5% (diverted away from landfill disposal). Sensitivity analysis is performed by adjusting the AD coefficients on these producers to reflect 10% and 20% increases in the supply of these materials, while maintaining a "break-even" condition.

Relative to the changes reported in the base case scenario, all evaluated factors (household incomes, tax revenues, number of households, employment, and wages) show increases in the amount of change, with the increases growing as the required supply increases (**Table 6-6**). This indicates that, at least for the levels of change simulated, a greater supply of recyclable material produces larger economic gains to the community.

Overall, household incomes increase by 1.1% over the base case change at the 10% increased consumption level and 10.5% over the base case change at the 20% increased consumption change. However, as with the base case, the majority of the income gains accrue to those in the lower wage groups (HH1-HH3), while there is a loss of income (negative change) in the higher household income groups (HH4-HH6), with HH4 and HH6 experiencing net losses. These results are not unexpected as this policy change requires additional sorting and preparation of the materials – a low skill (and wage) position (Appendix B). As noted in the base case portion of this chapter, as a result of the increased demand for lower skill workers the majority of the job growth is in the lower wage category (*W1*), with wages increasing the most in this group. This trend continues, with the employment and wage levels growing, as the percentage of required material provision grows.

Tax revenues increase as the material supply increases, with revenues at the 10% level up 7.1% over the base case and revenues at the 20% level up 21.4% over the base case outcomes. While all tax sectors showed increases in revenue collected, the majority (approximately 88%) of the increased collections comes from property taxes. This is most likely the result of increased employment and wages driving the housing market.

While this simulation is modeled to have total domestic supply sum to (near) zero (the "break-even" level), individual sectors may experience positive, negative, or neutral changes. Of particular interest are the results for the mining and landfill services sectors. Under the scenarios modeled here, both of these sectors have lower domestic supply outcomes, which grow more negative as the level of required supply increases (Appendix C). This result is consistent with the stated goals of the policy change.

Table 6-6: Sensitivity Analysis for Changes Due to Mandatory Increases in the Supply of Recycled Aggregates Materials

	10%		**20%**	
	Change in Output *	Change from Base Case**	Change in Output*	Change from Base Case**
HH Income	$0.58 million	1.8%	$0.67 million	10.5%
Tax Revenues	$0.30 million	7.1%	$0.34 million	21.4%
Total Households	107	9.7%	125	28.8%
Changes in Employment	346	9.8%	404	28.3%
Changes in Wages				
W1	0.0044%	---	0.0051%	---
W2	0.0018%	---	0.0021%	---
W3	0.0015%	---	0.0017%	---

* Output changes represent the total (overall) change.

** Change from Base Case represents percentage change from the base case simulations and is not an total (overall) change.

Chapter Seven: Conclusions

7.0 Introduction

Natural aggregate, as the second highest valued non-fuel commodity mined in the world today, is important in the operations of several industries and thus is essential to the economic well-being of communities. However, as a low value (per unit), high volume product, disposal of waste materials creates a burden to landfill operations forcing "premature" expansion or relocation of facilities. Additionally, the high demand for aggregates creates large scale operations that lead to the need for the development of new quarries. The relatively higher cost of land used for residential and commercial development forces new operations further from the communities and thus creates higher (transportation) costs. As a result, finding methods to extend the lives of existing landfills and quarries is an important element in the continuing economic well-being of the community. As such, several policies have been implemented in recent years that attempt to reduce the burden by increasing the lifespan of existing landfills and to encourage aggregates material recycling.

This dissertation utilizes a disaggregated Computable General Equilibrium model to analyze four of the policies presented in the literature – a tax on landfill deposits, a subsidy for the purchase of recycled aggregates materials, a policy that requires industries to increase their use of recycled aggregates, and a policy that requires the top five recyclable aggregates waste producing industries to increase the amount of the waste sent to recycling facilities.

7.1 Model Description

The Computable General Equilibrium model relies on data entered into a Social Accounting Matrix (SAM) with a total of sixty components in the matrix, two of which – Landfill Services (LF) and Recycling Services (DK) – are added to previous CGE models in order to distinguish the contribution of these sectors to the general economy. Inclusion of LF and DK sectors additionally allows for the implementation of designed policy changes (landfill taxes, recycled material purchase subsidies, and regulatory changes), which enables observation of the effects of waste removal policies on other sectors within the local economy.

The CGE software contains equations for eight separate activities of the community (production, household consumption, government actions, trade, investment, factor supply, migration, and model closure). Additionally, the model software contains equations that determine prices, quantities, income, expenditures, and equilibria in the model.

7.2 Dissertation Results

Due to the aggregates industry limitations (size of workforce and financial impact), neither the tax on depositing aggregate materials in the local landfill nor the subsidy for the purchase of recycled materials produces significant impacts on household incomes, tax revenues, job creation, wage movement, population, or local business output. For the base case (25% tax rate or 25% subsidy rate at the original landfilling-recycling mix), the tax is found to produce the greatest net revenues (Household Incomes + Tax Revenues) to the community. For the tax at this rate, the increases in collections outweigh the losses in household income, while for the subsidy; the gains in household incomes do not offset the losses in tax collections. This pattern is maintained as long as the original mix is modeled. However, when the recycling-landfilling mix is increased, the reverse conclusion occurs – subsidies produce small gains and taxes produce small losses. Despite the economic advantage of the subsidy at the higher mix levels, there is an additional drawback to the subsidy-only policy, as use of this policy leads to increased use of the landfill facilities, which may result in additional costs in the future. However, the subsidy-only policy may be politically a more viable option due to the absence of any increased levels of taxation. The small changes in economic well being do not mean that a tax or subsidy policy is not a worthwhile avenue to pursue. The relative "painless" impact of having a recycling program may influence the public to accept other recycling/alternative resource disposal approaches for other, larger consequence waste materials.

On the other hand, the policy changes that dictate the use of additional recycled aggregates materials or the increased production of material for recycling produce significant positive changes in the local economy, with large gains in all analyzed areas of the economy. However, these policy changes exclude several potentially negative effects which may negate much (or all) of the program gains and possibly render adoption of these policies unworkable at this time.

7.3 Research Limitations

The most significant limitation is the restrictive nature of functional forms utilized. In particular, the elasticities used to model the behavioral relationships in the consumption equations do not allow for the changes in the substitution between goods and services when there exists changes in incomes (income elasticities) and prices (cross price elasticities). While the intermediate goods input coefficients are allowed to vary in response to changing market conditions (prices), and thus, allow for substitution in the production process, there has been no attempt to allow for substitution between goods in other areas of the production process. Therefore, the demand equations are unlikely to accurately reflect changes in the demand for goods.

A second significant limitation to this research is the lack of data as it relates to increased administrative and monitoring costs when specific regulatory policies are changed. This limitation prohibits the calculation of benefits/costs under current (existing) conditions. However, by modeling a "break-even" result some detail is provided into how large the costs may be without incurring net losses to the community.

7.4 Additional Research

There are several additional avenues of investigation that can be developed based on the work contained in this dissertation. While the results produced by this model are limited, due to a large degree by the smaller contribution of the aggregates sector, it can be modified to handle larger reduction/recycling programs (both commercial and residential) without great difficulty.

In addition to broadening the area of investigation to include disposal of additional types of waste materials, there are other topics that can be addressed with modifications to this CGE model. Chief among these are adjustments to the landfill tax and materials purchase subsidy mechanisms. As currently designed, the tax is a positive component to the sales tax and the subsidy is a negative component to the sales tax. By including a separate element for both the disposal tax and the recycled material purchase subsidy, greater precision in determining the economic impacts of each may be produced.

This model may also be adapted to address different types of policies than were investigated here. In particular, taxes on virgin material use (an "upstream" tax) and subsidies on the return of aggregates waste to a recycling facility may be modeled. This type of subsidy would enable the analysis of a model that is more consistent with the Deposit-Refund System (DRS) approach to waste management and source reduction. The program can also be modified to investigate additional recycling regulations/standards (i.e. limit the amount of landfill disposal and set minimum use standards in building projects).

7.5 Final Comments

Despite the areas of research yet to be explored by CGE analysis, this dissertation has demonstrated that the model can be successfully applied to local waste disposal and environmental issues. In this case, the model provides decision makers with an additional tool as they analyze the implications of policy alternatives for aggregates waste disposal. CGE analysis, as performed here, produces objective results that contribute to the increased understanding of the consequences of changing policy approaches.

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Appendices

APPENDIX A

MODEL NOTATION

SETS, PARAMETERS, TAXES, AND VARIABLES

Set	Dimension	Symbol	GAMS Notation
All Social Accounting Matrix Accounts	60	$z \in Z$	Z
Factor Sectors - All	5	$f \in F$	F
Factors - Labor	3	$f \in L$	L
Factors - Land	1	$f \in LA$	LA
Factors - Capital	1	$f \in K$	K
Government Sectors - All	17	$g \in G$	G
Governments – Endogenous Purchasers	6	$g \in GN$	GN
Governments – Local Endogenous Purchasers	5	$g \in GNL$	GNL
Governments – Revenue Collectors	10	$g \in GX$	GX
Governments – Sales or Excise Taxes	4	$g \in GS$	GS
Governments – Use Tax	1	$g \in GK$	GK
Governments – Factor Taxes	4	$g \in GF$	GF
Governments – Income Tax	1	$g \in GI$	GI
Governments – Per Household Taxes	3	$g \in GH$	GH
Governments – Exogenous Transfer Payments	11	$g \in GY$	GY
Governments – Endogenous Transfer Payments	2	$g \in GT$	GT
Household Sectors - All	6	$h \in H$	H
Industry Sectors - All	27	$i \in I$ or $j \in I$	I
Production Sectors – All	23	$i \in IP$ or $j \in IP$	IP
Industry and Endogenous Government Purchasers	33	$i \in IG$ or $j \in IG$	IG

Parameters	Dimension	Symbol	GAMS Notation
Input Output Coefficients	60 x 60	--	A(Z,Z1)
Domestic Input Output Coefficients	27 x 27	α_{ij}	AD(Z,Z1)
Government Spending Shares of Net Income	32 x 17	α_{ig}, α_{fg}	AG(Z,G)
Factor Share Exponents in Production Function	5 x 27	α_{fi}	ALPHA(F,I)
Initial Shares of Consumption	27 x 6	α_{ih}	ALPHA(I,H)
Income Elasticities of Demand	27 x 6	β_{ih}	BETA(I,H)
Capital Coefficient Matrix (CAPCOM)	27 x 27	β_{ij}	CCM(I,J)
Depreciation Rate	1	δ	DEPR
Domestic Share Price Elasticities	27	η_i^{e}	ETAD(I)
Export Elasticity with Respect to Domestic Price	27	η_i^{ee}	ETAE(I)
Investment Supply Elasticity	1	η_i	ETAI(I)
Elasticity of Land Supply with Respect to Rates of Return	1 X 27	η_i^{lA}	ETAL(LA,I)
Elasticity of Labor Supply with Respect to Rates of Return	3 x 27	η_i^{L}	ETAL(L,I)

Elasticity of Capital Supply with Respect to Rates of Return	1 X 27	η_i^K	ETAL(K,I)
Elasticity of Labor Supply with Respect to Average Wage	6	η_h^L	ETARA(H)
Elasticity of Immigration with Respect to After Tax Household Income	6	η_h^{yd}	ETAYD(H)
Elasticity of Immigration with Respect to Unemployment	6	η_h^u	ETAU (H)
Household Response to Transfer Payments	6	η_h^{ttp}	ETATP(H)
External Wage	1 X 27	$Exwage_{li}$	EXWGE(L,I)
Elasticity of Labor Supply for Out Commuters	3	η_{cmo}^l	ECOMO(L)
Elasticity of Labor Supply for In Commuters	3	η_{cmi}^l	ECOMI(L)
Cross Price Elasticities	27 x 27	$\lambda_{ii'}$	Lambda (I,J)
Natural Rate of Population Growth	6	π_n	NRPG (H)
Miscellaneous Household Parameters (MISC file)	9 x 6	---	MISCH(H,*)
Miscellaneous Industry Parameters (MISC file)	33 x 5	---	MISCH(Z,*)
Intergovernmental Transfers (MISC file)	17 x 17	---	IGTD(G,G1)
Correction Factor between Households and Jobs	6 X 3	ε	JOBCR(H,L)
Substitution Exponent in Production Function	27	ρ_i	RHO(I)
Commuting Out	1	*cmo*	CMO
Commuting In	1	*cmi*	CMI

Tax	Dimension	Symbol	GAMS Notation
Indirect Taxes (Sales and Excise Taxes)	4 x 27	τ_{gi}^v	TAUQ(GS,I)
Consumption Tax Rates	4 x 27	τ_{gi}^c	TAUC(GS,I)
Import Duty Rates	4 x 27	τ_{gi}^m	TAUM(GS,I)
Export Taxes	1 x 27	τ_{gi}^x	TAUX(GK,I)
Factor Tax Rates	4 x 5 x 60	τ_{gfx}	TAUF(GF,F,Z)
Experimental Factor Tax Rates	4 x 5 x 60	τ_{fig}^x	TAUFX(GF,F,Z)
Household Taxes Other Than PIT	1 x 6	τ_{gh}^h	TAUH(GX,H)
Taxes on Intermediate Goods	4 x 27	τ_{qgi}^x	TAUV(GS,I)
Taxes on Investment Goods	4 x 27	τ_{qgi}^x	TAUN(GS,I)
Federal Taxes	4 x 27	τ_{qgi}^x	TAUG(GS,I)
Personal Income Taxes	17 x 6	τ_{gh}^h	PIT(G,H)

Variables	Dimension	Symbol	GAMS Notation
Government Consumption	27 x 17	c_{ig}	CG(I,G)
Private (Household) Consumption	27 x 6	c_{ih}	CH(I,H)
Number of Workers Commuting Into City	1 x 1	cmi	CMI
Number of Workers Commuting Out of City	1 x 1	cmo	CMO
Investment by Sector of Source	27	c_{in}	CN(I)
Consumer Price Index	6	p_h	CPI(H)
Export Consumption	27	e_i	CX(I)
Domestic Supply Share of Domestic Demand	27	d_i	D(I)
Domestic Demand	27	dd_i	DD(I)
Domestic Supply	27	q_i	DS(I)
Factor Demand	5 x 27	u_{fi}	FD(F,Z)

Intergovernmental Transfers	17 x 17	b_{ig}	IGT(G,GX)
Capital Stock	1 x 33	u_{ki}^{s}	KS(K,IG)
Land Stock	1 x 33	u_{lai}^{s}	LAS(LA,IG)
Number of Households	6	a_h	HH(H)
Number of Non-Working Households	6	a_h^{nn}	HN(H)
Number of Households	6	a_h^{ww}	HW(H)
Imports	27	m_i	M(I)
Gross Capital Investment by Sector of Designation	1 x 33	n_{ki}	N(K,IG)
Net Capital Inflow	1	nki	NKI
Nominal Capital Outflow	1	$kfor_k$	KPFOR(K)
Nominal Land Outflow	1	$lnfor_{la}$	LNFOR(LA)
Nominal Government Outflow	17	$gvfor_g$	GVFOR(G)
Aggregate Prices Paid by Sectors	27	p_i	P(I)
Domestic Prices	27	pd_i	PD(I)
Value Added Prices	27	pva_i	PVA(I)
Export Prices	27	pw_i	PW(I)
Import Prices	27	pw_i	PW(I)
Initial Sectoral Factor Rental Rates	5 x 60	r_{fi}	R (F,Z)
Average Sectoral Factor Rental Rates	5 x 60	ra_f	RA(F,Z)
Personal Income	1	q	SPI
Intermediate Demand	27	v_i	V(I)
Intermediate Demand for Aggregates Materials	27	dk_i	DK(I)
Nominal Government Social Security Payments	6 x 17	w_{hg}	TP(H,G)
Gross Household Income	6	y_h	Y(H)
Disposable Household Income	6	y_h^{d}	YD(H)
Government Income	17	y_g	Y(G)

APPENDIX B

COMPLETE GAMS MODEL

```
$TITLE ft collins ANALYSIS MODEL - ftCol3L(WRS:2-05)

*The standard model with Employment in actual workers & 3 Labor groups with SS
fixed

*-----------------------------------------------------------------------------------------------
---
* 1.1 CONTROLS PLACED ON OUTPUT GENERATION
*-----------------------------------------------------------------------------------------------
---

$OFFSYMLIST OFFSYMXREF

*OPTIONS SYSOUT=OFF, SOLPRINT=OFF, LIMROW=0, LIMCOL=0;

*-----------------------------------------------------------------------------------------------
---
* 1.2 SET UP FILE FOR SOLUTION VALUES
*-----------------------------------------------------------------------------------------------
---

FILE RES /e:\mike\ft500LE2.RES/; RES.PW=250; RES.ND = 6; RES.LW = 20;
RES.NW=20; RES.LJ = 1; PUT RES;


*-----------------------------------------------------------------------------------------------
---
* 2. SET DEFINITION
*-----------------------------------------------------------------------------------------------
---
* 2.1 EXPLICIT SET DECLARATION
*-----------------------------------------------------------------------------------------------
---

SETS  Z  ALL ACCOUNTS IN SOCIAL ACCOUNTING MATRIX /
AGPRO                AGRICULTURAL PRODUCTION
AGSER                AGRICULTURE SERVICES
CONST                CONSTRUCTION
MINNG                MINING
LF                   LANDFILL
AGPRS                AGRICULTURAL PROCESING
```

MANUF	MANUFACTURING
CMANF	COMPUTER MANUFACTURING
COMMU	COMMUNICATIONS
ELECT	LOCAL ELECTRIC
WATER	LOCAL WATER
RETAL	RETAIL
FIRE	FINANCEINSURANCE
LODGE	HOTELS MOTELS
EATING	RESTAURANTS AND BARS
LWSER	LOW SERVICES
HGSER	HIGH SERVICES
TRUTL	TRANSPORTATION AND UTILITIES
WHOLE	WHOLESALE
ELE2	POUDRE SCHOOL DISTRICT
UNIJC	UNIVERSITIES AND JUNIOR COLLEGES
DK	RECYCLED CAPITAL
DN	DEPRECIATED INVESTMENT TRANSFER
HS1	HOUSING SERVICES 1
HS2	HOUSING SERVICES 2
HS3	HOUSING SERVICES 3
HS4	HOUSING SERVICES 4
L1	LABOR 1
L2	LABOR 2
L3	LABOR 3
LAND	LAND
KAP	KAP
COMMO	COMMUTING OUT
COMMI	COMMUTING IN
HH1	MARGINAL CO TAX RATE HOUSEHOLDS LOW
HH2	MARGINAL CO TAX RATE HOUSEHOLDS MEDIUM LOW
HH3	MARGINAL CO TAX RATE HOUSEHOLDS MEDIUM
HH4	MARGINAL CO TAX RATE HOUSEHOLDS MEDIUM HIGH
HH5	MARGINAL CO TAX RATE HOUSEHOLDS HIGH
HH6	MARGINAL CO TAX RATE HOUSEHOLDS SUPER HIGH
INVES	INVESTMENT
USSOCL1	SOCIAL SECURITY 1
USSOCL2	SOCIAL SECURITY 2
USSOCL3	SOCIAL SECURITY 3
USPIT	FEDERAL AND STATE INCOME TAX
FEDTX	FEDERAL AND STATE FEES AND TAX
CNPRP	COUNTY PROPERTY TAX
CYNVT	
CYSTX	CITY SALES TAX
CYUSE	CITY USE TAX

CYORV	CITY OTHER REVENUE
CYGF	CITY GENERAL FUND
STFED	STATE AND FEDERAL GOVERNMENT
CYPOL	CITY POLICE
CYTRA	CITY TRANSPORTATION
CYLPR	CITY LIBRARY PARKS AND REC
CYFIR	CITY FIRE
CYADM	CITY ADMINISTRATION
ROW	REST OF WORLD /

F(Z)	FACTORS	/ L1,L2,L3, LAND, KAP/
CM(Z)	COMMUTERS OUT	/COMMO/
L(F)	LABOR	/L1, L2, L3/
LA(F)	LAND	/LAND/
K(F)	CAPITAL	/KAP/
G(Z)	GOVERNMENTS	/ USSOCL1, USSOCL2, USSOCL3, USPIT, FEDTX, CNPRP, CYNVT, CYSTX, CYUSE, CYORV, CYGF, STFED, CYPOL, CYTRA, CYLPR, CYFIR, CYADM/
GN(G)	ENDOGENOUS GOVS	/ STFED, CYPOL, CYTRA, CYLPR, CYFIR, CYADM /
GNL(G)	LOCAL ENDOG GOVS	/ CYPOL, CYTRA, CYLPR, CYFIR, CYADM /
GX(G)	EXOGENOUS GOVS	/ USSOCL1, USSOCL2, USSOCL3, USPIT, FEDTX, CNPRP, CYNVT, CYSTX,CYUSE, CYORV/
GS(G)	SALES OR EXCISE TAXES	/ FEDTX, CYNVT, CYSTX, CYORV /
GK(G)	USE TAX (KTAX)	/ CYUSE/
GL(G)	LAND TAXES	/ CNPRP/
GF(G)	FACTOR TAXES	/ USSOCL1, USSOCL2, USSOCL3, CNPRP/

GI(G)	INCOME TAX UNITS	/ USPIT /
GH(G)	HOUSEHOLD TAX UNITS	/ FEDTX, CNPRP, CYORV /
GY(G)	EXOGNOUS TRANSFER PMT	/ USSOCL1, USSOCL2, USSOCL3, USPIT, FEDTX, CNPRP, CYNVT, CYSTX, CYUSE, CYORV, STFED/
GTA(G)	EXOGNOUS TRANSFER PMT	/ USSOCL1, USSOCL2,USSOCL3, USPIT, FEDTX, CNPRP, CYNVT, CYSTX, CYUSE, CYORV,CYGF, STFED/
GT(G)	ENDOGENOUS TRANSF PMT	/ CYGF, STFED /
H(Z)	HOUSEHOLDS	/ HH1, HH2, HH3, HH4, HH5, HH6 /
IG(Z)	I+G SECTORS	/AGPRO, AGSER, CONST, MINNG, LF, AGPRS, MANUF, CMANF, COMMU, ELECT, WATER, RETAL, FIRE, LODGE, EATING, LWSER, HGSER, TRUTL, WHOLE, ELE2, UNIJC, DK, DN, HS1, HS2, HS3, HS4, STFED, CYPOL, CYFIR, CYTRA, CYADM, CYLPR/
I(IG)	INDUSTRY SECTORS	/AGPRO, AGSER, CONST, MINNG, LF, AGPRS, MANUF, CMANF, COMMU, ELECT, WATER, RETAL, FIRE, LODGE, EATING, LWSER, HGSER, TRUTL, WHOLE, ELE2, UNIJC, DK, DN, HS1, HS2, HS3, HS4/
IG2(IG)	ENDOGENOUS GOVS	/ STFED, CYPOL, CYTRA, CYLPR, CYFIR, CYADM /
IP(I)	PRODUCTION SECTORS	/AGPRO, AGSER, CONST, MINNG, LF, AGPRS, MANUF, CMANF, COMMU, ELECT, WATER, RETAL, FIRE, LODGE, EATING, LWSER, HGSER, TRUTL, WHOLE, ELE2, UNIJC, DK, DN/

```
FG(IG)   PRODUCTION GOV.              /STFED, CYPOL, CYFIR, CYTRA,
                                       CYADM, CYLPR/

HD(I)    HOUSING SERV.DEMAND          /HS1, HS2, HS3, HS4/

SM       SIMMLOOP                     /BASE, TODAY, simm/

R1H      REPORT 1 FOR SCALARS         /GFREV, SFREV, PIT, DGF, DSF, DDRE,
                                       PDRE, SPI, COMM, COMMO, GN, NKI,
                                       HH, W, W1, W2, W3, R, RD, RL, L, K,
                                       HN, HW, GFSAV, LD, CMO, CMI, HC,
                                       SSC, LAND, LAS /

R2H      REPORT 2 FOR STATUS          /M-STAT, S-STAT /

MS       LABELS FOR MODEL STATUS      /OPTIMAL, LOCALOP, UNBOUND,
                                       INFSBLE, INFSLOC, INFSINT,
                                       NOOPTML, MIPSOLN, NOINTGR,
                                       INFSMIP, UNUSED, UNKNOWN,
                                       NOSOLUT /

SS       LABELS FOR SOLVER STATUS     /OK, ITERATE, RESRCE, SOLVER,
                                       EVALUATE, NOTKNWN,
                                       NOTUSED, PRE-PROC, SETUP,
                                       SLVFAIL, SLVINTER, POST-PROC,
                                       METSYS /

*------------------------------------------------------------------------------------------
---
* 2.2 ALIASES
*------------------------------------------------------------------------------------------
---

ALIAS (I,J), (I,I1), (Z,Z1), (F,F1), (G,G1), (G,G2), (GI,GI1), (GS,GS1),(GX,GX1),
(GN,GN1), (GH,GH1), (GF,GF1), (H,H1), (HD, HD1), (IP,JP), (IG,JG),(GY,GY1),
(GT,GT1), (GY, GY2), (GNL, GNL1);

*------------------------------------------------------------------------------------------
---
* 3. PARAMETERS AND EXOGENOUS VARIABLES
*------------------------------------------------------------------------------------------
---
* 3.1 SOCIAL ACCOUNTING MATRIX, CAPITAL COEFFICIENT MATRIX AND
PARAMETERS
*-----------------------------------------------------------
```

```
TABLE SAM(Z,Z1) SOCIAL ACCOUNTING MATRIX
$ONDELIM
$INCLUDE e:\mike\fcsam500LE2.CSV
$OFFDELIM
$INCLUDE e:\mike\FCmisc500LE2.prn
TABLE BB(I,IG) CAPITAL COMP
$ONDELIM
$INCLUDE e:\mike\CAPCOM500LE2.CSV
$OFFDELIM
*was originaly capcomtest
*-----------------------------------------------------------------------------------------------------------
---
* 3.2 PARAMETER DECLARATION
*-----------------------------------------------------------------------------------------------------------
---


SCALARS
 DEPR        CALC   DEPRECIATION RATE FOR K
 ETAL2       CRCE   LAND SUPPLY ELASTICITY          / 3.0 /

PARAMETERS
* PARAMETERS CALCULATED FROM SOCIAL ACCOUNTING MATRIX AND
  TABLE DATA

A(Z,Z1)         IMPLAN       INPUT OUTPUT COEFFICIENTS
AD(Z,Z1)        IMPLAN       DOMESTIC INPUT OUTPUT COEFFICIENTS
AG(Z,G)         IMPLAN       GOVT SPENDING SHARES OF NET INCOME
AGFS(Z,G)
ALPHA(F,I)      IMPLAN       FACTOR SHARE EXPONENTS IN PRODUCTION
FUNCTION
ALPHA1(F,I)
B(I,IG)
B1(I,J)
CMOWAGE(L)
CMIWAGE(L)
FCONST(F,I)
GAMMA(I)        CALC         PRODUCTION FUNCTION SCALE
DELTA(I)
PIT(G,H)
PRIVRET1(H)
PRIVRET(H)
LFOR(LA)                     PROPORTION OF LAND INCOME OUTFLOW
KFOR(K)                      PROPORTION OF CAPITAL INCOME  OUTFLOW
GFOR(G)                      PROPORTION OF GOVT INCOME OUTFLOW
out(G1,G1)
```

TAUF(G,F,Z)	CITY	FACTOR TAXES
TAUFH(G,F)	CITY	AGG FACTOR TAXES
TAUFL(G,L)	CITY	EMPLOYEE PORTION OF FACTOR TAXES
TAUFLA(G,LA)	CITY	LAND FACTOR TAXES
TAUFK(G,K)	CITY	CAPITAL FACTOR TAXES
TAUFX(G,F,Z)		
TAUH(G,H)	CITY	HOUSEHOLD TAXES OTHER THAN PIT
TAUM(G,IG)	CITY	IMPORT DUTY RATES
TAUQ(G,IG)	CITY	AVERAGE SALES TAX RATES
TAUC(G,I)	CITY	EXPERIMENTAL CONSUM SALES TAX RATES
TAUCH(G,HD)	CITY	HOUSING CONSUMPTION SALES TAX RATES
TAUV(G,I)	CITY	EXPERIMENTAL CONSUM SALES TAX RATES
TAUN(G,IG)	CITY	EXPERIMENTAL CONSUM SALES TAX RATES
TAUX(G,IG)	CITY	EXPERIMENTAL CONSUM SALES TAX RATES
TAUG(G,I)	CITY	EXPERIMENTAL CONSUM SALES TAX RATES
TAXS(G,GX)	CITY	TAX DESTINATION SHARES
TAXS1(GNL)		
TEST10(Z,Z)		
TEST20(Z,Z)		
TEST30(Z)		

* ELASTICITIES AND TAX DATA IMPOSED

BETA(I,H)	CRCE	INCOME ELASTICITY OF DEMAND
BETAH(HD,H)	CALC	INCOME ELASTICITY OF HOUSING DEMAND
ETAD(I)	CALC	DOMESTIC SHARE PRICE ELASTICITIES
ETAE(I)	CRCE	EXPORT ELASTICITIES WITH RESPECT TO DOMESTIC PRICE
ETAI(IG)	CRCE	LAND ELASTICITY
ETAIX(K,IG)	CRCE	LAND ELASTICITY
ETAL(LA,IG)	CRCE	LAND ELASTICITY
ETAL1(IG)	CRCE	LABOR ELASTICITY
ETALB1(IG)	CRCE	LABOR ELASTICITY
ETALB(L,IG)	CRCE	LABOR ELASTICITY
ETARA(H)	CRCE	L SUPPLY ELASTICITY WITH RESPECT TO AVERAGE WAGE
ETAYD(H)	CRCE	RESPONSIVENESS OF INMIGRATION TO AFTER TAX EARNINGS
ETAU(H)	CRCE	RESPONSIVENESS OF INMIGRATION TO UNEMPLOYMENT
ETAPT(H)	CRCE	HOUSEHOLD RESPONSE TO TRANSFER PAYMENTS

ETAPIT(H)	STCO	L SUPPLY ELASTICITY WITH RESPECT TO TAXES
EXWGE1(L)	CALC	EXTERNAL WAGE commuting out
EXWGE2(L)	CALC	EXTERNAL WAGE commuting in
ECOMI(L)	CALC	ELASTICITY OF LABOR SUPPLY FOR IN
COMMUTTERS		
ECOMO(L)	CALC	ELASTICITY OF LABOR SUPPLY FOR OUT
COMMUTTERS		
HOUSECOR(H,HD)		HOUSEHOLD HOUSING RELATIONSHIP
JOBCOR(H,L)	CALC	CORRECTION FACTOR BETWEEN HOUSEHOLDS AND JOBS
LAMBDA(I,J)	CRCE	CROSS PRICE ELASTICITIES
LAMBDAH(HD,HD1)		HOUSING CROSS PRICE ELASTCITIES
NRPG(H)	CRCE	NATURAL RATE OF POPULATION GROWTH
RHO(I)	CRCE	EXPONENT IN PRODUCTION FUNCTION
RCP(IG)	RCP Program	

* ARRAYS BUILT TO EXPORT RESULTS TO SEPARATE FILE

R1(R1H,SM)	REPORT	SCALAR VARIABLES
R2(R2H,SM)	REPORT	SOLVER AND MODEL STATUS VALUES

* INITIAL VALUES OF ENDOGENOUS VARIABLES

CG0(I,G)	CITY	REAL GOVERNMENT CONSUMPTION
CG0T(I,G)		
CH0(I,H)	IMPLAN	REAL PRIVATE CONSUMPTION
CH0T(I,H)		
CMI0(L)	CALC	REAL NUMBER COMMUTING IN
CMO0(L)	CALC	REAL NUMBER COMMUTING OUT
CN0(I)	IMPLAN	REAL INVESTMENT BY SECTOR OF SOURCE
CN0T(I)		
CPI0(H)	CALC	PRICE CONSUMER PRICE INDICES
CPIN0(H)	CALC	PRICE NONHOUSING PRICE INDEX
CPIH0(H)	CALC	PRICE HOUSING PRICE INDEX
CX0(I)	CALC	REAL EXPORT CONSUMPTION
D0(I)	CALC	RATIO DOMESTIC SUPPLY SHARE OF DOMESTIC DEMAND
DD0(Z)	CALC	REAL DOMESTIC DEMAND
DS0(Z)	CALC	REAL DOMESTIC SUPPLY QUANTITIES
DQ0(Z)		
FD0(F,Z)	ES202	REAL FACTOR DEMAND
FDK0(F,Z)	ES202	REAL FACTOR DEMAND FOR DEPRECIATED CAPITAL
IGT0(G,GX)	CITY	NOMINAL INTER GOVERNMENTAL TRANSFERS

KS0(K,IG)	CALC	REAL CAPITAL STOCK
DKS0(I)	CALC	REAL DEPRECIATED AGGREGATES CAPITAL STOCK SUPPLY
DNS0(I)		
LAS0(LA,IG)	ASSESSOR	LAND STOCK
HH0(H)	DOF	HHDS NUMBER OF HOUSEHOLDS
HN0(H)	DOF	HHDS NUMBER OF NONWORKING HOUSEHOLDS
HW0(H)	DOF	HHDS NUMBER OF WORKING HOUSEHOLDS
M0(I)	IMPLAN	REAL IMPORTS
M01(Z)	IMPLAN	REAL IMPORTS
MI0(H)	CRCE	REAL IN MIGRATION
MO0(H)	CRCE	REAL OUT MIGRATION
N0(K,IG)	CALC	REAL GROSS INVESTMENT BY SECTOR OF DESTINATION
NKI0	CALC	NOMINAL NET CAPITAL INFLOW
KPFOR01(K)		
KPFOR0(K)	CALC	NOMINAL CAPITAL OUTFLOW
LNFOR0(LA)	CALC	NOMINAL LAND OUTFLOW
LNFOR01(LA)	CALC	NOMINAL LAND OUTFLOW
GVFOR0(G)	CALC	NOMINAL GOVT OUTFLOW
P0(I)	CALC	PRICE AGGREGATE PRICES
PDK0(I)		
PDN0(I)		
PH0(HD)	CALC	PRICE AGGREGATE HOUSING PRICES
PD0(I)	CALC	PRICE DOMESTIC PRICES
PVA0(I)	CALC	PRICE VALUE ADDED PRICES
PW0(I)	CALC	PRICE EXOGENOUS PRICES IN EXTERNAL MARKETS
PWM0(I)	CALC	PRICE IMPORT PRICE
Q0(Z)	CRCE	REAL SOCIAL ACCOUNTING MATRIX COLUMN TOTALS
Q10(Z)	CRCE	REAL SOCIAL ACCOUNTING MATRIX ROW TOTALS
R0(F,Z)	ES202	PRICE INITIAL SECTORAL RENTAL RATE FOR FACTOR
RD0(F,Z)	CALC	PRICE INITIAL SECTORAL RENTAL RATE FOR FACTOR
RA0(F)	CALC	AVERAGE RENTAL RATES FOR FACTORS
S0(Z)	CRCE	NOMINAL SAVINGS
SPI0	CALC	PERSONAL INCOME (OBJ FUNC)
V0(I)	IMPLAN	REAL INTERMEDIATE DEMAND
V1	IMPLAN	REAL INTERMEDIATE DEMAND
V2	IMPLAN	REAL INTERMEDIATE DEMAND
DK0(I)	CALC	INTERMEDIATE DEMAND FOR RECYCLED AGGREGATES MATERIAL

```
DN0(I)
V0T(I)
TP(H,G)          SSAD        NOMINAL GOVERNMENT SOCIAL SECURITY
                             PAYMENTS
TAUF0(G,F,Z)     CALC        SOCIAL SECURITY TAX
YD0(H)           CALC        NOMINAL AFTER TAX TOTAL HOUSEHOLD
                             INCOMES
Y0(Z)            CALC        NOMINAL GROSS HOUSEHOLD INCOME
Y01(H)
YT0(G)           CALC        GOV INCOMES
GCP10(I)         CALC        REAL   GROSS CITY PRODUCT
GCP0
SD3(GX)          >
SD7(L)           >
SD8              >           TESTS
SD9              >
SD10             >
DDCX(I);
*----------------------------------------------------------------------------------------------------
---
* 3.3 CALCULATIONS OF PARAMETERS AND INITIAL VALUES
*----------------------------------------------------------------------------------------------------
---

* CALCULATE COLUMN AND ROW TOTALS OF SAM TO COMPARE FOR
BALANCE

Q10(Z)=SUM(Z1,SAM(Z,Z1) );

Q0(Z)=SUM(Z1,SAM(Z1,Z) );  display q0;

DQ0(Z) = Q10(Z)-Q0(Z);

B1(I,J)=  SAM(I,J);

DISPLAY Q0, Q10, DQ0;


* READ IN ELASTICITY PARAMETERS FROM MISC.PRN

BETA(I,H)=MISC(I,'ETAY');

BETAH(HD,H)=MISC(HD,'ETAY');

DISPLAY BETA, BETAH;
```

```
LAMBDA(I,I)=MISC(I,'ETAOP');

LAMBDAH(HD,HD)=MISC(HD,'ETAOP');

ETAE(I)=MISC(I,'ETAE');

ETAM(I)=MISC(I,'ETAM');

RHO(I)=( 1 - MISC(I,'SIGMA') ) / MISC(I,'SIGMA');

ETARA(H)=MISCH(H,'ETARA');

ETAPIT(H)=MISCH(H,'ETAPIT');

ETAPT(H)=MISCH(H,'ETAPT');

ETAYD(H)=MISCH(H,'ETAYD');

NRPG(H)=MISCH(H,'NRPG');

ETAU(H)=MISCH(H,'ETAU');

RCP(IG)=MISC(IG,'RCP');

ECOMO('L1')=1.0;

ECOMO('L2')=2.0;

ECOMO('L3')=2.0;

EXWGE1('L1')=1.0;

EXWGE1('L2')=1.0;

EXWGE1('L3')=1.0;

EXWGE2('L1')=1.0;

EXWGE2('L2')=1.0;

EXWGE2('L3')=1.0;

ECOMI('L1')= .75;

ECOMI('L2')= 1.0;
```

```
ECOMI('L3')= 1.0;

ETAI(IG)= LANDCAP(IG,'ETAI1');

ETAW(IG)= LANDCAP(IG,'ETAW1');

ETAL1(IG)= LANDCAP(IG,'ETAL1');

ETALB1(IG)= LANDCAP(IG,'ETALB1');

ETAIX('KAP',IG)=ETAI(IG);

ETAL('LAND',IG)=ETAL1(IG);

ETALB(L,IG)=ETALB1(IG);


* CALCULATE TAX RATES FROM SAM INFORMATION

TAUQ(GS,I)=SAM(GS,I) /( SUM(J, SAM(I,J) ) + SUM(H, SAM(I,H)) +
              SAM (I, 'INVES') + SUM (G, SAM (I, G)) + SAM (I,'ROW') –
              SUM (GS1, SAM (GS1, I)));

TAUC(GS,I)=TAUQ(GS,I);
TAUV(GS,I)=TAUQ(GS,I);
TAUN(GS,I)=TAUQ(GS,I);
TAUG(GS,I)=TAUQ(GS,I);
TAUX(GS,I)=TAUQ(GS,I);

TAUM('CYUSE',I)$(SAM('ROW', I))=SAM('CYUSE',I) / (SUM(Z,SAM(I,Z) )-
                                      (SUM(J, B1(J,I))+SUM(F,SAM(F,I))+
                                       SUM(G, SAM(G,I))));

TAUF0(G,F,Z)=0;

TAUF(GF,F,I)$(SAM(F,I) AND TAUFF(GF,F))=SAM(GF,I) / SAM(F,I);

TAUF(GF,F,G)$(SAM(F,G) AND TAUFF(GF,F))=SAM(GF,G) / SAM(F,G);

TAUFX(GF,F,Z)=TAUF(GF,F,Z);

TAUFH(GF,F)$(TAUFF(GF,F)) =SAM(GF,F) / SUM(Z, SAM(Z,F));

TAUFL(GF,L)=SAM(GF,L) / SUM(Z, SAM(Z,L));

TAUFLA(GF,LA)=SAM(GF,LA) / SUM(Z, SAM(Z,LA));
```

```
TAUFK(GF,K)=SAM(GF,K) / SUM(Z, SAM(Z,K));

TAXS(G,GX)$(IGTD(G,GX) EQ 1)=SAM(G,GX) / SUM(G1$(IGTD(G1,GX) EQ 1),
                                   SAM(G1,GX) );

TAXS1(GNL)=SAM(GNL,'CYGF') / SUM(GNL1, SAM(GNL1,'CYGF'));

* SET INITIAL INTER GOVERNMENTAL TRANSFERS

IGT0(G,GX)=SAM(G,GX);

DISPLAY TAXS, TAXS1, IGT0;

* SET INITIAL PRICES TO UNITY LESS SALES AND EXCISE TAXES

PW0(I)=1;

PWM0(I)= 1/(1+SUM(GK,TAUM(GK,I)));

P0(I)=1;

PDK0(I) = 1;

PDN0(I) = 1;

PH0(HD)=1;

PD0(I)=1;

CPI0(H)=1;

CPIN0(H)=1;

CPIH0(H)=1;

* HOUSEHOLD TRANSFER PAYMENTS AND PERSONAL INCOME TAXES

HH0(H)=MISCH(H,'HH0');
```

```
HW0(H)=MISCH(H,'HW0');

HN0(H)= HH0(H) - HW0(H);

TP(H,G) = 0;

TP(H,G)$(HH0(H))= SAM(H,G) / ( HH0(H) );


* FACTOR RENTALS

JOBCOR(H,L)= JOBCR(H,L);

HOUSECOR(H,HD) = HOUSCR(H,HD);

R0(F, Z)=1 ;

RD0(F,Z)=1 ;

R0(F ,IG)$EMPLOY(IG,F)=SAM(F ,IG) / (EMPLOY(IG,F)) ;

RD0(F,IG)$EMPLOY(IG,F)=SAM(F ,IG) / (EMPLOY(IG,F)) ;

FD0(F,Z)=EMPLOY(Z,F); DISPLAY FD0;

KS0(K,IG)=FD0(K ,IG);

* KSD0(K,'AGPRO') = 0.1344254;
* KSD0(K,'AGSER') = 0.1500485;
* KSD0(K,'CONST') = 1.5636796;
* KSD0(K,'MINNG') = 4.08505;
* KSD0(K,'LF') = 2.042525;
* KSD0(K,'AGPRS') = 2.9542959;
* KSD0(K,'MANUF') = 24.0984728;
* KSD0(K,'CMANF') = 15.9620362;
* KSD0(K,'COMMU') = 0.5243064;
* KSD0(K,'ELECT') = 0.3747554;
* KSD0(K,'WATER') = 0.1521408;
* KSD0(K,'RETAL') = 2.6009418;
* KSD0(K,'FIRE') = 1.1932279;
* KSD0(K,'LODGE') = 0.2691221;
* KSD0(K,'EATING') = 1.7339612;
* KSD0(K,'LWSER') = 3.364027;
* KSD0(K,'HGSER') = 2.5919403;
* KSD0(K,'TRUTL') = 0.2854596;
* KSD0(K,'WHOLE') = 0.8388924;
```

```
* KSD0(K,'ELE2') = 0.359025;
* KSD0(K,'UNIJC') = 0.1122225;
* KSD0(K,'DK') = 0.000000;

LAS0(LA,IG)=FD0(LA ,IG);


* SHARES FOUND IN THE SOCIAL ACCOUNTING MATRIX DATA

A(Z,Z1)=SAM(Z,Z1) / Q10(Z1);

AG(I,G)$(SUM(J, SAM(J,G) ) + SUM(F, SAM(F,G) ) + SUM(GF, SAM(GF,G) ) )
     =SAM(I,G) / ( SUM(J, SAM(J,G) ) + SUM(F, SAM(F,G) )
     + SUM(GF, SAM(GF,G) ));

AGFS('L1',G)=SAM('L1',G)+SAM('USSOCL1',G);

AGFS('L2',G)=SAM('L2',G)+SAM('USSOCL2',G);

AGFS('L3',G)=SAM('L3',G)+SAM('USSOCL3',G);

AG(F,G)$(SUM(I, SAM(I,G) ) + SUM(F1, SAM(F1,G) ) + SUM(GF, SAM(GF,G) ) )
     =SAM(F,G) / ( SUM(I, SAM(I,G) ) + SUM(F1, SAM(F1,G) )
     + SUM(GF, SAM(GF,G) ) );

AG(L,G)$(SUM(I, SAM(I,G) ) + SUM(F1, SAM(F1,G) ) + SUM(GF, SAM(GF,G) ) )
     =AGFS(L,G) / ( SUM(I, SAM(I,G) ) + SUM(F1, SAM(F1,G) )
     + SUM(GF, SAM(GF,G) ) );


SD3(GX)=SUM(G1$(IGTD(G1,GX) EQ 1), SAM(G1,GX) ) ;


* TRADE INTERMEDIATES CONSUMPTION INVESTMENT INITIAL LEVELS

CX0(I)=SAM(I,'ROW')/P0(I) /( 1 + SUM(GS, TAUQ(GS,I) ) );

M01(I)= SAM('ROW',I) / PWM0(I);

M0(IP)= SUM(Z,SAM(IP,Z) )-(SUM(J, B1(J,IP))+SUM(F,SAM(F,IP))+
          SUM(G, SAM(G,IP))) ;

M0(I)= M0(I) / PWM0(I);

V0(I)=SUM(J, SAM(I,J) ) / P0(I) /( 1 + SUM(GS, TAUQ(GS,I) ) ) ;
```

```
V0T(I)=SUM(J, SAM(I,J) ) / P0(I) ;

CH0(I,H)=SAM(I,H) / P0(I)/ ( 1 + SUM(GS, TAUQ(GS,I) ) );

CH0T(I,H)=SAM(I,H) / P0(I);

CG0(I,GN)=SAM(I,GN) / P0(I)/ ( 1 + SUM(GS, TAUQ(GS,I) ) );

CG0T(I,GN)=SAM(I,GN) / P0(I);

DEPR= SUM(IG, SAM(IG,'INVES') ) / (SUM((K,IG), KS0(K,IG)));

SD8= SUM(IG, SAM(IG,'INVES'));
SD9= SUM((K,IG), KS0(K,IG));

DISPLAY SD8, SD9;

N0(K,IG)=(KS0(K,IG)) * (DEPR);

CN0(I)=0;

B(I,IG) = BB(I,IG);

CN0(I)=SUM(IG, B(I,IG) * SUM(K, N0(K,IG)) )  / P0(I)/ ( 1 + SUM(GS, TAUN(GS,I) )
);

CN0T(I)=SUM(IG, B(I,IG) * SUM(K, N0(K,IG)) )/P0(I)   ;

DD0(I)= SUM(H, CH0(I,H) ) + SUM(G, CG0(I,G) ) + CN0(I) + V0(I);

D0(I)= 1 - (M0(I) / DD0(I));


* CORRECT IMPORT ELASTICITY TO DOMESTIC SHARE ELASTICITY

ETAD(I)= - ETAM(I) * M0(I) / ( DD0(I) * D0(I) );


*  PRODUCTION DATA

DS0(I)=DD0(I) + CX0(I) - M0(I);

AD(I,J)= SAM(I,J) / P0(I) /(1 + SUM(GS, TAUQ(GS, I)))/ DS0(J)   ;

PVA0(I)= PD0(I) - SUM(J, AD(J,I) * P0(J)*(1 + SUM(GS, TAUQ(GS, J))));
```

```
RA0(F)=1;

TEST20(F,I) =  SUM(GF$TAUFF(GF,F), SAM(GF,I) ); DISPLAY TEST20;

 ALPHA1(F,I)  = ( SAM(F,I) + SUM(GF$TAUFF(GF,F), SAM(GF,I) ) )
                / ( SUM(F1, SAM(F1,I) ) + SUM(GF, SAM(GF,I) ) );


 ALPHA(F,I) =  ALPHA1(F,I)/(SUM(F1, ALPHA1(F1,I)));

 DELTA(I) = DS0(I)/ (PROD(F$ALPHA(F,I),FD0(F,I)**ALPHA(F,I)));


* OTHER DATA

PRIVRET(H) = SUM(Z,SAM(Z,H))-(SUM(F, SAM(H,F))+SUM(CM,SAM(H,CM))+
             SUM(GX,SAM(H,GX)) );

PRIVRET(H) = PRIVRET(H)/HH0(H);

Y0(F)= SUM(IG, SAM(F,IG) );

KPFOR01(K)=SAM('KAP', 'ROW');

KPFOR0(K) = SUM(Z,SAM(Z,K))-(SUM(IG, SAM(K,IG)));

LNFOR0(LA) = SUM(Z,SAM(Z,LA))-(SUM(IG, SAM(LA,IG)));

GVFOR0(G) = SAM(G, 'ROW');

GVFOR0(GT) = SUM(Z,SAM(Z,GT))-(SUM(I, SAM(GT,I))+
              SUM(F, SAM(GT,F)) +SUM(H,SAM(GT,H))+
              SUM(G1,SAM(GT,G1)));

A(H,L)=SAM(H,L) / HW0(H) / (Y0(L)+ SUM(Z,SAM(Z,L))-(SUM(IG, SAM(L,IG))))*
       (1 - SUM(G, TAUFL(G,L) ) );

A(H,'KAP')=SAM(H,'KAP') / HW0(H) / (Y0('KAP') + SUM(Z,SAM(Z,'KAP'))-
           (SUM(IG, SAM('KAP',IG))));

A(H,'LAND')=SAM(H,'LAND') / HW0(H) / (Y0('LAND') + SUM(Z,SAM(Z,'LAND'))-
            (SUM(IG, SAM('LAND',IG))))* ( 1 - SUM(G, TAUFLA(G,'LAND')) );

TAUH(GH,H)=SAM(GH,H) / HH0(H);
```

```
S0(H)=SAM('INVES',H);

YD0(H)=SUM(I, SAM(I,H) ) + S0(H);

Y0(G) = SUM(Z, SAM(G,Z)) - SAM(G,'ROW' );

S0(G)=SAM('INVES',G);

CMI0('L1') = 4572;

CMI0('L2') = 6858;

CMI0('L3') = 3810;

CMO0('L1') = 5126;

CMO0('L2') = 6592;

CMO0('L3') = 2929;

CMOWAGE('L1') = SAM('COMMO1', 'ROW')/CMO0('L1');

CMOWAGE('L2') = SAM('COMMO2', 'ROW')/CMO0('L2');

CMOWAGE('L3') = SAM('COMMO3', 'ROW')/CMO0('L3');

CMIWAGE(L) = SAM(L , 'ROW')/ CMI0(L);

LFOR(LA)=LNFOR0(LA)/(SUM(IG, SAM('LAND', IG)));

KFOR(K)=KPFOR0(K)/((SUM(IG, SAM('KAP', IG))));

GFOR(G)$(Y0(G))=GVFOR0(G)/(Y0(G));

DISPLAY GFOR , CMO0;

A(H, 'COMMO1')=SAM(H,'COMMO1' )/ (SUM(Z, SAM(Z, 'COMMO1')));

A(H, 'COMMO2')=SAM(H, 'COMMO2' )/ (SUM(Z, SAM(Z, 'COMMO2')));

A(H, 'COMMO3')=SAM(H, 'COMMO3' )/ (SUM(Z, SAM(Z, 'COMMO3')));

NKI0 = SUM(I, M0(I) * PWM0(I) ) - SUM(I, CX0(I) * PD0(I) )
       - SUM(H, PRIVRET(H)*HH0(H)) - SUM(LA, LNFOR0(LA))
       - SUM(K, KPFOR0(K)) - SUM(G, GVFOR0(G))- SUM(L,CMOWAGE(L)
       *CMO0(L)) - SUM(L,CMIWAGE(L)*CMI0(L));
```

```
Y0(H)= SUM(L,  A(H,L) * HW0(H) / SUM(H1, A(H1,L) * HW0(H1) )
       * (Y0(L)+ CMIWAGE(L)*CMI0(L))* ( 1 - SUM(G, TAUFL(G,L) ) ))
       + A(H, 'COMMO1')*CMOWAGE('L1')*CMO0('L1')
       + A(H, 'COMMO2')*CMOWAGE('L2')*CMO0('L2')
       + A(H, 'COMMO3')*CMOWAGE('L3')*CMO0('L3')
       + SUM(LA,  A(H,LA) * HW0(H) / SUM(H1, A(H1,LA) * HW0(H1))
        * (Y0(LA) * ( 1 - SUM(G, TAUFLA(G,LA)))+ LNFOR0(LA)) )
        + SUM(K,  A(H,K) * HW0(H) / SUM(H1, A(H1,K) * HW0(H1)) * (Y0(K)
        * ( 1 - SUM(G, TAUFK(G,K)))+ KPFOR0(K)) ) ;

SPI0= SUM(H, Y0(H) ) + SUM((H,G), TP(H,G) * HH0(H) )+ SUM(H,  PRIVRET(H) *
       HH0(H));

PIT(GI,H) = SAM(GI,H) / (HH0(H));

MI0(H)=HH0(H) * 0.04;

MO0(H)=HH0(H) * 0.04;

GCP0 =SUM((I,H), (CH0(I,H)))+ SUM(I, CN0(I))+ SUM((I,GN), (CG0(I,GN)))+
        SUM(I, CX0(I))-SUM(I, M0(I));

GCP10(I) = SUM(H, CH0(I,H))+ CN0(I)+ SUM(GN, CG0(I,GN))+ CX0(I)-M0(I);

SD7(L) =  SUM(H, HW0(H)* JOBCOR(H,L));

OPTION DECIMALS=6 ;

DISPLAY SD7, SD3;

*-----------------------------------------------------------------------------------------------------
---
* 4. VARIABLES
*-----------------------------------------------------------------------------------------------------
---
* 4.1 VARIABLE DECLARATION
*-----------------------------------------------------------------------------------------------------
---
VARIABLES
CG(I,G)           PUBLIC CONSUMPTION
CH(I,H)           PRIVATE CONSUMPTION
CMI(L)            COMMUTING IN
CMO(L)            COMMUTING OUT
CN(I)             GROSS INVESTMENT BY SECTOR OF SOURCE
CPI(H)            CONSUMER PRICE INDEX
```

CPIN(H)	NONHOUSING CONSUMER PRICE INDEX
CPIH(H)	HOUSING CONSUMER PRICE INDEX
CX(I)	EXPORT DEMAND
D(I)	DOMESTIC SHARE OF DOMESTIC DEMAND
DD(I)	DOMESTIC DEMAND
DS(I)	DOMESTIC SUPPLY
FD(F,Z)	SECTORAL FACTOR DEMAND
GCP	GROSS AGGREGATE CITY PRODUCT
GCP1(I)	GROSS CITY PRODUCT BY SECTOR
HH(H)	NUMBER OF HOUSEHOLDS
HN(H)	NUMBER OF NONWORKING HOUSEHOLDS
HW(H)	NUMBER OF WORKING HOUSEHOLDS
IGT(G,G1)	INTER GOVERNMENTAL TRANSFERS
KS(K,IG)	CAPITAL FLOW
LAS(LA,IG)	LAND FLOW
M(I)	IMPORTS
N(K,IG)	GROSS INVESTMENT BY SECTOR OF DESTINATION
NKI	NET CAPITAL INFLOW
LNFOR(LA)	LAND OUTFLOW
KPFOR(K)	CAPITAL OUTFLOW
GVFOR(G)	GOVT OUTFLOW
P(I)	AGGREGATE DOMESTIC PRICE PAID BY PURCHASERS
PDK(I)	
PDN(I)	
PD(I)	DOMESTIC PRICE RECEIVED BY SUPPLIERS
PVA(I)	VALUE ADDED PRICE
RA(F)	ECONOMY WIDE SCALAR RENTAL RATES OF FACTORS
R(F,Z)	SECTORAL RENTAL RATES
RD(F,Z)	SECTORAL RENTAL RATES
S(Z)	SAVINGS
SPI	PERSONAL INCOME (OBJECTIVE FUNCTION)
V(I)	INTERMEDIATE GOODS
Y(Z)	GROSS INCOMES
YD(H)	AFTER TAX TOTAL HOUSEHOLD INCOMES
YT(G,G1)	GOV INCOME

*DIFFERENCES FOR RESULTS INITIALIZED BELOW
DFCG(I,G)
DFCH(I,H)
DFCN(IG)
DFCPI(H)
DCX(I)
DFD(I)
DFDD(I)
DFS(I)
DGCP

```
DGCP1(I)
DFHH(H)
DFHN(H)
DFHW(H)
DFFD(F,Z)
DRR(F,Z)
DM(I)
DV(I)
DY(Z)
DDS(I)
DSS(G)
DDD(I)
DCH(I,H)
DLAS(LA,IG)
TAUTST(F,GN)
SD1(GN)
SD2(F,GN)
SD4(H)
SD5(H)
SD6(H);

*----------------------------------------------------------------------------------------------------------
---
* 4.2 INITIALIZATION OF VARIABLES AND REMOVING TRACE NUMBERS
*----------------------------------------------------------------------------------------------------------
---

P.L(I)=P0(I);                    PD.L(I) = PD0(I);
PDK.L(I)=PDK0(I);
PDN.L(I)=PDN0(I);
PVA.L(I)=PVA0(I);                RA.L(F) = RA0(F);
R.L(F,Z)=R0(F,Z);                RD.L(F,Z)=RD0(F,Z);
CPI.L(H) = CPI0(H);
CMI.L(L)=CMI0(L);                CMO.L(L)=CMO0(L);
DS.L(I)=DS0(I);                  DD.L(I)  = DD0(I);
V.L(I)=V0(I);                    FD.L(F,Z) = FD0(F,Z);
HH.L(H)=HH0(H);                  HN.L(H)  = HN0(H);
HW.L(H)=HW0(H);                  KS.L(K,IG) = KS0(K,IG);
CN.L(I)=CN0(I);                  N.L(K,IG) = N0(K,IG);
D.L(I)=D0(I);                    CX.L(I) = CX0(I);
M.L(I)=M0(I);                    NKI.L  = NKI0;
KPFOR.L(K)   = KPFOR0(K);        LNFOR.L(LA)     =LNFOR0(LA);
GVFOR.L(G)=GVFOR0(G);
Y.L(Z) = Y0(Z);
YD.L(H)=YD0(H);
IGT.L(G,GX)=IGT0(G,GX);          CH.L(I,H)   = CH0(I,H);
```

```
CG.L(I,G)=CG0(I,G);          S.L(Z) = S0(Z);
SPI.L=SPI0;
LAS.L(LA,IG) = LAS0(LA,IG);

* REMOVE TRACE NUMBERS FOR COMPUTATIONAL PURPOSES

P.L(I)$(ABS(P.L(I))                       LT 1)=0;
PDK.L(I)$(ABS(PDK.L(I))                   LT 1)=0;
PDN.L(I)$(ABS(PDN.L(I))                   LT 1)=0;
PD.L(I)$(ABS(PD.L(I))                     LT 0.00000001)=0;
PVA.L(I)$(ABS(PVA.L(I))                   LT 0.00000001)=0;
RA.L(F)$(ABS(RA.L(F))                     LT 1)=0;
R.L(F,Z)$(ABS(R.L(F,Z))                   LT 0.00000001)=0;
CPI.L(H)$(ABS(CPI.L(H))                   LT 0.00000001)=0;
CMI.L(L)$(ABS(CMI.L(L))                   LT 0.00000001)=0;
CMO.L(L)$(ABS(CMO.L(L))                   LT 0.00000001)=0;
DS.L(I)$(ABS(DS.L(I))                     LT 0.00000001)=0;
DD.L(I)$(ABS(DD.L(I))                     LT 0.00000001)=0;
V.L(I)$(ABS(V.L(I))                       LT 0.00000001)=0;
FD.L(F,Z)$(ABS(FD.L(F,Z))                 LT 0.00000001)=0;
HH.L(H)$(ABS(HH.L(H))                     LT 1)=0;
HN.L(H)$(ABS(HN.L(H))                     LT 1)=0;
HW.L(H)$(ABS(HW.L(H))                     LT 1)=0;
KS.L(K,IG)$(ABS(KS.L(K,IG))               LT 0.0000001)=0;
LAS.L(LA,IG)$(ABS(LAS.L(LA,IG))           LT 0.00000001)=0;
CN.L(I)$(ABS(CN.L(I))                     LT 0.00000001)=0;
N.L(K,IG)$(ABS(N.L(K,IG))                 LT 0.00000001)=0;
D.L(I)$(ABS(D.L(I))                       LT 0.00000001)=0;
CX.L(I)$(ABS(CX.L(I))                     LT 0.00000001)=0;
M.L(I)$(ABS(M.L(I))                       LT 0.00000001)=0;
NKI.L$(ABS(NKI.L)                         LT 0.00000001)=0;
LNFOR.L(LA)$(ABS(LNFOR.L(LA))             LT 0.00000001)=0;
KPFOR.L(K)$(ABS(KPFOR.L(K))               LT 0.00000001)=0;
GVFOR.L(G)$(ABS(GVFOR.L(G))               LT 0.00000001)=0;
Y.L(Z)$(ABS(Y.L(Z))                       LT 0.00000001)=0;
YD.L(H)$(ABS(YD.L(H))                     LT 0.00000001)=0;
IGT.L(G,G1)$(ABS(IGT.L(G,G1))             LT 0.00000001)=0;
CH.L(I,H)$(ABS(CH.L(I,H))                 LT 0.00000001)=0;
CG.L(I,G)$(ABS(CG.L(I,G))                 LT 0.00000001)=0;
S.L(Z)$(ABS(S.L(Z))                       LT 0.00000001)=0;
SPI.L$(ABS(SPI.L)                         LT 0.00000001)=0;
*CPIH.L(H)$(ABS(CPIH.L(H))                LT 0.00000001)=0;
```

```
*-----------------------------------------------------------------------------------------------------
---
* 4.2 INITIALIZATION OF VARIABLES AND REMOVING TRACE NUMBERS
*-----------------------------------------------------------------------------------------------------
---

P.LO(I)=P.L(I) / 1000;                    P.UP(I)   = P.L(I)     * 1000;
PD.LO(I)=PD.L(I) / 1000;                  PD.UP(I)  = PD.L(I)    * 1000;
PVA.LO(I)=PVA.L(I)/ 1000;                 PVA.UP(I) = PVA.L(I)   * 1000;
RA.LO(F)=RA.L(F) / 1000;                  RA.UP(F)  = RA.L(F)    * 1000;
CPI.LO(H)=CPI.L(H) / 1000;                CPI.UP(H) = CPI.L(H)   * 1000;
CMI.LO(L)=CMI.L(L) /1000;                 CMI.UP(L) = CMI.L(L)   *1000;
CMO.LO(L)=CMO.L(L) /1000;                 CMO.UP(L) = CMO.L(L)   *1000;
DS.LO(I)=DS.L(I) / 1000;                  DS.UP(I) = DS.L(I)     * 1000;
DD.LO(I)=DD.L(I) / 1000;                  DD.UP(I) = DD.L(I)     * 1000;
D.LO(I)=D.L(I) / 1000;                    D.UP(I) = D.L(I)       * 1000;
V.LO(I)=V.L(I)/ 1000;                     V.UP(I)  = V.L(I)      * 1000;
FD.LO(F,Z)=FD.L(F,Z)/ 1000;               FD.UP(F,Z) = FD.L(F,Z)  * 1000;
HH.LO(H)=HH.L(H) / 1000;                  HH.UP(H)  = HH.L(H)    * 1000;
HW.LO(H)=HW.L(H)/ 1000;                   HW.UP(H) = HW.L(H)     * 1000;
HN.LO(H)=HN.L(H) / 1000;                  HN.UP(H)  = HN.L(H)    * 1000;
KS.LO(K,IG)=KS.L(K,IG) / 1000;            KS.UP(K,IG)  = KS.L(K,IG)    * 1000;
LAS.LO(LA,IG)=LAS.L(LA,IG)/ 1000;         LAS.UP(LA,IG) = LAS.L(LA,IG) *1000;
M.LO(I)=M.L(I)/ 1000;                     M.UP(I) = M.L(I)       * 1000;
Y.LO(Z)=Y.L(Z)/ 1000;                     Y.UP(Z) = Y.L(Z)       * 1000;
YD.LO(H)=YD.L(H)/ 1000;                   YD.UP(H) = YD.L(H)     * 1000;
CH.LO(I,H)=CH.L(I,H)/ 1000;               CH.UP(I,H) = CH.L(I,H) * 1000;
CG.LO(I,G)=CG.L(I,G)/ 1000;               CG.UP(I,G) = CG.L(I,G)  * 1000;
CN.LO(I)=0;
CX.LO(I)=CX.L(I)/ 1000;                   CX.UP(I) = CX.L(I)     * 1000;
N.LO(K,IG)=0;
R.LO(F,IG)=R.L(F,IG)/ 1000;               R.UP(F,IG)  = R.L(F,IG)    * 1000;

*-----------------------------------------------------------------------------------------------------
---
* 5. PRE-MODEL CHECK OF PARAMETERS AND INITIAL VALUES OF
VARIABLES
*-----------------------------------------------------------------------------------------------------
---
* 5.1 PRINTING OF CALCULATED PARAMETERS AND EXOGENOUS
VARIABLES
*-----------------------------------------------------------------------------------------------------
---
OPTION DECIMALS=6;
DISPLAY  DELTA, JOBCOR, TAUF, TAUFH,TAUFL, TAUQ, TAUM, TAXS,
ALPHA, AG, AD, A, D0, CX0, M0, DD0,DS0,V0, V0T, FD0,RA0, CN0T, CN0,
```

```
DEPR, CG0, CG0T, KS0, N0, RHO, N0,R0, RD0, ALPHA, IGT0, TP, PIT, LFOR,
KFOR, NKI0, CH0,CH0T, Y0, TAUV, TAUC, TAUN, TAUFX, TAUH, GVFOR0
Y0,A;


*---------------------------------------------------------------------------------------------------------
---
* 5.2 SAVING OF INITIAL VALUES FOR VARIABLES
*---------------------------------------------------------------------------------------------------------
---
R1('SSC',SM)= SUM(IG, R.L('LAND',IG) * RA.L('LAND') * FD.L('LAND',IG));
R1('HC',SM) = D.L('COMMU');
R1('SPI',SM)=SPI.L;
R1('HH',SM)=SUM(H, HH.L(H) );
R1('HN',SM)=SUM(H, HN.L(H) );
R1('HW',SM)=SUM(H, HW.L(H) );
R1('W1',SM)= RA.L('L1');
R1('W2',SM)= RA.L('L2');
R1('W3',SM)= RA.L('L3');
R1('R',SM)=SUM(Z, R.L('KAP',Z));
R1('RL',SM)= RA.L('LAND');
R1('L',SM)=SUM((L,Z), FD.L(L,Z) );
R1('K',SM)=(SUM(Z, FD.L('KAP',Z) ) );
R1('LAND',SM)=SUM(IG, FD0('LAND',IG) );
 R1('GFSAV',SM)=S.L('CYGF');
*---------------------------------------------------------------------------------------------------------
---
* 6. EQUATIONS
*---------------------------------------------------------------------------------------------------------
---
* 6.1 EQUATION DECLARATION
*---------------------------------------------------------------------------------------------------------
---
EQUATIONS

* HOUSEHOLDS
CPIEQ(H)          CONSUMER PRICE INDICES
YEQ(H)            HOUSEHOLD GROSS INCOMES
YDEQ(H)           HOUSEHOLD DISPOSABLE INCOMES
CHEQ(I,H)         PRIVATE CONSUMPTION
SHEQ(H)           HOUSEHOLD SAVINGS

* PRODUCERS
PVAEQ(I)          VALUE ADDED
PFEQ(I)           PRODUCTION FUNCTION
FDEQ(F,I)         FACTOR DEMAND
```

VEQ(I)	INTERMEDIATE DEMAND
YFEQL(L)	LABOR FACTOR INCOME
YFEQK(K)	CAPITAL FACTOR INCOME
YFEQLA(LA)	LAND FACTOR INCOME
LANFOR(LA)	LAND INCOME OUTFLOW
KAPFOR(K)	CAPITAL INCOME OUTFLOW
GOVFOR(G)	GOVT OUTFLOW
* TRADE	
XEQ(I)	EXPORT DEMAND
DEQ(I)	DOMESTIC SHARES
MEQ(I)	IMPORT DEMAND
PEQ(I)	AGGREGATED PRICES
NKIEQ	NET CAPITAL INFLOW
* INVESTMENT	
NEQ(K,I)	GROSS INVESTMENT BY SECTOR OF DESTINATION
CNEQ(I)	GROSS INVESTMENT BY SECTOR OF SOURCE
KSEQ(K,IG)	CAPITAL STOCK
* FACTOR SUPPLY	
LSEQ1(H)	LABOR SUPPLY
LSEQ2(L)	COMMUTING INSUPPLY
LSEQ2a(L)	COMMUTING INSUPPLY
LSEQ2b(L)	COMMUTING INSUPPLY
LSEQ3(L)	COMMUTING OUTSUPPLY
LSEQ3a(L)	COMMUTING OUTSUPPLY
LSEQ3b(L)	COMMUTING OUTSUPPLY
LASEQ1(LA,I)	LAND SUPPLY1
* MIGRATION	
POPEQ(H)	POPULATION
ANEQ(H)	NUMBER OF NON WORKING HOUSEHOLDS
* GOVERNMENT	
YGEQ(GX)	GOVERNMENT INCOME
CGEQ(I,GN)	GOVERNMENT ENDOGENOUS PURCHASES OF GOODS AND SERVICES
GFEQ(F,GN)	GOVERNMENT ENDOGENOUS RENTAL OF FACTORS
GSEQL(G)	GOVERNMENT SAVINGS
GSEQJ1(G)	GOVERNMENT SAVINGS
*GSEQJ2(G)	GOVERNMENT SAVINGS
GSEQ(G)	GOVERNMENT SAVINGS
TDEQ(G,G1)	DISTRIBUTION OF TAXES
YGEQ1(GNL)	

```
YGEQ2 (GT)

* MODEL CLOSURE
SPIEQ              STATE PERSONAL INCOME
LMEQ(L)            LABOR MARKET CLEARING
KMEQ(K,IG)         CAPITAL MARKET CLEARING
LAMEQ(LA,IG)       LAND MARKET CLEARING
GMEQ(I)            GOODS MARKET CLEARING
DDEQ(I)            DEFINITION OF DOMESTIC DEMAND ;

*-----------------------------------------------------------------------------------------------------
---
* 6.2 EQUATION ASSIGNMENT
*-----------------------------------------------------------------------------------------------------
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* HOUSEHOLDS

CPIEQ(H).. CPI(H)=E= SUM(I, P(I)  * ( 1 + SUM(GS, TAUC(GS,I) ) ) * CH(I,H) )
                     / SUM(I, P0(I) * ( 1 + SUM(GS, TAUQ(GS,I) ) ) * CH(I,H) );

YEQ(H).. Y(H)=E= SUM(L,  A(H,L) * HW(H) / SUM(H1, A(H1,L) * HW(H1) ) *
                 (Y(L)+ (CMIWAGE(L)*CMI(L))) *( 1 - SUM(G, TAUFL(G,L)))) +
                 A(H, 'COMMO1')*CMOWAGE('L1')*CMO('L1') +
                 A(H, 'COMMO2')*CMOWAGE('L2')*CMO('L2') +
                 A(H, 'COMMO3')*CMOWAGE('L3')*CMO('L3') +
                 SUM(LA,  A(H,LA) * HW(H) / SUM(H1, A(H1,LA) * HW(H1)) *
                 (Y(LA)+ LNFOR(LA) ) * ( 1 - SUM(G, TAUFLA(G,LA) ) ) ) +
                 SUM(K,  A(H,K) * HW(H) / SUM(H1, A(H1,K) * HW(H1)) *
                 (Y(K) + KPFOR(K)) * ( 1 - SUM(G, TAUFK(G,K) ) ) );

YDEQ(H).. YD(H)=E=   Y(H) + (PRIVRET(H) * HH(H))+ SUM(G, TP(H,G) * HH(H) )
                     -   SUM(GI, PIT(GI,H)  * HH(H)) - SUM(G, TAUH(G,H)  *
                     -   HH(H));

CHEQ(I,H).. CH(I,H)=E=  CH0(I,H)  * ( ( YD(H)  / YD0(H)  ) / ( CPI(H) / CPI0(H) ) )
                     ** BETA(I,H)*PROD(J, (( P(J) *(1+SUM(GS,TAUC(GS,J))))
                     / ( P0(J) * (1+ SUM(GS, TAUQ(GS,J)))))**(LAMBDA(J,I)*1) ) ;

SHEQ(H).. S(H)=E= YD(H) - SUM(I, P(I) * CH(I,H) * (1+SUM(GS, TAUC(GS,I))));
```

```
* PRODUCERS

PVAEQ(I).. PVA(I) =E= PD(I) - SUM(J, AD(J,I)*P(J) *(1+SUM(GS, TAUQ(GS, J) )) );

PFEQ(I)..DS(I) =E= DELTA(I)*PROD(F$ALPHA(F,I),FD(F,I)**ALPHA(F,I));

FDEQ(F,I).. R(F,I) * RA(F) * ( 1 + SUM(GF,TAUFX(GF,F,I) ) ) * FD(F,I) =E=
            PVA(I) * DS(I) * ALPHA(F,I);

 VEQ(I).. V(I) =E= SUM(J, AD(I,J) * DS(J) );

YFEQL(L).. Y(L) =E= SUM(IG, R(L,IG) * RA(L) * FD(L,IG));

YFEQK(K).. Y('KAP') =E= SUM(IG, R('KAP',IG) * RA('KAP') * FD('KAP',IG));

YFEQLA(LA).. Y('LAND')=E=SUM(IG,R('LAND',IG)*RA('LAND') *
               FD('LAND',IG));

LANFOR(LA).. LNFOR(LA) =E= LFOR(LA)*Y(LA);

KAPFOR(K).. KPFOR(K) =E= KFOR(K)*Y(K);


* TRADE

XEQ(I).. CX(I) =E= CX0(I)*( (PD(I)*(1+SUM(GK,TAUX(GK,I))))
                  /(PW0(I)*(1+SUM(GK,TAUQ(GK,I))))) **(ETAE(I)*1.02);


DEQ(I)$PWM0(I).. D(I) =E= D0(I) * ( PD(I) / PWM0(I)/(1+SUM(GK,TAUM(GK,I))))
                          ** ETAD(I);

MEQ(I).. M(I)=E= ( 1 - D(I) ) * DD(I);

PEQ(I).. P(I)=E= D(I) * PD(I) + ( 1 - D(I) ) * PWM0(I)*(1+SUM(GK,TAUM(GK,I))) ;

NKIEQ.. NKI =E= SUM(I, M(I) * PWM0(I) ) - SUM(I, CX(I) * PD(I) )-
                SUM(H, PRIVRET(H)*HH(H)) - SUM(LA, LNFOR(LA))-
                SUM(K, KPFOR(K)) - SUM(G, GVFOR(G))-
                SUM(L,CMOWAGE(L)*CMO(L)) - SUM(L,CMIWAGE(L)
               *CMI(L)) ;
```

```
* INVESTMENT

NEQ(K,I).. N(K,I)=E= N0(K,I)*( R(K,I)/R0(K,I)) ** ETAIX(K,I)
                  * ( DS(I) / DS0(I))**(ETAIX(K,I)*2.0);

CNEQ(I).. P(I)* ( 1 + SUM(GS, TAUN(GS,I) ) )  * CN(I) =E= SUM(IG, B(I,IG) *
          (SUM(K, N(K,IG))) );

KSEQ(K,IG).. KS(K,IG)=E= KS0(K,IG) * ( 1 - DEPR) + N(K,IG) ;


* FACTOR SUPPLY

LSEQ1(H).. HW(H)/HH(H) =E= HW0(H)/HH0(H)   * ((SUM(L, RA(L) / RA0(L))/3)/
           (CPI(H) / CPI0(H))  * (SUM((Z,L), FD(L,Z))/(SUM(H1, HW(H1)*
           SUM(L, JOBCOR(H1,L)))+ SUM(L,CMI(L)))) +
           SUM(L,EXWGE2(L)/RA(L))/ 3*(SUM(L, CMO(L)) /(SUM(H1, HW(H1) *
           SUM(L,JOBCOR(H1,L)))+ SUM(L,CMI(L))))) ** (ETARA(H)*1) *
           ( SUM(G, TP(H,G) / CPI(H) )/SUM(G, TP(H,G) / CPI0(H) ))** ETAPT(H);

LSEQ2(L).. CMO('L1')=E= CMO0('L1')* (((EXWGE1('L1') / RA('L1') ))**
                        ECOMO('L1'));

LSEQ2a(L).. CMO('L2')=E= CMO0('L2')* (((EXWGE1('L2') / RA('L2') ))**
                         ECOMO('L2'));

LSEQ2b(L).. CMO('L3')=E= CMO0('L3')* (((EXWGE1('L3') / RA('L3') ))**
                         ECOMO('L3'));

LSEQ3(L).. CMI('L1')=E= CMI0('L1')* ((( RA('L1')/(SUM( H,  CPI(H))/6) /
                        EXWGE2('L1') ))** ECOMI('L1'));

LSEQ3a(L).. CMI('L2')=E= CMI0('L2')* (((RA('L2')/(SUM( H, CPI(H))/6) /
                         EXWGE2('L2') ))** ECOMI('L2'));

LSEQ3b(L).. CMI('L3')=E= CMI0('L3')* (((RA('L3')/(SUM( H, CPI(H))/6)/
                         EXWGE2('L3') ))** ECOMI('L3'));

LASEQ1(LA,I).. LAS(LA,I)=E=LAS0(LA,I)*(R(LA, I)/R0(LA,I)) ** (ETAL(LA,I)*1.0)
                         * ( DS(I) / DS0(I))**(ETAL(LA,I)*1.0);

display r0;
```

```
* MIGRATION

 POPEQ(H).. HH(H)=E=HH0(H)*NRPG(H) + MI0(H)*(( YD(H)/HH(H))
                      / ( YD0(H)/HH0(H)) / ( CPI(H) /CPI0(H))) * (ETAYD(H)*1.0)
                       * ( ( HN(H) / HH(H))/ ( HN0(H)  / HH0(H)  ) ) ** ETAU(H)
                       - MO0(H) * ( ( YD0(H)  / HH0(H) ) / ( YD(H)   / HH(H)   )
                       / ( CPI0(H) / CPI(H)  ) ) ** ETAYD(H)*( (HN0(H) / HH0(H)  )
                       / ( HN(H)   / HH(H)   ) ) ** ETAU(H);

ANEQ(H).. HN(H)=E= HH(H) - HW(H);


* GOVERNMENT

YGEQ(GX).. Y(GX)=E=   SUM(I, TAUV(GX,I) * V(I) * P(I) )
            + SUM(I, TAUX(GX,I)* CX(I) * PD(I))
            + SUM(I, TAUM(GX,I) * M(I)*PWM0(I))
            + SUM((H,I), TAUC(GX,I) * CH(I,H) * P(I) )
            + SUM(I, TAUN(GX,I) * CN(I) * P(I) )
            + SUM((GN,I), TAUG(GX,I) * CG(I,GN) * P(I) )
            + SUM((F,I), TAUFX(GX,F,I) * RA(F) * R(F,I) * FD(F,I) )
            + SUM((F,GN), TAUFX(GX,F,GN) * RA(F) * R(F,GN) * FD(F,GN) )
            + SUM(L, TAUFH(GX,L) * (Y(L) + CMIWAGE(L)*CMI(L)))
            + SUM(K, TAUFH(GX,K) * (Y(K)) )
            + SUM(LA, TAUFH(GX,LA) * (Y(LA)) )
            + SUM(H, PIT(GX,H) * HH(H) )
            + SUM(H, TAUH(GX,H) * HH(H) )
            + SUM(GX1, IGT(GX,GX1));

YGEQ2(GT).. Y(GT)=E= SUM(GX, IGT(GT,GX));

YGEQ1(GNL)..  Y(GNL)=E=TAXS1(GNL)*Y('CYGF');

GOVFOR(G).. GVFOR(G) =E= GFOR(G)*Y(G);

CGEQ(I,GN).. P(I) * ( 1 + SUM(GS, TAUG(GS,I) ) ) * CG(I,GN)
        =E= AG(I,GN) * (Y(GN)+ GVFOR(GN));

GFEQ(F,GN)..  FD(F,GN) * R(F,GN) * RA(F)*( 1 + SUM(GF, TAUFX(GF,F,GN)))
        =E= AG(F,GN) * (Y(GN)+ GVFOR(GN));


GSEQL(GN).. S(GN)=E= (Y(GN)+ GVFOR(GN)) - SUM(I, CG(I,GN) * P(I) *
                    (1+ SUM(GS, TAUG(GS,I)))) - SUM(F, FD(F,GN) * R(F,GN) *
                    RA(F) * ( 1 + SUM(GF, TAUFX(GF,F,GN))));
```

```
GSEQ(GX).. S(GX)=E= (Y(GX)+GVFOR(GX)) - SUM(H, (TP(H,GX) * HH(H)) ) -
                        SUM(G,IGT(G,GX) );

GSEQJ1('CYGF').. S('CYGF')=E= Y('CYGF') -  Y('CYGF');

TDEQ(G,GX)$(IGTD(G,GX) EQ 1).. IGT(G,GX) =E=
TAXS(G,GX) * ( Y(GX) + GVFOR(GX)- SUM(H, (TP(H,GX) * HH(H)) ));


* MODEL CLOSURE

SPIEQ.. SPI =E=  SUM(H, Y(H) )+ SUM((H,G), TP(H,G) * HH(H)  ) +
                 SUM(H, PRIVRET(H)*HH(H));

LMEQ(L).. SUM(H, HW(H)* JOBCOR(H,L)) + CMI(L) =E= SUM(Z, FD(L ,Z) )+
                                                   CMO(L);

KMEQ(K,IG).. KS(K,IG) =E= FD(K,IG);

LAMEQ(LA,IG).. LAS(LA,IG) =E= FD(LA,IG) ;

GMEQ(I).. DS(I)=E= DD(I) + CX(I) - M(I);

DDEQ(I).. DD(I)=E= V(I) + SUM(H, CH(I,H) ) + SUM(G, CG(I,G) ) + CN(I);

*----------------------------------------------------------------------------------------------------
---
* 6.3 MODEL CLOSURE
*----------------------------------------------------------------------------------------------------
---
IGT.FX(G,GX)$(NOT IGT0(G,GX))=0;

* FIX EXOGENOUS INTERGOVERNMENTAL TRANSFERS
IGT.FX(G,GX)$(IGTD(G,GX) EQ 2)=IGT0(G,GX);

* FIX INTER SECTORAL WAGE DIFFERENTIALS
 R.FX(L,Z)=R0(L,Z);

* FIX ECONOMY WIDE SCALAR
 RA.FX(LA)=RA0(LA);
 RA.FX(K)=RA0(K);
```

```
*-----------------------------------------------------------------------------------------------------
---
* 7. SOLVE AND OUTPUT PREPARATION
*-----------------------------------------------------------------------------------------------------
---

MODEL FTC0 /ALL/;

* EXPERIMENT LOOP


 LOOP(SM$(ORD(SM) GT 1),
  IF (
(ORD(SM)) >2,


*  TAUFX('CNPRP','LAND','MANUF')= TAUFX('CNPRP','LAND','MANUF')*.8;
*  TAUH('CNPRP',H)= TAUH('CNPRP',H)*(.86);
*  ks0(K, 'LF')=ks0(K,'LF')*1.1;
*  ks0(K, 'DN')=ks0(K,'DN')*1.05;
*  ks0(K, 'DK')=ks0(K,'DK')*1.05;

AD('dk','agpro')= 0.000235;
AD('minng','agpro')= 0.000625;

AD('dk','agser')= 0.000030;
AD('minng','agser')= 0.000079;

AD('dk','const')= 0.005050;
AD('minng','const')= 0.016952;

AD('dk','minng')= 0.049653;
AD('minng','minng')= 0.132409;

AD('dk','LF')= 0.024827;
AD('minng','LF')= 0.066205;

AD('dk','agprs')= 0.000234;
AD('minng','agprs')= 0.000623;

AD('dk','manuf')= 0.012731;
AD('minng','manuf')= 0.033950;

AD('dk','cmanf')= 0.000020;
AD('minng','cmanf')= 0.000052;
```

```
AD('dk','commu')= 0.000000;
AD('minng','commu')= 0.000000;

AD('dk','elect')= 0.035949;
AD('minng','elect')= 0.095863;

AD('dk','water')= 0.000000;
AD('minng','water')= 0.000000;

AD('dk','retal')= 0.000006;
AD('minng','retal')= 0.000016;

AD('dk','fire')= 0.000002;
AD('minng','fire')= 0.000006;

AD('dk','lodge')= 0.000017;
AD('minng','lodge')= 0.000045;

AD('dk','eating')= 0.000006;
AD('minng','eating')= 0.000016;

AD('dk','lwser')= 0.001095;
AD('minng','lwser')= 0.004371;

AD('dk','hgser')= 0.000004;
AD('minng','hgser')= 0.000011;

AD('dk','trutl')= 0.021207;
AD('minng','trutl')= 0.056552;

AD('dk','whole')= 0.000019;
AD('minng','whole')= 0.000049;

AD('dk','ele2')= 0.000039;
AD('minng','ele2')= 0.000104;

AD('dk','unijc')= 0.000000;
AD('minng','unijc')= 0.000000;

AD('dk','dk')= 0.012413;
AD('minng','dk')= 0.033102;

AG('dk','stfed')= 0.000447;
AG('minng','stfed')= 0.000447;
```

```
AD('agpro','dn')= 0.005704079;
AD('LF','agpro')= 0.001412071;

AD('agser','dn')= 0.006367015;
AD('lf','agser')= 0.009102214;

AD('const','dn')= 0.221172296;
AD('LF','const')= 0.002319608;

AD('minng','dn')= 0.017334112;
AD('lf','minng')= 0.00116105;

AD('LF','dn')= 0.005778037;
AD('LF','LF')= 0.008413109;

AD('agprs','dn')= 0.125359774;
AD('lf','agprs')= 0.007002801;

AD('manuf','dn')= 0.102257161;
AD('lf','manuf')= 0.000626923;

AD('cmanf','dn')= 0.033865891;
AD('lf','cmanf')= 0.000263414;

AD('commu','dn')= 0.001112396;
AD('lf','commu')= 0.000183339;

AD('elect','dn')= 0.000795101;
AD('lf','elect')= 0.000150002;

AD('water','dn')= 0.012911595;
AD('lf','water')= 0.008774457;

AD('retal','dn')= 0.011036588;
AD('lf','retal')= 0.00040562;

AD('fire','dn')= 0.050632295;
AD('lf','fire')= 0.001168629;

AD('lodge','dn')= 0.01141967;
AD('lf','lodge')= 0.002919348;

AD('eating','dn')= 0.073577256;
AD('lf','eating')= 0.006625338;
```

```
AD('lwser','dn')= 0.142745913;
AD('lf','lwser')= 0.004940298;

AD('hgser','dn')= 0.109983922;
AD('lf','hgser')= 0.002543713;

AD('trutl','dn')= 0.01211292;
AD('lf','trutl')= 0.001090359;

AD('whole','dn')= 0.03559676;
AD('lf','whole')= 0.001104655;

AD('ele2','dn')= 0.015234524;
AD('lf','ele2')= 0.001029733;

AD('unijc','dn')= 0.004761943;
AD('lf','unijc')= 0.000177836;


TAUC('CYSTX','LF')=  .75;
TAUC('CYSTX','DK')= -.75;
)
OPTION NLP=MINOS5;
FTC0.scaleopt = 1;
FTC0.OPTFILE = 0;
OPTION SYSOUT = ON;
SOLVE FTC0 MAXIMIZING SPI USING NLP;

R1 ('SPI',SM) = SPI.L;
R1('SSC',SM)= SUM(IG, R.L('LAND',IG) * RA.L('LAND') * FD.L('LAND',IG));
R1('HC',SM) = D.L('COMMU');
R1('HH',SM)=SUM(H, HH.L(H) );
R1('HN',SM)=SUM(H, HN.L(H) );
R1('HW',SM)=SUM(H, HW.L(H) );
R1('W1',SM)= RA.L('L1');
R1('W2',SM)= RA.L('L2');
R1('W3',SM)= RA.L('L3');
R1('R',SM)=SUM(Z, R.L('KAP',Z));
R1('RL',SM)= RA.L('LAND');
R1('L',SM)=SUM((Z,L), FD.L(L,Z) );
R1('K',SM)= (SUM(Z, FD.L('KAP',Z)));
R1('LAND',SM)=SUM(Z, FD.L('LAND',Z) );
R1('GFSAV',SM)=S.L('CYGF');
R2('M-STAT',SM)=FTC0.MODELSTAT;
```

```
R2('S-STAT',SM)=FTC0.SOLVESTAT);

CPIN.L(H)= SUM(IP, P.L(IP)  * ( 1 + SUM(GS, TAUC(GS,IP) ) ) * CH.L(IP,H) )
            / SUM(IP, P0(IP) * ( 1 + SUM(GS, TAUQ(GS,IP) ) ) * CH.L(IP,H) );

CPIH.L(H)= SUM(HD, P.L(HD)  * ( 1 + SUM(GS, TAUC(GS,HD) ) ) * CH.L(HD,H) )
            / SUM(HD, P0(HD) * ( 1 + SUM(GS, TAUQ(GS,HD) ) ) * CH.L(HD,H)
);

DFCG.L(I,G)=CG.L(I,G)-CG0(I,G);
DFCH.L(I,H)=CH.L(I,H)-CH0(I,H);
DFFD.L(F,Z) = FD.L(F,Z)-FD0(F,Z);
DV.L(I) = V.L(I)-V0(I);
DY.L(Z) = Y.L(Z)-Y0(Z);
DM.L(I) =M.L(I)-M0(I);
DDS.L(I) = DS.L(I)-DS0(I);
DDD.L(I) =DD.L(I) - DD0(I);
DCX.L(I) =CX.L(I) -CX0(I);
GCP1.L(I) =SUM(H, CH.L(I,H))+ CN.L(I)+ SUM(GN, CG.L(I,GN))+ CX.L(I)-M.L(I);
DGCP1.L(I) = GCP1.L(I) - GCP10(I);
DFHH.L(H)=HH.L(H)-HH0(H);
DFHN.L(H)=HN.L(H)-HN0(H);
DFHW.L(H)=HW.L(H)-HW0(H);
DCH.L(I,H) = CH.L(I,H) - CH0(I,H);
GCP.L =SUM((I,H), (CH.L(I,H)))+ SUM(I, CN.L(I))+ SUM((I,GN), (CG.L(I,GN)))+
SUM(I, CX.L(I))-SUM(I, M.L(I));
DGCP.L=GCP.L-GCP0;
DRR.L(F,Z) = R.L(F,Z)-R0(F,Z);

OPTION DECIMALS=6;
DISPLAY
CG0,CG.L,CH0,CH.L,CN0,CN.L,CPI0,CPI.L,CX0,CX.L,D0,D.L,DD0,DD.L,DS0,DS.L
,FD0,FD.L,HH0,HH.L,HN0,HN.L,HW0,HW.L,IGT0,IGT.L,KS0,KS.L,LAS0,LAS.L,M0
,M.L,N0,N.L,NKI0,NKI.L,LNFOR0,LNFOR.L,KPFOR0,KPFOR.L,GVFOR0,GVFOR.
L,P0,P.L,PD0,PD.L,PVA0,PVA.L, PWM0, RA0, RA.L,R0, R.L, S0, S.L, SPI0, SPI.L,
TP, V0,V.L,Y0,Y.L,YD0,YD.L,DFCG.L, DFCH.L, DFFD.L, DV.L, DY.L, DM.L,
DCX.L, DDS.L, DDD.L, DGCP1.L, GCP1.L,DGCP.L, GCP.L, GCP0,CMO0, CMO.L,
cmi0, CMI.L, DFHH.L,DFHN.L,DFHW.L, CPI.L, CPIN.L, CPIH.L, DRR.L, GVFOR0,
GVFOR.L, CPI.L, DY.L, DGCP1.L, DDS.L, AD;

* PUT RESULTS INTO OUTPUT FILE
PUT 'FTCOL          ';
LOOP(SM, PUT '   ',SM.TL);
PUT /;
```

```
PUT '  ','MODEL   ','              ';
LOOP(SM$(ORD(SM) GT 1), LOOP(MS$(R2('M-STAT',SM) EQ ORD(MS) ),
PUT MS.TL));
PUT /;

PUT ' ','SOLVER   ', PUT '      ';
LOOP(SM$(ORD(SM) GT 1), LOOP(SS$(R2('S-STAT',SM) EQ ORD(SS) ), PUT
SS.TL ) );
PUT /;

LOOP(R1H, PUT '         ';
PUT R1H.TL, LOOP(SM, PUT R1(R1H,SM) );
PUT / );
```

APPENDIX C

SELECTED RESULTS

Original Mix
Landfill Tax Rate = 5%

Category	Change
Total Households (#)	-9.772529
Non-Working Households (#)	4.358010
Working Households (#)	-14.130539
Wage Group 1 (%)	-0.000425
Wage Group 2 (%)	-0.000044
Wage Group 3 (%)	-0.000056
Labor (#)	-28.315930
Capital ($ Million)	-2.029631

Household Group	Change in Household Income ($ Million)
HH1	-0.020139
HH2	-0.073448
HH3	-0.188244
HH4	-0.051636
HH5	-0.188717
HH6	-0.427120
TOTAL	**-0.949305**

Tax Type	Change in Taxes Collected ($ Million)
CNPRP	-0.050550
CYNVT	-0.000029
CYSTX	0.792563
CYUSE	-0.006484
CYORV	-0.013625
TOTAL	**0.721875**

Change in Domestic Supply ($ Million)							
Sector	Change ($ Million)	Sector	Change ($ Million)	Sector	Change ($ Million)	Sector	Change ($ Million)
AGPRO	-0.018075	AGSER	-0.012795	CONST	-0.353975	MINNG	-0.015000
LF	-0.018415	AGPRS	-0.234517	MANUF	-0.228347	CMANF	-0.107520
COMMU	-0.002061	ELECT	-0.000486	WATER	-0.034054	RETAL	-0.039468
FIRE	-0.267900	LODGE	-0.043363	EATING	-0.137663	LWSER	-0.286147
HGSER	-0.302193	TRUTL	-0.036140	WHOLE	-0.128441	ELE2	-0.031954
UNIJC	-0.040796	DK	-0.001547	DN	-0.001402	HS1	-0.044846
HS2	-0.075245	HS3	-0.018283	HS4	-0.053143		
						TOTAL	**-2.533776**

APPENDIX C

SELECTED RESULTS

Original Mix
Landfill Tax Rate = 25%

Category	Change
Total Households (#)	-48.011821
Non-Working Households (#)	21.532009
Working Households (#)	-69.543831
Wage Group 1 (%)	-0.002104
Wage Group 2 (%)	-0.000216
Wage Group 3 (%)	-0.000279
Labor (#)	-133.601100
Capital ($ Million)	-9.934674

Household Group	Change in Household Income ($ Million)
HH1	-0.099005
HH2	-0.362377
HH3	-0.927759
HH4	-0.255389
HH5	-0.933705
HH6	-2.116096
TOTAL	**-4.694332**

Tax Type	Change in Taxes Collected ($ Million)
CNPRP	-0.250396
CYNVT	-0.000146
CYSTX	3.950069
CYUSE	-0.031860
CYORV	-0.067236
TOTAL	**3.600431**

Change in Domestic Supply ($ Million)							
Sector	Change ($ Million)	Sector	Change ($ Million)	Sector	Change ($ Million)	Sector	Change ($ Million)
AGPRO	-0.090298	AGSER	-0.063683	CONST	-1.748551	MINNG	-0.075741
LF	-0.090878	AGPRS	-1.168128	MANUF	-1.142279	CMANF	-0.537803
COMMU	-0.010445	ELECT	-0.002497	WATER	-0.164810	RETAL	-0.196117
FIRE	-1.293601	LODGE	-0.206323	EATING	-0.683341	LWSER	-1.421228
HGSER	-1.503969	TRUTL	-0.180196	WHOLE	-0.640708	ELE2	-0.160753
UNIJC	-0.202361	DK	-0.007488	DN	-0.006807	HS1	-0.220981
HS2	-0.371573	HS3	-0.090322	HS4	-0.261093		
						TOTAL	**-12.54197**

APPENDIX C

SELECTED RESULTS

Original Mix
Landfill Tax Rate = 50%

Category	Change
Total Households (#)	-94.095208
Non-Working Households (#)	42.480126
Working Households (#)	-136.575335
Wage Group 1 (%)	-0.004162
Wage Group 2 (%)	-0.000427
Wage Group 3 (%)	-0.000551
Labor (#)	-268.736271
Capital ($ Million)	-19.385028

Household Group	Change in Household Income ($ Million)
HH1	-0.194203
HH2	-0.713746
HH3	-1.824975
HH4	-0.504447
HH5	-1.844987
HH6	-4.187903
TOTAL	-9.270259

Tax Type	Change in Taxes Collected ($ Million)
CNPRP	-0.495409
CYNVT	-0.000288
CYSTX	7.869008
CYUSE	-0.062435
CYORV	-0.132439
TOTAL	**7.178437**

Change in Domestic Supply ($ Million)							
Sector	Change ($ Million)	Sector	Change ($ Million)	Sector	Change ($ Million)	Sector	Change ($ Million)
AGPRO	-0.180347	AGSER	-0.126602	CONST	-3.448429	MINNG	-0.153076
LF	-0.178932	AGPRS	-2.325091	MANUF	-2.284974	CMANF	-1.075702
COMMU	-0.021181	ELECT	-0.005138	WATER	-0.317514	RETAL	-0.389165
FIRE	-2.486348	LODGE	-0.390655	EATING	-1.354845	LWSER	-2.819303
HGSER	-2.991333	TRUTL	-0.359136	WHOLE	-1.277352	ELE2	-0.323571
UNIJC	-0.400878	DK	-0.014424	DN	-0.013156	HS1	-0.434572
HS2	-0.732538	HS3	-0.178142	HS4	-0.511701		
						Total	**-24.79411**

APPENDIX C

SELECTED RESULTS

25% Mix
Landfill Tax Rate = 5%

Category	Change
Total Households (#)	-6.352915
Non-Working Households (#)	2.832292
Working Households (#)	-9.185206
Wage Group 1 (%)	-0.000284
Wage Group 2 (%)	-0.000031
Wage Group 3 (%)	-0.000034
Labor (#)	-18.460191
Capital ($ Million)	-1.303223

Household Group	Change in Household Income ($ Million)
HH1	-0.013238
HH2	-0.048420
HH3	-0.122689
HH4	-0.033524
HH5	-0.123068
HH6	-0.276221
TOTAL	**-0.617161**

Tax Type	Change in Taxes Collected ($ Million)
CNPRP	-0.032631
CYNVT	-0.000020
CYSTX	0.530078
CYUSE	-0.004200
CYORV	-0.009011
TOTAL	**0.484216**

Change in Domestic Supply ($ Million)							
Sector	Change ($ Million)	Sector	Change ($ Million)	Sector	Change ($ Million)	Sector	Change ($ Million)
AGPRO	-0.022544	AGSER	-0.007928	CONST	-0.306985	MINNG	-0.008663
LF	-0.009862	AGPRS	-0.146079	MANUF	-0.141078	CMANF	-0.067411
COMMU	-0.001201	ELECT	-0.000267	WATER	-0.021279	RETAL	-0.024765
FIRE	-0.166642	LODGE	-0.026817	EATING	-0.089609	LWSER	-0.178498
HGSER	-0.191066	TRUTL	-0.022452	WHOLE	-0.079604	ELE2	-0.019425
UNIJC	-0.025961	DK	-0.012498	DN	-0.011727	HS1	-0.029126
HS2	-0.048639	HS3	-0.011796	HS4	-0.034701		
						Total	**-1.706623**

APPENDIX C

SELECTED RESULTS

25% Mix
Landfill Tax Rate = 25%

Category	Change
Total Households (#)	-31.406667
Non-Working Households (#)	14.054439
Working Households (#)	-45.461107
Wage Group 1 (%)	-0.001412
Wage Group 2 (%)	-0.000152
Wage Group 3 (%)	-0.000168
Labor (#)	-85.475579
Capital ($ Million)	-6.427767

Household Group	Change in Household Income ($ Million)
HH1	-0.065475
HH2	-0.240057
HH3	-0.607798
HH4	-0.166458
HH5	-0.611216
HH6	-1.373001
TOTAL	**-3.064005**

Tax Type	Change in Taxes Collected ($ Million)
CNPRP	-0.162163
CYNVT	-0.000098
CYSTX	2.644315
CYUSE	-0.020766
CYORV	-0.044678
TOTAL	**2.416610**

Change in Domestic Supply ($ Million)							
Sector	Change ($ Million)	Sector	Change ($ Million)	Sector	Change ($ Million)	Sector	Change ($ Million)
AGPRO	-0.112404	AGSER	-0.039521	CONST	-1.524720	MINNG	-0.043615
LF	-0.048956	AGPRS	-0.728545	MANUF	-0.705477	CMANF	-0.337056
COMMU	-0.006058	ELECT	-0.001360	WATER	-0.104157	RETAL	-0.123287
FIRE	-0.814689	LODGE	-0.129867	EATING	-0.445886	LWSER	-0.888603
HGSER	-0.952311	TRUTL	-0.112044	WHOLE	-0.397393	ELE2	-0.097506
UNIJC	-0.129091	DK	-0.062137	DN	-0.058305	HS1	-0.144274
HS2	-0.241267	HS3	-0.058525	HS4	-0.171560		
						Total	**-8.478614**

APPENDIX C

SELECTED RESULTS

25% Mix
Landfill Tax Rate = 50%

Category	Change
Total Households (#)	-61.973744
Non-Working Households (#)	27.858012
Working Households (#)	-89.831756
Wage Group 1 (%)	-0.002805
Wage Group 2 (%)	-0.000302
Wage Group 3 (%)	-0.000334
Labor (#)	-175.019910
Capital ($ Million)	-12.648173

Household Group	Change in Household Income ($ Million)
HH1	-0.129278
HH2	-0.475325
HH3	-1.202330
HH4	-0.330183
HH5	-1.212740
HH6	-2.726964
TOTAL	**-6.076820**

Tax Type	Change in Taxes Collected ($ Million)
CNPRP	-0.321991
CYNVT	-0.000194
CYSTX	5.273686
CYUSE	-0.040981
CYORV	-0.088469
TOTAL	**4.822051**

Change in Domestic Supply ($ Million)							
Sector	Change ($ Million)	Sector	Change ($ Million)	Sector	Change ($ Million)	Sector	Change ($ Million)
AGPRO	-0.224010	AGSER	-0.078734	CONST	-3.025238	MINNG	-0.087908
LF	-0.097059	AGPRS	-1.452466	MANUF	-1.410929	CMANF	-0.674008
COMMU	-0.012235	ELECT	-0.002777	WATER	-0.203141	RETAL	-0.245228
FIRE	-1.586824	LODGE	-0.250348	EATING	-0.886543	LWSER	-1.767666
HGSER	-1.897336	TRUTL	-0.223548	WHOLE	-0.793136	ELE2	-0.195857
UNIJC	-0.256458	DK	-0.123412	DN	-0.115806	HS1	-0.285360
HS2	-0.477991	HS3	-0.115980	HS4	-0.338558		
						Total	**-16.82856**

APPENDIX C

SELECTED RESULTS

50% Mix
Landfill Tax Rate = 5%

Category	Change
Total Households (#)	-3.154593
Non-Working Households (#)	1.400954
Working Households (#)	-4.555547
Wage Group 1 (%)	-0.000142
Wage Group 2 (%)	-0.000022
Wage Group 3 (%)	-0.000016
Labor (#)	-9.276295
Capital ($ Million)	-0.679765

Household Group	Change in Household Income ($ Million)
HH1	-0.006890
HH2	-0.025378
HH3	-0.063160
HH4	-0.017144
HH5	-0.064201
HH6	-0.142875
TOTAL	**-0.319649**

Tax Type	Change in Taxes Collected ($ Million)
CNPRP	-0.016782
CYNVT	-0.000010
CYSTX	0.271806
CYUSE	-0.002191
CYORV	-0.004619
TOTAL	**0.248204**

Change in Domestic Supply ($ Million)							
Sector	Change ($ Million)	Sector	Change ($ Million)	Sector	Change ($ Million)	Sector	Change ($ Million)
AGPRO	-0.005613	AGSER	-0.003932	CONST	-0.149533	MINNG	-0.004081
LF	-0.004979	AGPRS	-0.072950	MANUF	-0.076809	CMANF	-0.010036
COMMU	-0.001162	ELECT	0.000004	WATER	-0.010627	RETAL	-0.006139
FIRE	-0.084554	LODGE	0.001204	EATING	-0.018590	LWSER	-0.169266
HGSER	-0.101461	TRUTL	-0.011584	WHOLE	-0.041333	ELE2	-0.009853
UNIJC	-0.012554	DK	-0.022011	DN	-0.021009	HS1	-0.014797
HS2	-0.024864	HS3	-0.006033	HS4	-0.017716		
						Total	**-0.900278**

APPENDIX C

SELECTED RESULTS

50% Mix
Landfill Tax Rate = 25%

Category	Change
Total Households (#)	-15.676549
Non-Working Households (#)	6.974783
Working Households (#)	-22.651333
Wage Group 1 (%)	-0.000709
Wage Group 2 (%)	-0.000111
Wage Group 3 (%)	-0.000080
Labor (#)	-40.154516
Capital ($ Million)	-3.371158

Household Group	Change in Household Income ($ Million)
HH1	-0.034254
HH2	-0.126297
HH3	-0.314209
HH4	-0.085383
HH5	-0.319771
HH6	-0.711910
TOTAL	**-1.591824**

Tax Type	Change in Taxes Collected ($ Million)
CNPRP	-0.083619
CYNVT	-0.000052
CYSTX	1.356766
CYUSE	-0.010877
CYORV	-0.022975
TOTAL	**1.239243**

Change in Domestic Supply ($ Million)							
Sector	Change ($ Million)	Sector	Change ($ Million)	Sector	Change ($ Million)	Sector	Change ($ Million)
AGPRO	-0.028055	AGSER	-0.019628	CONST	-0.744780	MINNG	-0.020481
LF	-0.024804	AGPRS	-0.364277	MANUF	-0.383790	CMANF	-0.050001
COMMU	-0.005807	ELECT	0.000013	WATER	-0.052556	RETAL	-0.030466
FIRE	-0.417789	LODGE	0.006011	EATING	-0.092442	LWSER	-0.842908
HGSER	-0.506230	TRUTL	-0.057842	WHOLE	-0.206417	ELE2	-0.049351
UNIJC	-0.062555	DK	-0.109490	DN	-0.104502	HS1	-0.073595
HS2	-0.123744	HS3	-0.030029	HS4	-0.088037		
						Total	**-4.483552**

APPENDIX C

SELECTED RESULTS

50% Mix
Landfill Tax Rate = 50%

Category	Change
Total Households (#)	-31.119091
Non-Working Households (#)	13.876624
Working Households (#)	-44.995716
Wage Group 1 (%)	-0.001413
Wage Group 2 (%)	-0.000220
Wage Group 3 (%)	-0.000158
Labor (#)	-85.758207
Capital ($ Million)	-6.675102

Household Group	Change in Household Income ($ Million)
HH1	-0.068027
HH2	-0.251159
HH3	-0.624560
HH4	-0.169940
HH5	-0.636543
HH6	-1.417829
TOTAL	**-3.168059**

Tax Type	Change in Taxes Collected ($ Million)
CNPRP	-0.166532
CYNVT	-0.000103
CYSTX	2.707918
CYUSE	-0.021567
CYORV	-0.045661
TOTAL	**2.474055**

Change in Domestic Supply ($ Million)							
Sector	Change ($ Million)	Sector	Change ($ Million)	Sector	Change ($ Million)	Sector	Change ($ Million)
AGPRO	-0.056083	AGSER	-0.039180	CONST	-1.482537	MINNG	-0.041146
LF	-0.049387	AGPRS	-0.727370	MANUF	-0.766925	CMANF	-0.099545
COMMU	-0.011611	ELECT	0.000003	WATER	-0.103720	RETAL	-0.060376
FIRE	-0.823678	LODGE	0.012003	EATING	-0.183639	LWSER	-1.677376
HGSER	-1.009829	TRUTL	-0.115493	WHOLE	-0.412202	ELE2	-0.098899
UNIJC	-0.124582	DK	-0.217583	DN	-0.207672	HS1	-0.146241
HS2	-0.246087	HS3	-0.059726	HS4	-0.174757		
						Total	**-8.923638**

APPENDIX C

SELECTED RESULTS

Original Mix
Subsidy Rate 5%

Category	Change
Total Households (#)	2.156363
Non-Working Households (#)	-0.990960
Working Households (#)	3.147323
Wage Group 1 (%)	0.000118
Wage Group 2 (%)	0.000021
Wage Group 3 (%)	-0.000003
Labor (#)	6.535478
Capital ($ Million)	0.372973

Household Group	Change in Household Income ($ Million)
HH1	0.004715
HH2	0.018337
HH3	0.040797
HH4	0.010410
HH5	0.040777
HH6	0.079967
TOTAL	**0.195003**

Tax Type	Change in Taxes Collected ($ Million)
CNPRP	0.008885
CYNVT	0.000006
CYSTX	-0.181925
CYUSE	0.001256
CYORV	0.003071
TOTAL	**-0.168707**

Change in Domestic Supply ($ Million)							
Sector	Change ($ Million)	Sector	Change ($ Million)	Sector	Change ($ Million)	Sector	Change ($ Million)
AGPRO	0.014325	AGSER	0.000185	CONST	0.276568	MINNG	-0.004066
LF	0.000561	AGPRS	-0.000046	MANUF	0.002083	CMANF	0.009536
COMMU	0.000215	ELECT	-0.000382	WATER	0.013232	RETAL	0.011829
FIRE	0.048310	LODGE	-0.000855	EATING	0.017328	LWSER	0.117200
HGSER	0.025458	TRUTL	0.000045	WHOLE	-0.000243	ELE2	-0.003281
UNIJC	0.030424	DK	0.001446	DN	0.001217	HS1	0.009552
HS2	0.015009	HS3	0.003524	HS4	0.011982		
						Total	**0.601156**

APPENDIX C

SELECTED RESULTS

Original Mix
Subsidy Rate 25%

Category	Change
Total Households (#)	10.832282
Non-Working Households (#)	-4.970924
Working Households (#)	15.803204
Wage Group 1 (%)	0.000592
Wage Group 2 (%)	0.000105
Wage Group 3 (%)	-0.000016
Labor (#)	32.798798
Capital ($ Million)	1.879865

Household Group	Change in Household Income ($ Million)
HH1	0.023682
HH2	0.092020
HH3	0.204846
HH4	0.052242
HH5	0.204585
HH6	0.401183
TOTAL	**0.978557**

Tax Type	Change in Taxes Collected ($ Million)
CNPRP	0.044421
CYNVT	0.000032
CYSTX	-0.910285
CYUSE	0.006311
CYORV	0.015397
TOTAL	**-0.844124**

Change in Domestic Supply ($ Million)							
Sector	Change ($ Million)	Sector	Change ($ Million)	Sector	Change ($ Million)	Sector	Change ($ Million)
AGPRO	0.071777	AGSER	0.000920	CONST	1.387101	MINNG	-0.020368
LF	0.002822	AGPRS	-0.000229	MANUF	0.010570	CMANF	0.047818
COMMU	0.001076	ELECT	-0.001913	WATER	0.067090	RETAL	0.059314
FIRE	0.243244	LODGE	-0.004282	EATING	0.087033	LWSER	0.587752
HGSER	0.127816	TRUTL	0.000254	WHOLE	-0.001193	ELE2	-0.016449
UNIJC	0.152256	DK	0.007267	DN	0.006113	HS1	0.047959
HS2	0.075334	HS3	0.017688	HS4	0.060191		
						Total	**3.016961**

APPENDIX C

SELECTED RESULTS

Original Mix
Subsidy Rate 50%

Category	Change
Total Households (#)	21.793440
Non-Working Households (#)	-9.982937
Working Households (#)	31.776377
Wage Group 1 (%)	0.001188
Wage Group 2 (%)	0.000210
Wage Group 3 (%)	-0.000032
Labor (#)	65.907589
Capital ($ Million)	3.798127

Household Group	Change in Household Income ($ Million)
HH1	0.047799
HH2	0.185542
HH3	0.413346
HH4	0.105308
HH5	0.412254
HH6	0.808466
TOTAL	**1.972715**

Tax Type	Change in Taxes Collected ($ Million)
CNPRP	0.089576
CYNVT	0.000065
CYSTX	-1.828948
CYUSE	0.012767
CYORV	0.031042
TOTAL	**-1.695498**

Change in Domestic Supply ($ Million)							
Sector	Change ($ Million)	Sector	Change ($ Million)	Sector	Change ($ Million)	Sector	Change ($ Million)
AGPRO	0.144280	AGSER	0.001837	CONST	2.790146	MINNG	-0.040931
LF	0.002634	AGPRS	-0.000101	MANUF	0.022054	CMANF	0.096390
COMMU	0.002182	ELECT	-0.003842	WATER	0.136595	RETAL	0.119383
FIRE	0.492574	LODGE	-0.008537	EATING	0.176923	LWSER	1.177141
HGSER	0.258900	TRUTL	0.000700	WHOLE	-0.002112	ELE2	-0.033079
UNIJC	0.305526	DK	0.018277	DN	0.016775	HS1	0.096764
HS2	0.151929	HS3	0.035672	HS4	0.121537		
						Total	**6.079617**

APPENDIX C

SELECTED RESULTS

25% Mix
Subsidy Rate 5%

Category	Change
Total Households (#)	2.165312
Non-Working Households (#)	-0.995226
Working Households (#)	3.160537
Wage Group 1 (%)	0.000119
Wage Group 2 (%)	0.000021
Wage Group 3 (%)	-0.000003
Labor (#)	12.562585
Capital ($ Million)	0.374025

Household Group	Change in Household Income ($ Million)
HH1	0.004732
HH2	0.018401
HH3	0.040941
HH4	0.010444
HH5	0.040905
HH6	0.080230
TOTAL	**0.195653**

Tax Type	Change in Taxes Collected ($ Million)
CNPRP	0.008885
CYNVT	0.000006
CYSTX	-0.181925
CYUSE	0.001256
CYORV	0.003071
TOTAL	**-0.168707**

Change in Domestic Supply ($ Million)

Sector	Change ($ Million)	Sector	Change ($ Million)	Sector	Change ($ Million)	Sector	Change ($ Million)
AGPRO	0.014360	AGSER	0.000187	CONST	0.277090	MINNG	-0.004075
LF	0.000258	AGPRS	-0.000012	MANUF	0.002136	CMANF	0.009579
COMMU	0.000218	ELECT	-0.000383	WATER	0.013222	RETAL	0.011862
FIRE	0.048476	LODGE	-0.000851	EATING	0.017513	LWSER	0.116931
HGSER	0.025649	TRUTL	0.000057	WHOLE	-0.000221	ELE2	-0.003287
UNIJC	0.030493	DK	0.001809	DN	0.001660	HS1	0.009585
HS2	0.015061	HS3	0.003537	HS4	0.012025		
						Total	**0.602879**

APPENDIX C

SELECTED RESULTS

25% Mix
Subsidy Rate 25%

Category	Change
Total Households (#)	10.877204
Non-Working Households (#)	-4.992273
Working Households (#)	15.869476
Wage Group 1 (%)	0.000594
Wage Group 2 (%)	0.000105
Wage Group 3 (%)	-0.000016
Labor (#)	32.934633
Capital ($ Million)	1.885215

Household Group	Change in Household Income ($ Million)
HH1	0.023764
HH2	0.092343
HH3	0.205570
HH4	0.052411
HH5	0.205230
HH6	0.402503
TOTAL	**0.981820**

Tax Type	Change in Taxes Collected ($ Million)
CNPRP	0.044585
CYNVT	0.000032
CYSTX	-0.911770
CYUSE	0.006325
CYORV	0.015429
TOTAL	**-0.845399**

Change in Domestic Supply ($ Million)							
Sector	Change ($ Million)	Sector	Change ($ Million)	Sector	Change ($ Million)	Sector	Change ($ Million)
AGPRO	0.071950	AGSER	0.000927	CONST	1.389690	MINNG	-0.020415
LF	0.001303	AGPRS	-0.000054	MANUF	0.010835	CMANF	0.048030
COMMU	0.001091	ELECT	-0.001917	WATER	0.067052	RETAL	0.059479
FIRE	0.244090	LODGE	-0.004260	EATING	0.087959	LWSER	0.586385
HGSER	0.128773	TRUTL	0.000313	WHOLE	-0.001082	ELE2	-0.016481
UNIJC	0.152598	DK	0.009086	DN	0.008340	HS1	0.048125
HS2	0.075596	HS3	0.017750	HS4	0.060409		
						Total	**3.025572**

APPENDIX C

SELECTED RESULTS

25% Mix
Subsidy Rate 50%

Category	Change
Total Households (#)	21.793440
Non-Working Households (#)	-9.982937
Working Households (#)	31.776378
Wage Group 1 (%)	0.001188
Wage Group 2 (%)	0.000210
Wage Group 3 (%)	-0.000032
Labor (#)	65.907586
Capital ($ Million)	3.798127

Household Group	Change in Household Income ($ Million)
HH1	0.047799
HH2	0.185542
HH3	0.413346
HH4	0.105308
HH5	0.412254
HH6	0.808467
TOTAL	**1.972716**

Tax Type	Change in Taxes Collected ($ Million)
CNPRP	0.089576
CYNVT	0.000065
CYSTX	-1.828948
CYUSE	0.012767
CYORV	0.031042
TOTAL	**-1.695498**

Change in Domestic Supply ($ Million)							
Sector	Change ($ Million)	Sector	Change ($ Million)	Sector	Change ($ Million)	Sector	Change ($ Million)
AGPRO	0.144280	AGSER	0.001837	CONST	2.790146	MINNG	-0.040931
LF	0.002634	AGPRS	-0.000101	MANUF	0.022054	CMANF	0.096390
COMMU	0.002182	ELECT	-0.003842	WATER	0.136595	RETAL	0.119383
FIRE	0.492574	LODGE	-0.008537	EATING	0.176923	LWSER	1.177141
HGSER	0.258900	TRUTL	0.000700	WHOLE	-0.002112	ELE2	-0.033079
UNIJC	0.305526	DK	0.018277	DN	0.016775	HS1	0.096764
HS2	0.151929	HS3	0.035672	HS4	0.121537		
						Total	**6.079617**

APPENDIX C

SELECTED RESULTS

50% Mix
Subsidy Rate 5%

Category	Change
Total Households (#)	2.168054
Non-Working Households (#)	-0.996465
Working Households (#)	3.164519
Wage Group 1 (%)	0.000119
Wage Group 2 (%)	0.000021
Wage Group 3 (%)	-0.000003
Labor (#)	6.571226
Capital ($ Million)	0.374235

Household Group	Change in Household Income ($ Million)
HH1	0.004736
HH2	0.018417
HH3	0.040997
HH4	0.010457
HH5	0.040956
HH6	0.080346
TOTAL	**0.195909**

Tax Type	Change in Taxes Collected ($ Million)
CNPRP	0.008895
CYNVT	0.000006
CYSTX	-0.182030
CYUSE	0.001256
CYORV	0.003070
TOTAL	**-0.168803**

Change in Domestic Supply ($ Million)							
Sector	Change ($ Million)	Sector	Change ($ Million)	Sector	Change ($ Million)	Sector	Change ($ Million)
AGPRO	0.014367	AGSER	0.000189	CONST	0.277217	MINNG	-0.004076
LF	-0.000044	AGPRS	0.000014	MANUF	0.002168	CMANF	0.009571
COMMU	0.000219	ELECT	-0.000383	WATER	0.013203	RETAL	0.011881
FIRE	0.048589	LODGE	-0.000842	EATING	0.017433	LWSER	0.116522
HGSER	0.025823	TRUTL	0.000070	WHOLE	-0.000205	ELE2	-0.003286
UNIJC	0.030514	DK	0.003033	DN	0.002874	HS1	0.009599
HS2	0.015086	HS3	0.003542	HS4	0.012041		
						Total	**0.605119**

APPENDIX C

SELECTED RESULTS

50% Mix
Subsidy Rate 25%

Category	Change
Total Households (#)	10.890399
Non-Working Households (#)	-4.998209
Working Households (#)	15.888608
Wage Group 1 (%)	0.000595
Wage Group 2 (%)	0.000106
Wage Group 3 (%)	-0.000016
Labor (#)	38.976238
Capital ($ Million)	1.886212

Household Group	Change in Household Income ($ Million)
HH1	0.023786
HH2	0.092417
HH3	0.205839
HH4	0.052475
HH5	0.205471
HH6	0.403063
TOTAL	**0.983050**

Tax Type	Change in Taxes Collected ($ Million)
CNPRP	0.044633
CYNVT	0.000032
CYSTX	-0.912227
CYUSE	0.006328
CYORV	0.015422
TOTAL	**-0.845812**

Change in Domestic Supply ($ Million)							
Sector	Change ($ Million)	Sector	Change ($ Million)	Sector	Change ($ Million)	Sector	Change ($ Million)
AGPRO	0.071983	AGSER	0.000939	CONST	1.390240	MINNG	-0.020418
LF	-0.000215	AGPRS	0.000073	MANUF	0.010990	CMANF	0.047982
COMMU	0.001094	ELECT	-0.001919	WATER	0.066969	RETAL	0.059568
FIRE	0.244653	LODGE	-0.004215	EATING	0.087552	LWSER	0.584286
HGSER	0.129638	TRUTL	0.000379	WHOLE	-0.001006	ELE2	-0.016477
UNIJC	0.152690	DK	0.015219	DN	0.014420	HS1	0.048195
HS2	0.075714	HS3	0.017779	HS4	0.060486		
						Total	**3.036599**

APPENDIX C

SELECTED RESULTS

50% Mix
Subsidy Rate 50%

Category	Change
Total Households (#)	21.908879
Non-Working Households (#)	-10.036931
Working Households (#)	31.945809
Wage Group 1 (%)	0.001193
Wage Group 2 (%)	0.000212
Wage Group 3 (%)	-0.000031
Labor (#)	72.259370
Capital ($ Million)	3.810932

Household Group	Change in Household Income ($ Million)
HH1	0.047839
HH2	0.185678
HH3	0.413863
HH4	0.105431
HH5	0.412712
HH6	0.809541
TOTAL	**1.975064**

Tax Type	Change in Taxes Collected ($ Million)
CNPRP	0.089668
CYNVT	0.000065
CYSTX	-1.829697
CYUSE	0.012773
CYORV	0.031026
TOTAL	**-1.696165**

Change in Domestic Supply ($ Million)							
Sector	Change ($ Million)	Sector	Change ($ Million)	Sector	Change ($ Million)	Sector	Change ($ Million)
AGPRO	0.144335	AGSER	0.001861	CONST	2.791043	MINNG	-0.040936
LF	-0.000421	AGPRS	0.000153	MANUF	0.022353	CMANF	0.096274
COMMU	0.002188	ELECT	-0.003846	WATER	0.136453	RETAL	0.119552
FIRE	0.493702	LODGE	-0.008447	EATING	0.176092	LWSER	1.172802
HGSER	0.260616	TRUTL	0.000833	WHOLE	-0.001963	ELE2	-0.033071
UNIJC	0.305678	DK	0.030580	DN	0.028975	HS1	0.096899
HS2	0.152157	HS3	0.035728	HS4	0.121685		
						Total	**6.101275**

APPENDIX C

SELECTED RESULTS

Original Mix
5% Increased Materials Use

Category	Change
Total Households (#)	52.472963
Non-Working Households (#)	-24.988546
Working Households (#)	77.461509
Wage Group 1 (%)	0.003026
Wage Group 2 (%)	0.000543
Wage Group 3 (%)	-0.000016
Labor (#)	161.980973
Capital ($ Million)	8.528105

Household Group	Change in Household Income ($ Million)
HH1	0.107781
HH2	0.437372
HH3	0.820472
HH4	0.170256
HH5	0.680621
HH6	1.241966
TOTAL	**3.458467**

Tax Type	Change in Taxes Collected ($ Million)
CNPRP	-0.056758
CYNVT	-0.000178
CYSTX	0.105098
CYUSE	0.033257
CYORV	0.054018
TOTAL	**0.135437**

Change in Domestic Supply ($ Million)							
Sector	Change ($ Million)	Sector	Change ($ Million)	Sector	Change ($ Million)	Sector	Change ($ Million)
AGPRO	0.276640	AGSER	0.000617	CONST	6.564486	MINNG	0.225038
LF	-0.083413	AGPRS	-0.040886	MANUF	-9.428949	CMANF	-0.192197
COMMU	-0.005534	ELECT	-0.170918	WATER	0.287785	RETAL	0.172302
FIRE	0.926059	LODGE	-0.033314	EATING	0.708028	LWSER	2.643534
HGSER	0.866851	TRUTL	0.246680	WHOLE	-0.102204	ELE2	-0.162096
UNIJC	0.547591	DK	9.817161	DN	8.125580	HS1	0.169631
HS2	0.241150	HS3	0.055258	HS4	0.256339		
						TOTAL	**21.911219**

APPENDIX C

SELECTED RESULTS

Original Mix
10% Increased Materials Use

Category	Change
Total Households (#)	65.024551
Non-Working Households (#)	-30.284438
Working Households (#)	95.308989
Wage Group 1 (%)	0.003775
Wage Group 2 (%)	0.000827
Wage Group 3 (%)	0.000123
Labor (#)	202.648149
Capital ($ Million)	18.234436

Household Group	Change in Household Income ($ Million)
HH1	0.139843
HH2	0.554280
HH3	1.141652
HH4	0.257345
HH5	1.002640
HH6	1.940562
TOTAL	**5.036322**

Tax Type	Change in Taxes Collected ($ Million)
CNPRP	0.007157
CYNVT	-0.000046
CYSTX	0.145374
CYUSE	0.072141
CYORV	0.091963
TOTAL	**0.316589**

Change in Domestic Supply ($ Million)							
Sector	Change ($ Million)	Sector	Change ($ Million)	Sector	Change ($ Million)	Sector	Change ($ Million)
AGPRO	0.268324	AGSER	-0.003939	CONST	8.100536	MINNG	0.330977
LF	-0.075295	AGPRS	-0.064771	MANUF	-8.961427	CMANF	-0.305393
COMMU	-0.018980	ELECT	-0.142235	WATER	0.288032	RETAL	0.161905
FIRE	0.853238	LODGE	-0.049960	EATING	1.004728	LWSER	2.893198
HGSER	1.108287	TRUTL	0.301109	WHOLE	-0.133359	ELE2	-0.232180
UNIJC	0.493429	DK	14.875557	DN	12.313048	HS1	0.226393
HS2	0.331004	HS3	0.077082	HS4	0.326649		
						TOTAL	**33.965957**

APPENDIX C

SELECTED RESULTS

Original Mix
20% Increased Materials Use

Category	Change
Total Households (#)	93.467788
Non-Working Households (#)	-42.305679
Working Households (#)	135.773467
Wage Group 1 (%)	0.005429
Wage Group 2 (%)	0.001458
Wage Group 3 (%)	0.000446
Labor (#)	294.373359
Capital ($ Million)	41.696226

Household Group	Change in Household Income ($ Million)
HH1	0.211117
HH2	0.814831
HH3	1.845408
HH4	0.444321
HH5	1.694918
HH6	3.454051
TOTAL	**8.464645**

Tax Type	Change in Taxes Collected ($ Million)
CNPRP	0.152041
CYNVT	0.000269
CYSTX	0.233372
CYUSE	0.163623
CYORV	0.179025
TOTAL	**0.728330**

Change in Domestic Supply ($ Million)							
Sector	Change ($ Million)	Sector	Change ($ Million)	Sector	Change ($ Million)	Sector	Change ($ Million)
AGPRO	0.249776	AGSER	-0.014305	CONST	11.720592	MINNG	0.610097
LF	-0.055921	AGPRS	-0.120263	MANUF	-7.749174	CMANF	-0.542356
COMMU	-0.048865	ELECT	-0.067399	WATER	0.287935	RETAL	0.139452
FIRE	0.689442	LODGE	-0.086015	EATING	1.628435	LWSER	3.415730
HGSER	1.605186	TRUTL	0.434778	WHOLE	-0.198579	ELE2	-0.389129
UNIJC	0.370920	DK	24.997313	DN	20.689094	HS1	0.349598
HS2	0.525711	HS3	0.124470	HS4	0.482850		
						TOTAL	**59.049373**

APPENDIX C

SELECTED RESULTS

Original Mix
5% Increased Materials Supply

Category	Change
Total Households (#)	97.376661
Non-Working Households (#)	-50.191915
Working Households (#)	147.568576
Wage Group 1 (%)	0.003992
Wage Group 2 (%)	0.001608
Wage Group 3 (%)	0.001362
Labor (#)	315.408085
Capital ($ Million)	1.981836

Household Group	Change in Household Income ($ Million)
HH1	0.099651
HH2	0.113489
HH3	0.562331
HH4	-0.067014
HH5	0.063240
HH6	-0.206110
TOTAL	**0.565587**

Tax Type	Change in Taxes Collected ($ Million)
CNPRP	0.244110
CYNVT	0.000054
CYSTX	0.010014
CYUSE	0.008280
CYORV	0.013235
TOTAL	**0.275693**

Change in Domestic Supply ($ Million)							
Sector	Change ($ Million)	Sector	Change ($ Million)	Sector	Change ($ Million)	Sector	Change ($ Million)
AGPRO	-0.034206	AGSER	-0.028939	CONST	0.586777	MINNG	-0.234888
LF	-0.971132	AGPRS	1.977706	MANUF	0.800937	CMANF	-1.453328
COMMU	-0.066095	ELECT	-0.072680	WATER	-0.012450	RETAL	-0.369450
FIRE	-0.531812	LODGE	-0.059816	EATING	-0.170052	LWSER	1.798364
HGSER	0.676884	TRUTL	-0.090627	WHOLE	-0.460468	ELE2	-0.430033
UNIJC	-0.825992	DK	-0.103593	DN	-0.099456	HS1	0.033939
HS2	-0.007956	HS3	-0.007792	HS4	0.156496		
						TOTAL	**0.000338**

APPENDIX C

SELECTED RESULTS

Original Mix
10% Increased Materials Supply

Category	Change
Total Households (#)	106.865135
Non-Working Households (#)	-54.977945
Working Households (#)	161.843080
Wage Group 1 (%)	0.004369
Wage Group 2 (%)	0.001764
Wage Group 3 (%)	0.001489
Labor (#)	345.707730
Capital ($ Million)	2.088101

Household Group	Change in Household Income ($ Million)
HH1	0.109392
HH2	0.123050
HH3	0.611995
HH4	-0.076065
HH5	0.061195
HH6	-0.246447
TOTAL	**0.583121**

Tax Type	Change in Taxes Collected ($ Million)
CNPRP	0.263155
CYNVT	0.000056
CYSTX	0.010517
CYUSE	0.008442
CYORV	0.014346
TOTAL	**0.296516**

Change in Domestic Supply ($ Million)

Sector	Change ($ Million)	Sector	Change ($ Million)	Sector	Change ($ Million)	Sector	Change ($ Million)
AGPRO	-0.035764	AGSER	-0.031529	CONST	0.673251	MINNG	-0.257074
LF	-1.042039	AGPRS	2.102009	MANUF	0.792163	CMANF	-1.596196
COMMU	-0.072708	ELECT	-0.079632	WATER	-0.011524	RETAL	-0.405462
FIRE	-0.574376	LODGE	-0.065509	EATING	-0.185086	LWSER	1.922724
HGSER	0.770880	TRUTL	-0.100752	WHOLE	-0.506436	ELE2	-0.471194
UNIJC	-0.902832	DK	-0.055373	DN	-0.053756	HS1	0.035906
HS2	-0.011539	HS3	-0.009267	HS4	0.171151		
						TOTAL	**0.000036**

APPENDIX C

SELECTED RESULTS

Original Mix
20% Increased Materials Supply

Category	Change
Total Households (#)	125.373685
Non-Working Households (#)	-64.241553
Working Households (#)	189.615238
Wage Group 1 (%)	0.005095
Wage Group 2 (%)	0.002065
Wage Group 3 (%)	0.001737
Labor (#)	404.499320
Capital ($ Million)	2.318610

Household Group	Change in Household Income ($ Million)
HH1	0.128571
HH2	0.142217
HH3	0.710509
HH4	-0.093029
HH5	0.058643
HH6	-0.320225
TOTAL	**0.626685**

Tax Type	Change in Taxes Collected ($ Million)
CNPRP	0.300672
CYNVT	0.000060
CYSTX	0.011714
CYUSE	0.008991
CYORV	0.016629
TOTAL	**0.338066**

Change in Domestic Supply ($ Million)							
Sector	Change ($ Million)	Sector	Change ($ Million)	Sector	Change ($ Million)	Sector	Change ($ Million)
AGPRO	-0.039528	AGSER	-0.036498	CONST	0.854722	MINNG	-0.299628
LF	-1.182694	AGPRS	2.351573	MANUF	0.785036	CMANF	-1.871030
COMMU	-0.085388	ELECT	-0.092995	WATER	-0.010429	RETAL	-0.474347
FIRE	-0.657607	LODGE	-0.076177	EATING	-0.213221	LWSER	2.161887
HGSER	0.960627	TRUTL	-0.119707	WHOLE	-0.593963	ELE2	-0.550171
UNIJC	-1.051512	DK	0.016193	DN	0.014126	HS1	0.040164
HS2	-0.017768	HS3	-0.011938	HS4	0.200227		
						TOTAL	**-0.000046**