DISSERTATION

THREE APPLICATIONS OF REGIONAL CGE MODELS

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ABSTRACT

THREE APPLICATIONS OF REGIONAL CGE MODELS

This dissertation focuses on the development of the basic Colorado (CO) CGE model, a generalized multi-sector, multi-household dynamic, myopic, single region CGE model created for the State of Colorado in GAMS MPSGE. Three model variants are constructed and described, built in order to analyze specific policies in areas of the model for the same region with maximum detail while maintaining general model tractability. The first model variant, the Colorado Real Estate (CO-RE) model, adds significant detail to capital and property markets including one critical feature of such markets not generally found in CGE models – sluggish price and quantity adjustment. The second model variant, the Colorado Energy (CO-E) model adds significant detail to production and consumption of electricity. The third model variant, the Colorado Demography (CO-D) model, adds significant detail to the process of long-run, endogenous demographic change and the production of higher education. The three model variants are used to analyze the impacts on the Colorado economy of, respectively, a transition to alternative workplace strategies, Colorado energy and climate polices and the potential defunding of higher education in the state. This dissertation is an embodiment of and evidence for the greatest strength of the CGE modeling technique – such models are flexible and broadly applicable to nearly any economic issue or phenomenon.

Simulation results from the CO-RE model suggest that the economic impacts of a transition to alternative workplace strategies would be modest in terms of macroeconomic aggregates, but positive. The transition results in a fall in investment as shrinking office capital

stock outweighs increased investment into other property types. However, the productivity enhancement leads to increases in incomes, consumption and employment that offset the drop in investment. Increases in consumption and employment are small. Within the office property market, effects of such a transition would be dramatic with vacancy rates rising to 40% in and rents falling as much as 80%. A transition to AWS is expected to lead to falling property tax revenues for local governments as the size of the commercial property tax base shrinks.

As specified in the CO-E model, given a set of plausible assumptions regarding levelized costs of generation over the lifetime of a project, costs associated with intermittency and future federal subsidies the Colorado renewable portfolio standard has a positive impact on economic aggregates in the state relative to a baseline scenario. The impact of the Clean Air – Clean Jobs Act which accelerates a transition towards natural gas is negative on macroeconomic aggregates. The economy of the State of Colorado is found to be substantially exposed to rising natural gas prices due to decreasing natural gas sector productivity. The RPS is not a job creator, but the RPS adds to consumption and incomes in all scenarios but that with extremely low natural gas prices. The RPS is found to serve as a hedge for the state against rising natural gas prices, and a hedge with positive net benefit in many scenarios.

Defunding higher education reallocates money from higher education subsidies to production of government services. The defunding of higher education, by reducing production and consumption of higher education in the state, is found to reduce economic output and total real per capita consumption in the state though it does not always reduce employment in spite of the fact that the baseline scenario includes “excessive” production of higher education that causes the wage premium for college educated workers to fall. When total factor productivity is assumed to rise, the negative impact of defunding increases. Estimates for the real net per capita

consumption impact of defunding are found to be sensitive to a variety of plausible parameter estimates for the responsiveness of higher education demand to tuition and the wage premium, though impacts of defunding remain negative.

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Chapter 1

Introduction

1.1 Background

Regional computable general equilibrium (CGE) models are whole economy simulation models designed to fit specific subnational regions. In practice these regions boundaries tend to correspond to the borders of subnational government jurisdictions (Giesecke & Madden, 2013) such as cities or US states. The technique of computable general equilibrium modeling has achieved broad acceptance and is frequently used for analysis of regional, national and global policy shocks in peer-reviewed as well as gray literature (Partridge and Rickman 1998). The fundamental appeal is that the CGE technique allows a researcher to estimate impacts in hypothetical scenarios where empirical estimation techniques are not possible and to derive numerical results for complex scenarios in which pure analytical approaches will not be viable (Bohringer, Rutherford, & Wiegard, 2004).

This dissertation will focus on the development of the basic Colorado (CO) CGE model, a generalized multi-sector, multi-household dynamic, myopic, single region CGE model created for the State of Colorado in GAMS MPSGE. Three model variants are constructed and described, built in order to analyze specific policies in areas of the model for the same region with maximum detail while maintaining general model tractability. The first model variant, the Colorado Real Estate model, adds significant detail to capital and property markets including one critical feature of such markets not generally found in CGE models – sluggish price and quantity adjustment. The second model variant, the Colorado Energy model adds significant detail to production and consumption of electricity. The third model variant, the Colorado Demography model, adds significant detail to the process of long-run, endogenous demographic change and the production of higher education.

In general the specific formulation of a given regional CGE model is arrived upon as part of a tradeoff between realism and simplicity, in other words the complexity and tractability of a model and the need for accurate representation of behavior in key sectors of the economy for answering questions regarding specific shocks and policies. Desire for increased detail in one area may necessitate reduced detail and more simplifying assumptions in other areas in order to keep a given model analytically and computationally tractable (Arrow 2005, Pereira and Shoven 1988). No one Colorado model would be capable of incorporating the detail added in each of the three areas due to extreme nonlinearity and computational demand, however variants of any basic model can be constructed to do the same. This dissertation is an embodiment of and evidence for the greatest strength of the CGE modeling technique – such models are flexible and broadly applicable to nearly any economic issue or phenomenon.

Within a CGE model, representative domestic households are given endowments of factors of production and are assumed to demand a bundle of goods and services with a given specification and parameterization in order to maximize household welfare or utility. Representative domestic firms produce this bundle of goods and services using these factors of production with a given specification and parameterization of production functions in order to maximize profits or minimize costs. Representative government entities levy taxes on inputs or outputs and use the revenues for income transfers or in order to produce government services. Markets are assumed to clear, prices and quantities assumed to adjust in order to keep the regional economy in equilibrium in all goods markets and all factor markets at all times (Shoven 1992).

Within this broad and general framework, there is significant diversity within regional CGE models due to the inherent flexibility of the technique (in certain respects), constraints imposed by computing power and the demand of a given scenario (Partridge and Rickman 1998). Any number of functional forms with any number of parameters may be used for production and utility. Representative agents may be subdivided in a variety of ways, with more or less detail in one area of the economy or in another. Models may be dynamic or comparative static or dynamic, if dynamic they may be myopic or forward-looking. They may focus on a single region or only many linked regions. Migration or commuting may be modeled or ignored as can the spatial dimension (Partridge and Rickman 2010).

However, the CGE modeling approach – be it at a national or regional level – is not without its detractors. One group of such detractors calls into question the validity of the representative agent approach that underlies all CGE modeling (Kirman 1992), preferring agent-based modeling approaches with stronger micro foundations and the possibility for grounding in cutting edge behavioral theories (Axtell 2000, Bonabeau 2002) (Tesfatsion 2006) (Tesfatsion 2002). However, the current state of technology does not allow the creation of such bottom-up models for whole economies with the degree of detail desired for models used in top-down policy simulation despite having a variety of other intriguing and desirable features (De Grauwe 2010). The second group of detractors focuses on specific difficulties in proper construction of regional CGE models. Any and all results from simulations using a regional CGE model will be sensitive to certain parameters included in utility functions, production functions or side equations (McKitrick 1998). Though these parameters are often borrowed from the literature

(Partridge and Rickman 1998), they may also be estimated econometrically for the region in question. However, in both cases there will be uncertainty involved in parameter estimates leading to uncertainty regarding key results. The appropriate response to such a critique would appear to be a simple one: assumptions made in specifying and parameterizing in the model must be clear rather than opaque (Bohringer, Rutherford and Wiegard 2004) and while a best attempt should be made for perfect parameterization of key equations any study should take these parameter estimates with a grain of salt and provide for sensitivity analysis of results with respect to key parameters within a defined confidence interval or range (Hertel, et al. 2007).

1.2 Organization of the Study

This dissertation consists of six chapters. Chapter one introduces the framework, history and range of applications of regional computable general equilibrium models. General equilibrium models make heroic assumptions regarding specification and parameterization of behavioral relationships, but are capable of providing meaningful results when analyzing a variety of hypothetical scenarios that neither pure analytical or empirical econometric approaches are useful for. Chapter one concludes with a description of the organization of the dissertation.

Chapter two provides a detailed description of the basic Colorado (CO) computable general equilibrium model upon which the CO-RE, CO-E and CO-D model variants are based. The code and syntax for the basic CO model are provided in Appendix A.

Chapter three introduces the Colorado Real Estate (CO-RE) CGE model variant and its application to estimation of the economic impacts of a predicted exogenous transition towards alternative workplace strategies (AWS) over 15 years. Part one of chapter three begins with a discussion of research into alternative workplace strategies and the related, though separate, phenomenon of telecommuting as well as the motivation for the study and the approach taken in simulating AWS. The term "alternative workplace strategies", broadly speaking, refers to the use of open floor plan offices in which office workers have no assigned space. Though a variety of costs and benefits to workers, firms and cities from AWS have been hypothesized none are certain aside from the ability to cut firm costs by reducing office space usage when many workers are already frequently out of the office. This study simulates the transition to AWS as a technological innovation in the production functions of office-using sectors, allowing them to produce an equivalent amount of output with 50% less office space than before. Part two of chapter three introduces the CO-RE model and describes the integration of a Torto-Wheaton stock adjustment framework for commercial property markets into a CGE model for the State of Colorado. Parameters are estimated for the relationships between office space absorption, construction and rents (with changes in vacancies determined by absorption and construction) using three-stage least squares. Office rents as well as quantities demanded and supplied adjust only sluggishly to shocks, resulting in persistent disequilibrium in commercial property markets.

Part three of chapter three describes the results of a series of simulations of the effects of a forecast transition to AWS on the Colorado economy using four different scenarios: one in which target office space usage changes immediately and all sectors are affected, a second in which target office space usage changes immediately but only core office-using sectors are affected, a third in which target office space usage changes gradually over a period of 7 years and all sectors are affected and a fourth in which target office space usage changes gradually and only core-office using sectors are affected. Part four of chapter three presents recent data from the Denver metropolitan office property market to compare recent observations to predicted results of the transition to AWS from the CO-RE model. AWS is found to lead to small but tangible economic benefits, creating jobs through improving the competitiveness of local firms. The impact on local tax revenues, however, is negative due to falling property tax receipts.

Chapter four introduced the Colorado Energy (CO-E) CGE model variant of the CO model, with an application to analysis of the State of Colorado's Renewable Portfolio Standard (RPS) and Clean Air – Clean Jobs Act (HB-1365) under different scenarios regarding future natural gas prices. Part one provides an overview of state level climate and clean energy policy initiatives as well as cost-benefit analysis approaches used. HB-1365, as part of a drive to comply with EPA mandates for non-carbon emissions in the Denver air shed, accelerates a transition towards natural gas electricity generation and away from coal-fired electricity generation by retiring some coal-fired plants, fuel-switching others to run on natural gas and installing advanced emissions controlling technologies at other coal-fired plants. Colorado's RPS requires utilities to generate or purchase a certain, steadily increasing, percentage of the electricity sold on their grid from renewable sources. Although many generation types are allowed, in practice this has meant and will likely continue to mean a transition away from fossil fuel generation and toward wind power though the "solar carve-out" also mandates that a specified small percentage of electricity come from distributed generation in the form of rooftop solar arrays using net metering.

Part two gives information regarding recent trends and future uncertainty for natural gas output and prices in the United States and around the world. The effect of the fracking boom on domestic natural gas prices was not foreseen, current prices have been well below what has been estimated to be average cost of production and environmental impacts and therefore the future regulatory framework for hydraulic fracturing of shale gas deposits are uncertain. For these reasons the future price of natural gas and future productivity of the natural gas industry in the

United States remain highly uncertain. Part three of chapter four describes the CO-E model, with particular attention given to specification of production in electricity sectors, energy data sources, and the formulation used for simulating the RPS as well as HB-1365. The RPS is simulated as an exogenous, policy determined, change in input share parameters of different electricity types for the grid transmission sectors. HB-1365 is modeled as embodying three simultaneous but independent shocks: the creation of a “fuel-switching” sector which uses fuel inputs of the natural gas generation sector but all other input proportions, including capital types, of coal generation, the elimination of a certain stock of coal generation capital and an increase in the amount of generic capital required to produce one unit of coal generation sector output due to mandates for advanced emissions controls. Part four of chapter four presents simulation results detailing the impacts on the Colorado economy of shocks to natural gas productivity with HB-1365, with the RPS and in the absence of both. Part five of chapter four gives conclusions and policy analysis for the two policies given uncertainty for the State of Colorado regarding future natural gas prices and the existing exposure of the state economy to gas price fluctuations. The Clean Air – Clean Jobs Act is found to impose economic costs on the State of Colorado while increasing susceptibility to the effects of a natural gas productivity shock. The Renewable Portfolio Standard is found to provide economic benefits to the State of Colorado while decreasing susceptibility to the effects of a natural gas productivity shock.

Chapter five introduces the Colorado Demography (CO-D) CGE model variant with an application to analysis of the long-run economic impacts of “defunding” higher education by the State of Colorado. Part one of chapter five describes the policy framework and gives a review of the literature regarding human capital accumulation, higher education and CGE-based analysis of the two. Higher education is generally viewed as a channel for investment in human capital, increasing the productive capability of workers. In the present scenario of decreasing labor force growth across the developed world or a shrinking labor force, increased investment in human capital is viewed as a way to offset the negative economic effects of population aging. Part two of chapter five introduces the CO-D model and details the process of demographic transition within the model as well as describing how higher education demand and output are modeled. With household groups defined by the age of household head and labor groups defined by educational attainment as well as age, households and workers progress from one group to the next between five-year periods in the CO-D model with additions to the youngest age groups determined by fertility and subtractions at all age groups due to mortality. The role of the higher education sectors is considered to be the transformation of L1 workers (those without college degrees) into L2 workers (those with bachelor degrees) or the transformation of L2 workers into L3 workers (those with advanced degrees). Current State of Colorado policy regarding higher education is modeled as a subsidy on consumption of domestic public undergraduate and graduate higher education output by domestic households.

Part three provides results of baseline simulations using the CO-D model to forecast changes in demography and economic variables such as employment and per capita real consumption over the next 50 years, with special attention given to the role played in the CO-D model by positive net in-migration, which tends to be skewed towards younger working-age individuals. Part four gives results for simulations involving the defunding of higher education by the State of Colorado over the next 50 years, assuming either zero growth in total factor productivity or 1% annual growth in total factor productivity. Part five of chapter five displays results from a sensitivity analysis of simulations on the economic impact of defunding higher education when key parameters of the higher education demand functions are varied within a range of possible values taken from the literature. Parameters investigated include the responsiveness of higher education demand to changes in tuition or fees and to changes in the wage premium that is assumed to accompany a degree and provide return on investment. Elimination of higher education subsidies by the State of Colorado is found to reduce real total per capita consumption by 2060. This result is not sensitive to parameterization of the higher education demand functions, within a range of plausible values.

Chapter six gives concluding remarks, beginning with a general summary of results and findings from the CO-RE, CO-E and CO-D models in chapters 3, 4 and 5. Part two of chapter 6 suggests policy recommendations or appropriate policy responses in the areas of office property markets, energy policy and higher education funding based upon results from simulations in chapters 3, 4 and 5. Part three of chapter six describes future avenues for research suggested by the findings and further applications for or potential improvements in the CO-RE, CO-E and CO-D models, which concludes the dissertation. Appendices A, B, C and D contain the full GAMS MPSGE code for the CO model, CO-RE model, CO-E model and CO-D model respectively.

Chapter 2

The Colorado (CO) Model Description

A Computable General Equilibrium (CGE) model is a whole-economy simulation incorporating profit-maximizing firms, utility-maximizing firms, government entities, interregional migration and trade and endogenous supply of factors of production. As illustrated in figure 1.1, the structure of the economy follows a circular flow: households are endowed with factors of production (labor, land, and capital) as well as streams of income from outside the region (such as social security income) and demand goods and services and housing. Firms rent factors of production from households and demand intermediate goods from other firms, using these to produce an output that can be sold to local households, local government entities and exported outside the region. Local governments levy taxes, revenues from which are spent on goods and services as well as factors of production. Production and consumption decisions depend upon relative prices; endogenous supply of factors of production depends upon returns.

The CO model incorporates seven representative local household groups defined by income level ranging from HH1 with incomes under $10,000 to HH7 with household incomes greater than $100,000 as well as a non-local household group representing owners of Colorado capital and land outside the region. Each representative household is endowed with a certain initial allocation of land, each of five types of labor and each of twenty types of capital. In addition local household groups receive exogenously determined streams of non-Colorado sourced income such as pensions, social security payments and returns to prior investments.

The representative non-local household group (RAF) is endowed with land and each type of capital, but not with labor.

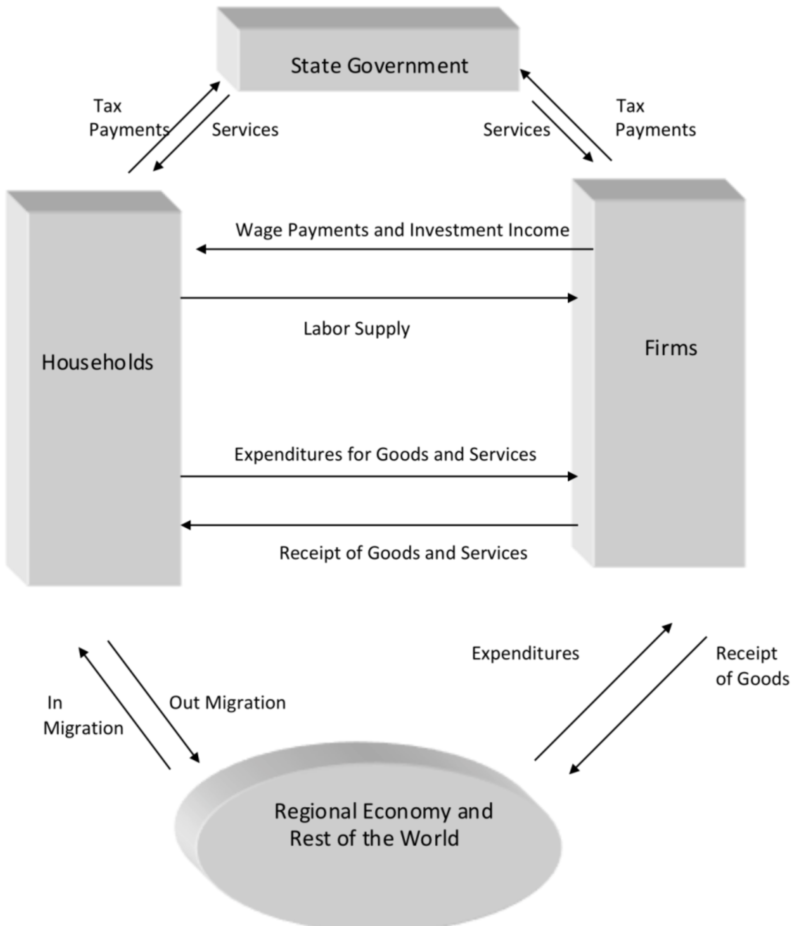


Figure 1.1

The majority of local household capital endowments are composed of single family residential capital with proportions derived from 5-year American Community Survey (ACS) public use microdata (PUMS). Average income levels for each Colorado household group are shown in table 2.1 below, note that incomes include implicit rents for owner-occupied housing

Table 2.1 – Household Groups

Household Group	Average Income
HH1	$21,898
HH2	$26,019
HH3	$44,172
HH4	$58,329
HH5	$73,156
HH6	$118,757
HH7	$185,384

The majority of the non-local household endowment is composed of multi-family and non-residential capital. Local households demand only welfare produced using a consumption bundle of Demand for Colorado exports is represented by a separate household group endowed with a steam of "foreign exchange", non-Colorado sourced and monetary income.

The CO model includes, in addition to a single homogeneous land type, five labor groups defined by relative wage level as a proxy for skill level, and a single capital type. Average annual wages for each labor/leisure group are given in table 2.2 below, note that no distinction is made between full-time and part-time work. Wage and employment data is derived from the Quarterly Census of Employment and Wages for the state of Colorado.

The Federal government collects income tax and payroll tax revenues, which flow out of the region. State and local governments are funded by retail sales taxes, levied on sales of goods and services in proportions derived from Colorado Department of Revenue data, personal income taxes, business income taxes, property taxes and fees for permits or services. State and local tax revenues are used to fund five government service sectors: education, administration, justice/law enforcement, transportation and health.

Table 2.2 – Labor Groups

Labor Group	Average Wage
L1	$7,870
L2	$41,789
L3	$68,699
L4	$95,317
L5	$197,176

Production sectors are largely organized along the lines of 2-digit National Industry Classification System (NAICS) definition with the Mining and Utilities sectors split into subsectors. In addition, production of housing services is organized into six sectors for multifamily housing, attached housing and four detached single family housing sectors grouped by price range. Government services are organized into production sectors as mentioned above, but are demanded solely by state and local governments and funded solely by tax revenues. Table 2.3 gives a complete list of production sectors.

Goods and services consumed as intermediate inputs or in the generation of welfare/utility for household consumption are first aggregated with their non-local equivalents following an Armington (1969) formulation. Domestic households consume only welfare/utility, produced using goods and services and housing with a CES specification much like that for goods and services.

Table 2.3 – Industry Sectors

Model Identifier	2-digit NAICS Code(s)	NAICS Industry Tigle
Agric	11	Agriculture, Forestry, Fishing & Hunting
Mining	21	Mining
Coal	21	Mining
NaturalGas	21	Mining
Electricity	22	Utilities
Util	22	Utilities
Const	23	Construction
Manuf	31, 32, 33	Manufacturing
Whole	42	Wholesale Trade
Retail	44, 45	Retail Trade
Trans	48, 49	Transportation and Warehousing
Info	51	Information
Fin	52	Finance and Insurance
Real	53	Real Estate Rental and Leasing
Serv	54	Professional, Scientific and Technical Services
Manage	55	Management of Companies and Enterprises
Admin	56	Administrative and Support and Waste Management and Remediation Services
Educ	61	Education
University	61	Education
Health	62	Health Care and Social Assistance
Arts	71	Arts, Entertainment and Recreation
LodgeRest	72	Accommodation and Food Services
Other	81	Other Services (except Public Administration)
PubAdm	92	Public Administration

Source: 2012 NAICS Structure, www.naics.com/naicsfiles/2012_NAICS_Changes.pdf (accessed March 26, 2013)

Elasticities of substitution (σ_H) in production of utility/welfare are set to 1, a Cobb-Douglas functional form. Each representative household's consumption bundle "d" includes 24 goods or services and 6 housing categories. Though the elasticity of substitution for all households and all pairs of goods is set to unity, leading to a simple Cobb-Douglas specification, household utility in GAMS MPSGE takes the basic CES form and elasticities of substitution may be varied in model variants or in individual simulations. The basic formulation, as in Rutherford (2009) is shown below in equation 1.1, the set I includes all industry outputs as well as housing services but not government services which are not assumed to generate utility.

Equation 2.1) $U_{H,t} = F\left(\sum \alpha_I Q_{H,I,t}^{\rho_H}\right)^{1/\rho_H}$

The parameter F is a calibrated "productivity" parameter in household utility, α_i parameters represent consumption shares, ρ_H equals $(\sigma_H\text{-}1)/\sigma_H$ where σ_H is the exogenously determined elasticity of substitution. Given such a formulation, the demand for any good or service by any household can be expressed as:

Equation 2.2) $$Q_{i,h,t} = \frac{\left({(P_{i \in I,t} + TX_{i \in I,H,t})}/{\alpha_{i \in I,H}} \right)^{-\sigma_H}}{\alpha_{i \in I,H}^{\sigma}(P_{i \in I,t} + TX_{i \in I,t})^{1-\sigma_H} + \sum_I (\alpha_{I,H})^{\sigma_H} (P_{I,t} + TX_{I,H,t})^{1-\sigma_H}}$$

Where $P_{I,t}$ is the pre-tax price of good I in period t, $TX_{I,H,t}$ is the effective tax rate on good i for household H at time t and set J refers to all members of set I but the individual member in question. In GAMS MPSGE a CES utility function is calibrated, by determining values for F and for $\alpha_{I,H}$, based on an assumed elasticity of substitution σH and benchmark prices $P0_I$, benchmark tax rates $TCOPIT1_H$, $TUSPIT1_H$, $TCFEE_H$ – which are all represented as consumption taxes on industry sector output - and $TKH0_H$ a property tax rate on housing as well as benchmark demand quantities $QKDH0_{HD,H}$ and $QYDH0_{IP,H}$ where sets HD and IP are both subsets of set I and benchmark utility $QW1_H$. $T1_H$ is equal to the sum of $TCOPIT1_H$, $TUSPIT1_H$ and $TCFEE_H$. As demonstrated in (Rutherford 1998), when CES utility is calibrated from benchmark prices and quantities in such a matter values for $\alpha_{I,H}$ are derived as follows:

Equation 2.3) $$\alpha_{IP,H} = \frac{(P0_{ip \in IP} + T1_H)(QYDH0_{ip \in IP,H})^{1/\sigma}}{(P0_{ip \in IP} + T1_H)(QYDH0_{ip \in IP,H})^{1/\sigma} + \sum_{IP}(P0_{IP} + T1_H)(QYDH0_{IP,H})^{1/\sigma} + \sum_{HD}(P0_{HD} + TKH0_H)(QKDH0_{HD,H})^{1/\sigma}}$$

Equation 2.4) $$\alpha_{HD,H} = \frac{(P0_{hd \in HD} + T1_H)(QYDH0_{hd \in HD,H})^{1/\sigma}}{(P0_{hd \in HD} + T1_H)(QYDH0_{hd \in HD,H})^{1/\sigma} + \sum_{IP}(P0_{IP} + T1_H)(QYDH0_{IP,H})^{1/\sigma} + \sum_{HD}(P0_{HD} + TKH0_H)(QKDH0_{HD,H})^{1/\sigma}}$$

Where set HSD, like set J, includes all elements in HD other than the element of HD in question.

Mathematically, production of goods and services is assumed to take place using a nested constant elasticity of substitution (CES) functional form (Rutherford 1998). Reference input and output quantities for production functions are obtained by scaling IMPLAN input-output proportions to fit BEA regional output quantities for the reference year of 2009. To reflect complementarity between labor and capital (and between different capital types) an elasticity of substitution between labor and different capital types (and therefore for substitution between capital types as well) is set at 0.4 for all production functions following Kemfort (1998), Raval (2011) and Young (2012). Intermediate goods used in production are included in a Leontief nest with elasticity of substitution of zero. Substitution elasticities between these two nests and land are set to one as has been empirically estimated (Thorsnes 1997) and (Clapp 1979). The resulting two-level nested CES production function, as illustrated in Sato (1967), has the basic CES form but will lack the constant elasticity of substitution property (Uzawa 1962). For each industry "I", within the capital/labor (kl) nest and within the intermediate (j) nest substitution elastiticities in producing the input aggregates $Z1_{i,t}$ and $Z2_{i,t}$ (σ_{KL} and σ_J respectively) are set to 0.4, and 0. The land factor input is part of neither the KL nest nor the J nest but will nonetheless contribute to the top-level nest of the production function for $Y_{I,t}$ as "land nest" $Z3_{I,t}$. The production function for the KL aggregate $Z2_{I,t}$, in the lower-level nest is shown in equation 1.2 below, the set subscript KL refers to the subset of F, "factors of production", which contains all capital types and labor groups but not land while $kl \epsilon KL$ refers to an element within the set KL. The parameter $\rho_{KL} = (\sigma_{KL}-1)/\sigma_{KL}$ where σ_{KL} is the elasticity of substitution between capital and labor, set to 0.4. The top-level production function, by which input nests $Z1_{I,t}$, $Z2_{I,t}$ and $Z3_{I,t}$ are converted into output $Y_{I,t}$ is given below in equation 1.5 where $\rho_Y = (\sigma_Y-1)/\sigma_Y$ and σ_Y is the top-level elasticity of substitution (set at unity).

Equation 2.5) $Y_{I,t} = PROD\left(\beta_{1,I}Z1_{I,t}^{\rho_Y} + \beta_{2,I}Z2_{I,t}^{\rho_Y} + \beta_{3,I}Z3_{I,t}^{\rho_Y}\right)^{1/\rho_Y}$

The production function for the J set (intermediate goods) aggregate $Z2_{I,t}$, in the lower-level nest is shown in equation 1.6 below, J is an alias for set I, jϵJ refers to an element within the set J. The parameter $\rho_J = (\sigma_J\text{-}1)/\sigma_J$ where σ_J is the elasticity of substitution between capital and labor, set initially to 0 for Leontief production technology in the intermediate nest. $Z1_{I,t}$ is produced from Armington composite goods from the set of industries/commodities J.

Equation 2.6) $Z1_{I,t} = \left(\sum_J \beta_{I,J} Q_{I,J,t}^{\rho_J}\right)^{1/\rho_J}$

The production function for the KL aggregate $Z2_{I,t}$, in the lower-level nest is shown in equation 1.7 below, the set subscript KL refers to the subset of F, “factors of production”, which contains all capital types and labor groups but not land while klϵKL refers to an element within the set KL. The parameter $\rho_{KL} = (\sigma_{KL}\text{-}1)/\sigma_{KL}$ where σ_{KL} is the elasticity of substitution between capital and labor, set to 0.4.

Equation 2.7) $Z2_{I,t} = F\left(\sum_{KL} \beta_{I,KL} Q_{I,KL,t}^{\rho_{KL}}\right)^{1/\rho_{KL}}$

As the basic CO model contains only one land type, the land set contains only one member: LAND. The input aggregate Z3I,t is therefore equal to the quantity of the land input used as shown in equation 1.8 below.

Equation 2.8) $Z3_{I,t} = Q_{I,LAND,t}$

As in equations 1.3 and 1.4 pertaining to parameterization of CES utility functions in the CO model in GAMS MPSGE from initial values, values for the $\beta_{I,J}$, $\beta_{I,KL}$, $\beta_{I,1}$, $\beta_{I,2}$ and $\beta_{I,3}$ parameters are calibrated based on initial prices and initial quantities for the KL and LAND factors and for intermediate inputs J. Equations 1.9 – 1.13 below illustrate the derivation of calibrated parameters from base data.

Equation 2.9) $\beta_{I,J} = \frac{(PA0_{j\epsilon J})(QADY0_{j\epsilon J,I})^{1/\sigma_J}}{(PA0_{j\epsilon J})(QADY0_{j\epsilon J,I})^{1/\sigma_J} + \sum_J (PA0_J)(QADY0_{J,I})^{1/\sigma_J}}$

Equation 2.10) $\beta_{I,KL} = \frac{(PF0_{kl\epsilon KL} + TFI0_{kl\in KL,I})(QKLDY0_{kl\epsilon KL,I})^{1/\sigma_{KL}}}{(PF0_{kl\epsilon KL} + TFI0_{kl\in KL,I})(QKLDY0_{kl\epsilon KL,I})^{1/\sigma_{KL}} + \sum_{KL}(PF0_{KL} + TFI0_{KL,I})(QKLDY0_{KL,I})^{1/\sigma_{KL}}}$

Equation 2.11) $\beta_{I,1} = \frac{(PZ10_I)(QZ10_I)^{1/Y}}{(PZ10_I)(QZ10_I)^{1/\sigma_Y} + (PZ20_I)(QZ20_I)^{1/\sigma_Y} + (PZ30_I)(QZ30_I)^{1/Y}}$

Equation 2.12) $\beta_{I,2} = \frac{(PZ20_I)(QZ20_I)^{1/\sigma_Y}}{(PZ10_I)(QZ10_I)^{1/\sigma_Y} + (PZ20_I)(QZ20_I)^{1/\sigma_Y} + (PZ30_I)(QZ30_I)^{1/Y}}$

Equation 2.13) $\beta_{I,3} = \frac{(PZ30_I)(QZ30_I)^{1/\sigma_Y}}{(PZ10_I)(QZ10_I)^{1/\sigma_Y} + (PZ20_I)(QZ20_I)^{1/\sigma_Y} + (PZ30_I)(QZ30_I)^{1/\sigma_Y}}$

$PA0_J$ is the initial price for the Armington aggregate of good J, $PF0_{KL}$ is the initial pre-tax price of KL factors of production, $TF0_{KL,I}$ is the initial tax rate on said factors of production through commercial property taxes and payroll taxes. Values for PZI's and QZI's are derived from initial values used to calibrate the lower level nests, which then determine $\beta_{I,1}$, $\beta_{I,2}$ and $\beta_{I,3.}$

Production of government services follows an identical specification to that of industry sectors, though government sectors are assumed to face no output taxes and to use no capital. Though this is a heroic assumption, as government entities real property is not subject to property taxation estimates of the quantity and value of government owned property are scarce. The flow of residential housing services HD consumed by households is also assumed to be produced in a similar fashion to government services and industry output, though production of HD requires only land, capital and a selection of intermediate inputs such as maintenance from the construction sector.

The endogenous supply of land as existing land is zoned, platted and prepared for development is represented through a side constraint equation which sets households' endowment of land relative to the current price of land with an elasticity of 2.5. Empirical estimates for the price elasticity of the supply of developable land vary dramatically with local geography, economic conditions and policies. However, even empirical estimates of a single nationwide elasticity, which might be more broadly applicable to large regions such as US states, range from near-zero to near-infinite. Capital supply is treated as a positive endowment to local and non-local households; capital investment expenditures to build new capital or offset depreciation of existing capital are treated as negative endowments. Capital supply and capital investment expenditures for each capital type are subject to a similar constraint with a single-period elasticity of supply of unity (Goolsbee 1998). Lower estimates of the elasticity of capital supply (Zheng, Chau and Hui 2012) based on data from urban areas may not be applicable to larger aggregated regions such as US states, in which much development is suburban or exurban and less constrained by policy and land availability. In the dynamic model, capital and land supply constraints follow a "moving average" process, which will cause short-run deviations in prices to die out over time.

The representative local household's endowment of labor is also set subject to two side constraints in order to first represent migration into or out of the state (MIG(h)) and second flexible labor supply decisions by existing households (LSUP(h)) as a result of changes in wages, employment opportunities and the cost of living. As studies have shown very limited migration responses to tax and wage differentials (Day and Winer 2006), (Coomes and Hoyt 2008) and (Young and Varner 2011) the single-period elasticity of migration with respect to changes in the real wage is set to 0.1, the elasticity of labor supply by existing households with respect to changes in the real wage is set to 0.3 (Eviers, De Mooij and Van Vuuren 2008). In the dynamic model, migration responses follow a “moving average” specification, with continuing in-migration so long as the real wage remains above the baseline. Labor supply responses by existing households are one-off, so over a long time period the labor supply response by non-residents will dominate (Bartik 1993).

Chapter 3

Regional CGE for Property Market Analysis
Estimating the Regional Impacts of Alternative Workplace Strategies

3.1 Introduction

Data suggests that office square footage used per worker has declined significantly since the end of 2009 (Miller, 2012). Surveys conducted by CoreNet Global, the Building Owners and Managers Association International (BOMA) and others indicate a trend toward increased efficiency of office space usage. This trend can be attributed to a variety of changes the way businesses operate referred to as alternative workplace strategies or AWS (CoreNet), including telework, office hoteling, open floor plans and more. CoreNet forecasts a decline in actual office space usage per worker in the neighborhood of 1/3 from 2010 to 2017 and give a current "best practice" target of around ½ of the nationwide average in office space per worker as of 2010.

An accurate forecast of office demand - as well as how a long-run trend toward more efficient utilization of office space will affect rents, prices and construction - will be of paramount importance to owners, managers and investors in office property. However, the broader impacts of such a transition on a regional economy may also be significant. Improved efficiency would lower costs and increase profits for firms in office-using sectors, but decreased office rents and property values could mean lower tax revenues and income from property investments for local households. If efficiency gains lead the output of office-using sectors to rise, this might increase demand for other property types but low rents might lead some firms to substitute or repurpose office space instead. The endogeneity of firm responses to such a technology shock, through the effect that a reduction in office demand would have on office rents, suggests that rather than taking survey responses regarding actual office space usage (as opposed to a best-practice target) at least a partial equilibrium approach would be necessary. Given the expectation of broader economic growth effects as a result of this productivity-enhancing technological change, which should increase the domestic and rest-of-world demand for goods and services produced using office space and hence office-using employment, a general equilibrium approach such as the one outlined in this study seems the only appropriate method for estimation. In addition, only through whole economy simulations is it possible to assess the impacts that a transition to AWS will be expected to have on economic aggregates of interest such as total investment (across all property types) and total tax revenues.

The concepts of alternative workplace strategies and telecommuting are intertwined in practice, in the literature and in public perception. Though this study focuses on the impacts of alternative workplace strategies, some explanation of the two concepts and most importantly how they differ may be required. In principle the terms telework or telecommuting refer to replacing a physical commute to the office with telecommunications technology, which eliminates the need to be physically present at a given location in order to perform critical job responsibilities. The result can be that a home office replaces a work office, with less commercial office space utilized by that particular worker at least at certain points during a workweek. According to Safirova (2002) the concept of telework or telecommuting was first researched by Nilles et al. (1976) with case studies on productivity and social implications. As Safirova and Nilles et al. have described, chief among the promoted benefits of telecommuting were assumed to be a reduction in traffic and time spent behind the wheel and flexible working hours which would improve the standard of living and productivity for telecommuters by improving their ability to balance the demands of work and family.

It should be noted that where there is a connection between telecommuting and adoption of AWS, the connection could be lagged or contemporaneous. This study will analyze the impacts of a predicted transition to AWS and it is therefore a relevant question whether there should be any strong expectation that recent trends toward AWS occur contemporaneously with trends toward increased telecommuting. Studies such as Noonan & Glass (2012) have shown that the prevalence of telecommuting has not risen greatly since the 1990s after reaching approximately 20% of the urban workforce (including those who work from home occasionally), and perhaps not in such a way as to truly transform the nature of work. Though the dataset used by Noonan & Glass was discontinued after 2004, other sources (Walls, Safirova & Jiang 2007) corroborate the finding. Yahoo! and Hewlett-Packard have recently suspended telecommuting options, requiring all workers to be physically present in the office (CNET).

Recent research may suggest some reasons why this might be the case. According to a survey based study by Neufeld & Fang (2005) 47% of telecommuters reported higher self-assessed productivity than when they were working from the office, but the remaining 53% reported lower self-assessed productivity. Among those who reported lower productivity, key reasons given were the lack of face-time with managers and co-workers and distractions involved in mixing work and family. Noonan & Glass (2012) found no evidence that those who would theoretically benefit from flexible work schedules, namely those with children, were more likely to telecommute. Singles were found to be more likely to telecommute than married people as well, perhaps because while the benefits of flexible hours for work/family balance do improve well-being such situations are not inherently conducive to productivity. This result is confirmed by Safirova & Walls (2004) who find that telecommuters are more likely to be male and from smaller households.

According to an experiment by Dutcher (2012) productivity for telecommuters is higher than for those in the office only for creative tasks, while for mundane tasks productivity in the office is higher. These findings are supportive of the idea that, in terms of productivity, telecommuting is appropriate only for certain workers in certain work situations and is not without drawbacks. In terms of improvement in quality of life for the telecommuter, Noonan & Glass found that the only variable that strongly varied between telecommuters and non-telecommuters was increased work hours for telecommuters, as they may be "always on call". In addition, Peters, Tijdens & Wetzels (2004) found that a majority of those who had been offered the opportunity to telecommute had declined. In explanation Safirova and Walls (2004) find that those workers most enthusiastic about telecommuting are those with less education who are less likely to be allowed or encouraged to telecommute by managers perhaps because the tasks involved in their work would be more "mundane" and their productivity would be negatively affected. If this is the case, we may not expect a strong push for telecommuting from workers themselves or any kind of a wage effect.

However, it has also been proposed that an important benefit for telecommuters would be reduced time spent in traffic. According to a survey of the literature by Walls & Safirova (2004) most studies indicated reduced vehicle miles by telecommuters, however many studies looked only at travel to the workplace. Sridhar & Sridhar (2003) found empirical evidence for a complementary relationship between telecommuting and face-time, either with clients or managers. This need by those who telecommute to commute in order to meet face to face with others may explain why many telecommute only part of the time as Zhu's (2012, 2013) findings using a larger sample and more recent data than those included in the survey by Walls & Safirova that telecommuters make longer trips to work (though less frequently) and engage in more non-commute work travel. Zhu's findings cast some doubt on the oft-assumed negative relationship between telecommuting and vehicle miles traveled or congestion.

As detailed by Becker and Steele (1990, 1995) Alternative Workplace Strategies or AWS is a concept from the discipline of facilities management and like the concept of telecommuting, not new. Fundamentally, AWS refers to the elimination of assigned workspace and movement towards shared workspace through what is often referred to as "office hoteling" or "hot desking"[1]. As Haynes & Price (2004) note: "offices or workstations are notoriously underutilized" (p. 9) and this tendency is exacerbated by increases in the prevalence of telecommuting. As such, a transition to AWS involves a rationalization (Duffy, 2000) of the office in response to current usage patterns rather than a drive to change usage patterns. As Duffy (2000) laments, the pace of change in office organization has been slow and has not kept up with predictions made decades earlier with blame laid upon conservatism by suppliers and organizational hierarchies.

The reduction in costs (Duffy 2000, Sridhar & Sridhar 2003, Young 1995, Kaczmarzyk 2005) has been the predominant concern for individual firms transitioning to AWS with potential impacts on workplace productivity either ignored or simply less touted. To the extent that telecommuting increases office underutilization a transition to AWS could be due to a concurrent increase in telecommuting, but as such office rationalizations may occur with significant lags it may be more likely a reaction to past increases in telecommuting. If related to concurrent increases in telecommuting, the empirical impacts of telecommuting on worker productivity,

[1] The two concepts differ only in whether shared office space is available on a first-come first-serve basis (hot desking) or is reserved for some period in advance (office hoteling) (Gibson, 2003)

worker quality of life and vehicle miles traveled remain ambiguous. Where office workers are frequently away from their assigned space for reasons other than telecommuting; business travel, meetings, etc… AWS may produce the same benefits. For these reasons, this study will model a transition to AWS of the pace and scale predicted by CoreNet and BOMA exclusively as a reduction in operating expenses for affected firms due to decreased office space requirements as the impact of AWS on space requirements is unambiguous and, according to Duffy (2000) the chief driver of the trend.

This paper describes a regional computable general equilibrium (CGE) model, the Colorado Real Estate (CO-RE) model, designed for analysis of impacts originating in or of particular relevance to local property markets and its application to the issue of reduced office space per worker requirements. The model represents the Colorado economy in the baseline year of 2010, the peak year for office space per worker, built upon a series of key assumptions: perfect competition, market clearance, utility maximization by households and profit maximization/cost minimization by firms. The model features, in addition to 24 industry sectors and 7 household groups defined by household income, 5 labor groups and 7 tax categories, 20 capital categories corresponding to important classes of real and personal property. The model is capable of estimating the impact of exogenous shocks and changes in production technology (as in the case of office sharing) on regional real estate markets as well as the impact of shocks to regional real estate markets on the broader economy, regional employment and tax revenues.

3.2 Real Property Markets in the CO-RE Model

One novel innovation of the Colorado Real Estate model is the inclusion of 20 types of capital based upon asset definitions used by the US Bureau of Economic Analysis in their National Income and Product Account (NIPA) tables. Estimates for the total residential and non-residential capital stock for the state of Colorado are obtained from the Colorado Department of Local Affairs (DOLA) Property Tax Division, estimates for the breakdown of non-residential capital into real and personal property categories are obtained using asset proportions from the NIPA tables adjusted to reflect the structure of the Colorado economy. A list of property types used and the corresponding NIPA definitions can be found in table 3.1 on the following page.

Commercial property markets have been understood to be characterized by certain specific features and phenomena (Pyhrr, Roulac & Born 1999, McDonald 2002) including slow adjustment of stocks and price, disequilibrium and cyclicality without attention to which economic impacts of or on commercial property markets cannot be accurately understood or explained. Through side equations the CGE model is adapted to fit the general Torto-Wheaton stock adjustment model (Wheaton 1987, Torto & Wheaton 1988, Wheaton, Torto & Evans 1997) with some adaptations to fit the idea of a balanced-growth path and some limitations of the Arrow-Debreu general equilibrium framework.

Torto & Wheaton model absorption, period-to-period changes in occupied stock of a given real property type, as the product of the slow adjustment process from desired occupied space ($OCCSF^*_t$) from the previous periods occupied space ($OCCSF_{t-1}$) where desired occupied space is a function of the number of office workers (EMP_t) and an interaction term between the number of office workers and lagged office rents (EMP_tR_{t-1}).

The occupied stock adjustment equation $OCCSF_t - OCCSF_{t-1} = \tau(OCCSF_t^* - OCCSF_{t-1})$ (1)

Becomes $ABSORPTION_t = \tau(\beta_0 + \beta_1 EMP_t - \beta_2 EMP_t R_{t-1}) - \tau OCCSF_{t-1}$ (2)

New construction starts in the Torto-Wheaton model are a function of current rents (R_t), current vacancy rates ($vacper_t$), current interest rates (I_t) and a current construction cost index (CCI_t).

Table 3.1 – Capital Types in the CO-RE Model

Model Identifier	NIPA Categories
SingleResSF	
MultiResSF	
TechK	Mainframes, PCs, Printers, Terminals, Storage Devices, System Integrators, Prepackage Software, Custom Software, Own Account Software
OtherK	Communications, Nonelectro Medical Instruments, Electro Medical Instruments, Nonmedical Instruments, Photocopy and Related Equipment, Office and Accounting Equipment, Nuclear Fuel, Other Fabricate Metals, Household Furniture, Other Furniture, Household Appliances, Other Electrical, Other
MachineryK	Steam Engines, Internal Combustion Engines, Metalworking Machinery, Special Industrial Machinery, General Industrial Equipment, Other Agricultural Machinery, Farm Tractors, Other Construction Machinery, Mining and Oilfield Machinery, Service Industry Machinery
GridK	Electric, Transmission and Distribution
AutoK	Light Trucks (including utility vehicles), Other Trucks, Buses and Truck Trailers, Autos
OtherTransK	Aircraft, Ships and Boats, Railroad Equipment
OfficeSF	Office
MedicalSF	Hospitals, Special Care, Medical Buildings
WarehouseSF	Warehouses
MobileSF	Mobile Structures
RetailSF	Multimerchandise Shopping, Food and Beverage Establishments
ManufacturingSF	Manufacturing
InfrastructureSF	Electric, Gas, Petroleum Pipelines, Wind and Solar, Communication, Petroleum and Natural Gas, Mining, Air Transportation, Other Transportation, Other Railroad, Track Replacement, Local Transit Structures, Other Land Transportation, Water Supply, Sewage and Waste Disposal, Public Safety, Highway and Conservation and Development
ChurchSF	Religious
SchoolSF	Educational and Vocational
RecreationSF	Amusement and Recreation
HotelSF	Lodging
FarmSF	Farm

Source: U.S. Bureau of Economic Analysis, "Detailed Data for Fixed Assets and Consumer Durable Goods," www.bea.gov/national/FA2004/Details/Index.html (accessed August 10, 2010)

In the absence of data for construction starts, net changes in stocks (S_t) can be modeled as a function of lags of these independent variables.

$$S_t - S_{t-1} = \gamma_0 + \gamma_1 R_{t-1} - \gamma_2 vacper_{t-1} - \gamma_3 I_{t-1} - \gamma_4 CCI_{t-1} \quad (3)$$

The absorption and construction equations combined with the identity

$$VACANCY_t = S_t - OCCSF_t \quad (4)$$

determine vacant stock ($VACANCY_t$) and the vacancy rate ($vacper_t$) relative to total occupied stock. The addition of a price adjustment equation incorporating the observed negative relationship between rents and vacancy rates completes the system of equations, in which each variable of interest can be explained by lagged values and exogenous shocks to employment, interest rates and construction costs.

$$R_t - R_{t-1} = \sigma(R_t^* - R_{t-1}) \quad (5)$$

$$P_t = \sigma\left(\alpha_0 - \alpha_1 vacper_{t-1} + \alpha_2 \frac{ABSORPTION_{t-1}}{OCCSF_{t-1}}\right) + (1-\sigma)P_{t-1} \quad (6)$$

It has been observed by Torto & Wheaton (1994), Grenadier (1995) and others that regional property markets do not adjust to shocks at the same speed nor do they exhibit identical characteristics such as natural or baseline vacancy rates. As such we have estimated values in three-stage least square for the parameters in equations (1) through (6) using CBRE data on the office market in the Denver metropolitan area from 1987 to 2012 to represent the State of Colorado rather than applying and scaling earlier published estimates for the United States as a whole. Variable values are scaled such that the 2010 values in the CBRE dataset are equal to the starting values in the Social Accounting Matrix; rents are normalized to unity and values for stocks and employment converted to abstract “units of capital” and “units of labor” as in the SAM. Parameter estimates for the absorption, construction (Ct) and rent equations are shown below with T-statistics in parenthesis. Estimates show a negative but insignificant relationship between lagged absorption rates and current rents, but a strong positive contemporaneous relationship between the two so lagged absorption rates have been replaced with contemporaneous absorption rates in equation (9).

$$ABSORPTION_t = 0.31\left(\frac{303.981}{(33.087)} + \frac{0.081}{(0.016)}EMP_t - \frac{0.009}{(0.005)}EMP_t R_{t-1}\right) - \frac{0.31}{(0.144)}OCCSF_{t-1}$$

(7)

$$C_t = \frac{-45.693}{(28.474} + \frac{76.826}{(10.476)}R_{t-1} - \frac{67.665}{(29.331)}vacper_{t-1} - \frac{15.664}{(24.457)}CCI_{t-1} - \frac{0.252}{(2.157)}I_{t-1} \quad (8)$$

$$R_t = \frac{0.608}{(0.13)} - \frac{1.27}{(0.248)}vacper_{t-1} + \frac{8.523}{(2.04)}\frac{ABSORPTION_t}{OCCSF_t} + \frac{0.591}{(0.092)}R_{t-1} \quad (9)$$

The construction equation (8) is incorporated in the CGE model nearly as-is: converted from net new construction to gross new construction with the addition of (δ)St-1 where δ is the BEA property-type-specific depreciation rate and scaled to fit the BGP with baseline rental rates, vacancy rates, interest rates and construction costs. Rents, vacancy and construction costs are determined endogenously within the CO-RE model, interest rates are an exogenous parameter assumed to be determined outside the region.

Absorption equation (7) shows that slightly under one third of the impact of any change in input demand (using office employment as a proxy) is felt in the first period following the shock and relatively low demand elasticity for real property. Equation (7) likewise requires some transformation to fit the concept of the BGP, eliminating β_0 and scaling up β_1 and β_2 such that at baseline rent levels a 1% increase in EMP_t leads to a 1% increase in the desired level of occupied stock $OCCSF^*_t$. In addition, given a value for τ of 0.31 the economy will not begin on the BGP unless a certain amount of pressure has already built up – a gap between desired and actual occupied stock equal to $(GRO/\tau)OCCSF_{t-1}$ where GRO is the assumed BGP growth rate – so β1 and β2 are scaled up by (GRO/τ) so that the economy begins on and continues on an approximation of the BGP.

Equations (7) and (8) together determine endogenous vacancy, included in the CO-RE model as a “negative endowment” of real property capital types by household groups.

$$VACANCY_t = (1-\delta)VACANCY_{t-1} + C_t - ABSORPTION_t \text{ (10)}$$

An Arrow-Debreu general equilibrium model is not naturally compatible with the idea of sticky prices or exogenous prices or with the concept of disequilibrium – though our vacancy equation avoids this through a modeling technique. As prices are determined endogenously within a CGE model, the positive relationship between absorption and rents occurs naturally. However, it is necessary to parameterize a relationship between rents and vacancy rates through a side constraint setting an endogenous pricing instrument. If such a relationship is not explicitly declared, higher vacancy rates will imply less available stock – all else equal – and put upward pressure on rents rather than downward pressure. This pricing instrument sets SLUGP_K1(t) for each property type equal to the pricing equation (9) above, depending upon SLUGP_K1(t-1) rather than the R(t-1) determined within the model. SLUGP_K1(t) is then used to set an endogenous “tax” or “subsidy” SLUGP_K(t) for each capital type, with owners of capital footing the bill for a “subsidy” or receiving the benefits from a “tax”, such that:

$$SLUGP\_K1_t = R_t * (1 + SLUGP\_K_t) \text{ (10)}$$

3.3 AWS Simulation Results

In a CGE model, the abstract need for or desire to use office space can be separated from the actual demand or utilization. A variety of reasons may exist for a firm’s target usage per worker to differ significantly from its actual usage including prices (DiPasquale and Wheaton 1996) as well as complicating factors such as uncertainty and inflexible contracts (Miller). Here the change represented by phenomena such as telecommuting and office hoteling is represented in terms of a change in parameterization of the production functions for office-using sectors to reflect a new ability to produce the reference level of output while using 50% less of the "OfficeSF" capital type providing usage of other factor and intermediate inputs remains unchanged. The simulation is further broken down into one in which the change in target office space use is assumed to take place instantaneously, as of the end of 2009, and one in which the change occurs gradually over 7 years from 2011 to 2017.

According to the BEA, all broadly-defined 2-digit NAICS sectors are office-using to some degree. Relative importance ranges from a high of 43.4% of total capital requirements for the Management of Companies and Enterprises sector to a low of 0.94% of total capital requirements for the Accommodation and Food Service sector. Public Administration and government services sectors are assumed to demand none of the capital types utilized by other sectors. While this assumption may seem unrealistic, offices of government entities tend to be government-owned rather than privately owned and as they are not subject to taxation accurate valuation estimates are more difficult to acquire. Since it is unclear, theoretically or empirically, whether a change in business practices (i.e. "technology") leading to more efficient office space utilization should impact only sectors conventionally defined as office-using such as Finance and Insurance or all sectors which demand any amount of the OfficeSF capital type, two pairs of simulations are run. In the first pair , the change in production technology is assumed to impact all sectors equally either immediately (Fast) or over a span of seven years (Slow). In the second pair, the change in production technology is confined to the five sectors with the highest office space requirements, as a percentage of their total capital requirements; Fin, Real, Serv, Manage and Admin[2] either Fast or Slow. While Miller (2012) proposes that the gap between actual and target office usage can be largely explained by factors such as employee turnover, search costs

[2] Finance and Insurance, Real Estate Rental and Leasing, Professional, Scientific and Technical Services, Management of Companies and Enterprises, Administrative and Support and Waste Management and Remediation Services

and delays in hiring and lease length - in a perfectly competitive economy such as that simulated by a CGE model all of that gap can be and must be explained by prices. While there can be a negative capital supply response, by allowing depreciation to occur without capital investment to offset it, this response is neither large nor quick for real property and all properties in existence must be occupied (though this is the functional equivalent of assuming a constant vacancy rate) by some firm in some sector. Rents will immediately adjust across the board until it becomes worthwhile for some firm to utilize a property for some purpose, perhaps a purpose very different from that for which it was designed. While the model, as presently constructed, does not include the possibility of permanently converting a property from one type to another (due to a lack of data on the costs involved in such a conversion) we can assume that much of the end result of such conversions will show up in added office demand from unconventional sources at low prices.

The impact on office rents is expected to be negative; we should see a decrease in office space demand from office-using sectors, which far outstrip the decrease in supply due to depreciation. The only question is, if we assume instantaneous price adjustment to clear the office market, how large the decline in office rents will be. By assumption, any change in rents will be instantaneously capitalized in assessed property values. As shown in Table 3.1 (below) if we assume a sudden shift towards a far lower target level of office space per worker, existing office stock will decrease by a maximum of 2.4% per year (BEA) as existing structures are allowed to depreciate. If allowed to correct immediately and fully, office rents will need to decline by over 80% in the first year in order to clear the market. The market correction will occur only through reductions in stock by depreciation and a slow increase in demand due to economic growth (at an assumed 3% per year). Office rents will recover, though slowly, after the initial plunge but will still be only 1/3 of 2009 levels by 2019. It will take over years for rents to recover to 2009 levels at which time office stock growth would resume.

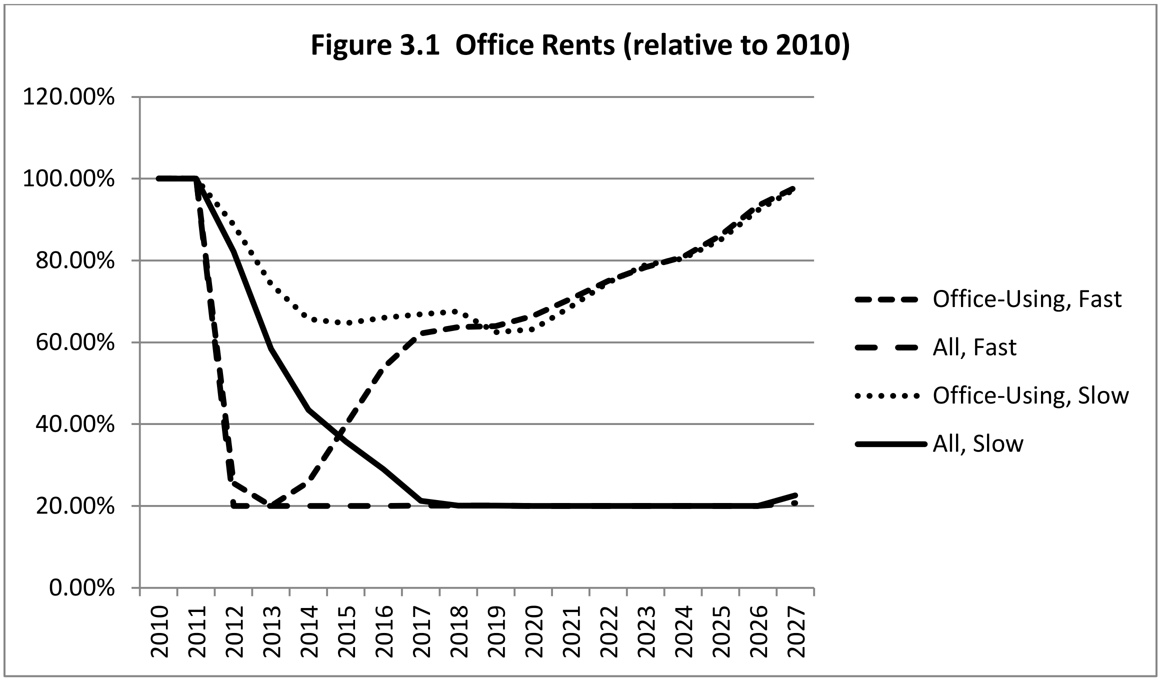
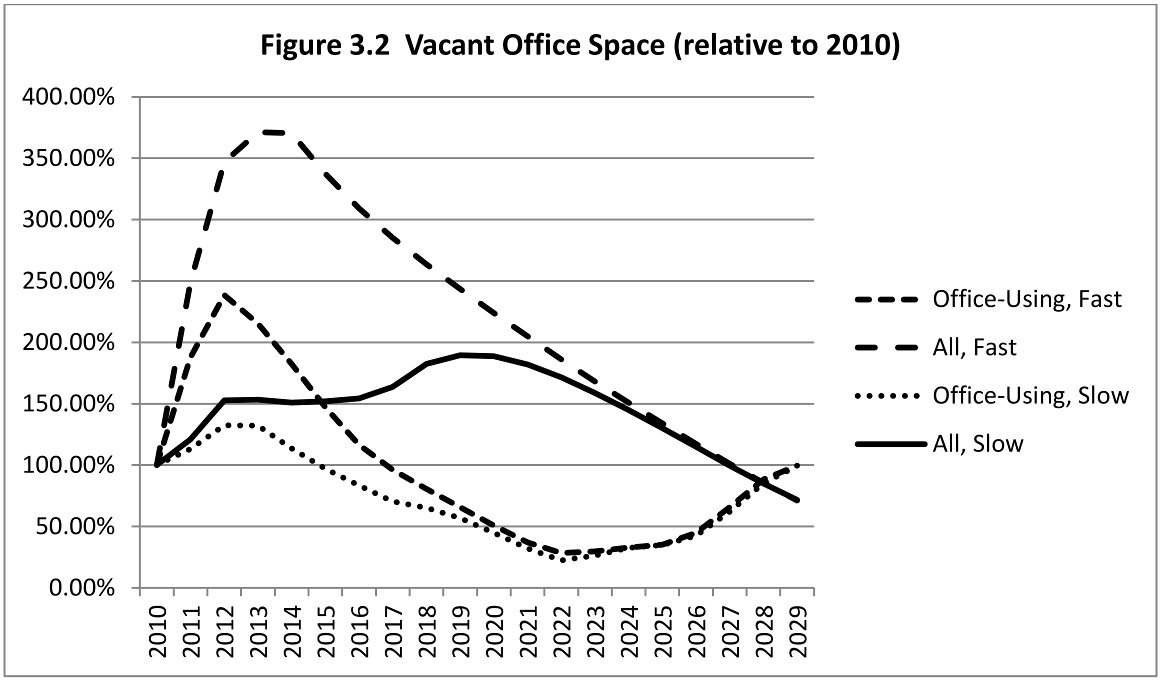


Figure 3.2 (below) shows the effect on vacant office space. In each simulation but the "mildest" (office-using sectors only with a slow transition) we see a dramatic increase in vacancy rates relative to the baseline vacancy rate of approximately 16.5%. However, in no simulation are these high vacancy rates indefinitely maintained. As the regional office market recovers, after a period of low rents and high vacancy rates, those low rents spur additional absorption while the combination of low rent and high vacancy strongly discourages construction. Vacancy rates "overshoot" the baseline 16.5% on the recovery in every simulation as construction is slow to pick up, but return to the baseline given enough time. In the two "office-using" simulations this requires approximately 20 years from the beginning of the initial transition to AWS, for the two "all" simulations even more time is required. After 10 years, most of the construction boom

has run its course and the impact on property values and rents for non-office property types will dissipate.



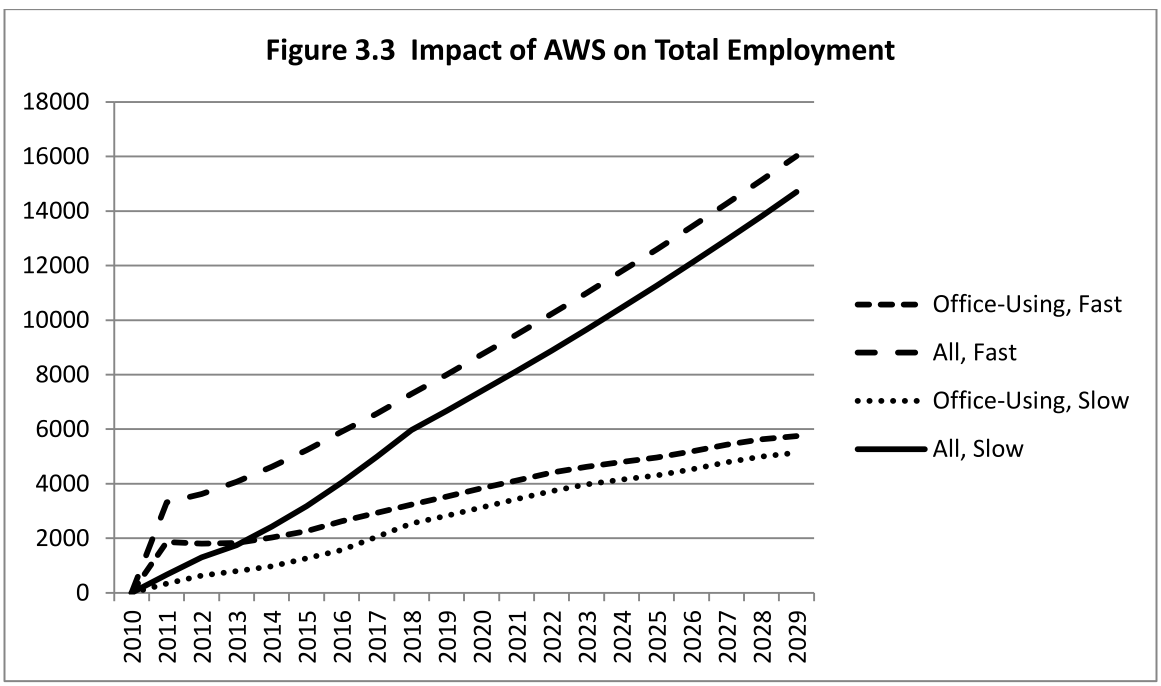
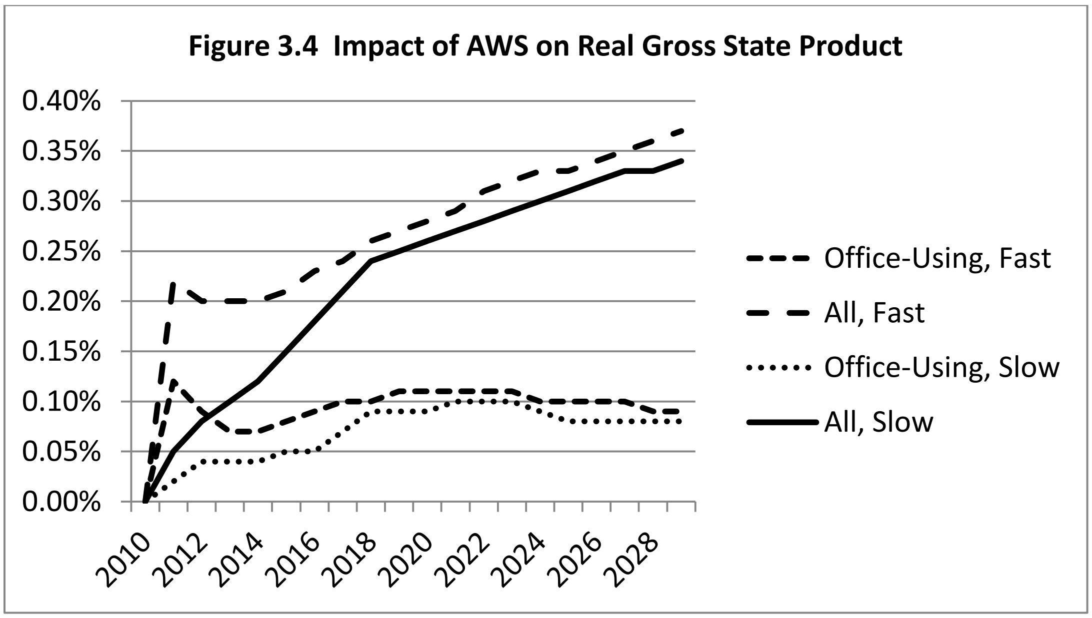
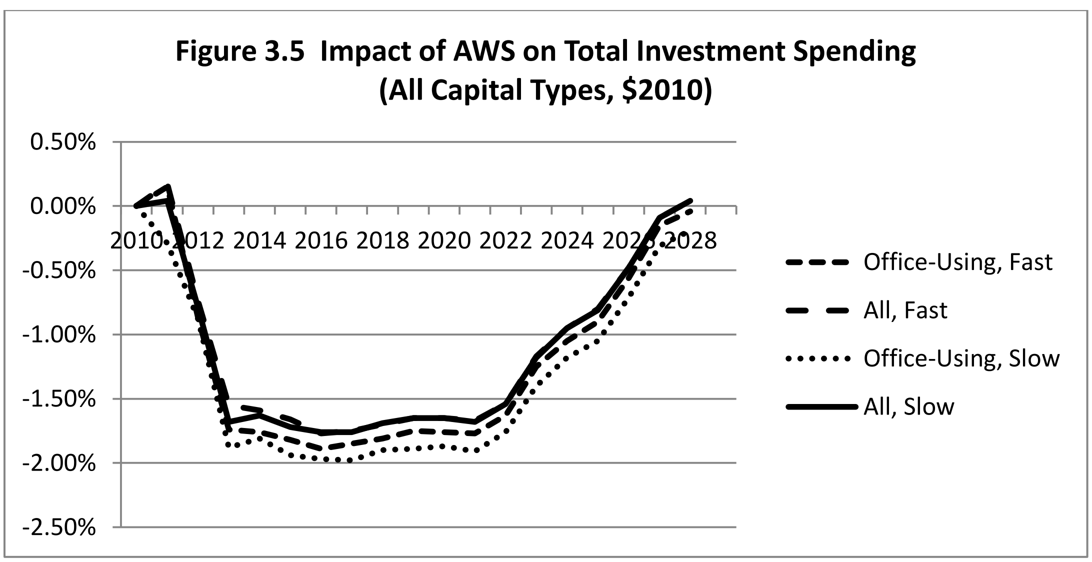


Figure 3.3 (above) shows the increase in total employment in the state due to the productivity enhancing effects of the transition to AWS. Increases in job creation are significantly more

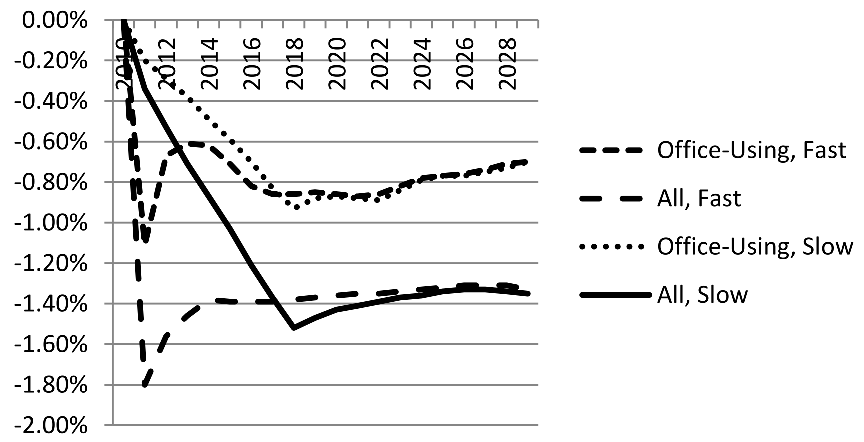
pronounced in the pair of simulations in which all sectors transition to AWS rather than only primary office-using sectors. In part this and the increased impact on total output in figure 3.4 (below) can be explained by the dramatic decrease in office rents which further lower the cost of doing business in the state. Once rents have returned to normal levels in the two office-using simulations the impacts on real output begin to slowly diminish.



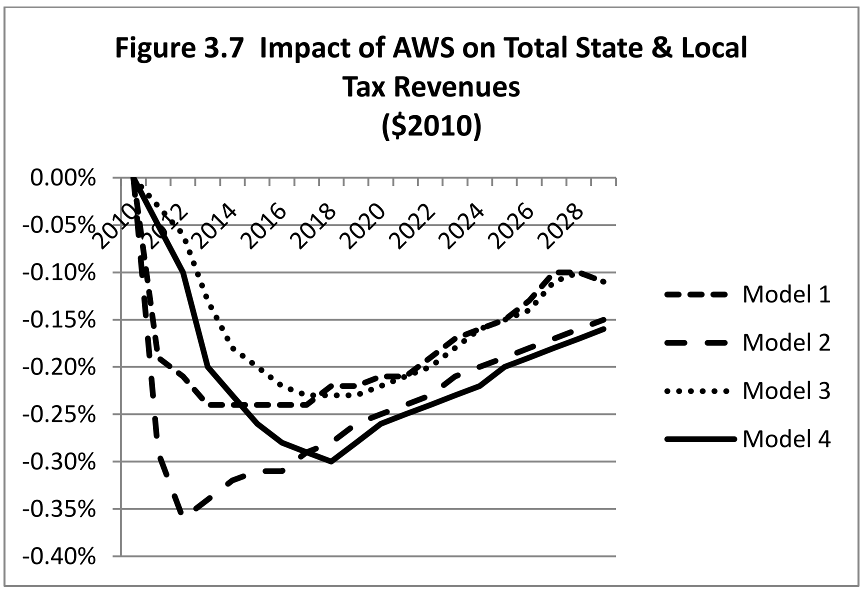


As shown in figure 3.6, though the change in business “technology” increases gross state product and leads to the creation of jobs, property tax revenues fall due to the sharp reduction in assessed valuation of office properties. After 20 years, when regional property markets have stabilized, at least in the less extreme “office-using” simulations, the net negative impact on property tax revenues comes to approximately 0.7% or 1.3% of total property tax revenues – relative to 2010 revenues of approximately $5.8 billion. The loss in office property tax revenues on office buildings more than offsets increased revenues from taxes on other property types. This result could be at least partly due to factors unique to the state of Colorado, which depends disproportionately on property taxes levied on commercial property due to the Gallagher Amendment to the state constitution in 1982 limiting property tax increases on residential property. Property tax revenues slowly recover, as office rents/values rise over time and increased investment in other property types increases the tax base but the new steady state which regional property markets approach is one with less real property than would otherwise have existed.

Figure 3.6 Impact of AWS on Property Tax Revenues ($2010)



As shown in figure 3.7 (below), in all simulations the negative impact on local government finances of reduced property tax revenues more than offsets any revenue gains from other taxes and fees. Property tax revenues represent approximately 2/3 of local government revenues in the state of Colorado and approximately ¼ of combined state and local tax revenues. The State government is responsible for covering property tax revenue shortfalls for local school funding in the state of Colorado through the state general fund, so the impact on combined state and local revenues may be a more appropriate benchmark for state policy makers than state revenue alone.



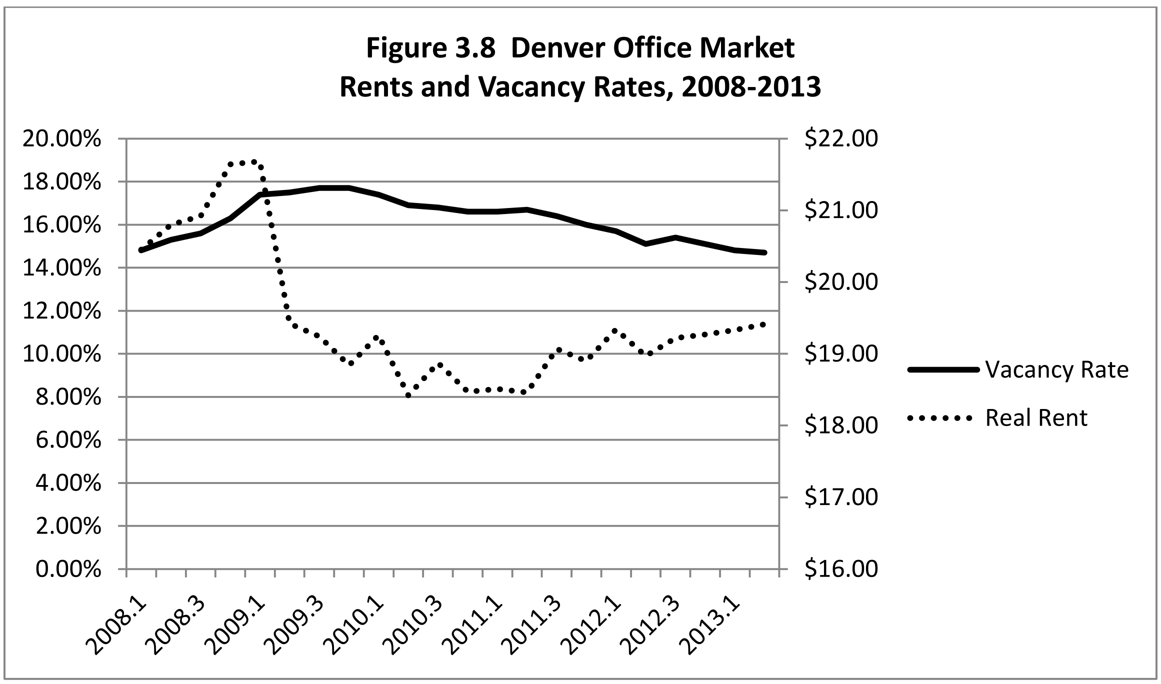
3.4 Conclusion & Avenues for Future Research

A regional CGE model such as the Colorado Real Estate model is capable of providing theoretically sound estimates of the impacts of phenomena which input-output and econometric models may be unable to appropriately analyze. When applied to the question of the impacts of alternative workplace strategies such as telecommuting on local property markets and the local economy, estimates provided by the Colorado RE model suggest that the trend will be beneficial for output and employment growth. AWS is expected to spur investment in non-office property types, though increases in non-office commercial rents are expected to be short-lived. Property tax receipts are expected to fall overall due to the greatly diminished valuation of office properties. In the state of Colorado, in which the property tax burden falls disproportionately on the office sector, this fall in property tax revenues more than offsets increases in other tax revenues at all levels of state and local government. In addition, it is possible due to the Colorado Gallagher Amendment which constrains property taxation that we may see a decrease in assessment ratios for residential properties as the value of office properties falls in order to maintain the ratio of commercial to residential property tax revenues. Should this occur, these results would understate the true impact of AWS on aggregate property tax revenues.

The perfectly competitive market assumptions of most CGE models, including the CO-RE CGE model where real property is not concerned, are usually quite attractive compared to most feasible specifications with market imperfections such as those described in Willenbockel (2004), however the assumption that all markets clear appears untenable when dealing with property markets. The real world office vacancy rate is will display a non-zero average over any significant time horizon and shocks to either office demand or office supply can be expected to influence not only office rents and valuations but also the short-run vacancy rate (De Francesco 2008). CoreNet Global, for example, suggests that AWS could result in 40% office vacancy rates by 2020 if all office-using firms follow through on their stated plans to reduce square footage per worker (CoreNet, 2012). This is not far from the CO-RE model vacancy estimate for the same scenario, in which all firms in all sectors begin an immediate transition to AWS. In property markets, we should expect significant lags: an immediate shock to demand should result in a lagged impact on vacancies, which will result in a lagged impact on rents and values. This sluggish supply side response built into the Colorado RE CGE model. Although rents are sticky on the downside, the scale of the shock to office demand implied in the CoreNet projection is more than sufficient to cause large and rapid changes in rents.

As it has been some time since survey data regarding intentions of managers was collected by CoreNet, it is not unfair to assume that the forecast transition to AWS – though it is expected to be potentially fully realized only by 2017 – should already be underway. The observed data regarding office rents and vacancies do not entirely support this prediction.

Figure 3.8 Denver Office Market – Rents and Vacancy Rates 2008-2013



Since 2011 office vacancy rates in metropolitan Denver have continued to fall and real office rents in metropolitan Denver have continued to rise. The assumptions of the CO-RE model call for property markets which begin each simulation at a steady state and along a balanced growth path, wherein at current rent levels, with current vacancy rates, rents and vacancies remain stable as the economy grows along the balanced growth path. If 2011 rents are, in fact, below such a "steady state" level the natural tendency would be to see rents rise while vacancy falls provided underlying demand for office property is growing and this upward pressure on the price could produce the observed changes in spite of some degree of downward pressure on office demand especially when the near-zero rate of office construction is considered. However, the predictions of a 50% drop in desired office space per worker would indicate a rather dramatic decrease in underlying office demand. Even if this transition is confined to primary office-using sectors, the decrease in underlying office demand is approximately 30%. Clearly the sudden shock to the office market included in the pair of "fast" simulations is not in keeping with observed data from the Denver metro area over the past 8 quarters. The relatively mild impacts on the office market resulting when the transition is limited to primary office-using sectors and occurs over an extended period of time would be the best fit. We must also entertain the possibility that, since the predictions for employment and tax revenues from the CO-RE model merely indicate what we should expect for the broader regional economy should CoreNet's predictions come to pass, that they may have overstated the scale or pace of the transition to AWS. As Miller (2012) argues, there may be significant differences between plans and preferences stated by managers and their ultimate choices.

Chapter 4

Colorado Energy Policy: Natural Gas Price Sensitivity

4.1 Regional Energy Policy

With a majority in the House of Representatives and a 60 vote supermajority in the Senate, the Democratic Party took up the issue of energy and climate policy in 2009. On June 26 of that year, the House of Representatives passed the Waxman-Markey Bill (H.R. 2454) also known as the American Clean Energy and Security Act with only 8 Republican votes. The bill would have created a cap-and-trade system for carbon emissions reduction as well as a 20% renewable electricity standard (Hitt and Power 2009). Senate Democrats abandoned their attempt to pass the bill the following year (Hulse and Herszenhorn 2010), unable to secure the sixty votes necessary for a cloture vote.

With the federal government unwilling to pass comprehensive legislation to reduce carbon emissions, the onus has fallen upon individual states to do the same where such policies find stronger support within the state than in the United States at large. A number of states have already passed such legislation; including Massachusetts' Global Warming Solutions Act of 2008 (Massachusetts State Legislature), California's Global Warming Solutions Act of 2006 and SB X1-2 of 2011 - which strengthened their emissions reduction target and increased their renewable portfolio standard to 20% (ca.gov 2014) and Colorado's Amendment 37 of 2004 and Clean Air-Clean Jobs Act of 2010 (Rudolph 2014). While anthropogenic climate change is clearly a global problem and energy security at the least a national one, it would appear that for the foreseeable future the scale of policy on these issues in the United States will be regional, taken up by state and local governments. As such, the appropriate scale at which to gauge the economic or environmental impacts and desirability of given policy paths will be regional as well.

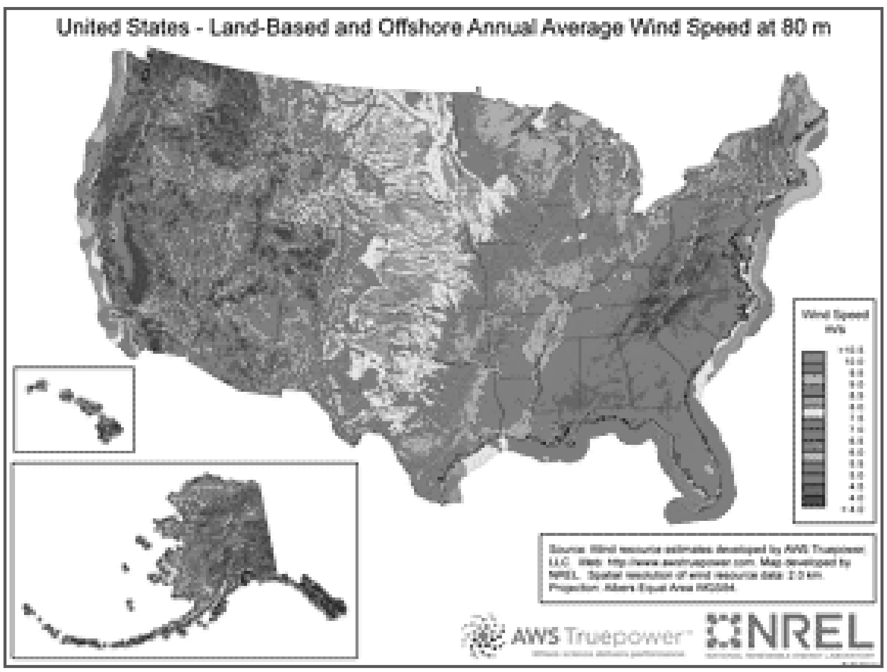
In such a policy context, the optimal policy may be national but politically impossible. Regional policies, such as Colorado's Renewable Portfolio Standard (RPS) and Clean Air – Clean Jobs Act, must be evaluated – in terms of economic costs – at a regional level though policy impacts are dependent upon national policies and trends as well. Any policy analysis must be conducted using a general equilibrium approach rather than a partial equilibrium approach so as to accurately reflect the broader economic impacts of electricity price changes as well as likely demand responses. A regional policy analysis should assess not only the relative merits of actual or proposed regional energy policies but also the sensitivity of impact estimates to trends and fluctuations to which the particular regional economy is exposed, which in this study is the productivity of the natural gas sectors as the State of Colorado is both a significant consumer and producer of natural gas.

Colorado Energy Policies

Amendment 37, a ballot initiative, established the state's renewable portfolio standard (RPS) later strengthened by House Bills 1281 and 1001. House Bill 1365 in 2010 called for the replacement of coal-fired generating capacity with natural gas-fired capacity as well as retrofitting of existing coal plants with NOX emissions reducing technologies (Rudolph 2014). The Colorado RPS consists of three critical components; separate renewable energy requirements for municipal electric utilities and investor-owned electric utilities as well as a requirement for distributed generation purchases by investor-owned electric utilities. Under the current standard, 12% of energy used by investor-owned electric utilities must be derived from “renewable” sources, a percentage which rises to 20% in 2015 and 30% in 2020 (U.S. Department of Energy). Municipal electric utilities, which primarily supply electricity to small towns or rural areas, are held to a less stringent standard: 3% of energy used must be derived from “renewable” sources, which rises to 6% in 2015 and 10% in 2020. Eligible energy sources include: Solar Thermal Electric, Photovoltaics, Landfill Gas, Wind, Biomass, Hydroelectric, Geothermal Electric, Recycled Energy, Anaerobic Digestion and Fuel Cells using Renewable Fuels (U.S. Department of Energy). Investor-owned utilities are required to generate or purchase 1.25% of electricity for retail sale using Distributed Generation (DG), rising to 1.75% in 2015, 2% in 2017 and 3% in 2020 half of which must come from “retail” rather than “wholesale” DG. “Wholesale” DG refers to small-scale power plants of any type located close to consumers, “retail” DG to electricity customer-owned, on-site generating capital as in renewable systems with net metering. House Bill 10-1365 of 2010, the Clean Air – Clean Jobs Act, mandated the early retirement of 551 megawatts (MW) of coal-fired generating capacity, fuel-switching 463 MW of coal generation to natural gas and retrofitting 742 MW of coal-fired plants with emissions reducing technologies between 2011 and 2017.

Trends in US Electricity Generation

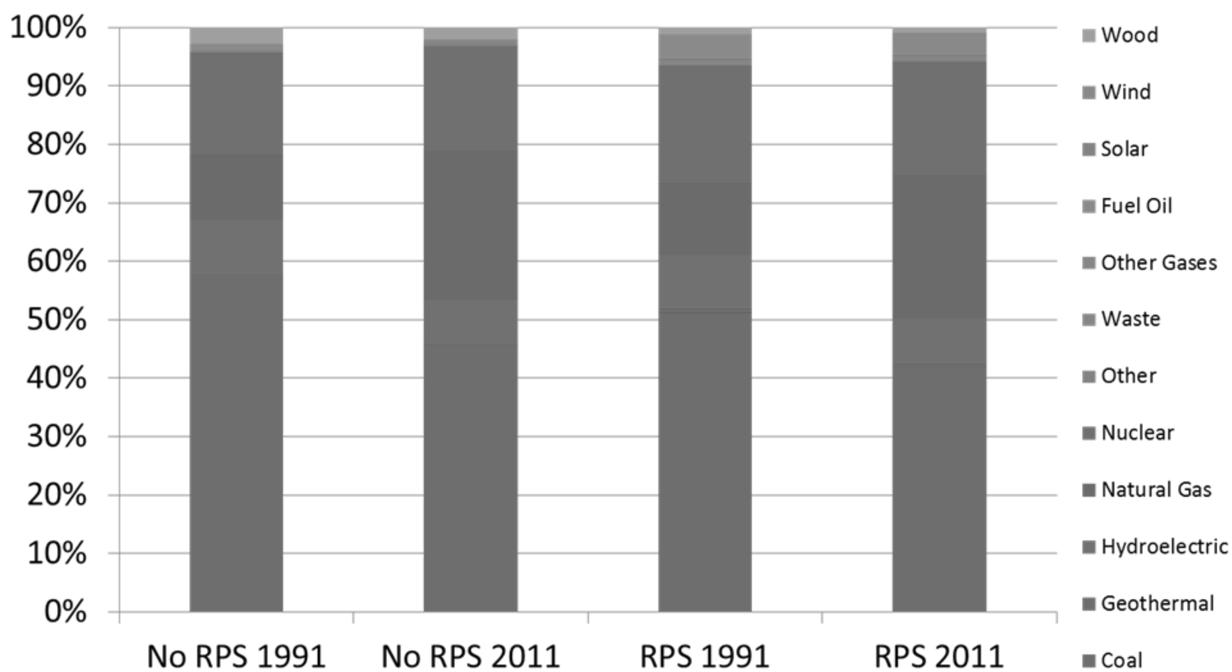
The State of Colorado is far from unique in its adoption of policies to promote clean energy in the electricity sector. Currently 38 of the 50 states have adopted a renewable portfolio standard in electricity generation of one form or another (U.S. Department of Energy) with Alabama, Alaska, Arkansas, Georgia, Idaho, Kentucky, Louisiana, Mississippi, Nebraska, South Carolina, Tennessee and Wyoming as the remaining holdouts. Though other studies have not found statistical support for the influence of political party control on energy policy outcomes (Maguire 2012) the twelve US states without a renewable portfolio standard seem to have little in common economically. States with ample resources of fossil fuels such as coal and natural gas are represented in both the RPS and non-RPS groups, for example ten of the top twelve US states by coal output in 2012 have renewable portfolio standards (Electricity Information Administration 2014). Likewise, as shown in figure 1.1 (National Renewable Energy Laboratory 2014) below while many of the non-RPS states in the American South lack abundant onshore wind resources so do many of those states, particularly in the Northeast and Midwest, that have passed RPS legislation. Nebraska and Wyoming, states without a renewable portfolio standard are located in the mid-country belt including the Rocky Mountain and Great Plains regions where wind resources are most abundant.



Source: National Renewable Energy Laboratory

Figure 4.1 – Wind Map

For the purposes of this study, the presence or lack of a renewable portfolio standard is assumed to represent an exogenous policy shock rather than an endogenous decision based on local resource abundance. As the first legislation creating the Colorado renewable portfolio standard was passed in 2004, it is important for the purposes of this study to establish what the likely path for the Colorado electricity generation mix would have been in the absence of this exogenous policy shock, perhaps driven by local preferences for environmental benefits and co-benefits of renewable energy (Holt and Wiser 2007). It is assumed that in the absence of an RPS, Colorado would have followed roughly the same path as the group of twelve states, including neighboring Wyoming from which Colorado purchases abundant cheap coal (EIA).



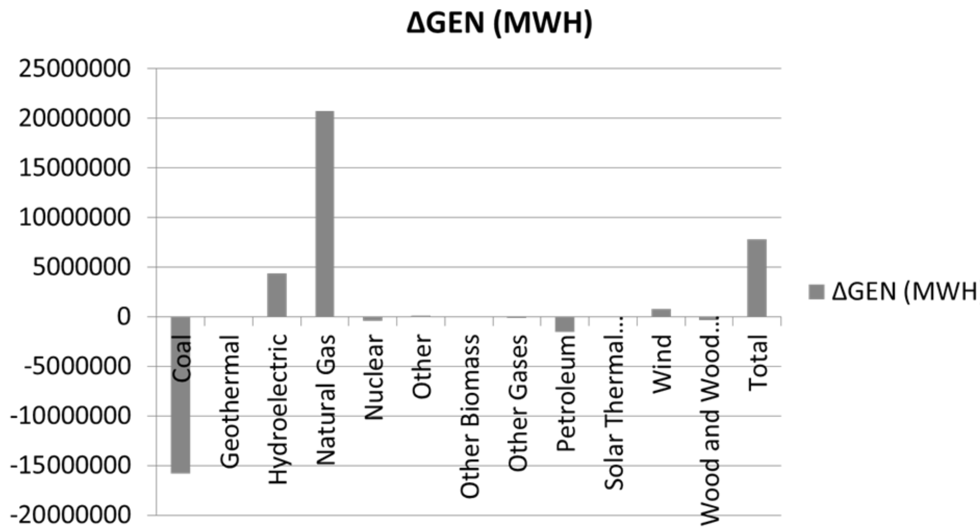
Source: Energy Information Administration

Figure 4.2 – Electricity Generation Shares by Generation Technology

As shown in figure 1.2 above, in 1991 RPS and non-RPS states differed somewhat in their dependence on coal for generation with RPS states somewhat less dependent on coal and somewhat more dependent upon nuclear power and fuel oil (chiefly in the Northeast).

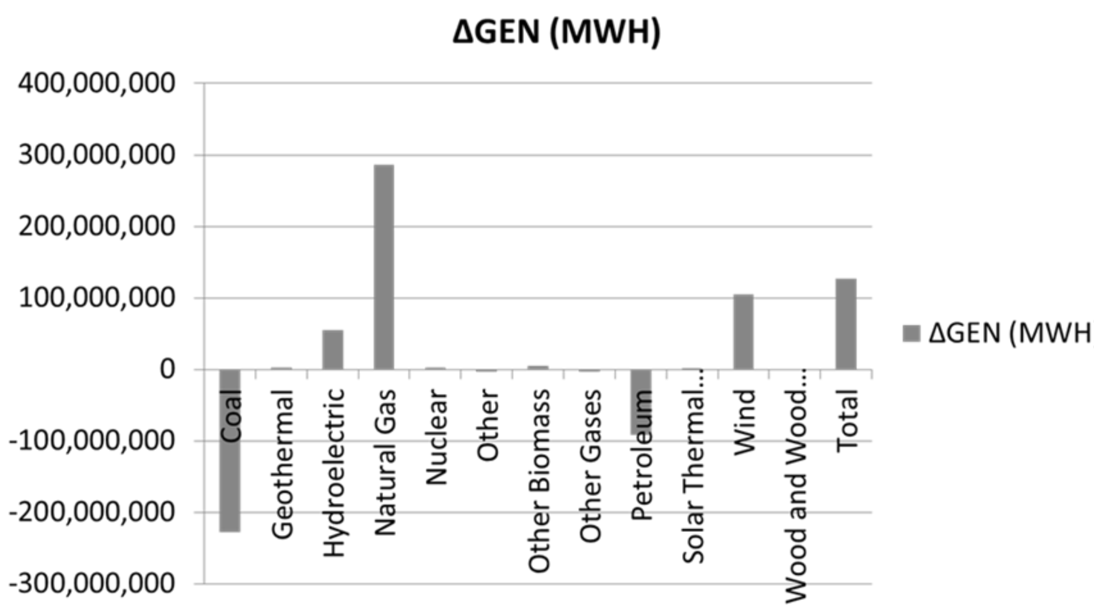
Renewable energy technologies other than hydroelectric represented a trivially small proportion of total electricity generation in the United States in both RPS and non-RPS states as of 1991. As shown in figures 1.3 and 1.4 below, both states with and without renewable portfolio standards have shown similar generation trends in some respects over the years since the ratification of Colorado's RPS. Both groups have seen dramatic reductions in both coal generation and petroleum (fuel oil) generation with a dramatic increase in generation from natural gas. In those states where petroleum was once the "peaker" technology (plants typically unused or underused that can be switched on during periods of peak demand), high oil prices and improved technology in gas generation have led to a transition to gas as the "peaker" of choice. According to EIA levelized cost estimates, a truly dramatic decrease in the price of fuel oil would be necessary to make petroleum "peakers" cost-competitive with natural gas "peakers" to reverse this trend. Improved technology in combined-cycle natural gas plants as well as increased capital costs for new coal-fired plants have also led to a transition from coal plants to base load natural gas plants, with the decrease in coal-fired generation coming at about 2 - 2.5% per year for both groups, presumably as older coal plants are allowed to depreciate.

The one noteworthy difference between the change in electricity generation in the non-RPS group (in figure 1.3 above) and the RPS group (in figure 1.4 below) is the sizeable increase in wind generation in the states in the RPS group. Though other renewable generation technologies, such as geothermal, biomass, etc… are supported and encouraged by the Colorado RPS as well as those of many other states (U.S. Department of Energy) only wind power has seen enough investment to become a significant portion of the generation mixes in these states. According to EIA levelized cost estimates, wind power is and has been by far the most cost competitive of the group with lifetime project costs little higher than those for base load natural gas plants, thanks in part to federal tax benefits.



Source: Energy Information Administration

Figure 4.3 – Change in Electricity Output by Generation Type: 2004 – 2013 (no RPS)



Source: Energy Information Administration

Figure 4.4 – Change in Generation Output by Technology: 2004 – 2013 (RPS)

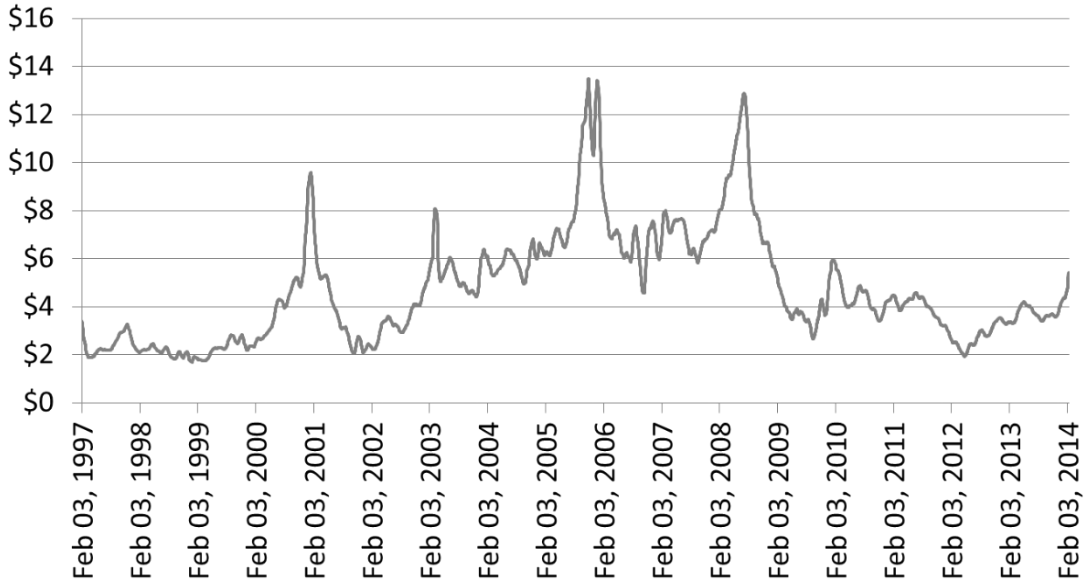
In states without renewable portfolio standards we see a decreased reliance on coal for base load power as older coal plants depreciate (at approximately 2% per year) and are replaced with new combined cycle natural gas plants for base load power. We see petroleum (fuel oil) “peakers” replaced by natural gas plants as well, though these are low-efficiency gas plants rather than the high-efficiency plants used for base load power. In states with renewable portfolio standards, we see the same long-run transition away from coal plants as older coal plants are allowed to depreciate and the same transition toward natural gas and away from petroleum for “peaker” plants. However, in the RPS states a significant portion of the new base load generation capacity takes the form of wind farms. Wind power appears to be displacing new gas generation capacity as well as old coal generation capacity. However, since wind and other variable or intermittent generation technologies increase the system requirements for “peaker” plant use (Joskow 2011), increased wind generation capacity may require the installation of more natural gas “peaker” capacity.

4.2 Natural Gas Price Uncertainty

The burning of natural gas to produce electricity produces only 0.5675 tons of CO2 per mWh, compared to 1.1245 tons of CO2 per mWh for electricity produced by burning coal (EPA). As a result, natural gas has been seen as an important bridge to a low-carbon future powered by renewable energy sources and to be among the lowest cost methods by which to achieve modest short-term reductions in carbon emissions. Despite the lack of any comprehensive federal legislation, in recent years technological innovations in the natural gas industry have greatly reduced the cost of reductions in carbon and other emissions through transition from coal-powered to gas-powered electricity generation. However, the reduced cost of gas-generated electricity may have the secondary effect of increasing the economic burden and reducing the desirability of such policies as renewable portfolio standards which mandate that a certain percentage of total energy or total electricity must come from sources classified as "renewable". While the transition away from coal and petroleum for electricity production in states without an RPS leads almost exclusively to a transition towards natural gas generation, in states with an RPS this transition moves towards both wind and natural gas, which suggests that a renewable portfolio standard is likely to decrease reliance on natural gas generation (Moniz, Jacoby and Meggs 2010).

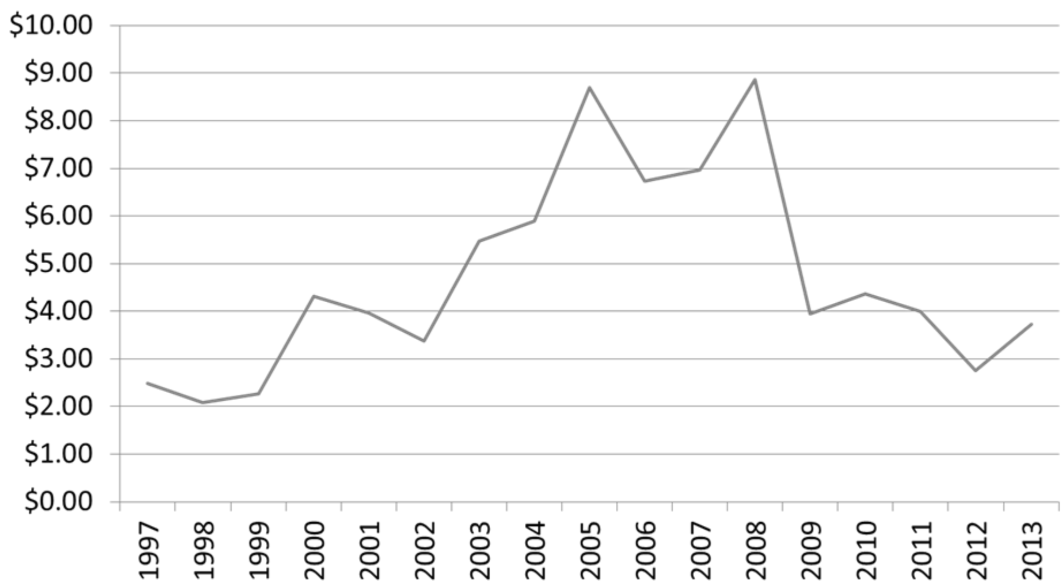
However, a great deal of uncertainty exists surrounding production of natural gas from nonconventional sources, which has played a dominant role in the recent American natural gas boom. As shown in figure 1.5 (a 20 business day average) and figure 1.6 (an annual average) even smoothed spot prices for natural gas are anything but stable. Natural gas spot prices, as calculated at the Henry Hub in Louisiana (the closest approximation to a national price) have ranged from near $2 per mBTU in the late 1990s to more than $6 or $7 during the housing boom and down again to the neighborhood of $3 per mBTU in 2012 and 2013, even ignoring the kind of seasonal variation that sent gas prices in the US northeast through the roof in the winter of 2013-2014.

Forecasting long and short-run variation in natural gas prices is difficult. Prior to 2008, few would have foreseen the dramatic increase in natural gas supply associated with innovations in hydraulic fracturing and the extraction of shale gas. Looking toward the future from 2007, we would have likely been concerned about rising costs of imports of liquefied natural gas that would be required by the US electricity sector and now we ponder whether demand for natural gas will expand quickly enough to meet new supply (Wang and Krupnick 2013) (Krupnick, Wang and Wang 2013) (Joskow 2013).



Source: Energy Information Administration

Figure 4.5 – Henry Hub Natural Gas Spot Price per mBTU, 20-business day average



Source: Energy Information Administration

Figure 4.6 – Henry Hub Natural Gas Spot Price per mBTU, annual average

As illustrated below in figure 1.7, short run natural gas price forecasts (based on futures contracts) as of January 2007 included a fairly wide confidence band, with prices expected to range between $3 and $20 per mBTU as of January 2008. Actual prices fell in the middle of the band through the middle of 2008, but have since held close to the minimum of the 5% confidence band as of January 2007 due to some combination of the recession and the “fracking boom”.

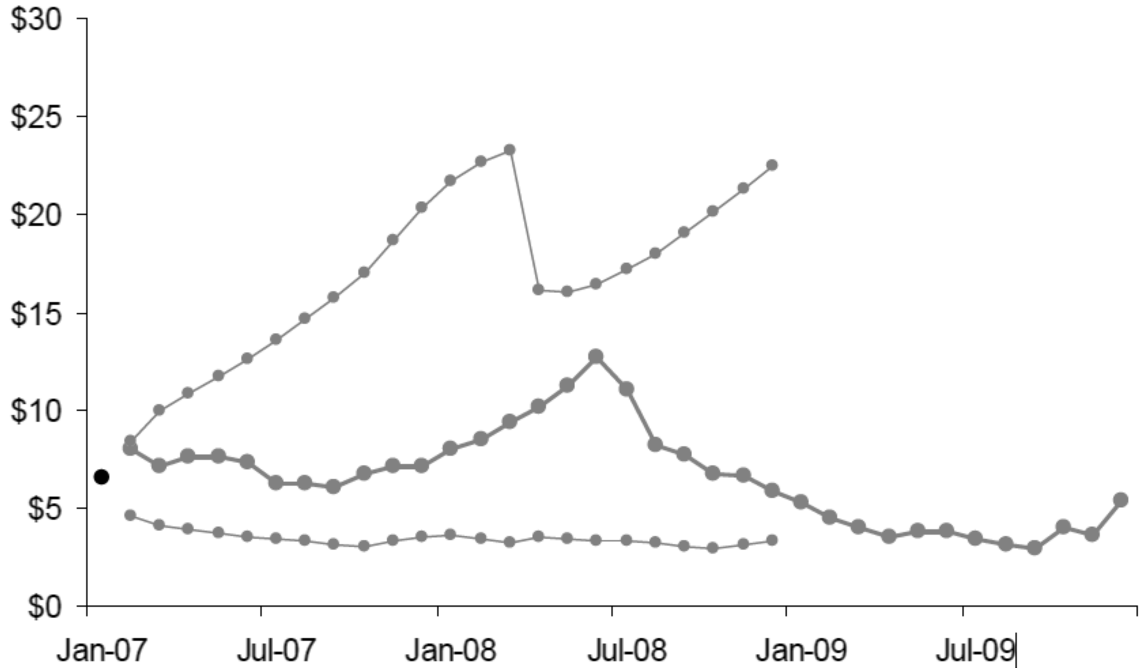


Figure 4.7 – Short-Term Natural Gas Price Forecasts, January 2007

Source: EIA Short-Term Energy Outlook (2007)

As difficult as it would have been to correctly forecast the scale of the fracking boom and the associated impacts on US natural gas supply and natural gas prices, it will be similarly difficult to correctly forecast the future trajectory of shale gas in the United States and globally. Stocks of technically recoverable nonconventional natural gas reserves, costs involved in extraction from shale plays, rates of decline in production from existing wells and costs associated with future environmental regulation or increased enforcement of existing legislation regarding hydraulic fracturing all exhibit significant uncertainty which will impact future expected natural gas productivity and market prices (Joskow 2013) . While short run natural gas price forecasts tend to be based upon futures markets, long run natural gas price forecasts tend to be based on assessments of extraction costs (Moniz, Jacoby and Meggs 2010), given assumptions of perfectly competitive markets which would lead excessively costly projects to be abandoned.

Natural Gas Price Scenarios

Current natural gas prices fall below the level assumed to be necessary to cover all project costs, leading to expectations that US natural gas prices over time will regress toward a $6 per mBTU level. It is such an assumption upon which levelized cost estimates are based for newly planned natural gas generation projects, which will have a lifespan spanning several decades. Over such a time horizon it is potentially equally valid to consider two alternative scenarios, a doubling or a halving of long run natural gas prices relative to the baseline scenario included in the levelized cost (LCOE) estimates. In the former, we might assume that US natural gas prices converge towards the global average spot price due to strict controls placed on hydraulic fracturing in the US to protect groundwater supplies (Logan 2013) making the US a potential market for LNG imports again. In the latter, we might assume either further innovation in hydraulic fracturing technology or a long-run maintainence of today’s natural gas market status quo, which could be considered to be unsustainable, in which natural gas drilling remains economically viable despite low natural gas prices due to high prices for natural gas liquids (Electricity Information Administration 2013) or other incentives. Neither scenario is likely to result in a significant divergence from the current electricity generation technology path of transition (Logan 2013) as the cost of natural gas generation would remain below that of advanced coal generation, but the costs associated with local energy policies such as HB-1365 and the Colorado RPS could be dramatically different.

Energy Policy Review

This study will attempt to quantify the economic impacts of Colorado energy legislation, given a variety of possible paths for natural gas industry productivity and hence natural gas prices. The medium and long-run economic costs of these policies will be assessed using a dynamic CGE model of the Colorado economy designed in conjunction with the National Renewable Energy Laboratory (NREL) under a variety of assumptions regarding future productivity in the natural gas industry in Colorado and the United States as a whole. A baseline impact of each policy component will be estimated independently compared to a counterfactual simulation of the Colorado economy given no policy-induced restrictions or changes to the electricity sector after 2010 under the mean assumption for domestic natural gas wellhead prices from the EIA. Special attention will be paid to the effect of each distinct policy component in increasing or decreasing the exposure of the Colorado electricity sector and broader economy to fluctuations in the price of natural gas.

A number of studies have performed analyses along the same lines in order to consider the economic impacts of renewable portfolio standards and other state and local energy policies. Though RPS policies in the United States are typically a form of state or local government leveslation, Palmer & Burtraw (2005) and Kydes (2007) analyze the national impacts using partial equilibrium energy models. A renewable portfolio standard is found to raise electricity prices and primarily displaces natural gas generation hence the impact of the RPS on electricity prices is sensitive to assumptions about natural gas prices (Palmer and Burtraw 2005). Stricter RPS standards, requiring greater than 15% or 20% renewables overall are estimated to incur higher costs as variability costs rise particularly. However, using the EIAs National Energy Modeling System, Kydes (2007) estimates that a nationwide RPS of 20% would raise US electricity prices by 3% by 2020 relative to a baseline scenario.

Chen et al. (2007) review a number of studies that attempt to assess the economic and other costs of actual or proposed renewable portfolio standards at the state level, 28 studies in 20 states. Few studies surveyed are peer-reviewed, most produced by consultancies sometimes as part of the policy review process by one interested party or another. Though the degree of academic and mathematical rigor associated with the results is unknown, most point to a relatively modest impact of renewable portfolio standards. In contrast to the EIA NEMS estimate of a 3% increase in electricity price, the vast majority of studies reviewed by Chen et al. (2007) predict an increase in electricity prices of 1% or less. These studies are do not involve complete CGE models, which have been demonstrated to be necessary for a full picture of the costs and impacts of emissions controls (Bergman 1991), however most project a small increase in electricity prices as a result of policy.

In a general equilibrium context, an increase in electricity prices will have effects that ripple throughout the broader economy, decreasing real incomes and raising costs of production. Though use of fully-fledged CGE models to analyze renewable portfolio standards and other state-level energy policies is somewhat rare neither is it novel. Bohringer et al. (2012) use a CGE model designed for the Canadian province of Ontario to analyze the economic impacts of a feed-in tariff for local solar distributed generation.

In analyzing the concept of "green jobs", Bohringer et al. (2012) find that while the feed-in tariff creates jobs in green sectors it decreases employment overall, they argue that energy policies intended to benefit the environment should be promoted based on environmental benefits rather than as job creating programs. In analyzing renewable energy and energy efficiency scenarios, CGE results from the state-level Berkeley Energy and Resource (BEAR) Model (Roland-Holst and Kahrl 2009) find the opposite result. Renewable energy is found to be "job intensive" relative to fossil fuel generation and stronger pushes towards energy efficiency and renewable electricity generation are found to lead to greater job gains.

According to Goulder & Stavins (2010) some have sought to analyze state and local policy not simply because this is the form that much energy and climate policy in the United States, due to the inability to pass legislation or lack of interest at the federal level. Such studies may be of interest theoretically in order to assess the desirability of state and local policy relative to national policy in cases where national policy is also under consideration (Goulder and Stavins 2010). In assessing the impact of state and local climate policy, in which the potential global benefits of CO2 emissions reductions are not affected by physical relocation of emissions producing activities, "leakage" of such activities across state (or national) lines is of importance in determining the amount of actual CO2 reduction and associated global benefit associated with the policy (Bushnell, Peterman and Wolfram 2008). This study will not attempt to quantify CO2 reductions of Colorado energy policies and will instead focus on local economic benefits and costs of the policies. An alternative line of analysis for state level policies is the optimal design of a system of state and federal policies (Bushnell, Peterman and Wolfram 2008) and of state level policies within an existing federal framework. In the case of Colorado, the desirability of certain environmental policies, particularly the RPS, is directly dependent upon the existing incentive framework created by the production tax credit, a framework which is not considered as a policy variable.

4.3 Energy Sector Modeling

Inclusion of Colorado energy policy changes in the model requires several modifications. The existing model includes five generation types, coal, natural gas, wind, utility-scale solar and hydroelectric power as well as a transmission sector which buys electricity from generators and sells it on the grid to end consumers. Application of the RPS requires a nesting in the transmission sector production function which allows substitution between electricity produced using coal and natural gas and among renewable sources (in this model only wind, solar and hydroelectric) but forbids substitution between the renewable and non-renewable nests. The proportion of transmission sector electricity input that must be purchased from renewables is determined exogenously by policy – given a higher cost for renewable than non-renewable (chiefly natural gas) electricity generation, no simulation would induce a higher percentage of renewable generation were model specified in such a way as to allow this to occur.

Because Colorado's RPS treats investor-owned (largest-scale) utilities different from municipal utilities and small-scale independent generators, these must be treated as separate sectors for the purposes of model specification. Since municipal utilities are typically located in areas that are not served by larger IOUs, representative households and production sectors demand electricity from IOU and municipal transmission sectors with no possibility of substitution between the two electricity inputs. Small-scale "wholesale distributed generation", which represents plants of any generation type with a nameplate capacity of 30 MW or lower modeled after the actual assortment of such generators in the state of Colorado today. The output of wholesale DG plants is assumed to be sold only to the IOU transmission sector, at higher cost, in the proportions mandated by RPS legislation.

For the purposes of model specification, "retail distributed generation" is considered to represent only residential and commercial use of photovoltaic solar arrays with net metering. This necessitates the creation of two new sectors, Commercial PV and Residential PV. Commercial PV produces electricity, which it sells to both industry sectors and the IOU transmission sector. Residential PV produces electricity, which it sells to both households and the IOU transmission sector. This electricity is treated as a separate production input or consumption good than the electricity purchased from either the IOU or municipal transmission sectors, with a higher willingness-to-pay explained by corporate social responsibility (CSR) and environmental concerns.

In the Colorado Energy (CO-E) CGE model, wholesale electricity produced by generation (IE sectors defined largely by production technology GENcoal (coal), GENgas (base load natural gas), GENpeak (natural gas "peaker"), GENwind (wind), GENhydro (hydroelectric), UTILpv (utility-scale photovoltaic for wholesale distributed generation), RESpv and COMMpv (residential and commercial photovoltaic, respectively, for retail distributed generation). Other generation types such as geothermal or nuclear are absent from the model because they represent an insignificant share of total generation in the state of Colorado and do not receive special treatment under the RPS legislation as solar photovoltaic does.

IE sectors demand a fuel-type-specific capital type (for coal, natural gas, wind, hydroelectric and solar photovoltaic) which is not demanded outside the IE sectors. This specification differs from a sector-specific capital type formulation primarily in that an existing natural gas plant could be used by either GENpeak or GENgas, as base load or "peaker" generation depending on relative demand and that existing solar arrays are assumed to be transferrable between the three solar sectors. Baseline estimates for these capital stocks are provided by the National Renewable Energy Laboratory and the Energy Information Administration as of 2011 and scaled back based on changes in state generation capacity estimates for the baseline simulations' starting point of 2006, the year before the first RPS requirements in the state.

For each IE sector a productivity parameter $PROD_{ie,t}$ determines a non-unitary baseline price, $P0_{ie}$, based on recent median EIA levelized cost of energy (LCOE) estimates. Levelized cost estimates represent an estimation of the average cost of generation over the lifetime of the plant, which typically lasts several decades, where the planning and construction process begins today but the plant is assumed to come online in approximately five years.

Equation 4.1

$$YE_{ie,t} = PROD_{ie,t} L_{l,ie,t}^{\alpha_{l,ie}} LA_{ie,t}^{\alpha_{la,ie}} K_{k,ie,t}^{\alpha_{k,ie}} Y_{i,ie,t}^{\alpha_{i,ie}} FX_{ie,t}^{\alpha_{fx,ie}}$$

$$\text{Where } \sum_l \alpha_l + \sum_k \alpha_k + \sum_i \alpha_i + \alpha_{la} + \alpha_{fx} = 1 \text{ for all } ie$$

$YE_{ie,t}$ = Real Output for Generation Sector *ie* at time *t*

$PROD_{ie,t}$ = Productivity Parameter for Sector *ie* at time *t*

$L_{l,ie,t}$ = Labor Inputs for Sector *ie* at time *t*

$LA_{ie,t}$ = Land Input for Sector *ie* at time *t*

$K_{k,ie,t}$ = Capital Inputs for Sector *ie* at time *t*

$Y_{i,ie,t}$ = Intermediate Goods Input for Sector *ie* at time *t*

$FX_{ie,t}$ = Import Inputs for Sector *ie* at time *t*

As shown in equation 4.1 above, electricity generation by IE sectors is specified using a simple Cobb-Douglass production function with constant returns to scale in all inputs. Among IE sectors, GENpeak and solar sectors have the highest LCOEs and hence the smallest values for

$PROD_{ie,t}$, GENgas and GENwind the lowest LCOEs and hence the largest values for $PROD_{ie,t}$. All $PROD_{ie,t}$ values are scaled such that the average cost of wholesale electricity in the base year remains unity. Of the seven IE sectors, only the outputs of COMMpv and RESpv are demanded directly by firms and households respectively. This represents demand for commercial and residential solar array output by owners, rather than indirectly through the grid. While COMMpv and RESpv output is demanded both by end consumers and grid sectors, output of other IE sectors is demanded exclusively by grid sectors as an intermediate input as shown in equation 4.2 below.

The three grid (GR) Sectors are IOU (investor-owned utilities), COOP (electric cooperatives) & MUNI (municipal utilities). COOP & MUNI assumed to service primarily non-urban consumers, their output is therefore demanded disproportionately by those industries and household groups most often found outside of metropolitan areas, with breakdowns based on estimates from the American Community Survey Public Use Microdata (ACS PUMS). Based on estimates from the Colorado Rural Electric Association, COOP is assumed to be 10% less productive than IOU while MUNI is assumed to be approximately 17% more productive than IOU due to differences in electric meters (customers) per kilometer of grid. This effect is represented by the productivity parameter $PROD_{gr,t}$, leading to non-unity baseline prices for each generation type but an average baseline electricity price of approximately unity for the system as a whole.

Equation 4.2

$$Y_{gr,t} = PROD_{gr,t} L_{l,gr,t}^{\alpha_{l,gr}} LA_{gr,t}^{\alpha_{la,gr}} K_{k,gr,t}^{\alpha_{k,gr}} A_{i,gr,t}^{\alpha_{i,gr}} ELEC_{gr,t}^{\alpha_{elec,gr}}$$

Production of the grid sector output $Y_{gr,t}$, retail electricity, is specified using a simple Cobb-Douglass functional form with constant returns to scale. In addition to labor (L), land

(LA), capital (K) and intermediate inputs (A) each grid sector demands a sector specific wholesale electricity bundle $ELEC_{gr,t}$.

Equation 4.3

$$ELEC_{gr,t} = MIN\left(\frac{RENEW_{gr,t}}{\gamma_{gr,t}^{RENEW}}, \frac{NONRENEW_{gr,t}}{\gamma_{gr,t}^{NONRENEW}}\right)$$

As shown in equation 4.3 above, ELECgr,t is produced using a Leontief formulation from a renewable energy bundle RENEWgr,t and a non-renewable energy bundle NONRENEWgr,t with the required shares determined by technology or policy parameters $\gamma_{gr,t}^{RENEW}$ and $\gamma_{gr,t}^{NONRENEW}$.

Equation 4.4

$$NONRENEW_{gr,t} = YE_{\text{GENgas,t}}^{\beta_{GENgas,ie,t}} YE_{GENcoal,t}^{\beta_{GENcoal,ie,t}} YE_{GENpeak,t}^{\beta_{GENpeak,ie,t}}$$

As shown in equation 4.4 above, the nonrenewable energy bundle for each sector is created using a simple Cobb-Douglas production function to transform GENgas, GENcoal and GENpeak into NONRENEW assuming an elasticity of substitution of unity. Baseline generation shares in the NONRENEW bundle are calibrated based on 2006 proportions for the Colorado electricity sector as a whole. As opposed to changes in the generation type mix due to renewables standards and the like, proportions of different fossil fuel types are not mandated by a regulatory authority and thus substitution in response to changes in relative prices can take place.

As shown in equation 4.5 below, the renewable energy bundle for each sector is policy determined and hence follows a Leontief production technology with no substitution between $YEGENhydro_{gr,t}$ and the solar and wind bundles.

Equation 4.5

$$RENEW_{gr,t} = MIN\left(\frac{YE_{GENhydro,gr,t}}{\gamma_{gr,t}^{GENhydro}}, \frac{SOLAR_{gr,t}}{\gamma_{gr,t}^{SOLAR}}, \frac{WIND_{gr,t}}{\gamma_{gr,t}^{WIND}}\right)$$

The bundle WINDgr,t, a component of the renewable energy bundle, includes a fixed proportion of both YEGENwind and YEGENpeak, as shown in equation 2.6 below. Due to the intermittent or variable nature of wind, which can neither be feasibly ramped up or down due to current demand conditions and which cannot be relied upon to operate at capacity when demand is predictably high (as base load GENcoal can) an increase in the share of wind generation is assumed to necessitate additional usage of and capacity for low-efficiency GENpeak. The amount of YEGENpeak bundled with a unit of YEGENwind is derived from estimates by Xcel energy of the total system costs associated with the variable nature of wind power (Wiser and Bolinger).

Equation 4.6

$$WIND_{gr,t} = MIN\left(\frac{YE_{GENwind,gr,t}}{1/_{1.048}}, \frac{YE_{GENpeak,gr,t}}{0.048}\right)$$

Equations 4.7 and 4.8 show the creation of the solar energy bundle $SOLAR_{gr,t}$ using Leontief production technology (with no opportunity for substitution due to policy) from

YE_{UTILpv} and the distributed generation bundle $DG_{gr,t}$, which is in turn created (see equation 2.8) from YE_{RESpv} and YE_{COMMpv}. Proportions are determined by the parameters $\gamma_{gr,t}^{UTILpv}$, $\gamma_{gr,t}^{DGpv}$, $\gamma_{gr,t}^{COMMpv}$ and $\gamma_{gr,t}^{RESpv}$. In the baseline scenario these are defined in order to calibrate the model to 2006 generation type shares, in RPS simulations these γ parameters are policy determined.

Equation 4.7

$$SOLAR_{gr,t} = MIN\left(\frac{YE_{UTILpv,gr,t}}{\gamma_{gr,t}^{UTILpv}}, \frac{DG_{gr,t}}{\gamma_{gr,t}^{DG}}\right)$$

Equation 4.8

$$DG_{gr,t} = YE_{RESpv,gr,t}^{\alpha_{RESpv,gr,t}} YE_{COMMpv,gr,t}^{(1-\alpha_{RESpv,gr,t})}$$

Whereas additional dependence on wind energy by the grid is expected to lead to an increased need for "peaker" plants due to the inherently intermittent and variable nature of the resource and the generation technology, the inherently intermittent and variable nature of solar energy is not expected to lead to the same result. Solar energy, by coincidence rather than by design, has a tendency to generate the most electricity at times of the day and times of the year when electricity demand is at its highest, when businesses are operating and when air conditioners are running (Kassakian and Shmalensee 2011) (Boyle 2012). Wind, on the other hand, has no such natural tendency to blow hardest when the days are hot or during the workday.

4.4 Policy Simulations

In general, the rigidity associated with electricity bundling in the CGE model is based upon requirements of the RPS itself. Estimates of the impact of the RPS on the electricity sector and the Colorado economy are solely derived from modification of the required proportions rather than the rigidity associated with these requirements, which is a given even in non-RPS simulations. As such, simulation results are best taken as representative of the impact of scaling up the RPS from its original, relatively modest level rather than from the system rigidity that the RPS brought upon the system. In fact, baseline values for γ parameters (in equations 4.3 and 4.5) in the absence of an RPS requirement lead to greater usage of renewables overall than the initial, low requirement in 2007 that the RPS mandated as the actual renewable share of generation capacity in 2006 was more than adequate.

The energy policy changes included in HB-1365 consist of three critical changes which must be modeled independently. The first is the early retirement of 551 MW of coal-fired generating capacity, equal to approximately 10% of existing stock. This is modeled as a simple reduction in the endowment of "coal generation capital" for the Colorado economy. The second and third changes are more complex. The bill mandates the retrofitting of 742 MW, approximately 13.6% of existing stock, with enhanced emissions controls. This is modeled as representing the change from conventional to advanced coal-fired generation as defined by the EIA, which increases capital requirements per mWh by approximately 28.5%. The production function for coal-fired generation is modified by the policy to require approximately 4% more capital per unit of output. Finally, the bill requires two power station units, with a combined capacity of 463 MW, currently fueled by coal but capable of burning natural gas to "fuel-switch" to natural gas in 2014 and 2017 respectively. Natural gas is the more expensive fuel by far as measured by energy content; however coal-fired stations require significantly larger capital investments per MW of nameplate capacity. This hybrid generating sector must be modeled independently; a sector which requires the non-fuel inputs of coal-fired generation but the fuel inputs of gas-fired generation. This sector will produce no output in the model prior to year 2014.

Current policy requires a 12% RPS for IOUs, a 3% RPS for municipal utilities and requires that 0.625% of electricity sold by the IOU transmission sector be purchased from wholesale DG and 0.625% from retail DG. 213 MW of the 551 MW of coal-fired capacity to be retired has already been retired. Simulations will estimate the economic impact of mandated increased in RPS requirements in 2015, 2017 and 2020 as compared to a counterfactual policy scenario under which current requirements are maintained in perpetuity.   The economic impact of each component (the RPS requirement for IOUs, the RPS requirement for municipal utilities, the wholesale DG carve-out, the retail DG carve-out, coal capacity requirement, coal plant retrofitting and fuel-switching) will be assessed separately and in combination under a variety of scenarios involving natural gas sector productivity and hence the natural gas price, ranging from a 50% decrease in productivity relative to mean EIA expectations to a 100% increase in productivity relative mean EIA expectations.

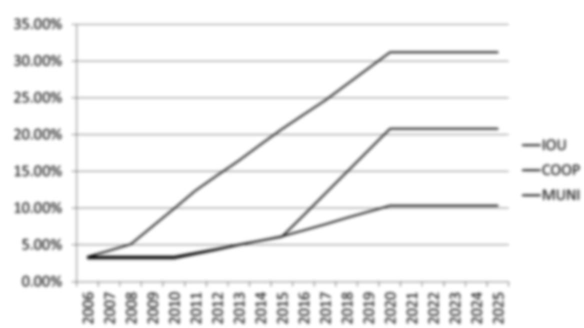


Figure 4.8 – Smoothed RPS Requirements for Model

In order to simulate Colorado's RPS:

- Set $\gamma_{gr,t}^{RENEW}$ and $\gamma_{gr,t}^{NONRENEW}$ to match RPS mandate
- $\gamma_{gr,t}^{RENEW}$ > mandated % due to inclusion of $YE_{GENpeak}$ in the bundle

- Set $\gamma_{gr,t}^{SOLAR}$ to match "solar carve-out", the required proportions of UTILpv, COMMpv and RESpv are already calibrated in the baseline scenario
- Set $\gamma_{gr,t}^{GENhydro}$ and $\gamma_{gr,t}^{GENwind}$ to force investment in wind (least-cost renewable) over hydroelectric
- Simulation begins in 2006, the last year before RPS mandate
- Assumed to move steadily towards the next binding mandate (initial mandates too low to constrain utilities) – as shown in figure 2.1 above

In order to simulate HB10-1365, the Clean Air – Clean Jobs Act

- Shock to endowment of Kcoal in 2012 (10% decrease)
- Additional K input requirement in production of $YE_{GENcoal,t}$ beginning in 2012 equivalent to 4.76% of Kcoal input use per unit, raising cost per unit by approximately 3%
- GENhybrid sector created, which requires fuel inputs in same proportions as GENgas per unit of output, other inputs as per GENcoal and is typically inactive in the model as it is a higher cost method of producing GENgas sectoral output
- ~8% of Kcoal converted to Kfs (fuel switching), the technology-specific capital type used by GENhybrid to turn on GENhybrid

Results

Costs of production in the electricity sectors are based upon recent LCOEs, assuming that the generation cost for any given technology is identical to the cost that would be incurred over the life cycle of a newly built plant no matter when that plant was originally built. This ignores both the possibility of uncertain potential innovations in generation technologies in the near future, and also the potential differences in generation costs between existing plants, which may have lower productivity but also cheaper and less environmentally friendly technologies "grandfathered in" (Katzer, et al. 2007), and newly built plants – as these are unknown. This modeling decision is deliberate, necessitated by the lack of plant-level efficiency data and by the extreme uncertainty surrounding assumed technology paths in solar and wind generation specifically. As a result, impacts of a transition toward solar and wind over the next decade or more could be considered to be a "worst-case scenario" with little if any productivity enhancing innovation to reduce the cost of renewable energy.

Due to assumptions regarding levelized costs and the transition path for electricity generation technology shares in the absence of a renewable portfolio standard, in the baseline scenario – a steady transition towards natural gas and away from coal for base load generation – we see a slow and steady decrease in the cost of electricity and hence the price of electricity given competitive market assumptions. Given current natural gas prices and current projections of future natural gas prices, the cost of natural gas generation (over the life of the plant) is approximately 2/3 of that of coal generation. As shown in figure 4.9 below, from 2006 – 2025 the price of electricity is expected to decline by approximately 8% as older and less efficient coal plants are replaced by newer and more efficient combined cycle natural gas plants

In the two alternative baseline simulations, with increased and decreased natural gas productivity respectively, the transition towards natural gas and away from coal is expected to continue unabated. Even with natural gas prices twice as high as currently forecast levels, combined cycle natural gas generation remains less costly than new coal-burning plants. As aresult, electricity prices decline over time in the low productivity simulation (in which natural gas prices approximately double) as well, though from a somewhat higher initial level.

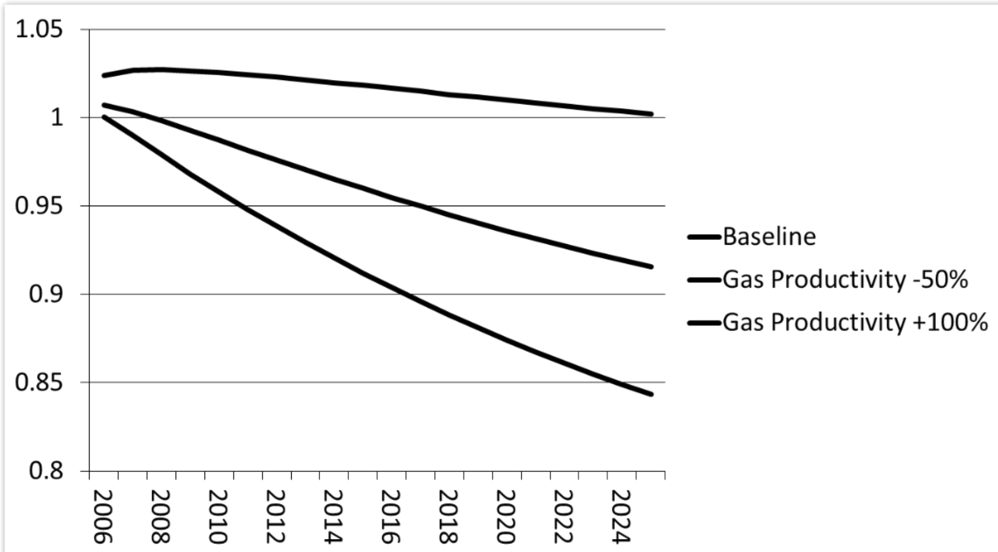


Figure 4.9 – Retail Electricity Price Paths, Baseline Scenarios

Relative to the baseline scenario with no shock to the natural gas sector, large shocks to natural gas productivity can be expected to have a relatively profound impact on the Colorado economy by 2025 as shown in table 4.1 below. The impact on employment is relatively modest, particularly for an increase in natural gas sector productivity which creates fewer than 100 jobs overall, but the change in state and local tax revenues (nearly $1 billion in current $) and real household consumption (a loss of $5.658 billion with low natural gas productivity, a gain of $1.891 billion with high natural gas productivity) – a proxy for welfare - are substantial. The impact on government revenues represents an increase or decrease of approximately 2.7% of expected revenues in 2025 in the baseline scenario. The impact on real household consumption represents a drop of approximately 2.5% relative to expected consumption in 2025 in the baseline scenario when natural gas productivity is low and an increase of approximately 0.8% when natural gas productivity is high.

The impact of changing natural gas productivity is felt through several different channels, the most important of which are the reduction in electricity and heating costs which benefit consumers and some industries more than others and also through a net export effect. Demand for Colorado "exports" to the ambiguously defined rest-of-world is assumed to follow a fairly simple ad-hoc formulation, with a unitary elasticity of demand and no explicit requirement for exports to equal imports. Demand for "imports" within Colorado, on the other hand, follows an Armington specification wherein Colorado firms and households demand a composite good composed of both domestic and "foreign" varieties of the same good. As a result, when productivity increases lower the price of both Colorado and imported natural gas their respective shares in the composite good do not change. In situations such as this, where Colorado demand for the Armington natural gas good exhibits inelastic demand overall the effect of the productivity shock can be a significant increase in net exports of natural gas from Colorado. This increase in net exports lifts the prices of domestic homes, capital and land, raises prices for certain (less traded) sectoral outputs and leads to an increase in real wages barely balancing an increased cost of living. Migration in the CO-E model responds exclusively to changes in real wages, rather than to changes in capital or other income. Most of any long-run increase in total employment is due to changes in migration; hence the impact of the net export effect on total employment is rather muted despite the large gains in consumption and income.

With natural gas productivity and prices based upon long run assumptions in recent EIA LCOEs, which is to say no additional shocks to natural gas sector productivity, both HB-1365 and the Colorado RPS are expected to lead to higher electricity prices and decreased overall employment. In the case of HB-1365, this is accompanied by falling state and local tax revenues and falling real household consumption. As modeled, HB-1365 represents both a more rapid and less efficient transition towards natural gas than the assumptions underlying the baseline scenario as well as an increase in the cost of base load coal-fired generation in order to control non CO2 emissions (such as SO2, NOX and particulates).

Table 4.1 - Impact of Natural Gas Prices

All Values in 2025	-50% Productivity Shock	+100% Productivity Shock
Employment	-64,793.76	96.96
State Total Tax Revenue (mil. of $)	-597.58	597.21
Local Total Tax Revenue (mil. of $)	-409.25	355.18
Total Real Household Consumption (mil. of $)	-5,658.60	1,891.10
HH1 ≤ $10,000	-313.88	63.92
$10,001 < HH2 ≤ $20,000	-242.59	55.22
$20,000 < HH3 ≤ $40,000	-400.36	104.59
$40,000 < HH4 ≤ $50,000	-405.69	81.51
$50,000 < HH5 ≤ $70,000	-751.50	118.92
$70,000 < HH6 ≤ $100,000	-1,105.11	297.00
$100,000 < HH7	-2,439.41	1,169.94

A key modeling assumption is that grid sectors have at least a slight preference for the status quo in terms of generation technology mix and that different generation types such as base load coal and base load gas are not perfect substitutes. Were this not the case, GENcoal and GENgas output would sell for the same price as GENgas, with any policy impacts felt first and foremost in dramatic swings in the market price of the fuel-type-specific capital Kcoal or Kgas. This would be plausibly compatible with assumptions of perfect competition built into CGE models, provided a genuinely infinite or near infinite elasticity of substitution between coal and gas generation. However, past research (Dagher 2011) (Energy Information Administration 2012) has found elasticities of substitution to be significantly lower, particularly in the short run.

In addition, and assumption of rapid changes in electricity prices due to changes in the price of generation capital may be compatible with assumptions of perfect competition but they may be wholly incompatible with the way that electricity prices are set in a market which is wholly uncompetitive, but heavily regulated to imitate a perfectly competitive outcome (DORA n.d.). As a result, as GENcoal output is made more costly to produce through legislation, and as the relatively inefficient GENhybrid fuel-switching sector is activated these cost increases are passed on to consumers in HB-1365 simulations through higher electricity prices.

Unlike with HB-1365, for the RPS simulation independent of HB-1365 a larger decrease in overall employment in 2025 (by which time each policy's full effects should be felt) is accompanied by rising state and local tax revenues and rising real household consumption, though not for the highest income household groups. Though perhaps somewhat counterintuitive, this apparently paradoxical result can be explained relatively simply: wind and solar electricity generation is vastly more capital intensive than traditional fossil fuel generation. As a result, the RPS mandate has the effect of tilting the balance ever so slightly towards increasing the capital share of income and decreasing the labor share of income in addition to raising the price of electricity above the assumed transition-to-gas baseline. Since migration and labor supply are driven by changes in real wages rather than changes in capital or other income there is nothing inherently strange in such a result, that employment falls while consumption and incomes rise.

The simple fact that the effect on real household consumption is positive, rather than negative, despite the fact that the Colorado RPS raises electricity prices above what they would have been in the transition-to-gas baseline has a simple explanation as well.

Table 4.2 - Impact of Energy Policies

All Values in 2025	HB-1365	RPS	HB-13-65 & RPS
Employment	-6,013.14	-14,204.88	-19,044.96
State Total Tax Revenue (mil. of $)	-11.26	73.74	64.08
Local Total Tax Revenue (mil. of $)	-10.96	27.75	18.93
Total Real Household Consumption (mil. of $)	-329.60	72.40	-197.00
HH1 ≤ $10,000	-19.34	72.63	55.28
$10,001 < HH2 ≤ $20,000	-12.21	59.50	48.45
$20,000 < HH3 ≤ $40,000	-22.62	32.11	12.91
$40,000 < HH4 ≤ $50,000	-24.15	17.61	-2.49
$50,000 < HH5 ≤ $70,000	-48.17	17.60	-21.62
$70,000 < HH6 ≤ $100,000	-73.80	-57.78	-116.52
$100,000 < HH7	-129.29	-69.26	-173.00

Though the difference in cost between wind power and base load natural gas generation is substantial if federal tax benefits (chiefly the production tax credit) are ignored when these are included the total system costs are quite comparable. In addition, as this is a regional rather than a national model the assumption is that subsidy payments (or tax credit pseudo subsidies) represent a burden that falls primarily on taxpayers outside of the state. Hence, an increase in wind and solar generation leads to an increase in net transfers from the federal government to the state economy. A similar impact can be expected to that of an increase in social security payments, a decrease in federal taxes or an increase in net exports. As such the assumption that the US production tax credit for wind energy will be maintained is critical to the result: were this legislation to fail to be extended, the Colorado RPS would unquestionably lead to lower real incomes and lower real consumption as well as a substantially larger increase in electricity prices than under these assumptions. However, the prevalence of renewable portfolio standards and other state and local wind energy policies suggests that broad support for the continuation of the policy is likely to be found – as these policies may make sense at the state and local level only given certain complementary federal policies.

Of great interest is how the economic impacts of HB-1365 (which increases Colorado dependence on natural gas) and the RPS (which decreases Colorado dependence on natural gas) differ in the two alternative baseline scenarios. Table 4.3 displays results with a negative productivity shock and hence high natural gas prices and table 4.4 displays results with a positive productivity shock and hence low natural gas prices. The negative economic effects of HB-1365 are increased with high natural gas prices, but the increase in the burden is fairly modest: 11.6% more job losses and a 12.5% greater reduction in real household consumption. However, in the low natural gas price scenario the reduction in economic burden associated with HB-1365 is more dramatic with fewer than ½ as many job losses as in the baseline scenario with no natural gas productivity shock and 44.2% lower drop in real household consumption, chiefly due to the improved price competitiveness of "fuel-switching" plants with standard coal plants as natural gas prices decline. It should be noted that the sign associated with the effects of HB-1365 is unaffected by any decrease in natural gas prices: the effect on employment, government revenues and consumption remains negative.

Whereas higher natural gas prices can be expected to increase the negative impacts of HB-1365 the opposite would be expected to be true of Colorado's RPS. The impact of the RPS on total employment remains negative in all three scenarios, though job losses are nearly 4,000 lower when natural gas prices are high than in the baseline scenario with no natural gas productivity shock. The effect on employment is nearly symmetrical when natural gas sector productivity is low with an increase in job losses of slightly more than 4,000.

Using real household consumption as a proxy for total welfare, unlike in HB-1365 simulations the impact of the Colorado RPS is either positive or negative depending on the price of natural gas.

Table 4.3 - Impact of Energy Policies with -50% Natural Gas Productivity Shock

All Values in 2025	HB-1365	RPS	HB-13-65 & RPS
Employment	-6,714.40	-10,271.30	-16,012.00
State Total Tax Revenue (mil. of $)	-11.12	70.20	59.55
Local Total Tax Revenue (mil. of $)	-11.17	30.76	20.87
Total Real Household Consumption (mil. of $)	-370.70	259.00	-59.00
HH1 ≤ $10,000	-22.77	74.56	54.03
$10,001 < HH2 ≤ $20,000	-14.34	59.23	46.24
$20,000 < HH3 ≤ $40,000	-25.93	41.66	18.89
$40,000 < HH4 ≤ $50,000	-27.52	30.03	6.16
$50,000 < HH5 ≤ $70,000	-53.57	42.56	-3.21
$70,000 < HH6 ≤ $100,000	-81.97	-7.09	-76.35
$100,000 < HH7	-144.65	18.06	-104.81

In the high gas price scenario, the increase in real household consumption with the RPS is greater by $176 million. In the low gas price scenario, which assumes further improvements in fracking technology or other reasons to continue shale gas projects for which gas revenues do not cover costs, the impact of the RPS on real household consumption becomes negative overall, though four of the seven household groups see increases in consumption. Total real household consumption falls $144.4 million below the estimated value in 2025 given the assumed transition-to-gas path with high natural gas productivity.

The interaction between HB-1365 and the Colorado RPS when both policies are simulated together does not show any dramatic complementarities. In terms of gross impact, HB-1365 effects on real household consumption dominate while RPS effects dominate for employment and tax revenues. RPS impacts are vastly more sensitive to assumption about natural gas prices and productivity hence combined impacts generally vary in the same way as RPS impacts.

Table 4.4 - Impact of Energy Policies with +100% Natural Gas Productivity Shock

All Values in 2025	HB-1365	RPS	HB-13-65 & RPS
Employment	-2,760.26	-18,227.22	-21,038.92
State Total Tax Revenue (mil. of $)	-13.85	76.65	69.98
Local Total Tax Revenue (mil. of $)	-13.67	24.33	18.10
Total Real Household Consumption (mil. of $)	-183.80	-144.40	-318.60
HH1 ≤ $10,000	-11.36	67.61	56.12
$10,001 < HH2 ≤ $20,000	-7.53	57.66	50.29
$20,000 < HH3 ≤ $40,000	-10.90	20.17	8.52
$40,000 < HH4 ≤ $50,000	-11.11	2.98	-8.98
$50,000 < HH5 ≤ $70,000	-37.29	-11.11	-39.22
$70,000 < HH6 ≤ $100,000	-45.63	-113.69	-152.43
$100,000 < HH7	-59.95	-167.94	-232.86

In general, negative impacts of the combined policies are slightly lower than would be assumed by simply adding the impacts of the two policies together. For example, with no natural gas productivity shock HB-1365 leads to a loss of 6,013 and the RPS leads to a loss of 14,205 jobs but the combined policy leads to a loss of 19,045 jobs rather than 20,218. Also worth of note is the fact that impacts of the combined policies overall are negative as far as both employment and real consumption are concerned for all three alternative scenarios. Though the impact of the RPS on consumption is positive with high or moderate natural gas prices the impact of the RPS and HB-1365 combined remains negative.

4.5 Conclusions

At first glance it might appear appropriate, given total real household consumption as the most appropriate proxy for economic welfare to view HB-1365 and the Colorado RPS as risky policies. HB-1365 has uncertain costs, which vary with natural gas price assumptions, but could be justifiable based on environmental and health benefits. Though the Colorado RPS will also have associated environmental and health benefits given certain assumptions about future natural gas prices (and federal tax credits) the RPS could be beneficial even in the absence of environmental benefits. It would be tempting, in particular, to imagine the RPS as a gamble – one that would result in losses should the price of natural gas stay low but result in gains otherwise. Such a policy might be preferred to the status quo, the transition-to-gas path followed by non-RPS states, given a relatively low probability of low natural gas prices and/or a relatively risk-neutral state government.

The addition of potentially substantial environmental benefits would alter the equation substantially. Previous studies such as Cutler et al. (2013) have estimated the damages associated with NOx and SO2 associated with fossil fuel electricity in Colorado to be approximately $540 and $1,052 per ton respectively using the APEEP model (Muller and Mendelsohn 2007). However, as emissions of SO2 in particular are dramatically lower from natural gas plants than from coal plants the additional ancillary benefit associated with the Colorado RPS are fairly modest, estimated to be between $4 and $6 million per year above and beyond the approximately $35 million per year associated with the transition-to-gas path (Cutler, et al. 2013). The Colorado RPS would also result in substantial reductions in CO2 emissions of potentially between 4 and 5 million tons (Cutler, et al. 2013). With an estimated appropriate value of carbon dioxide emissions reductions of between $13 and $31 depending upon the choice of appropriate discount rate (Greenstone, Kopits and Wolverton 2013) CO_2 reductions associated with the Colorado RPS represent a substantial ancillary benefit, potentially enough to balance out the negative impact on total real household consumption with low gas prices. In addition, these estimates of potential ancillary benefits ignore the other environmental impacts of natural gas production in the state and outside of the state, including possible groundwater contamination and potentially large methane emissions from the wellhead or in transmission of natural gas from the wellhead, estimated to be between 3.6% and 7.9% of all natural gas extracted (Howarth, Santoro and Ingraffea 2011). However, while most ancillary benefits associated with NO_2 and SO_2 emissions are relatively localized ancillary environmental benefits associated with CO_2 and methane emissions reductions are global and only a minute fraction of the total \$13 to \$31 impact could be expected to be felt within a state. For the purposes of state or local energy policy, it may not be rational to use global ancillary benefits as justification for policy, unless the "warm glow" effect is expected to be equivalent to the actual global damages averted. It is well and good that the Colorado RPS appears potentially desirable when local impacts are considered exclusively as other benefits, though potentially large, may not give an appropriate benchmark.

If we assume that the three natural gas scenarios given above are equally likely, the Colorado RPS is fairly simple to analyze using an expected utility framework with constant relative risk aversion. With an expected value over the gamble of \$62.47 million, only a strongly risk averse state would prefer the status quo to the "risky" expected benefit of \$62.47 million in additional consumption given a 2/3 chance of exceeding that expected benefit and the relatively small gains or losses compared to baseline consumption. However – this line of reasoning would seem incorrect in one critical area. While the size of and even existence of a net benefit from a renewable portfolio standard is uncertain, and hence such an RPS would represent a layer of uncertainty for the Colorado economy, as shown in table 3.1 the Colorado economy is already fairly heavily exposed to the uncertainties and economic risks associated with natural gas prices themselves. Potential gains and losses to the Colorado economy in terms of total real household consumption from natural gas productivity shocks themselves, as for any region which is both a substantial producer and consumer of natural gas, dwarf the expected impacts of the RPS and push the economy in opposite directions. Given an uncertain baseline scenario, the Colorado RPS acts as an insurance policy against economic risks associated with natural gas productivity shocks. What is more, in contrast to other potential means of hedging or insuring against such risks in state energy policy (such as long-term contracts for "imported" natural gas or derivatives contracts) the expected value of the RPS is estimated to be positive rather than negative – a deal too good to pass up.

Chapter 5

The Long-Run Regional Impacts of Defunding Higher Education

5.1 Introduction

In recent years the long-term trend of decreasing state support for higher education (Hemelt and Marcotte 2011) has accelerated due to falling state revenues during the Great Recession (Colorado Commission on Higher Education 2013). Largely as a result of recent decreases in state funding, resident undergraduate tuition rates for Colorado public universities have increased by between 24.4% and 68.7% over the last 5 years (Colorado Commission on Higher Education 2010). Though a rebound in tax receipts for the state of Colorado and many other local governments around the country has alleviated budgetary pressures, given the long-term trends a future without public funding of higher education does not seem implausible. In the context of Colorado, this would likely be due to mandatory spending increases on other government services coupled with restrictions on tax rate changes, but similar scenarios may be present in other regions with other contexts (Vossensteyn 2004). Vossensteyn (2004) describes a general global trend towards forcing students and households to bear a greater share of the burden of higher education expenditures.

Education in general and higher education specifically are considered to provide several types of benefits to a regional economy – the most important of these being increased productivity in the workplace (Erosa, Koreshkova and Restuccia 2010). In addition, higher education is considered to generate a number of social benefits (Psacharopoulos and Patrinos 2004), which improve public health and safety (Cohn and Geske 1992), diminish the need for expensive state services (Venniker 2000) and help to improve the productivity (as measured in quality of output rather than cost) of K-12 education for the next generation (Oreopoulos, Page and Stevens 2006). An increase in the share of the labor force with degrees of one percentage point has been estimated to raise wages for those without degrees by 1.6% to 1.9% (Moretti 2004) indicating a tangible external economic benefit as well as the direct. All of these benefits, though potentially substantial, have two important characteristics from a policy perspective. They are a function of the proportion of the population with degrees rather than the production of higher education itself and take a significant period of time to manifest. As a result, were all institutions of higher learning in a region to close their doors today, the effects would not be felt tomorrow as the proportion of the population with degrees would remain largely unchanged. In addition, a region benefits from an individual's education whether or not that individual was educated within that region.

This study will attempt to quantify the long-run (30 years or more) economic impacts of cuts in funding to higher education in the state of Colorado over the past 5 years as well as the further impact of complete defunding of higher education in the state should the budgetary picture worsen using a dynamic CGE model for the state of Colorado custom designed for analysis of issues surrounding human capital and education.

Though many studies have shown a positive economic impact of government spending on higher education, in some ways it may be reasonable to imagine both that these studies may overstate the impact through estimates used for sensitivity of higher education demand to changes in tuition or college wage premiums and also that the State of Colorado may be a special case. Colorado has one of the highest rates of educational attainment in the United States despite relatively modest spending on education in general and particularly higher education compared to other states. The reason for this is positive net in-migration, which tends to be biased towards younger and better-educated individuals who are more likely to move, which has not only allowed Colorado to benefit from other states' education expenditures in the past but may also cushion future impacts of funding cuts for Colorado higher education. In part this study aims to serve as a sensitivity analysis for general equilibrium studies of higher education funding in general; if it is found that higher education spending remains beneficial – and that defunding is economically damaging – even in the State of Colorado and even with extreme assumptions regarding sensitivity of higher education demand to changes in tuition and wage premiums it is likely to be beneficial quite nearly everywhere.

Theoretical Basis for Human Capital Models

Investment in education has long been viewed as a channel to create "human capital", increasing the skills and productivity of the labor force (Mankiw, Romer and Weil 1992), and hence to bear tangible economic benefits both for the individual in question (W. E. Becker 1992) and for the local economy (Benhabib and Spiegel 1994, Blundell, et al. 1999) . However, as much of the benefit accrues to the individual in the absence of inefficiencies private markets and transactions might be expected to result in an optimal rate of investment in higher education as with other capital investments (Marglin 1963). What is more, education is often viewed as having both an investment good aspect and also a consumption good aspect (Oreopoulos and Salvanes 2011) (Oreopoulos and Salvanes 2009), leading some to suggest the potential for "overinvestment" in higher education from a real return perspective (Bishop 1996).

Demand for higher education and the associated output of human capital can be expected to be negatively related to the price of higher education (W. E. Becker 1990) as with any other investment or consumption good and positively related to the wage premium or return on investment (Freeman, Demand for education 1987). However, due to higher education's dual role with characteristics of both consumption and investment goods (Jacob, McCall and Strange 2013) it would not be appropriate to assume a demand specification common for pure investment goods: wherein quantity demanded rises to hold real risk-adjusted returns (Modigliani and Modigliani 1997) constant across investment types. Education's corollary utility benefits would be expected to lead to lower than normal risk-adjusted returns (Ashworth 1997) in the absence of inefficiencies in the market for higher education and no obvious role for government. However, ample research has shown that such inefficiencies are widespread and represent significant constraints to individual investment in higher education and human capital formation (Kane 2006).

Borrowing constraints have been shown to limit access to higher education, particularly for disadvantaged social groups (Walters 1986). Differing perceptions of the value of time (Freeman, Overinvestment in college training? 1975, Betts and McFarland 1995) and the social value of a degree (Staff and Kreager 2008) as well as expectations of access (Carneiro and Heckman 2003) or treatment (Gibbs 1973) have been suggested to be related to widely different enrollment and attainment rates across groups (Orfield 1992, Paulsen 1998). If higher education is perceived as a risky investment, this may lead to underinvestment and lead to a potential role for government (Arrow and Kruz 2013) as it is not possible to diversify an individual's portfolio in this area. The innate skills of the student may themselves be considered as an important input in the production of higher education and human capital, imposing a greater unobservable cost in time and effort on some (Schultz 1961, Card 2001) and further limiting total human capital investment when those in possession of innate skills are not those with access (Stark, Helmenstein and Prskawetz 1997). For these reasons, as well as the potential external benefits of individual investment in human capital formation through higher education, a case can be made for government incentives or provision of higher education (Kane 2006).

Other Demographic and Education Models

Colorado faces budgetary pressures threatening the reduction of state incentives for higher education while simultaneous expecting long run shifts in the labor market and increases in the dependency ratio as the “baby boomer” generation retires. (Heckman, Lochner and Taber, Human capital formation and general equilibrium treatment effects: a study of tax and tuition policy 1999) have argued that the computable general equilibrium approach is necessary for proper evaluation of the impacts of education spending as partial equilibrium models tend to give overly optimistic estimates of what education policy can achieve. A number of other studies have been conducting using computable general equilibrium or overlapping generations models to estimate the broader economic impacts of human capital investments and changing population demographics. Human capital formation is inefficient and suboptimal, government policies to foster creation and maintenance of human capital are both efficient and equitable (Heckman and Jacobs 2010). Some have approached the issue of human capital formation and current demographic trends using OLG models (Kim and Hewings 2013a, Kim and Hewings 2013c, Kim and Hewings 2013b), where government incentives increase human capital formation they may provide positive net benefits when taxes are not too distortionary (Annabi, Harvey and Lan 2011). Also in the context of an aging Canada (Fougere, Mercenier and Merette 2007, Fougere, Harvey, et al. 2009) endogenous human capital formation through higher education is found to reduce the negative economic consequences of the fall in labor supply. A similar result is found in the case of an aging China (Peng 2005), wherein increases in public education spending provide net economic benefits and help to offset the effects of an aging population.

Demand for Higher Education

Part one of this study will describe the Colorado Demography model, a detailed, multi-sector dynamic computable general equilibrium model of the economy. Part two will illustrate the baseline projections for the Colorado economy based on current population trends to 2050 under alternative specifications regarding migration and total factor productivity growth. Colorado, like Canada (Fougere, Harvey, et al. 2009), Scotland (Lisenkova, et al. 2010), China (Peng 2005), Chicago (Park and Hewings 2007) and most of the developed world faces slowing labor force growth and rising dependency ratios in the not too distant future. In Colorado the impacts may be lessened by net in-migration, primarily of working-age adults. However, whereas in other circumstances increased government investment in higher education has been proposed as a way to offset the effects of the labor supply impacts of demographic change, the policy question in Colorado – and in truth many other regions as well – is whether to reduce government investment in higher education in order to reallocate funds elsewhere, putting more of the burden of higher education spending on households. As such, the critical questions that must be answered are how much total spending on higher education will decrease as households find college less and less affordable (Heller 2001) and to what extent migration can offset the impacts not only of demographic transition but also of declining state funding for higher education through the in-migration of educated workers.

Many studies have attempted to provide estimates for the key parameters in education demand; responsiveness to tuition, fees and financial aid, responsiveness to income, responsiveness to the wage premium associated with the degree and responsiveness to the price of other types of higher education (private vs. public, in-state vs. out-of-state). Strong responses to the wage premium or to the price of public universities in private university demand would serve to minimize the overall household demand response to a reduction in state funding, as would a weak response to tuition, fees and financial aid or a weak response to the price of in-state universities in the demand for out-of-state universities. There is a rich literature attempting to quantify these parameters, much of which is reviewed in (R. G. Ehrenberg 2004), (Freeman, Demand for education 1987), (Leslie and Brinkman 1987) and (Heller 1997). However, estimates vary widely – in the case of the own-price elasticity of demand for higher education from insignificance (Shin 2006) to an average from older studies of -0.73 (Leslie and Brinkman 1987).

Much of the variation may be due to differing specifications regarding selectivity (R. G. Ehrenberg 2004), but it may also be due to control variables and econometric specification, classification of the enrollment variable, different time frames and regions of analysis. It has been argued that tuition and fees should be treated as endogenous (Neill 2009) due to tuition adjustments to cover fixed costs and that estimates which take this endogeneity into account will give larger elasticity estimates than those that do not. Studies looking at short-term decisions by current students have tended to find very small elasticities with respect to tuition and fees (Bryan and Whipple 1995, Sterken 1995). Analyses of individual institutions (Allen and Shen 1999, Wetzel, O'Toole and Peterson 1998) have tended to find somewhat larger estimates, suggesting that the scale of the region or system in question may affect price sensitivity as empirical results from gravity models show that enrollment probability at specific institutions is inversely related to distance (Alm and Winters 2009), so smaller regions or systems may have more "close substitutes" in neighboring regions. Furthermore, failing to control for tuition changes at out-of-state substitutes may bias tuition elasticity estimates downwards (Hilmer 1998). (Hemelt and

Marcotte 2011) have found that the tuition elasticity varies for different types of public institution, with research institutions more strongly affected.

Those who have analyzed aggregate enrollment rates (rather than institutions, or micro data for analysis of enrollment probability) for US states and have also reached varying conclusions, from an elasticity of -0.15 (Fortin 2004) to approximately -0.6 (Berger and Kostal 2002) though the latter is not specified as a true elasticity. Some have found greater responsiveness to financial aid awards than tuition (Heller 1999) or greater responsiveness by some ethnic or social groups than others. Estimates from European countries may be difficult to compare, as many institutions charge no tuition or fees or tuition changes may be from zero to some positive number. However, when measured in terms of enrollment rate change per $1000 results are similar to those from the US and Canada and equally varied, from no discernible effect (Canton and De Jong 2005) to a 6.5% change in enrollment for a $1000 increase in tuition and fees (Hubner 2012).

Estimates for the cross-price effects of university tuition and fees are likewise mixed. (McDuff 2007) finds a negative, though statistically insignificant in some models, relationship between public university enrollment and private university tuition. (Thompson and Zumeta 2001) offer an explanation for this confusion: when analyzing demand for private universities, demand for the top tier is wholly unresponsive to changes in public university tuition while demand for lower tiers is highly responsive. Looking at the introduction of fees in Germany, a significant increase in out-of state enrollments was found to have occurred in regions where fees were introduced (Dwenger, Storck and Wrohlich 2012). Income elasticities have been found to be close to one (Canton and De Jong 2005) though accurate parameters are difficult to come by in studies using regional aggregate data as much of the effect may be picked up in coefficients on wages or wage premiums (Berger and Kostal 2002) though more likely to be inelastic than elastic in this respect. Estimates for the elasticity of demand with respect to the college wage premium (Mattila 1982) (Freeman 1987) tend to be greater than one, sometimes much greater than one.

Sadly, all that is generally accepted in parameterization of the demand for higher education is that the elasticity of demand with respect to tuition, fees and aid is inelastic – perhaps somewhat inelastic and perhaps highly inelastic. The elasticity with respect to income is positive, perhaps close to one. The elasticity with respect to price of substitutes, if properly specified, might range from very high to nearly zero depending on the institutional characteristics but should be positive. Demand for higher education is probably elastic with respect to the college wage premium, perhaps somewhat elastic and perhaps highly elastic. As a result of the uncertainty involved – primarily as regards the size of parameter estimates rather than their significance or sign – in part 3 this study will attempt to quantify the impacts of a potential cut in higher education funding under a variety of different assumptions regarding key parameters of the higher education demand function. As in the Colorado case, this cut in funding certain to be directly connected to a reallocation to K-12 education and other government services, tax rates will remain unchanged. This study will focus only on higher education, ignoring the impacts on human capital and skill formation of K-12 spending, which may be not only substantial but also complementary to higher education investments (Heckman 2000). An extension to include potential labor market effects of an increase in K-12 spending will be left for future research.

5.2 Model and SAM Structure

The social accounting matrix (SAM) of the Colorado Demography (CO-D) model is similar to that of the basic Colorado model, and the CO-RE and CO-E models, with some important differences. The CO-D model is built to incorporate long run changes to the economy associated with education, experience and the aging of the population. As such, the inclusion of additional rows/columns to enable the CO-D model to accurately reflect such changes has necessitated the removal of others. The CO-D model lacks the capital and energy sector detail of the CO-RE and CO-E models, as well as the "Public Administration" sector and the "Land" factor of production.

In the Colorado Demography model household groups are defined by the age of the household head, in five-year increments, based on information derived from 2007-2011 ACS PUMS data for the state of Colorado. HH1 households have a household head between the ages of 16 and 20 all the way up to HH12 households with household heads 71 and older. HH13 represents households defined by the Bureau of the Census as "Group Quarters", chiefly those residing in dormitories, prisons and military bases. In the absence of consumer spending data broken down by age, household spending proportions are derived from IMPLAN estimates using household income level to define household groups. Income levels are first determined for HH1 through HH13 based on ACS data and BEA income aggregates, spending proportions are then assigned based on the estimated income level of the household groups.

As opposed to labor groups defined by wage level (as a proxy for skill) as in the basic Colorado, CO-RE and CO-E models, the CO-D model uses labor groups defined by educational attainment. There are six labor groups, with three (L1, L2 and L3) representing raw labor with no college degree, a bachelor degree and a graduate or professional degree respectively and three

(HK1, HK2, HK3) representing accumulated human capital or experience for workers with no college degree, a bachelor degree and a graduate or professional degree respectively. Total labor payments (defining initial endowments) to households are derived from 2007-2011 ACS PUMS data proportions scaled to fit total 2011 wage and self-employment income for the State of Colorado from the BEA. Subdivisions between raw labor and human capital/experience are based upon an assumption of an identical baseline wage for all L1, L2 or L3 labor as a full-time equivalency with excess wage payments considered to be due to the household's endowment of human capital/experience. The initial baseline wage for L1 is set at $12,000 with $27,000 for L2 and $50,000 for L3.

The CO-D model SAM includes three types of health insurance: EMPHI, OLHI and POHI referring to employer-based health benefits, Medicare benefits (chiefly for the elderly) and Medicaid (chiefly for the poor) respectively. These columns indicate direct allocation of HealthCare sector output to households, independent of expenditures by households which represent out-of-pocket expenses. In addition, the CO-D model includes PENSFUND to represent money set aside for pensions by firms and paid out to households as private pension benefits. Values for EMPHI, OLHI, POHI and PENSFUND are allocated to household groups based on proportions derived from 2007-2011 ACS PUMS data and scaled to fit BEA 2011 aggregate estimates for the State of Colorado.

The final major innovation present in the SAM for the CO-D model is the subdivision of the UNIJC (universities and junior colleges) sector from the base Colorado model into four subsectors: STATEUG, STATEG, PRIVATEUG and PRIVATEG. These represent public undergraduate, public graduate, private undergraduate and private graduate education respectively. STATEUG and PRIVATEUG produce an identical output (L2 labor) as do

STATEG and PRIVATEG (L3 labor), STATEUG and STATEG are subsidized by the State of Colorado while PRIVATEUG and PRIVATEG are not. Intermediate input and factor demand proportions are assumed identical for each, the size of each sector is estimated based on enrollment figures and cost-per-student estimates from the Colorado Department of Education (given as approximately $10,780 per student). As a simplifying assumption, cost to educate graduate and undergraduate, public and private, in and out-of-state students is assumed constant for all sectors. Imports of the higher education subsectors are set to represent education of young Coloradans out of state while exports of higher education sectors are set to represent education of out-of-state and international students in Colorado. The proportion of Coloradan students studying elsewhere is assumed to fit the national average of 13.7% (US Dept. of Ed.), which makes Colorado a slight net exporter of higher education based on enrollment figures from the State Department of Education. All Colorado households spend on higher education, as in IMPLAN estimates based on income levels, not only "college aged" households such as HH1, HH2, HH3 and HH13. STATEUG and STATEG also receive subsidy payments from the general fund, CYGF.

Demographic Data

In addition to the financial accounts reflected in the social accounting matrix, operation of the CO-D model depends heavily on a number of tables of population levels and proportions as well as parameter vectors that reflect expected evolution of the population over time. Tables make use of an additional set as well as households and labor groups: "peeps" which represents persons in each age group in five-year increments. All households, by definition, must contain at least one individual (the household head) whose age group increment matches that which defines the household, but will contain other household members in other age groups. The tables

$POP0_{H,PEEPS}$ and $POPRATIO_{H,PEEPS}$ define the initial population of each age group in each household group category and the proportion of all individuals in each age group that fall in each household group category. All population data is derived from 2007-2011 ACS PUMS proportions scaled to fit Census 2010 aggregate levels.

Table 5.1 – $POP0_{H,PEEPS}$

	0 to 5	6 to 10	11 to 15	16 to 20	21 to 25	26 to 30	31 to 35	36 to 40	41 to 45	46 to 50	51 to 55	56 to 60	61 to 65	65 to 70	71+
HH1	1.32%	0.08%	0.19%	9.09%	1.92%	0.27%	0.07%	0.11%	0.14%	0.10%	0.05%	0.06%	0.02%	0.02%	0.01%
HH2	9.17%	1.70%	0.28%	2.62%	49.71%	5.00%	1.06%	0.28%	0.26%	0.34%	0.26%	0.15%	0.09%	0.08%	0.05%
HH3	19.88%	10.72%	2.59%	0.91%	7.24%	66.42%	6.59%	1.72%	0.49%	0.32%	0.36%	0.35%	0.23%	0.13%	0.08%
HH4	25.84%	19.68%	11.35%	2.59%	2.01%	8.34%	69.74%	6.82%	1.77%	0.50%	0.35%	0.40%	0.51%	0.20%	0.15%
HH5	21.68%	25.69%	19.83%	9.19%	1.36%	2.60%	9.01%	70.21%	6.76%	1.84%	0.66%	0.48%	0.66%	0.54%	0.31%
HH6	10.48%	21.52%	25.64%	17.72%	4.06%	1.17%	2.61%	9.51%	70.92%	5.89%	1.81%	0.68%	0.71%	0.81%	0.66%
HH7	5.25%	11.27%	21.58%	21.75%	8.86%	2.13%	1.29%	3.01%	9.54%	72.60%	6.60%	2.18%	0.75%	0.87%	1.02%
HH8	2.61%	4.51%	10.67%	14.53%	8.66%	3.61%	1.66%	1.20%	2.90%	9.51%	73.65%	6.39%	2.11%	0.91%	1.24%
HH9	1.77%	2.39%	3.72%	5.68%	5.65%	3.33%	2.17%	1.43%	1.40%	3.12%	8.90%	75.83%	5.96%	1.84%	1.28%
HH10	0.97%	1.09%	1.84%	2.34%	2.39%	1.81%	1.60%	1.56%	0.89%	1.05%	2.94%	8.26%	76.74%	5.66%	1.59%
HH11	0.50%	0.64%	0.90%	0.95%	0.81%	0.58%	0.68%	0.98%	1.29%	0.87%	0.91%	2.09%	8.04%	76.67%	2.76%
HH12	0.50%	0.70%	0.94%	1.14%	1.03%	0.73%	0.68%	0.81%	1.64%	2.30%	2.22%	2.10%	3.26%	11.15%	85.01%
HH13	0.03%	0.02%	0.47%	11.47%	6.30%	4.02%	2.83%	2.36%	2.00%	1.55%	1.28%	1.04%	0.91%	1.11%	5.84%

Table 1.1 above shows the proportion of each age group (coded 1 through 15 in the model) to be found in each household group. Note the high proportion found in "own-age" pairs for age groups 26-30 and beyond (HH5 - Age Group 36-40, etc…). Children in the first four age groups are spread, if not evenly, more evenly through the household groups. Children 0-5 are most commonly found in HH4, corresponding to a household head between 31 and 35. Logically children 6-10 are then most commonly found in HH5 and children 11-15 are most commonly found in HH6 as they grow up and their parents grow old. Beginning in Age Group 4 (16-20) a significant portion of individuals are found in "own-age" households and group quarters, a process that is amplified in Age Group 5 (21 – 25). As currently specified, the CO-D model subdivides the population by age and educational attainment, but not gender for the sake of simplicity. The addition of a gender component in the future may open further avenues for research.

The Model

The functioning of the dynamic CGE model itself is fairly similar to that in the basic Colorado, CO-RE and CO-E models. Cost-minimizing sectors demand inputs and intermediates from other firms and households endowed with capital, labor and other income streams. Households demand a household-specific welfare bundle produced from a variety of housing services as well as Armington aggregate consumption goods composed of domestic and "foreign" varieties of goods and services. Utility and production functions follow a fairly routine CES specification, with increased elasticities of substitution/transformation set to 2 rather than 1 to reflect the longer time period in the CO-D model which allows for greater possibilities for adjustment. Firms require pension fund and health expenditures as part of their production functions, revenues from which may be redistributed to households. Export demand is treated as partially exogenous, though with an elasticity of demand of one with respect to the domestic price of sectoral output. Capital investment and therefore capital stocks respond to changes in the rental rate of capital in a similar fashion to the Colorado and CO-E models albeit with a larger investment supply elasticity of 5.0 to reflect the longer time periods, as the elasticity of 1.0 used in the Colorado and CO-E models reflects the adjustment in a single year. Like the Colorado, CO-RE and CO-E models, the CO-D model is dynamic, but with myopic agents and no role for intertemporal choice.

Population Demographics

Aside from scaling of payments to households in the CO-D SAM, where the CO-D primarily diverges from the basic Colorado model is in its treatment of population and labor supply changes over time. The equation $POP_{PEEPS,T}$ determines the size of each age cohort (with age groups 1-15 representing individuals 0-5 through 71+) at period T, set initially to

EQ 5.1 $TPOP0_{PEEPS} = \sum_H POP0_{H,PEEPS}$ at T = 1. The mechanistic component of $POP_{PEEPS,T}$ is represented by

$$POP_{PEEPS,T} = ([1 - MORTALITY_{PEEPS}]\ x\ POP_{PEEPS-1,T-1})$$

for age groups 2 to 14,

EQ 5.2 $$POP_{15,T} = ([1 - MORTALITY_{15}]\ x\ POP_{14,T-1}) + ([1 - MORTALITY_{15}]\ x\ POP_{15,T-1})$$

for age group 15 (those aged 71+) and

EQ 5.3 $$POP_{1,T} = ([1 - MORTALITY_{1}]\ x\ BABIES_T)$$

for age group 1 (aged 0 through 5) where

EQ 5.4 $$BABIES_T = \sum_{PEEPS}(FERTILITY_{PEEPS}\ x\ POP_{PEEPS,T}).$$

The number of persons advancing to age group 5 between periods will be equal to those in age group 4 in the previous period, less those who passed away (between periods). Fertility and mortality are scalar parameter vectors derived from 2007-2011 ACS PUMS and CDC WONDER data respectively and are shown in Table 5.2 below. As the CO-D model as specified does not track gender, $FERTILITY_{PEEPS}$ is an average for both genders.

Migration, as in the Colorado, CO-RE and CO-E models is initially of labor group / household pairs (representing, for example, an L1 worker from HH5) specified as:

EQ 5.5 $$MIG_{L,H,T} - 1 = MIGPROP_L\ \ x\ MIGPROP1_H\ x\ \left(\left\{0.5\ x\ \left[\frac{P\_L_{L,T-1}}{P\_W_{H,T-1}} - 1\right]\right\} + 0.030309165\right)$$

If T ≠ 1 and $MIG_{L,H,T} = 1$ if T = 1. Where $P\_L_{L,T-1}$ represents last period's normalized nominal wage for labor group L and $P\_W_{H,T-1}$ is a normalized welfare price index for household group H.

0.03030916 represents the percentage increase in the Colorado population due to net in-migration to meet the forecast of 1.5% annual total population growth over the period 2011-2015 from the State of Colorado Office of Demography.

Table 5.2 – Colorado 5-year Mortality and Fertility Percentages

AGE GROUP	MORTALITY	FERTILITY
0 to 5	0.007555	0
6 to 10	0.000656	0
11 to 15	0.000909	0.001887623
16 to 20	0.003107	0.093732425
21 to 25	0.004409	0.2308338
26 to 30	0.004643	0.292421746
31 to 35	0.004643	0.253225806
36 to 40	0.008439	0.134465462
41 to 45	0.008439	0.038787024
46 to 50	0.017351	0.014806494
51 to 55	0.017351	0
56 to 60	0.036105	0
61 to 65	0.036105	0
66 to 70	0.091685	0
71+	0.271364	0

$MIGPROP_L$ and $MIGPROP1_H$ are scalar parameter vectors for migration propensity based on educational attainment and age of household head as shown in Tables 5.3 and 5.4 below. The difference in migration propensity, derived from 2007 – 2011 ACS PUMS data for the state of Colorado, between labor groups based on educational attainment is not large. However, the difference in migration propensity based on age of household head is substantial with younger households much more likely to migrate.

Table 5.3 – Migration Propensity Scalar by Labor Group

	MIGPROP
L1	0.982015
L2	1.021322
L3	0.992985
HK1	0.982015
HK2	1.021322
HK3	0.992985

Table 5.4 – Migration Propensity Scalar by Household Group

HH GROUP	MIGPROP1
HH1	2.884355
HH2	3.100802
HH3	1.896107
HH4	1.298309
HH5	1.040013
HH6	0.885812
HH7	0.703994
HH8	0.700576
HH9	0.676899
HH10	0.585955
HH11	0.417514
HH12	0.296809
HH13	3.074998

As a result of $MIGPROP1_H$, with no change in $P\_L_{L,T-1}$ or $P\_W_{H,T-1}$ migration will be sufficient to increase total population by approximately 3.03% over what it would have been based upon natural increase alone and new in-migrants will come disproportionately from younger household groups and HH13.

The increase in the number of households (normalized to one) due to in-migration is derived from $MIG_{L,H,T}$ as follows:

EQ 5.6 $$HMIG_{H,T} - 1 = \sum_L \left(SUPPORTSHARE_{H,L}\ x\ \left[MIG_{L,H,T} - 1\right]\right)$$

where $SUPPORTSHARE_{H,L}$ represents the share of FTE workers in each labor group supporting representative household H such that $\sum_L SUPPORTSHARE_{H,L} = 1$ for all H. The estimated number of FTE workers for "human capital" labor groups is calculated using the FTE wage for raw labor with the same level of educational attainment and total human capital earnings for that household group. Finally, normalized household migration is converted into total population migration by the equation

EQ 5.7 $$POPMIG_{PEEPS,T\neq 1} = \sum_H \left[\left(HMIG_{H,T} - 1\right)\ x\ POPRATIO_{H,PEEPS} TOTPOP0_{PEEPS}\right]$$

where $POPRATIO_{H,PEEPS}$ is a coefficient matrix of the proportion of the base population in each age group that falls in a given household group such that $\sum_H POPRATIO_{H,PEEPS} = 1$ for all PEEPS. The variable $POPMIG_{PEEPS,T}$ is then included additively in the $POP_{PEEPS,T}$ equations listed above which become:

EQ 5.8 $$POP_{PEEPS\neq 2,15,T} = POPMIG_{PEEPS,T\neq 1} + \left(\left[1 - MORTALITY_{PEEPS}\right]\ x\ POP_{PEEPS-1,T-1}\right)$$

EQ 5.9 $$POP_{15,T} = POPMIG_{PEEPS,T\neq 1} + \left(\left[1 - MORTALITY_{15}\right]\ x\ POP_{14,T-1}\right) + \left(\left[1 - MORTALITY_{15}\right]\ x\ POP_{15,T-1}\right)$$

EQ 5.10 $$POP_{1,T} = POPMIG_{PEEPS,T\neq 1} + \left(\left[1 - MORTALITY_{1}\right]\ x\ \sum_{PEEPS}\left(FERTILITY_{PEEPS}\ x\ POP_{PEEPS,T}\right)\right)$$

For age groups 2 through 14, age group 15 and age group 1 respectively. The equation $HMEMBERS_{H,T}$ is a normalized sum of the population of all age groups in each representative household group and is used to scale non-factor income "endowments" for household groups from sources such as Social Security and Medicaid.

EQ 5.11 $$HMEMBERS_{H,T} = \frac{\left(\sum_{PEEPS} POP_{PEEPS,T} POPRATIO_{H,PEEPS}\right)}{\left(\sum_{PEEPS} POP0_{PEEPS} POPRATIO_{H,PEEPS}\right)}$$

Labor and Education

The pool of available labor by age group is tracked as well, with a similar progression from period to period as the $POP_{PEEPS,T}$ equation. For the LAB subset of L, representing the three raw labor groups (L1, L2 and L3) the equation $SKILLS_{L,PEEPS,T}$ defines the available labor pool, scaled to the number of FTE workers employed in the state from the BEA with age and skill level proportions from the 2007-2011 ACS PUMS data. Initial $SKILLS_{L,PEEPS,T}$ is set at the base value $TOTALEDAGEWORKING_{L,PEEPS}$ in period 1 and

$$SKILLS_{LAB,PEEPS,T} = WORKMIG_{L1,PEEPS,T}\left[\left(PARTICIPATION_{PEEPS}SKILLS_{L1,PEEPS-1,T-1}\right) - \left(214{,}600 * UGPROP_{PEEPS-1}NEWBA_{PEEPS-1,T-1}\right) + \left(0.66\, x NEWB_{L1}POP_{3,T-1}\right)\right]$$

EQ 5.12

For labor group 1, representing "unskilled" raw labor without a college degree:

EQ 5.13

$$SKILLS_{L2,PEEPS,T} = WORKMIG_{L2,PEEPS,T}\left[\left(PARTICIPATION_{PEEPS}SKILLS_{L2,PEEPS-1,T-1}\right) + \left(214{,}600 * UGPROP_{PEEPS-1}NEWBA_{PEEPS-1,T-1}\right) - \left(38{,}260 * GPROP_{PEEPS-1}NEWPHD_{PEEPS-1,T-1}\right) + \left(0.66 * NEWB_{L2}POP_{3,T-1}\right)\right]$$

for labor group L2, representing "skilled" raw labor with a college degree and

EQ 5.14

$$SKILLS_{L3,PEEPS,T} = WORKMIG_{L3,PEEPS,T}\left[\left(PARTICIPATION_{PEEPS}SKILLS_{L3,PEEPS-1,T-1}\right) + \left(38{,}260 * GPROP_{PEEPS-1}NEWPHD_{PEEPS-1,T-1}\right) + \left(0.66 * NEWB_{L3}POP_{3,T-1}\right)\right]$$

For labor group L3, representing "highly skilled" raw labor with a graduate or professional degree. $PARTICIPATION_{PEEPS}$ is a parameter vector which scales labor endowments from period to period as labor group – age group pairings reflecting the predictable pattern of changes in labor market participation with age, shown in Table 5.6 below.

Table 5.6, Percentage Change in Labor Force Participation with Age

AGE GROUP	PARTICIPATION
5	1.334
6	1.025
7	1.070
8	0.994
9	0.982
10	0.994
11	0.970
12	0.871
13	0.724
14	0.546
15	0.312

Prior to age group 4 there is assumed to be no labor force participation, hence there is no $PARTICIPATION_{PEEPS}$ scalar prior to that marking the transition from age group 4 to age group 5 in which labor force participation increases by 33.4%. Labor force participation continues to increase with age until 31 – 35 (age group 7) and then begins to decline. Workers who remain in age group 15 are assumed to "retire" at the same rate (a decrease in participation of 68.8%) as workers transitioning from age group 14 to age group 15 between time periods.

The vector $NEWB_{LAB}$, representing the proportion of "new" young (potential) workers transitioning from age group 3 to age group 4 that begin in each of the three LAB groups, is set to 1.0 for L1 and zero for L2 and L3 somewhat arbitrarily. According to the 2007 – 2011 ACS PUMS data a small proportion of workers in age group 4 (aged between 16 and 20) report having a bachelor degree or professional degree (approximately 2%). However, these individuals also report being currently enrolled in university therefore this may be due to response error on the ACS survey. Total new additions to L1 in age group 4 are based on an assumed initial participation rate of 66% and population estimates for age group 4 from $POP_{PEEPS-1,T-1}$.

In the CO-D model all new workers begin their adult lives in labor group L1 as "unskilled" labor. As these workers age, labor force participation rates first rise and then fall. Workers are transitioned from L1 to L2 and from L2 to L3 as a result of investment in higher education. The equation $NEWBA_{PEEPS,T}$ is a normalized representation of new undergraduate degrees awarded by age group, $NEWPHD_{PEEPS,T}$ is a normalized representation of new graduate/professional degrees awarded such that when the same number of degrees are awarded to age group 5 individuals in time period T as in the base case, $NEWBA_{PEEPS,T}$ takes on a value of 1.

EQ 5.15 $$NEWBA_{PEEPS,T} = \frac{(154{,}597 * A\_Y_{STATEUG,T} + 60{,}003 * A\_Y_{PRIVATEUG,T})}{214{,}600}$$

EQ 5.16 $$NEWPHD_{PEEPS,T} = \frac{(17{,}178 * A\_Y_{STATEG,T} + 21{,}082 * A\_Y_{PRIVATEG,T})}{38{,}260}$$

Where the numbers represent baseline 5-year degree award estimates for public and private universities from the State of Colorado Department of Education and A_Y represents the normalized activity level in the sectors STATEUG, STATEG, PRIVATEUG and PRIVATEG in time T. Though real-world institutions of higher education may differ greatly in quality (Epple, Romano and Sieg 2006) all are here assumed to be representative firms for their type, with an identical output in terms of skills. The parameter vectors UGPROPPEEPS and GPROPPEEPS represent the proportion of all individuals reporting being enrolled in an undergraduate (UGPROP) or graduate (GPROP) program that fall in each age group according to the 2007 – 2011 ACS PUMS data for the State of Colorado such that $\sum_{PEEPS} UGPROP_{PEEPS} = \sum_{PEEPS} GPROP_{PEEPS} = 1$. All students are assumed to take one full five-year period to matriculate, so new additions to labor group – age group pairs are based on the previous period's and previous age group's values for $NEWBA_{PEEPS,T}$, $NEWPHD_{PEEPS,T}$, $UGPROP_{PEEPS}$ and $GPROP_{PEEPS}$. Values for $UGPROP_{PEEPS}$ and $GPROP_{PEEPS}$ can be found in Table 1.7 below.

Table 5.7 – Proportion of Undergraduate and Graduate Enrollees by Age Group

Age Group	UGPROP	GPROP
1	0.0000	0.0000
2	0.0000	0.0000
3	0.0001	0.0000
4	0.3389	0.0006
5	0.3167	0.1931
6	0.1158	0.2586
7	0.0684	0.1403
8	0.0519	0.1213
9	0.0370	0.0886
10	0.0304	0.0743
11	0.0192	0.0583
12	0.0114	0.0366
13	0.0041	0.0168
14	0.0023	0.0057
15	0.0038	0.0059

The model uses $UGPROP_{PEEPS}$ and $GPROP_{PEEPS}$ only to allocate new degrees between age groups rather than to determine an aggregate number of degrees awarded. As proportion of students is used to proxy proportion of new graduates, implicit is the simplifying assumption that enrollees probability of graduation does not vary with age. The largest proportions of undergraduate students fall in age groups 4 through 6 while the largest proportions of graduate students fall in age groups 5 through 8. However, the number of students, and therefore degrees awarded, to older age groups is non-trivial. Approximately 2% of all undergraduate degrees and 5% of all graduate degrees are expected to be awarded to those over 60 years of age. As many, perhaps most, undergraduate and graduate students participate in the labor market during their study (Ehrenberg and Sherman 1987), individuals are assumed to continue to supply L1 labor during the period in which they are transitioning to L2 and L2 labor during the period in which they are transitioning to L3

Migration of labor follows more directly from $MIG_{L,H,T}$, aggregating and rescaling using the $WORKMIG_{L,T}$ equation below for $T \neq 1$. When T=1, $WORKMIG_{L,T} = 1$.

EQ 5.17

$$WORKMIG_{L,PEEPS,T} = MIGPROP_{L,PEEPS} \sum_{H} LABORSHARE_{L,H}(MIG_{L,H,T} - 1)$$

Table 5.8 – Migration Propensity Scalar by Age Group and Educational Attainment

	L1	L2	L3	HK1	HK2	HK3
1	0.849	0.950	1.202	1.168	1.274	1.486
2	0.683	0.764	0.967	0.939	1.025	1.195
3	0.570	0.638	0.807	0.784	0.855	0.998
4	1.489	1.665	2.108	2.047	2.233	2.605
5	2.250	2.515	3.185	3.093	3.374	3.936
6	1.675	1.873	2.372	2.303	2.513	2.931
7	1.115	1.246	1.578	1.533	1.672	1.950
8	0.795	0.889	1.125	1.093	1.192	1.390
9	0.624	0.697	0.883	0.857	0.935	1.091
10	0.464	0.518	0.657	0.638	0.695	0.811
11	0.421	0.470	0.596	0.578	0.631	0.736
12	0.421	0.471	0.596	0.579	0.631	0.736
13	0.406	0.454	0.574	0.558	0.608	0.710
14	0.301	0.337	0.427	0.414	0.452	0.527
15	0.281	0.314	0.397	0.386	0.421	0.491

$MIGPROP_{L,PEEPS}$ is a scalar matrix representing differential migration propensity by workers of different age groups, shown in Table 1.8 below. For all L, MIGPROPL,PEEPS is scaled such that $\sum_{PEEPS} MIGPROP_{L,PEEPS} LABGRPSHARE_{L,PEEPS} = 1$ where $LABGRPSHARE_{L,PEEPS}$ refers to the proportion of total labor supply in labor group L that falls within age group PEEPS. As with $MIGPROP_{L}$ and $MIGPROP1_{H}$, $MIGPROP_{L,PEEPS}$ reallocates migrants but does not rescale aggregate net migration.

Endowments of human capital / experience progress through time in a similar fashion to raw labor. Each human capital type, HK1, HK2 and HK3 (the subset HUMANK of set L) refer to the accumulation of experience and special talents that make a given worker of a given raw labor group able to earn more than other workers of similar educational attainment levels. The initial economy-wide endowment of age group – human capital type pairs is given by the equation $KSKILLS_{HUMANK,PEEPS,T}$, equal to initial value $TOTALAGEHK_{HUMANK,PEEPS}$ when T=1 and for all other time periods:

EQ 5.18

$$KSKILLS_{HUMANK,PEEPS,T} = WORKMIG_{HUMANK,PEEPS,T} * EXPERIENCE_{PEEPS,HUMANK} * PARTICIPATION_{PEEPS} * KSKILLS_{HUMANK,PEEPS-1,T-1}$$

For age groups 8 through 14 (as in equation 5.18 above).

EQ 5.19

$$KSKILLS_{HUMANK,15,T} = WORKMIG_{HUMANK,15,T} * EXPERIENCE_{15,HUMANK} * PARTICIPATION_{15} * \left(KSKILLS_{HUMANK,14,T-1} + KSKILLS_{HUMANK,15,T-1}\right)$$

Equation 5.19 above shows human capital levels for age group 15 (those aged 71+). There is no human capital endowment for those just entering the labor force in a specific educational attainment category. Age group 4 possesses no human capital of any type. Age group 5 possesses only HK1, age group 6 possesses both HK 1 and HK2 and age group 7 possesses HK1, HK2 and HK3. For these three age groups initial allocation of new human capital is determined based on the number of L1, L2 or L3 workers in the previous age group in the previous period and the average human capital per worker for these age groups derived from the 2007 – 2011 ACS PUMS data. For age groups 5, 6 and 7 $KSKILLS_{HUMANK,PEEPS,T}$ is equal to the basic $KSKILLS_{HUMANK,PEEPS,T}$ equation with an addition of another term for the pairs HK1 – age group 5, HK2 – age group 6 and HK3 – age group 7.

EQ 5.20

$$KSKILLS_{HK1,5,T}=WORKMIG_{HK1,5,T}*\begin{bmatrix} EXPERIENCE_{5,HK1}*PARTICIPATION_{5}* \\ KSKILLS_{HK1,4,T-1}+\left(0.00468*SKILLS_{L1,5,T-1}\right) \end{bmatrix}$$

EQ 5.21

$$KSKILLS_{HK2,6,T}=WORKMIG_{HK2,6,T}*\begin{bmatrix} EXPERIENCE_{6,HK2}*PARTICIPATION_{6}* \\ KSKILLS_{HK2,5,T-1}+\left(0.01337*SKILLS_{L2,6,T-1}\right) \end{bmatrix}$$

EQ 5.22

$$KSKILLS_{HK3,7,T}=WORKMIG_{HK3,7,T}*\begin{bmatrix} EXPERIENCE_{7,HK3}*PARTICIPATION_{7}* \\ KSKILLS_{HK3,6,T-1}+\left(0.02089*SKILLS_{L3,7,T-1}\right) \end{bmatrix}$$

The coefficient vector $PARTICIPATION_{PEEPS}$ is the same for human capital as for raw labor, the coefficient matrix $EXPERIENCE_{PEEPS,HUMANK}$ describes the expected growth in human capital per worker through experience as the worker ages based on 2007-2011 ACS PUMS data. Values for $EXPERIENCE_{PEEPS,HUMANK}$ are given below in Table 5.9.

Table 5.9 – Growth in Human Capital Per Worker by Age Group

Age Group	HK1	HK2	HK3
1	0.000	0.000	0.000
2	0.000	0.000	0.000
3	0.000	0.000	0.000
4	0.000	0.000	0.000
5	0.000	0.000	0.000
6	2.928	0.000	0.000
7	1.292	1.828	0.000
8	1.176	1.378	2.126
9	1.098	1.137	1.111
10	1.081	1.044	1.140
11	1.041	0.955	0.809
12	0.916	0.855	0.749
13	0.843	0.714	0.658
14	0.605	0.611	0.018
15	0.738	0.245	0.000

When age group 5 is first endowed with HK1 the amount of human capital per worker is relatively small, however as these workers progress to age group 6 and beyond HK1 endowments initially grow rapidly. This increased endowment is best thought of as job-specific skills, training and experience that is not a product of the educational system and can only be acquired over time. Human capital endowment growth slows before, at a certain point, becoming negative at age 50 or 55. The additional "productivity" associated with experience appears to begin to decline at around this time, perhaps as workers natural abilities plateau or decline or as the pace of technology renders hard-won talents obsolete.

Raw labor (LAB) and human capital (HUMANK) are re-allocated to household groups in each period based on $LABORAGEHOUSE_{LAB,PEEPS,H}$ AND $HKAGEHOUSE_{HUMANK,PEEPS,H}$ respectively which are matrices of coefficients that display the proportion of each labor group – age group pair found in each household group such that

EQ 5.23

$$\sum_H LABORAGEHOUSE_{LAB,PEEPS,H} = \sum_H HKAGEHOUSE_{HUMANK,PEEPS,H} = 1 \text{ for all L and PEEPS}$$

The relevant equations are as follows:

EQ 5.24

$$BASELSUP_{LAB,H,T} = \frac{\sum_{PEEPS} SKILLS_{LAB,PEEPS,T} LABORAGEHOUSE_{LAB,PEEPS,H}}{LENDOWMENT_{H,LAB}}$$

EQ 5.25

$$BASEHKSUP_{HUMANK,H,T} = \frac{\sum_{PEEPS} KSKILLS_{HUMANK,PEEPS,T} HKAGEHOUSE_{HUMANK,PEEPS,H} HKPAYRATIO_{H,HUMANK}}{HKPAYMENTS0_{H,HUMANK}}$$

Where $LENDOWMENT_{H,LAB}$ and $HKPAYMENTS0_{H,HUMANK}$ are base endowments of raw labor and human capital to households respectively to scale $BASELSUP_{LAB,H,T}$ and $BASEHKSUP_{HUMANK,H,T}$ to one. The coefficient matrix $HKPAYRATIO_{H,HUMANK}$ is necessary as a correction, as HK per age group and HK per household from the 2007-2011 ACS PUMS data lead to slightly different aggregates. $BASELSUP_{LAB,H,T}$ and $BASEHKSUP_{HUMANK,H,T}$ are the "fixed" component of total period labor supply, determined partially endogenously through the $WORKMIG_{L,T}$ equation but only as a function of past prices. Current period labor supply,

$LSUP_{LAB,H,T}$ and $HKSUP_{HUMANK,H,T}$ are functions of $BASELSUP_{LAB,H,T}$ and $BASEHKSUP_{HUMANK,H,T}$ but also respond to current real wages albeit inelastically.

EQ 5.26
$$LSUP_{LAB,H,T}=BASELSUP_{LAB,H,T}+\left[0.3*\ BASELSUP_{LAB,H,T}*\ \left(\frac{P\_L_{LAB,T}}{P\_W_{H,T}}-1\right)\right]$$

EQ 5.27
$$HKSUP_{HUMANK,H,T}=BASEHKSUP_{HUMANK,H,T}+\left[0.3*BASEHKSUP_{HUMANK,H,T}*\left(\frac{P\_L_{HUMANK,T}}{P\_W_{H,T}}-1\right)\right]$$

Where $P\_L_{L,T}$ is the normalized nominal wage for labor group L at time T and $P\_W_{H,T}$ is the normalized price of a unit of welfare for household group H at time T. Starting household endowments of labor are scaled based on the $LSUP_{LAB,H,T}$ and $HKSUP_{HUMANK,H,T}$ equations such that a value of 1.01 for $LSUP_{LAB,H,T}$ indicates an endowment of LAB for household group H at time T 1% higher than the initial value given.

Demand for Higher Education

Additions to L2 and L3, and by virtue of the KSKILLS equation to HK2 for age group 6 and HK3 for age group 7, are a function of NEWBAPEEPS,T and NEWPHDPEEPS,T which are themselves functions of activity levels in the four higher education industry sectors (subset HED of industry set IP). As activity levels in HED are themselves endogenous, investment in higher education – which converts L1 labor into L2 and L3 labor – is dependent upon demand for the output of the higher education sectors. In the CO-D model, demand for HED output is extracted from the typical specification (as inputs into the production of welfare) used for housing and the Armington output of other sectors and specified independently. Demand for higher education is considered to be a function of household income, the after-subsidy price of higher education, the after-subsidy price of the most appropriate higher education substitute type and the wage premium associated with that degree.

Eight independent demand functions are specified, for domestic output of STATEUG, STATEG, PRIVATEUG and PRIVATEG and for imports of STATEUG, STATEG, PRIVATEUG and PRIVATEG. Native Coloradans studying in institutions in other states or countries are considered to represent demand for imported HED variants by domestic households. The most appropriate substitute is assumed to be PRIVATEUG for STATEUG and PRIVATEG for STATEG and vice versa. Subsidies exist in the baseline scenario only for consumption of the domestic variant of STATEUG and STATEG. Households pay the full pre-subsidy price, but receive a reimbursement equal to the subsidy rate multiplied by the quantity consumed. As many households finance tuition expenditures for students in other households, no link is drawn in the model between individual household demand for higher education and individual household allocations of newly produced degrees. The equation given below for household demand for STATEUG is representative of demand functions for all HED types. $EDDEMAND1_{H,T}$ is used to scale the "negative endowment" for household group H of the output of STATEUG at time T.

$$EDDEMAND1_{H,T} = \left\{\left[EDIELAS * \left(\frac{RA_{H,T}}{INCOME_H} - 1\right)\right] + 1\right\} * \left\{\left[EDPELAS * \left(\frac{1 + EDSUB0_{STATEUG}}{P_{Y_{STATEUG,T}} + EDSUB_{STATEUG}} - 1\right)\right] + 1\right\} * \left\{\left[EDCELAS * \left(P_{Y_{PRIVATEUG,T}} - 1\right)\right] + 1\right\} * \left\{\left[EDWELAS * \left(\frac{P_{L_{L2,T}}}{P_{L_{L1,T}}} - 1\right)\right] + 1\right\} \quad \text{EQ 5.28}$$

Here $INCOME_H$ represents initial baseline income for household group H, $RA_{H,T}$ represents current income for household group H at time T, $EDSUB0_{STATEUG}$ represents the initial subsidy rate for STATEUG and $EDSUB_{STATEUG}$ represents the current subsidy rate for STATEUG. $P\_Y_{STATEUG,T}$ and $P\_Y_{PRIVATEUG,T}$ are the normalized pre-subsidy prices of domestic output of STATEUG and PRIVATEUG respectively. $P\_L_{L2,T}$ and $P\_L_{L1,T}$ are the normalized nominal wages for L1 raw labor and L2 raw labor respectively at time T. The wage premium $P\_L_{L2,T}/P\_L_{L1,T}$ for L2 workers is determined endogenously within the model by relative supply and relative demand for L2 labor compared to L1 labor. EDIELAS, EDPELAS, EDCELAS and EDWELAS are parameters – initially set to a value of one but varied in simulations – which determine the responsiveness of demand for higher education to changes in income, own-price, cross-price and wage premium respectively.

5.3 Simulations

The long-run impacts, after 10 periods representing a span of 50 years, of a potential elimination of state funding for higher education in Colorado (relative to a baseline in which 2011 funding levels are maintained in perpetuity) are estimated in order to allow the labor market to fully adjust, after all individuals who obtained degrees or migrated to the state under earlier policy regimes have left the labor market. With respect to human capital and educational attainment, policy-induced changes occur at a glacial rate but are equally enduring once they have begun to take effect. The first set of simulations involves no changes to policy, but describes the natural evolution of the state population and economy in the absence of shocks.

Colorado Economy – the Next 50 Years

The baseline scenario for the CO-D model is a forecast into Colorado's future based on demographic trends, rather than a conventional expectation of a balanced growth path in which all factors of production increase steadily at the same rate. Population increases over time, due to local residents fertility and mortality as well as baseline net in-migration sufficient to meet the Colorado Office of Demography estimate of 1.5% annual growth over the next five years in the "business as usual" (BAU) case. Factor endowments, particularly labor, vary over time not only due to real wage sensitivity but also due to predictable changes in the size of the labor force and labor force participation due to changes in population demographics – in this case largely due to the aging of the population. Furthermore, the transition of workers from L1 to L2 between periods due to education spending (and from L2 to L3) is calibrated to actual degrees granted rather than the number necessary to maintain stable labor force proportions. Inflows of non-factor income such as pensions vary with population. Baseline capital investment is sufficient in time period one to allow capital stocks to grow at the same rate as population, however as rents diverge from initial values as the economy evolves so to may capital-labor ratios. As such the BAU reference case for the Colorado economy itself represents an economy in flux, as is appropriate for any such long-range simulation of an actual, rather than abstract, economy.

While the actual economy of 2060 will undoubtedly diverge in significant ways from such a forecast based on unforeseeable shocks and technological changes, a baseline prediction bathe next 50 years from the Colorado economy of today; two of which we can forecast and one of which we must guess about. First, like the rest of the United States and the developed world the population and labor force of Colorado are aging. Second, the number of degrees granted by Colorado institutions is in excess of that necessary to maintain the proportion of L2 to L1 workers. Third, labor productivity in Colorado as elsewhere should not be expected to remain constant and increases may favor one type of labor over another. The primary baseline run will assume – to create a reference point – zero growth in total factor productivity over time and detail expected changes in population, demographic proportions and dependency ratios, the size of the labor force and labor group proportions, wage premiums and changes in total real consumption and total real consumption per capita.

The two baseline runs, with and without migration, are run for 10 five-year periods ahead from the starting point of 2010. In the second run, I assume zero net migration such that there is no migration component to baseline population growth and there is no migration response to changing real wages.

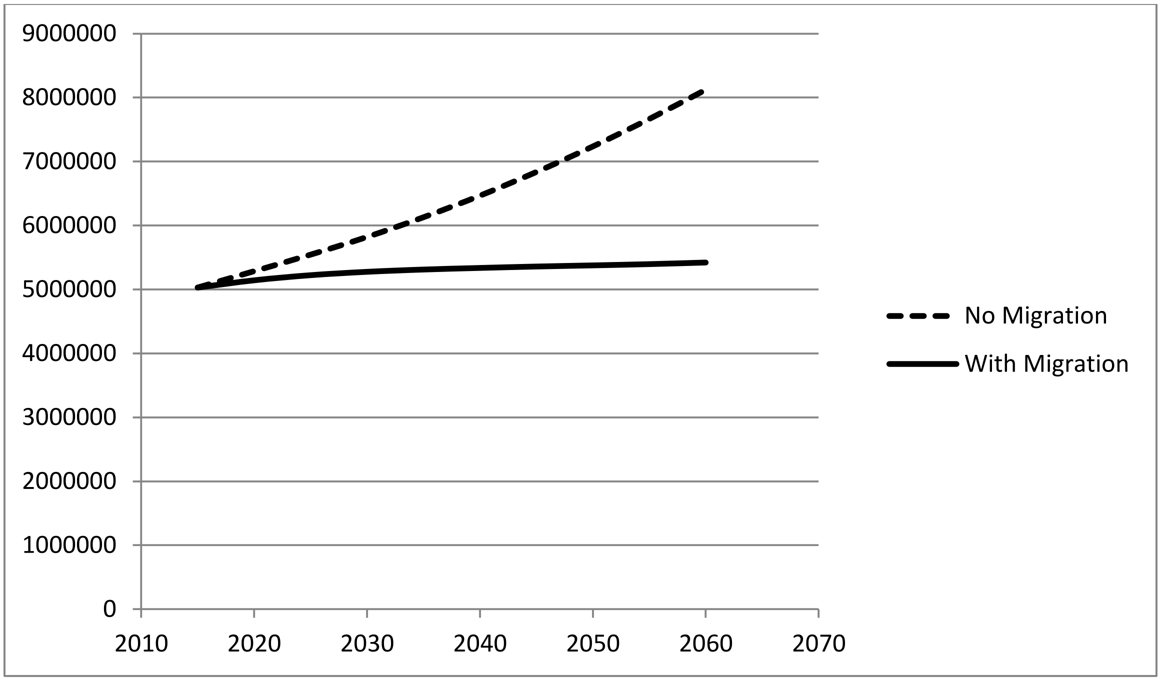


Figure 5.10 - Total Population With and Without In-Migration

In the absence of net in-migration, Colorado experiences very slight overall population growth over the next 50 years due to greater overall fertility than mortality with population growth averaging only 0.15% and total population growth over that period of 7.8%. With in-migration, migration is responsible for the vast majority of total population growth, leading to average population growth of slightly less than 1% per year and total population growth of 61.5%.

Without migration, the size of the Colorado labor force will increase in period (2011 to 2015) and then begin a slow decline until 2050 when it begins to grow again. These changes are the result of predictable changes in labor force participation with age and the state's current demographic profile. As they are caused by the demographic "bulge" that the boomer generation represents, these changes could be expected to be broadly representative of the situation faced by other states as well. However, as a target for net in-migration when migration is allowed the

Colorado labor force can be expected to continue to grow steadily over the next 50 years with average labor force growth of 0.73% per year and total labor force growth of 44%.

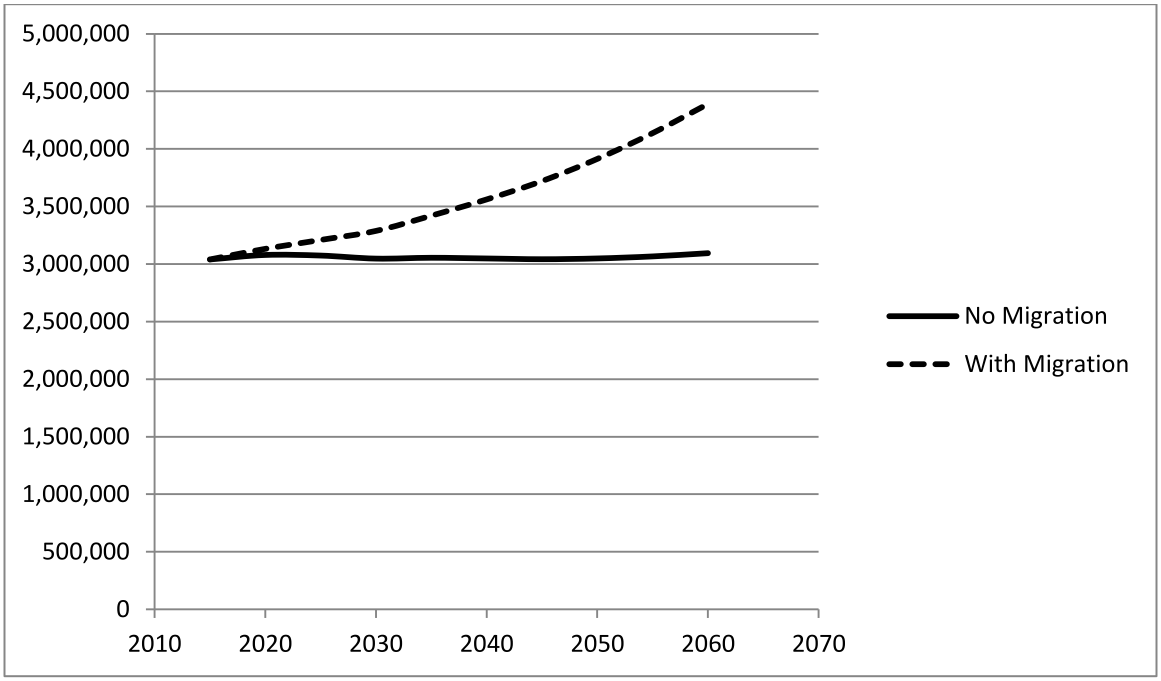


Figure 5.11 - Raw Labor Pool – With and Without Migration

As shown in figure 5.12 and figure 5.13 below, the demographic profile of the state will be evolving over time largely as a function of the aging of the baby boomer generation. As in-migrants are disproportionately young adults (in prime child-bearing years) migration partially mitigates but does not entirely alleviate this greying of the population.

One commonly used measure to illustrate the likely economic and social impacts of population aging (as well as changes in fertility) is the so-called dependency ratio: the proportion of the population either 65 and over or 15 and under divided by the proportion of the population between the ages of 15 and 65. Colorado's dependency ratio is estimated at 47.8% as of the base year: for every adult of working age, there are 0.478 dependents. With or without in-migration

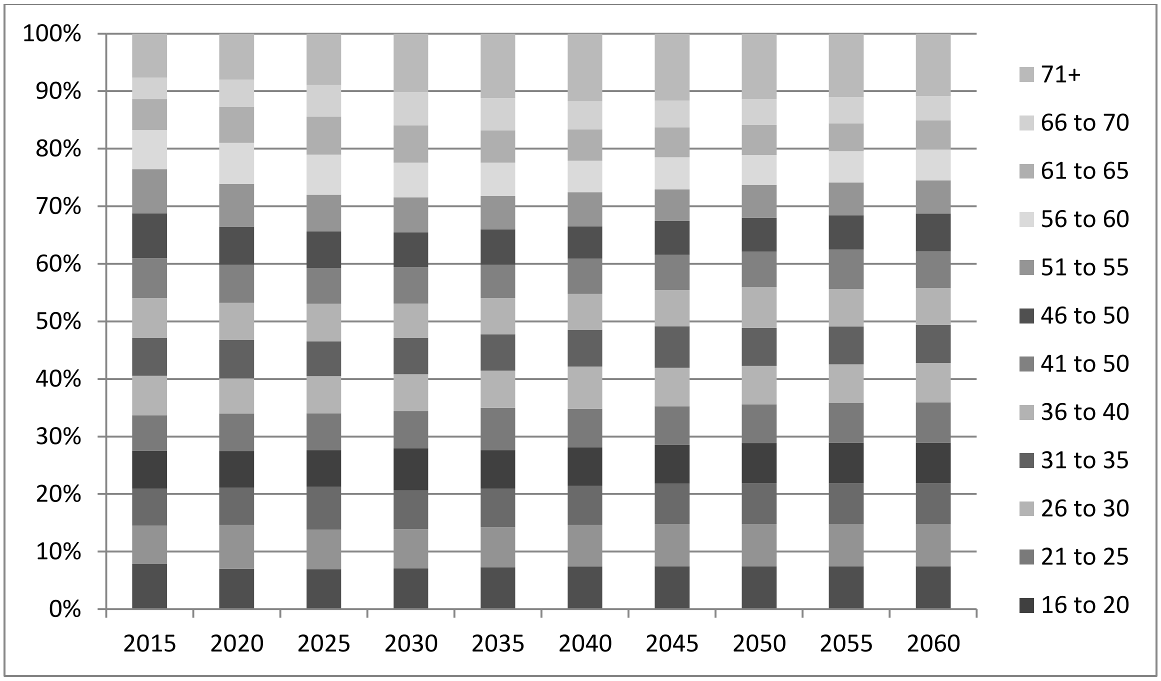


Figure 5.12 - Demographic Proportions – With Migration

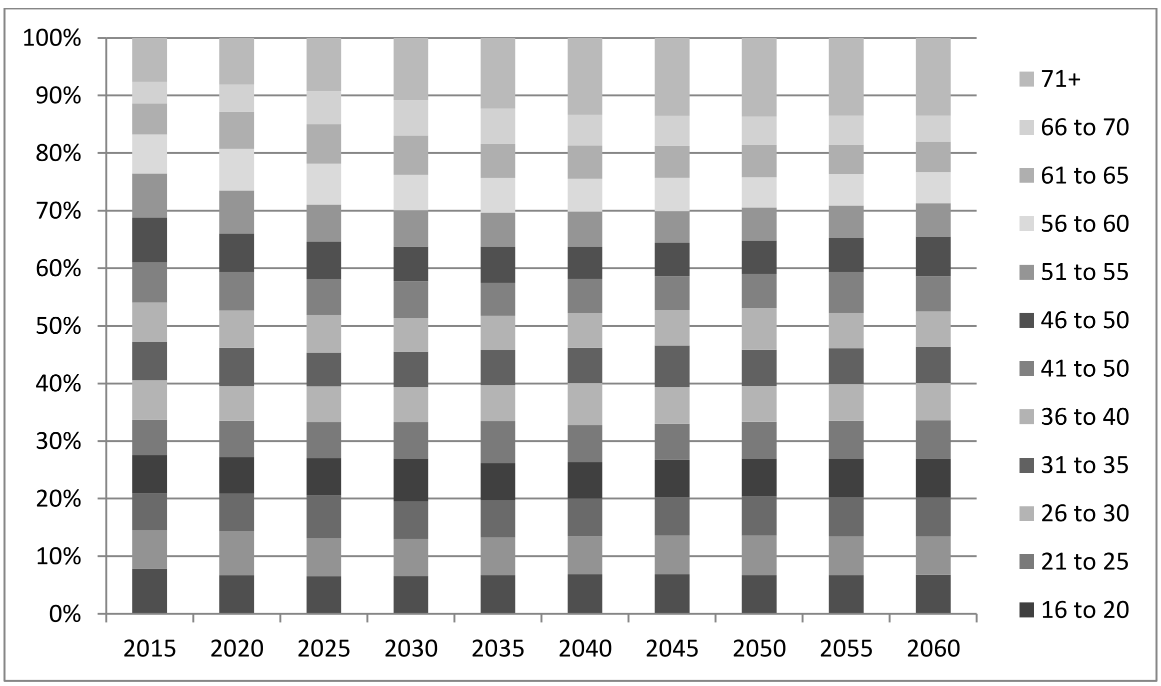


Figure 5.13 - Demographic Proportions – Without Migration

to the state this ratio is expected to increase as the population ages, however in-migration somewhat mitigates the rise past 2030. By 2045 to 2050 the dependency ratio is predicted to fall. Note that simulations do not make any assumption about increasing lifespans over time, current mortality rates by age cohort are simply projected into the future. If lifespans are assumed to significantly increase, this will lower mortality rates for the 71+ cohort and increase their proportion in the population, raising dependency ratios – perhaps substantially.

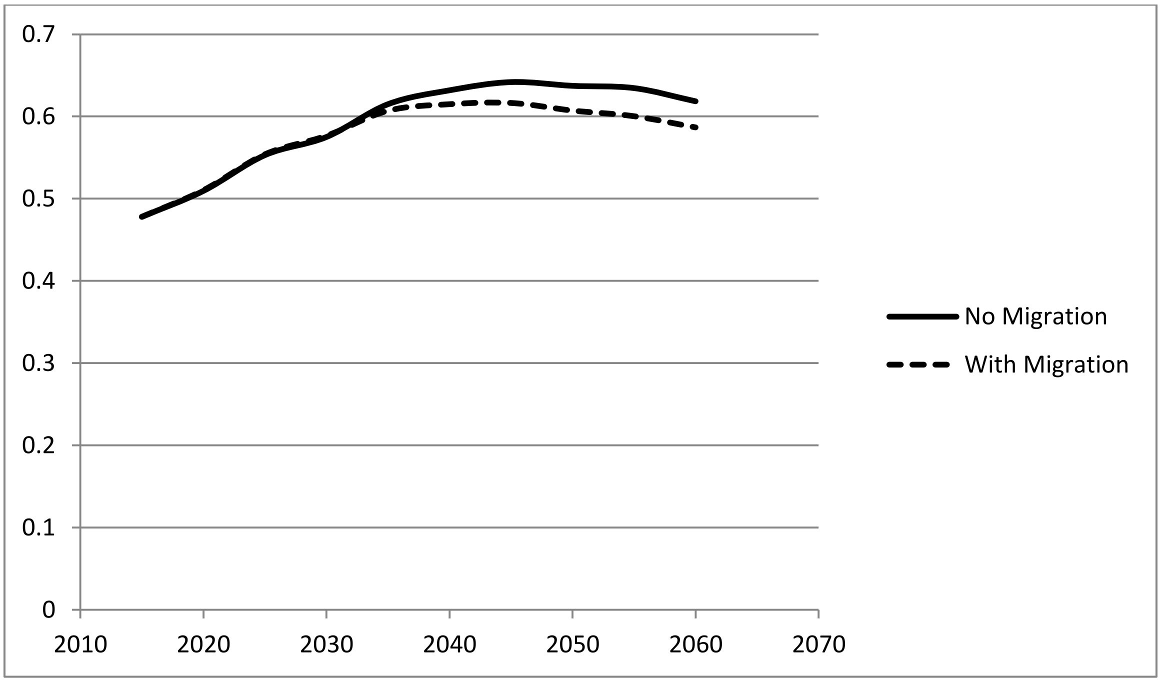


Figure 5.14 - Dependency Ratios – With and Without In-Migration

As shown in figures 5.15 and 5.16 below, in the absence of migration Colorado's labor force remains stable overall but the proportions of L1, L2 and L3 workers do not. Without migration, the number of graduates produced by Colorado institutions of higher education (both public and private) – combined with assumptions about labor force participation of new graduates based on age – is greater than what would be necessary to reproduce existing labor group proportions of L2 workers relative to L1 workers.

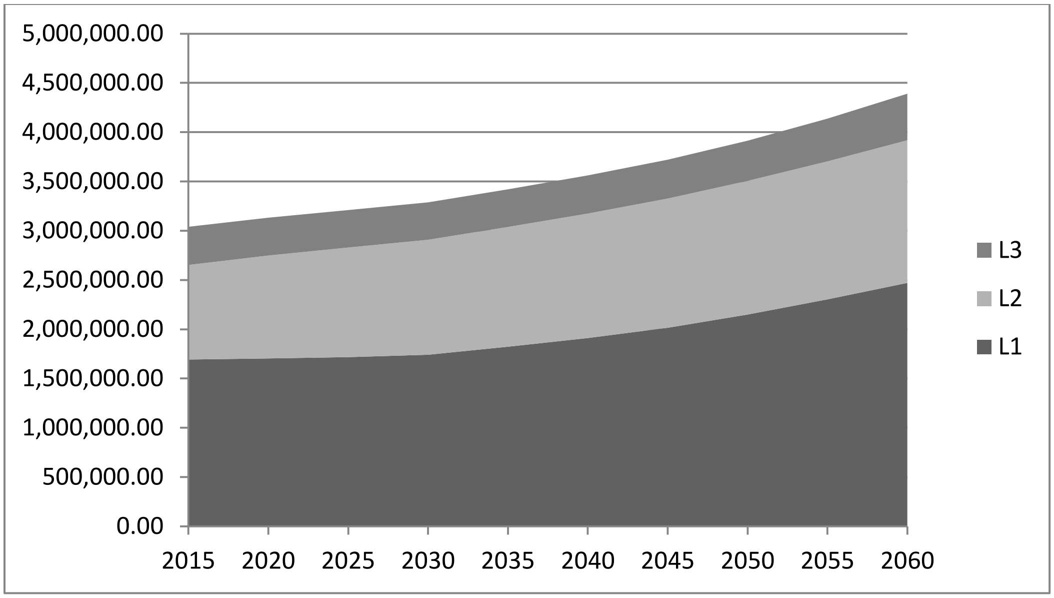


Figure 5.15 - Labor Force Proportions – With Migration

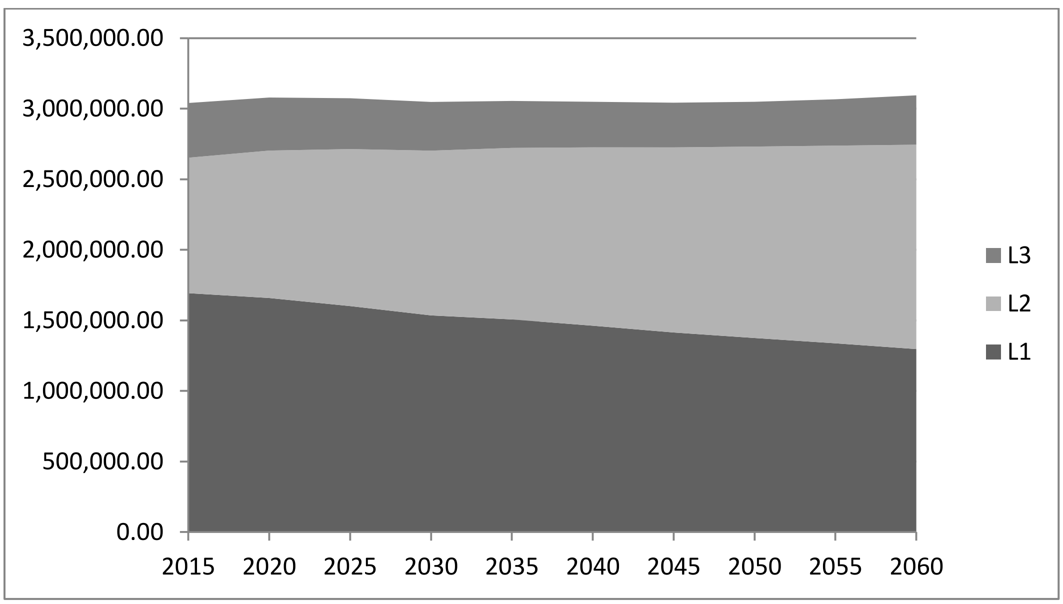


Figure 5.16 - Labor Force Proportions – Without Migration

The number of L2 workers can be expected to grow over time relative to the number of L1 workers based on current trends, the number of L3 workers can be expected to grow relative to the number of L1 workers but shrink relative to the number of L2 workers. When net in-migration is allowed, all three labor groups show steady growth over time and the change in labor group proportions decreases but is not eliminated. As shown in figure 5.17 below, we can expect the wage premium associated with a bachelor's degree to decrease over time, by approximately 25% to 2060 without migration or 9% to 2060 with migration. Due to divergence in real wages, future in migration into Colorado is expected to slant away from L2 workers and toward L1 and L3 workers as a result of the effects on labor markets of current enrollment trends.

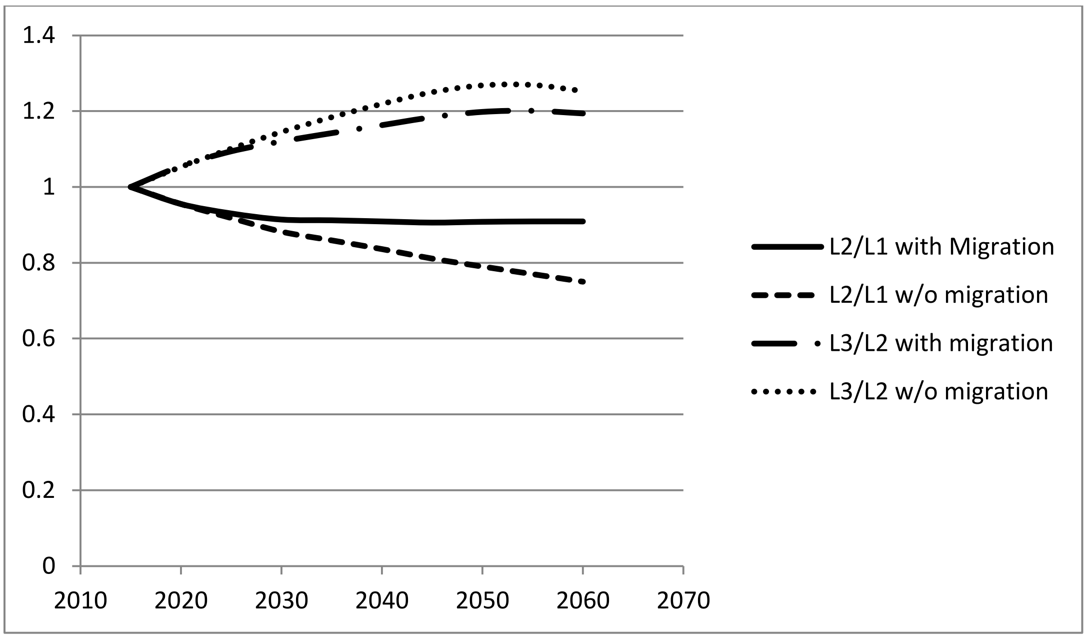


Figure 5.17 - Wage Premiums for L2 and L3, Relative to Base Year

As a result of in-migration of L1 and L3, the wage premium for L2 workers drops by a lesser amount with migration than without and the wage premium for L3 workers relative to L2 workers rises somewhat less as well. If a current L2 worker (without human capital) can expect to earn 225% of what an L1 worker does, with in-migration that same L2 worker in 2060 will expect to earn only 204.5% of what an L1 worker does. As shown in Figure 5.18 below, the size of the Colorado economy overall and per capita, as measured by real total consumption, is expected to continue to rise over the next 50 years. In the absence of migration, total real consumption is projected to grow at an annualized rate of 0.9% while per capita real consumption is projected to grow at an annualized rate of 0.75%. With migration these rates are 1.27% and 0.32% respectively.

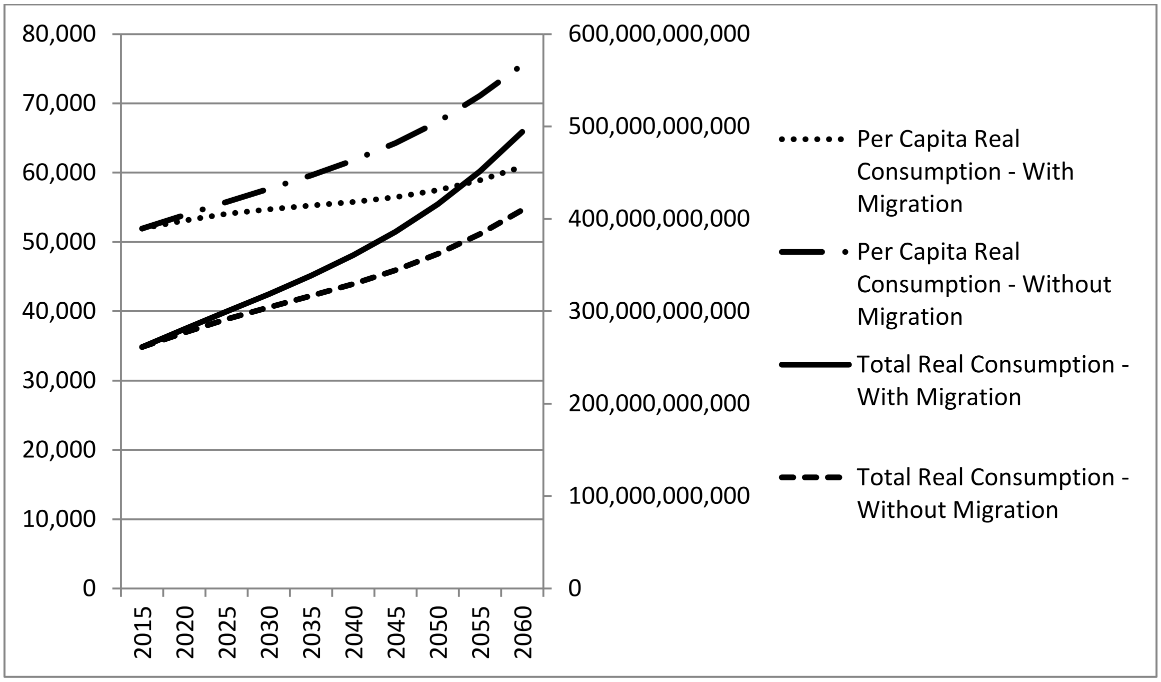


Figure 5.18 - Real Consumption – With and Without Migration

In both scenarios, with and without migration, growth in per capita incomes is largely due to slow increases in the K/L ratio over time and to estimated growth in Colorado "export" markets of 1.5% per year. Productivity is assumed constant. If 1% annual growth in total factor productivity (coming to approximately 5.1% between 5-year periods in the CO-D model) is assumed, not only is the rise in real per capita consumption predictably greater (to an annualized 1.48% with migration), higher overall growth has the effect of mitigating the decrease in the L2 wage premium, which in the with-migration scenario falls to 2030 before beginning to rise again. However, total factor productivity growth causes the L3 wage premium to rise rather than fall as shown in figure 5.19 below.

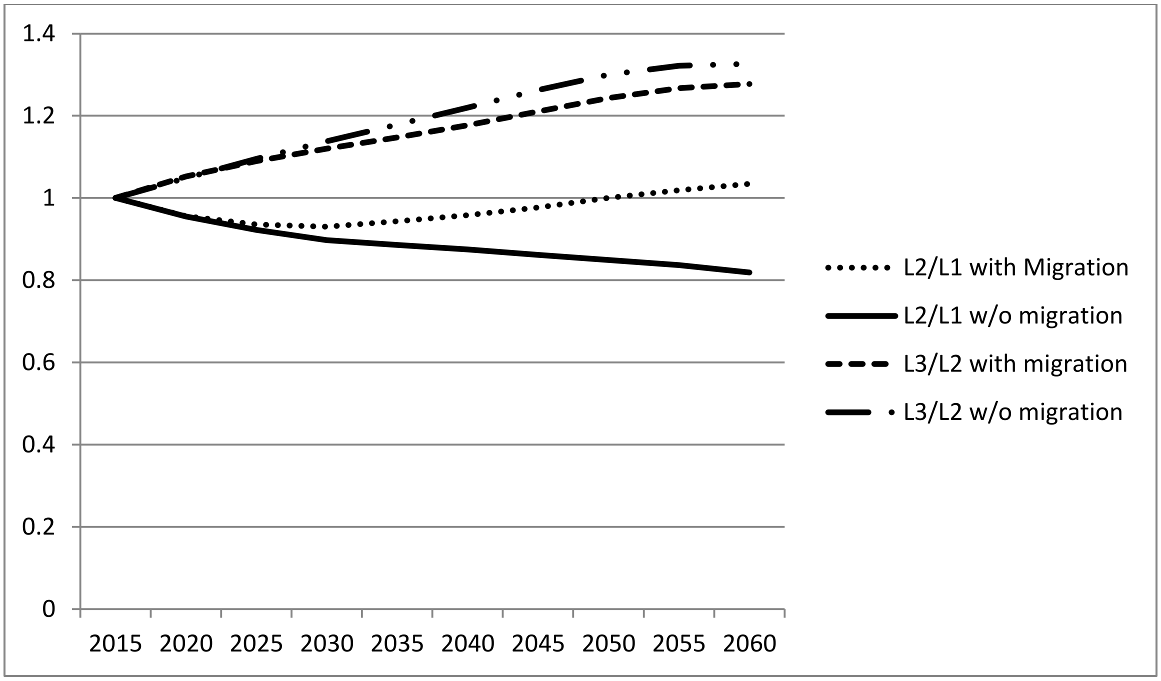


Figure 5.19 – L2 and L3 Wage Premiums With 5.1% per Period TFP Growth

With positive net in-migration, higher overall economic growth is sufficient for current trends in university enrollment and degrees granted in the state to avoid lowering the wage premium (or "value" of the degree as an investment) for those with a bachelor degree. However, higher overall economic growth will not be expected to have a similar result for the increasing L3 wage premium as current enrollments and degrees granted are not estimated to be on pace to produce enough workers with graduate and/or professional degrees. Increased economic growth will increase the demand for such workers more than the supply (through additional spending on higher education with rising incomes). The L3 wage premium can only be maintained with relative stability – given estimates for current trends in degree awards – if productivity enhancements are biased towards those with bachelor degrees or no degrees and away from those with graduate or professional degrees.

5.4 Shocks to Higher Education

All of the above baseline runs include the assumption of maintenance of current (rather than pre-recession) levels of higher education subsidy. In the demand equations for higher education, EDIELAS, EDCELAS and EDWELAS are set at 1.0 while EDPELAS is set at 0.25 – similar to Freeman (1986), Shires (1996) and Bardhan, Hicks & Jaffee (2013). For the set of simulations which will look at the economic impacts of an elimination in this state subsidy, relative to the baseline scenarios, the range of estimates surrounding these parameter estimates becomes critical. Estimates for EDPELAS, the responsiveness of demand for higher education to the after-subsidy price of higher education, range from 0.05 (Shires 1996) to close to 1 (Leslie & Brinkman 1987). Estimates for EDWELAS, the responsiveness of demand for higher education to changes in the wage differential range from close to 1 to 1000 (Freeman 1986).

Table 5.20 – Simulation Results, EDSUB = 0, no TFP growth

In 2060	With Subsidy	No Subsidy	Change	% Change
Real Consumption	$494.05 billion	$491.48 billion	-$2.565 billion	-0.519%
Per Capita Real Consumption	$60,828	$60,529	-$300	-0.492%
L1 Employment	2,006,207	2,033,792	27,585	1.375%
L2 Employment	1,372,334	1,349,977	-22,357	-1.629%
L3 Employment	386,929	382,218	-4,712	-1.218%
Total Employment	3,765,470	3,765,987	516	0.014%
L2 Wage Premium	90.90%	92.34%	1.4400%	1.584%
L3 Wage Premium	119.16%	119.77%	0.6118%	0.512%
Non-HED State Spending	$52.87 billion	$53.67 billion	$799.98 million	1.513%
State Taxes	$17.73 billion	$17.61 billion	-$124.16 million	-0.700%
Local Taxes	$17.02 billion	$16.94 billion	-$78.93 million	-0.464%

Baseline estimates of the impact of elimination of state subsidy are given below in table 5.20 for changes in real consumption, per capita real consumption, employment, wage premiums, state and local government spending and state and local government tax revenues.

Table 5.21 below shows the same set of results, given an assumption of 1% annualized total factor productivity growth in all sectors (and imports as well). As shown in the previous section, increased total factor productivity can counteract the effects of excess higher education spending on the L2 wage premium by increasing the demand for L2 labor.

Table 5.21 - Simulation Results, EDSUB = 0, 5.1% TFP growth per Period

in 2060	With Subsidy	No Subsidy	Change	% Change
Real Consumption	$1,573 billion	$1,566 billion	-$6.545 billion	-0.416%
Per Capita Real Consumption	$108,729	$108,255	-$474	-0.436%
L1 Employment	7,761,135	7,874,744	113,609	1.464%
L2 Employment	4,112,132	3,947,684	-164,448	-3.999%
L3 Employment	782,265	786,750	4,484	0.573%
Total Employment	12,655,532	12,609,178	-46,355	-0.366%
L2 Wage Premium	103.46%	106.32%	2.86%	2.764%
L3 Wage Premium	127.76%	124.88%	-2.88%	-2.254%
Non-HED State Spending	$202.85 billion	$204.2 billion	$1.354 billion	0.668%
State Taxes	$96.86 billion	$96.29 billion	-$566.9 million	-0.585%
Local Taxes	$79.42 billion	$79.11 billion	-$313.7 million	-0.395%

In both simulations, government revenues not spent on higher education subsidies are reallocated to a basket of state and local services including K-12 education, administration, courts, transportation, etc… Tax rates are unchanged. Compared to a baseline scenario with in-migration according to the MIG function described in section 2 and an assumption of 1% annual (5.1% per 5-year period) total factor productivity growth, the impact of removing subsidies for higher education on total employment is negative. Employment rises greatly for L1 workers, due to more abundant supply as L1 workers are not being transformed into L2 workers and slightly for L3 workers but both gains are overmatched by the fall in L2 employment resulting in a net loss of 46,355 jobs relative to the baseline in 2060. However, when we hold total factor productivity constant (perhaps an extreme, if not uncommon, assumption) the increase in L1 employment is greater than falls in both L2 and L3 employment resulting in very slight overall employment gains.

When TFP is held constant, current production of undergraduate degrees is in excess of what is required to maintain existing labor force proportions and as a result in the baseline scenario the L2 wage premium is only 90.9% of its base year value by 2060. As the elimination of the state higher education subsidy results in fewer degrees granted overall – with undergraduate degrees down approximately 5% and graduate degrees down approximately 3% - the wage premium for L2 workers relative to L1 workers rises by 1.44 percentage points by 2060 with the elimination of the subsidy. Somewhat surprisingly, the wage premium for L3 relative to L2 workers rises as well despite the increase in L2 wages. When we assume 5.1% per (5-year) period total factor productivity growth, which both expands the productive capacity of the local economy and makes it a more attractive destination for job-seeking migrants (resulting in a 2060 state population 78% higher than without TFP growth) and investors, this impact is not observed with the wage premium for L2 relative to L1 rising substantially (from a positive baseline, rather than regressing toward unity) with removal of the higher education subsidy but the wage premium for L3 relative to L2 falling.

In both simulations, two important sets of results stand out. First, though in both cases state & local government non-higher education spending rises, due to the reallocation of funds currently spent on higher education, tax revenues and total consumption fall. Without TFP growth the State of Colorado avoids spending $1.003 billion on subsidies for higher education, but loses $203 million in tax revenues (both quoted in real terms) as a result of lower overall output and consumption. With 5.1% per period TFP growth, the state avoids spending $2.235 billion on subsidies for higher education, but loses $881 million in tax revenues. Total real household consumption falls in both scenarios, though by significantly more with TFP growth where demand for L2 labor was tighter in the base scenario; by $2.565 and $6.545 billion respectively.

If we make the simple assumption that government services, such as roads, prisons and preschools provide equivalent benefits to the local population in terms of aggregate welfare with no TFP growth by eliminating higher education subsidies local residents sacrifice $2,565 million in lost consumption for $799 million in additional spending on roads, prisons and preschools – a net annualized loss of $1.765 billion. With an assumed 5.1% per period growth in TFP, the sacrifice is far greater at $6,545 million in lost consumption for $1,354 million in roads, prisons and preschools, a net loss of $5,190 million. One might assume that part of the loss in overall consumption, output, employment and tax revenues is due to a decrease in in-migration in both the TFP and no TFP scenarios, however effects of the removal of the subsidy on in-migration are minimal. In the no TFP growth scenario, the removal of the education subsidy results in a decrease in the 2060 population of 2,186 persons – a change of only 0.027%. Based on per capita consumption estimates, this decrease in population could be responsible (crudely speaking) for perhaps $121 million of the $2.565 billion in lost consumption. In the 5.1% per period TFP growth scenario, the removal of the education subsidy results in an *increase* in the 2060 population of 2,870 persons – suggesting an additional $311 million in consumption as a result of migration rather than the effect of higher education on wages and incomes per capita.

As a result, the impact on total real household consumption is also reflected fully in lost per capita real household consumption. This amounts to $300 per person lost due to the elimination of higher education subsidies without TFP growth and $474 per person lost due to the elimination of higher education subsidies with 1% TFP growth. If we factor in the potential benefits of other state and local spending, this loss comes down to $199 and $383 per person, per annum by 2060. We can expect variance with TFP growth for estimates of the net per capita impact of removal of higher education subsidies, as shown in figure 3.1 below.

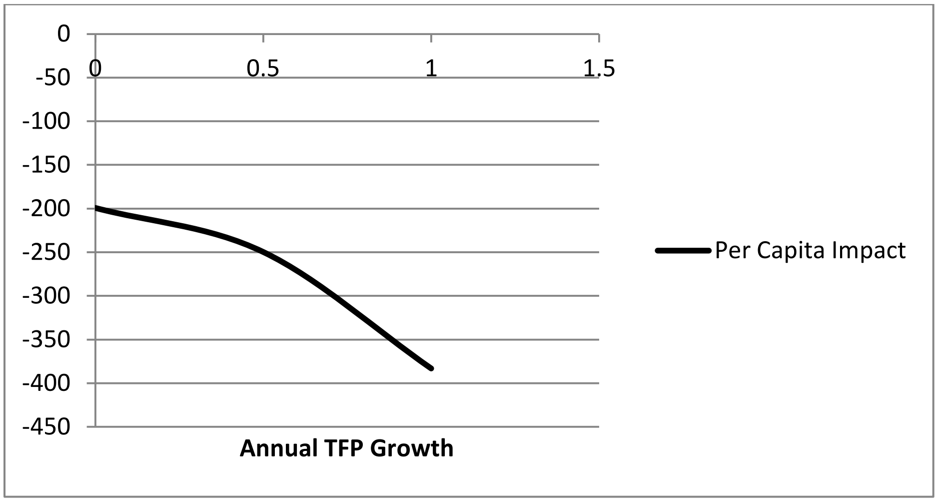


Figure 5.22 – Net Per Capita Consumption Change with TFP Growth

Spending on higher education is beneficial to the regional economy in spite of the fact that current trends may project an "excessive" output of higher education, depressing the wage premium and thereby lowering the return on education. As shown in figure 5.22, lower TFP growth is associated with smaller negative impacts of defunding of higher education (or smaller positive impacts of current education subsidies). Nonetheless, with an expectation of zero TFP growth such spending has a net benefit beyond the cost. Unless we assume a downward trend in TFP, variation in productivity growth will not be the deciding factor in whether Colorado's education subsidies are worthwhile.

5.5 Sensitivity Analysis

Demand for education, and hence impacts of policy regarding higher education, is also sensitive to two important parameters: EDPELAS and EDWELAS representing the sensitivity of higher education demand to changes in its own after-subsidy price and changes in the wage premium respectively. Unfortunately, as is often the case in the economics literature, there is little consensus regarding the appropriate size of these coefficients aside from the general notion that demand for higher education is inelastic with respect to tuition and fees (Leslie and Brinkman 1987) and unit elastic or elastic with respect to the wage premium (Freeman, Demand for education 1987). Elasticity estimates for tuition vary from -0.05 (Shires 1996) to -0.08 (Mincer 1994) to -0.23 (Bardhan, Hicks and Jaffee 2013) to -0.65 (Campbell and Siegel 1967) and beyond (Leslie and Brinkman 1987). As should be expected if the true value might be quite low, some studies such as Shin & Milton (2006) found the impact of tuition on enrollment to be statistically insignificant. Elasticity estimates for the wage premium range from 0.77 (Mincer 1994) to those cited in Freeman (1987) which range from 1.3 to 1000, though the higher estimates may be due to misspecification. Although EDPELAS and EDWELAS are not true constant elasticities, they will have a similar effect around the initial starting values and these elasticity estimates are used to set appropriate values for EDPELAS and EDWELAS (though EDPELAS would be the absolute value of the elasticity) – initially at 0.25 and 1.0 respectively. Figures 5.23 and 5.24 below illustrate how estimates for the total net per capita impact of the defunding of higher education in Colorado (as in figure 3.1 above) vary with assumptions about EDPELAS (Figure 5.23) and EDWELAS (Figure 5.24). For simulations with different values for EDPELAS, EDWELAS is assumed to be 1.0 (as in the baseline scenario). For simulations with different values for EDWELAS, EDPELAS is assumed to be 0.25.

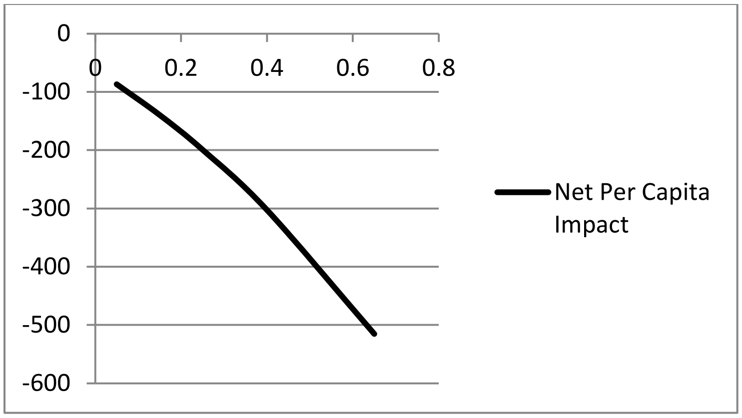


Figure 5.23 – Net Per Capita Impact of Defunding Higher Education by EDPELAS

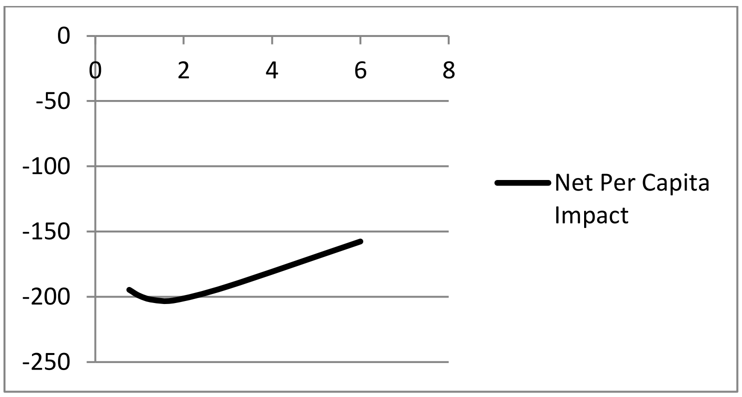


Figure 5.24 – Net Per Capita Impact of Defunding Higher Education by EDWELAS

Though estimates for the net per capita impact of defunding diminish with lower estimates for EDPELAS and higher estimates for EDWELAS, they do not change sign. With a value for EDPELAS of 0.05 the demand response to the removal of subsidies is slight, but the net per capita impact remains -$87 per capita. With a value for EDWELAS of 6.0 changes in the wage premium as a result of any decrease in degree production do more to encourage investment in higher education by households, but the net per capita impact falls only from -$199 to -$157. If we include both the low EDPELAS estimate of 0.05 and the high EDWELAS estimate of 6.0 the net per capita impact of defunding higher education is still a loss of $73. Though impact estimates are sensitive to variation in assumptions for key parameters (EDPELAS, EDWELAS and TFP growth) reasonable estimates for these parameters cannot alter the basic finding that subsidies for higher education provide a net economic benefit for the state.

Conclusions

Using the current process of demographic transition in the State of Colorado as a baseline, the elimination of subsidies for higher education in order to reallocate funding to other government services imposes a net economic cost on the region in terms of income and consumption lost that. Estimates for the net per capita impact range from -$73 to -$515 on an annual basis as of 2060. If potential consumption benefits of higher education itself were included, these loss estimates would be larger still. Such calculations make the assumption of a linear relationship between consumption and welfare and treat government services as equivalent consumption goods. It is possible that under alternative specifications for the value of government services, such as infrastructure spending, that the overall economic benefits of such spending might be well in excess of that suggested by a one-to-one conversion between government services and consumption. This study provides an estimate, in such a case, for the return that would be necessary for such spending to provide net benefits should funding be reallocated away from subsidies from higher education, starting at a 70% annual return if our assumptions lead to a fairly minimal net benefit from the higher education subsidy (EDPELAS of 0.05, EDWELAS of 6, no TFP growth).

Chapter 6

Concluding Remarks

6.1 Summary of Results

Simulation results from the CO-RE model suggest that the economic impacts of a transition to alternative workplace strategies would be modest in terms of macroeconomic aggregates, but positive. The transition results in a fall in aggregate investment as the shrinking office capital stock more than offsets increased investment into other property types, such as strip malls and hotels. However, the productivity enhancement leads to increases in incomes, consumption and employment that more than offset the drop in investment leading to overall economic benefits. Increases in consumption and employment are small, ranging from 0.1% to 0.3%, but in the right direction. Within the office property market, effects of such a transition would be dramatic with vacancy rates rising to 40% in some simulations and rents falling 80% to a minimal threshold. Based on stock adjustment parameters estimated for the regional office market, responsiveness of office demand to changes in rents is relatively weak, which leads to sizable cyclical swings as a result of negative shocks to employment or other factors affecting underlying office demand. Despite a positive overall economic impact, a transition to AWS is expected to lead to falling property tax revenues for local governments as the size of the commercial property tax base shrinks.

As modeled, given a set of plausible assumptions regarding levelized costs of generation over the lifetime of a project, costs associated with intermittency and future federal subsidies the Colorado renewable portfolio standard has a positive impact on economic aggregates in the state relative to a baseline scenario of a slow transition from coal-fired electric generation to natural gas-fired electric generation. This is strongly dependent upon the assumption of continued federal tax subsidies for wind power, which bring levelized cost estimates for wind power close to those for natural gas and cause wind generation to pull federal dollars into the state acting as an export. The impact of the Clean Air – Clean Jobs Act which accelerates a transition towards natural gas is negative on macroeconomic aggregates. The economy of the States of Colorado is substantially exposed to rising natural gas prices due to decreasing natural gas sector productivity, a doubling of natural gas prices could cause annualized consumption losses in the billions and cost the state more than 60,000 jobs. The RPS is not a job creator, due to the extreme capital intensivity of wind and solar electric generation, but the RPS adds to consumption and incomes in all scenarios but that with extremely low natural gas prices. The RPS is found to serve as a hedge for the state against rising natural gas prices, and a hedge with positive net benefit in many scenarios.

Defunding higher education reallocates money from higher education subsidies to production of government services. The defunding of higher education, by reducing production and consumption of higher education in the state, is found to reduce economic output and total real per capita consumption in the state though it does not always reduce employment. This effect is found in spite of the fact that the baseline scenario for comparison includes "excessive" production of higher education due in part to subsidies that causes the wage premium for college educated workers to fall over time. When total factor productivity is assumed to rise over time, the negative impact of defunding higher education increases as productivity-induced growth increases the demand for skilled labor. Estimates for the real net per capita consumption impact of defunding are found to be sensitive to a variety of plausible parameter estimates for

EDPELAS and EDWELAS, the responsiveness of higher education demand to tuition and the wage premium respectively. EDPELAS is generally considered to be inelastic, EDWELAS elastic. However, even when very small estimates for EDPELAS and very large estimates for EDWELAS are used, defunding higher education continues to have a negative impact though this effect is substantially smaller.

Though it is not possible for any version of the Colorado model to appropriately simulate all three shocks, it may be likely that the future for the State of Colorado includes a transition to AWS alongside demographic transition, a defunding of higher education and the steady progression of the Renewable Portfolio Standard towards full implementation. In addition it is quite possible, if far from certain, that in the future Colorado will be subjected to a significant increase in natural gas prices. Transition to AWS would be expected to negatively impact government finances, diminishing the ability of state government to allocate revenues towards funding of higher education and making the eventual defunding of higher education more likely. What is demonstrated by the baseline simulations in the demographic model is that not only does higher education spending increase the supply of college educated workers and thereby decrease the college wage premium, current levels of spending are sufficient to increase this supply over time relative to the labor pool as a whole and cause this premium to fall. Demand for office space has been shown to be far more responsive to changes in office employment than to changes in office rents, which makes it difficult for office markets to smoothly adjust to large shocks such as a transition to AWS. Since office-using employment is disproportionately likely to be college educated, a reduction in the college wage premium over time due to maintenance of current levels of higher education funding will increase underlying demand for office space and mitigate the negative impacts on the sector itself (and those who depend upon it, such as local governments) of the transition to AWS. Defunding of higher education, by reducing the supply of college educated workers, would exacerbate the impacts of the aforementioned transition.

6.2 Policy Recommendations

It is by no means certain that a genuinely transformative transition to AWS, like the one forecast by CoreNet, is underway. More modest transitions have not been simulated in this dissertation, though some policy recommendations can be made should local government entities wish to prepare for such a transition. The broad macroeconomic impact is positive and thus AWS should not be considered to be something to discourage. However, cities may find themselves with blighted, vacant office buildings and areas as a result of a permanent drop in core underlying office demand. As this change would be permanent rather than cyclical, it would behoove city planners and other government entities to accelerate the normally slow process of approving rezoning of such areas so that vacant office space might be renovated and repurposed – increasing the aggregate economic benefits of the transition to AWS while mitigating the pain experience by property owners. As property tax revenues collected from office properties are likely to fall due to falling rents leading to falling assessed values and decreased investment and construction of office properties, local government revenues – often necessary for funding programs such as libraries, fire departments and K-12 education – may fall substantially if the legal framework in the state is not changed to allow them to compensate with increased tax rates on other types of real property such as housing. This is currently not possible due to a combination of the Gallagher amendment and the state's Taxpayer Bill of Rights.

The Colorado RPS is found to be broadly beneficial for the local economy, though it does not wind up being a big creator of net green jobs. HB-1365 is found to impose economic costs, though the environmental benefits of reduced emissions could be large enough for these costs to be justifiable. As the RPS would result in similar if not greater decreases in emissions, the RPS is found to be the superior energy policy approach. In addition, the costs of HB-1365 are greater when natural gas prices are higher, amplifying the state's existing exposure to risks associated with fluctuations in natural gas prices and productivity. The RPS reduced the state's exposure to natural gas price fluctuations while providing a positive net benefit for total real household consumption as well as corollary external environmental benefits not quantified in this study.

Defunding higher education is found to impose non-negligible economic costs on the state, causing a decrease in total consumption far greater than the increase in government spending on programs such as prisons and roads. Though Colorado's status as a target for amenity-driven in-migration may moderate these negative impacts, they are far from eliminated. Even when demand for higher education is assumed to be very weakly responsive to after-subsidy tuition and fees, the slight decrease in higher education consumption causes a drop in state output and consumption. In the State of Colorado many decisions regarding allocation of state revenues are imposed upon legislators by ballot initiatives and legislators freedom to act and to make welfare maximizing decisions may be limited, forcing defunding of higher education by default should another recession lead to a drop in revenues. Citizens voting on ballot initiatives to allocate funds for higher education should seriously consider the impact on the state economy as a whole of investment in higher education, which leads to increases in overall output and standard of living that other government services may not.

6.3 Avenues for Future Research

The treatment of AWS in chapter three leaves one big question unanswered: can we determine whether or not a transition to AWS is underway and what shape that transition may be taking? While a CGE approach like that employed here may be able to provide some evidence for this one way or another, this cannot constitute proof. Moreover, any valid test using a CGE approach should involve a more carefully calibrated historical path rather than an assumption that the economy begins in equilibrium and on the balanced growth path prior to shocks as is done here. A panel econometric approach, looking at data from other regions over the same time horizon could give complementary insights.

The analysis of clean energy policy as an insurance policy for states exposed to fossil fuel price or productivity shocks in chapter four could be further expanded upon. Calculation of local external benefits of HB-1365 and the RPS due to reduced emissions would allow calculation of total net benefits of the policy under a wide variety of price assumptions for natural gas, including a threshold point at which the policy becomes economically viable. Coupling this analysis with a more detailed probability distribution for long-run natural gas industry productivity and prices would allow the generation of a range of risk aversion coefficients to be created to assess under what conditions or assumptions a state level government would prefer to insure or to gamble.

The analysis of higher education funding in chapter five has examined only one of the many impacts of higher education – the transformation of unskilled labor into skilled labor – but has ignored a variety of other public and private benefits that higher education (and indeed education in general) has long been assumed to have. A full examination of the value of higher education ought to incorporate these external effects, such as extending lifespans, decreasing crime rates and delaying fertility decisions. In addition, as the fundamental scenario likely to play out in the State of Colorado is the reallocation of funding away from higher education towards K-12 education proper estimation of the overall impacts of such a policy ought to incorporate the positive effects of K-12 spending in greater detail than the model currently has.

Increased K-12 spending could increase future labor productivity, decrease crime rates, increase the likelihood of attending college and more.

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Appendix A

CO Model in GAMS/MPSGE

```
$TITLE COLORADO

*--------------------------------------------------------------------------------

* 1.1 CONTROLS PLACED ON OUTPUT GENERATION

*---------------------------------------------------------------------------------------------------------------

$OFFSYMLIST OFFSYMXREF

*---------------------------------------------------------------------------------------------------------------

* 2. SET DEFINITION

*---------------------------------------------------------------------------------------------------------------

* 2.1 EXPLICIT SET DECLARATION

*---------------------------------------------------------------------------------------------------------------

SETS  Z  ALL ACCOUNTS IN SOCIAL ACCOUNTING MATRIX /

Agric

Mining

Coal

Elec

NatGas

Utilities

Const

Manuf
```

WHTR

Retail

TransWare

Info

FinIns

RealEst

HGSER

Manage

Admin

Educ

unijc

HealthCare

Arts

LodgeRest

OtherServ

PubAdm

HS1

HS2

HS3

HS4

HS5

HS6

L1

L2

L3

L4

L5

LAND

KAP

HH1

HH2

HH3

HH4

HH5

HH6

HH7

INVES

USSOCL1

USSOCL2

USSOCL3

USSOCL4

USSOCL5

USPIT

COPIT

CORPTAX

CNPRP

FEES

COSTX

LOCSTX

CYGF

SUBS

FED

STED

STHEALTH

STJUST

STADM

CDOT

ROW /

F(Z) FACTORS / L1,L2,L3,L4,L5,LAND,KAP/

L(F) LABOR /L1,L2,L3,L4,L5/

LA(F) LAND /LAND/

K(F) CAPITAL /KAP/

G(Z) GOVERNMENTS / USSOCL1, USSOCL2, USSOCL3,USSOCL4, USSOCL5,

USPIT, COPIT, CORPTAX,CNPRP,FEES,

COSTX,LOCSTX,

CYGF,SUBS,FED,STED,STHEALTH,STJUST,STADM,CDOT/

H(Z) HOUSEHOLDS / HH1, HH2, HH3, HH4, HH5, HH6,HH7 /

WORK(L,H) WORKERS /L1.(HH1,HH2,HH3,HH4,HH5,HH6,HH7)

L2.(HH2,HH3,HH4,HH5,HH6,HH7)

L3.(HH5,HH6,HH7)

L4.(HH6,HH7)

L5.(HH7)/

IG(Z) I+G SECTORS / Agric, Mining,Coal,Elec,NatGas, Utilities, Const,Manuf, WHTR, Retail,TransWare, Info,FinIns,RealEst,HGSER,Manage,

Admin,Educ,unijc,HealthCare,

Arts,LodgeRest,OtherServ,PubAdm,HS1,HS2,HS3,HS4,HS5,HS6,

FED,STED,STHEALTH,STJUST,STADM,CDOT/

I(IG) INDUSTRY SECTORS / Agric, Mining,Coal,Elec,NatGas,

Utilities, Const,Manuf, WHTR, Retail,TransWare, Info,FinIns,RealEst,HGSER,Manage,

Admin,Educ,unijc,HealthCare,

Arts,LodgeRest,OtherServ,PubAdm,HS1,HS2,HS3,HS4,HS5,HS6/

IP(I) PRODUCTION SECTORS /Agric, Mining,Coal,Elec,NatGas, Utilities, Const,Manuf, WHTR, Retail,TransWare,

Info,FinIns,RealEst,HGSER,Manage,Admin,Educ,unijc,HealthCare,

Arts,LodgeRest,OtherServ,PubAdm/

FG(IG) PRODUCTION GOV. /FED,STED,STHEALTH,STJUST,STADM,CDOT/

FSL(FG) STATE AND LOCAL GOV. /STED,STHEALTH,STJUST,STADM,CDOT/

FEDR(FG) FEDERAL GOV. /FED/

HD(I) HOUSING SERV.DEMAND /HS1, HS2, HS3, HS4, HS5, HS6/

SF(HD) DETACHED HOUSING /HS1,HS2,HS3,HS4,HS5/

MUF(HD) ATTACHED HOUSING /HS6/

```
SM        SIMMLOOP               /BASE,TODAY,SIMM1/

R1H       REPORT 1 FOR SCALARS     / GFREV, SFREV, PIT,

                         DGF, DSF, DDRE, PDRE, SPI,COMM,COMMO,

                         GN, NKI, HH, W, W1, W2, W3, R,RL, L, K, HN,HW, GFSAV, LD,

                          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), (H,H1), (HD, HD1), (IP,JP), (IG,JG);

*------------------------------------------------------------------------------------------------------------

* 3. PARAMETERS AND EXOGENOUS VARIABLES

*------------------------------------------------------------------------------------------------------------
```

```
* 3.1 SOCIAL ACCOUNTING MATRIX, CAPITAL COEFFICIENT MATRIX AND PARAMETERS
*--------------------------------------------------------------
TABLE SAM(Z,Z1) SOCIAL ACCOUNTING MATRIX
$ONDELIM
$INCLUDE c:\Users\Chris\Documents\COSAM.csv
$OFFDELIM
*---------------------------------------------------------------------------------------------------------
* 3.2 PARAMETER DECLARATION
*---------------------------------------------------------------------------------------------------------
PARAMETERS
* PARAMETERS CALCULATED FROM SOCIAL ACCOUNTING MATRIX AND TABLE DATA
HH0(H)      DOF    HHDS    NUMBER OF HOUSEHOLDS
HN0(H)      DOF    HHDS    NUMBER OF NONWORKING HOUSEHOLDS
HW0(H)      DOF    HHDS    NUMBER OF WORKING HOUSEHOLDS;
* 3.3 CALCULATIONS OF PARAMETERS AND INITIAL VALUES
OPTION DECIMALS=8 ;
TABLE MISCH(H,*) MISC.  HH DATA
          HH0           HW0
HH1       122862        121827
HH2       175378        171415
HH3       385109        366882
```

```
HH4      182306          171916

HH5      365070          339473

HH6      250286          235032

HH7      405588          376157;

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

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

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

PARAMETER TKI0(I)   PROPERTY TAXES ON COMMERCIAL CAPITAL;

TKI0(IP)=SAM("CNPRP",IP)/((sum(RP,SAM(RP,IP)))+sum(LA,SAM(LA,IP)));

PARAMETER TKH0(H) PROPERTY TAXES ON RESIDENTIAL CAPITAL;

TKH0(H)=(SAM("CNPRP",H)/(SUM(HD,SAM(HD,H))));

DISPLAY TKI0, TKH0;

PARAMETER TLDI0(L,I)  PRIVATE EMPLOYER SHARE OF PAYROLL TAXES;

  TLDI0("L1",IP)= SAM("USSOCL1",IP)/SAM("L1",IP);

  TLDI0("L2",IP)= SAM("USSOCL2",IP)/SAM("L2",IP);

  TLDI0("L3",IP)= SAM("USSOCL3",IP)/SAM("L3",IP);

  TLDI0("L4",IP)= SAM("USSOCL4",IP)/SAM("L4",IP);

  TLDI0("L5",IP)= SAM("USSOCL5",IP)/SAM("L5",IP);

PARAMETER TLDG0(L,FG)  PUBLIC EMPLOYER SHARE OF PAYROLL TAXES;

  TLDG0("L1",FG) = SAM("USSOCL1",FG)/SAM("L1",FG);

  TLDG0("L2",FG) = SAM("USSOCL2",FG)/SAM("L2",FG);

  TLDG0("L3",FG) = SAM("USSOCL3",FG)/SAM("L3",FG);

  TLDG0("L4",FG) = SAM("USSOCL4",FG)/SAM("L4",FG);
```

```
 TLDG0("L5",FG) = SAM("USSOCL5",FG)/SAM("L5",FG);
PARAMETER LI0(L);
 LI0(L)=SUM(H,SAM(H,L));
PARAMETER TLS0(L)   EMPLOYEE SHARE OF PAYROLL TAXES;
 TLS0("L1") = SAM("USSOCL1","L1")/(LI0("L1")+SAM("USSOCL1","L1"));
 TLS0("L2") = SAM("USSOCL2","L2")/(LI0("L2")+SAM("USSOCL2","L2"));
 TLS0("L3") = SAM("USSOCL3","L3")/(LI0("L3")+SAM("USSOCL3","L3"));
 TLS0("L4") = SAM("USSOCL4","L4")/(LI0("L4")+SAM("USSOCL4","L4"));
 TLS0("L5") = SAM("USSOCL5","L5")/(LI0("L5")+SAM("USSOCL5","L5"));
PARAMETER TLS1(L) PAYROLL TAX RATE FOR MPSGE;
 TLS1(L) = TLS0(L);
TABLE WORK0(L,H)
        HH1           HH2          HH3          HH4          HH5
L1      1963.200402   883.467607   848.743351   751.908112   1156.110615
L2      0             2285.337821  4077.302229  5991.492537  7193.962546
L3      0             0            0            0            7027.453123
L4      0             0            0            0            0
L5      0             0            0            0            0
+       HH6           HH7
L1      1039.999790   1113.363917
L2      9054.106853   7075.077710
L3      5759.216302   8730.033725
L4      7918.629220   12364.851540
```

```
L5       18.394169       33887.143330;

PARAMETER DEPRECIATE(K);

DEPRECIATE("KAP") = 0.070;

PARAMETER KLAOUT0 NON-RESIDENT OWNERSHIP OF LAND AND CAPITAL,

        QKSF0(K)  NON-RESIDENT OWNERSHIP OF CAPITAL,

        QLASF0 NON-RESIDENT OWNERSHIP OF LAND;

 QKSF0(K) = -SAM(K,"ROW");

 QLASF0 = -SAM("LAND","ROW");

 KLAOUT0 = SUM(K,QKSF0(K)) + QLASF0;

PARAMETER WORK1(L,H)  WORKERS BY HOUSEHOLD BY LABOR GROUP,

        LABGRPSHARE(L,H),

        QFICA(L,H),

        WORKPROP(L,H),

        WRKSUM(H),

        QLABSUP0(L,H);

  WORK1(L,H) = WORK0(L,H)$WORK(L,H);

  LABGRPSHARE(L,H) = WORK1(L,H)/LI0(L);

  QFICA("L1",H) = LABGRPSHARE("L1",H)*(SAM("USSOCL1","L1"));

  QFICA("L2",H) = LABGRPSHARE("L2",H)*(SAM("USSOCL2","L2"));

  QFICA("L3",H) = LABGRPSHARE("L3",H)*(SAM("USSOCL3","L3"));

  QFICA("L4",H) = LABGRPSHARE("L4",H)*(SAM("USSOCL4","L4"));

  QFICA("L5",H) = LABGRPSHARE("L5",H)*(SAM("USSOCL5","L5"));

  QLABSUP0(L,H) = WORK1(L,H)+QFICA(L,H);
```

```
 WRKSUM(H) = SUM(L,WORK1(L,H));
 WORKPROP(L,H) = WORK1(L,H)/WRKSUM(H);
DISPLAY LABGRPSHARE;
PARAMETER FEDPROD0 FEDERAL GOVERNMENT EXPENDITURES AT LOCAL LEVEL;
FEDPROD0 = (SUM(Z,SAM(Z,"FED")));
DISPLAY QKSF0, QLASF0, KLAOUT0, FEDPROD0;
PARAMETER INVESOUT1,
          INVESOUT2(H),
          INVESOUT3,
          INVESOUT4(H),
          INVESD1(H),
          INVESD2(I),
          INVESD3;
 INVESOUT1 = SAM("INVES","ROW");
 INVESOUT2(H) = SAM("INVES",H);
 INVESOUT3 = (SUM(H,INVESOUT2(H)));
 INVESOUT4(H) = INVESOUT2(H)/INVESOUT3;
 INVESD1(H)= SAM("INVES",H);
 INVESD2(I) = SAM(I,"INVES");
 INVESD3 = (SUM(I,INVESD2(I)));
PARAMETER INVESOUT0(H),
          INVESD0(I,H);
```

```
 INVESOUT0(H)$(SAM("INVES",H) ne 0) = INVESOUT1*INVESOUT4(H);
 INVESD0(I,H)$INVESD1(H) = (INVESD2(I)/INVESD3)*(INVESD1(H)+INVESOUT0(H));
DISPLAY INVESD0;
DISPLAY INVESOUT0;
PARAMETER    QLS0(L,H) QUANTITY OF LABOR SUPPLIED BY HH,
            QDLEI0(L,H) LEISURE CONSUMPTION BY HOUSEHOLD,
            QADH0(IP,H) HOUSEHOLD ARMINGTON CONSUMPTION DEMAND,
            QHSDH0(HD,H) HOUSEHOLD HOUSING DEMAND,
            INVESD9(H);
 QDLEI0(L,H) = WORK1(L,H);
 QADH0(IP,H) = SAM(IP,H);
 QHSDH0(HD,H) = SAM(HD,H);
 INVESD9(H) = SUM(IP,INVESD0(IP,H));
PARAMETER TUSPIT0(H) US PERSONAL INCOME TAX,
         TCOPIT0(H) COLORADO PERSONAL INCOME TAX,
         TCOPIT1(H),
         TUSPIT1(H),
         THFEE0(H) FEES PAID BY HOUSEHOLDS TO STATE AND LOCAL
GOVERNMENT,
         QW0(H) UTILITY BY HOUSEHOLD GROUP,
         QW1(H) UTILITY BY HOUSEHOLD WITHOUT LEISURE,
         HSDSUM(H),
         ADSUM(H),
```

```
        LEISUM(H),
        QKSH0(K,H),
        CONSUMPTION0(H),
        INVESTMENT0(H),
        WORKSUM(H);
 QKSH0("KAP") = SAM(H,"KAP");
 CONSUMPTION0(H) = SUM(IP,QADH0(IP,H));
 INVESTMENT0(H) = SUM(K,QKSH0(K,H));
 TCOPIT0(H)= SAM("COPIT",H)/(CONSUMPTION0(H));
 TUSPIT0(H)= SAM("USPIT",H)/(CONSUMPTION0(H));
 THFEE0(H) = SAM("FEES",H)/(SUM(IP,QADH0(IP,H)));
 HSDSUM(H) = SUM(HD,QHSDH0(HD,H))*(1+TKH0(H));
 ADSUM(H) = SUM(IP,QADH0(IP,H))*(1+TUSPIT0(H)+TCOPIT0(H)+THFEE0(H));
 LEISUM(H) = SUM(L,QDLEI0(L,H));
 WORKSUM(H) = SUM(L,WORK1(L,H));
DISPLAY QDLEI0, QADH0, QHSDH0, HSDSUM, ADSUM, LEISUM, WORKSUM,
TUSPIT0, TCOPIT0, CONSUMPTION0, INVESTMENT0;
PARAMETER   QGC0(FG)  GOVERNMENT CONSUMPTION,
*GOVERNMENT OUTPUT CALCULATED WITHOUT TAX EXPENDITURES
          QLDG0(L,FG),
          QADG0(JP,FG),
          QGCDG0(FG),
          QFXDG0;
```

```
QGC0(FG) = (SUM(Z,SAM(Z,FG))-(SAM("SUBS",FG)));
QLDG0(L,FG) = SAM(L,FG);
QADG0(JP,FG) = SAM(JP,FG);
QGCDG0(FG) = SUM(Z,SAM(Z,FG));
QFXDG0 = SUM(Z,SAM("FED",Z))-(SAM("FED","ROW"))-(SAM("SUBS","FED"));
DISPLAY QGC0, QLDG0, QADG0, QGCDG0, QFXDG0;
PARAMETER    QY0(I)  DOMESTIC PRODUCTION OF GOODS AND SERVICES FOR DOMESTIC CONSUMPTION,
        QE0(IP)  DOMESTIC PRODUCTION OF GOODS AND SERVICES FOR EXPORT,
        QLDY0(L,I)  LABOR DEMAND FOR PRODUCTION OF GOODS AND SERVICES,
        QLADY0(I)   LAND DEMAND FOR PRODUCTION OF GOODS AND SERVICES,
        QKIDY0(K,I)    COMMERCIAL AND INDUSTRIAL CAPITAL DEMAND FOR PRODUCTION OF GOODS AND SERVICES,
        QADY0(JP,I)  INTERMEDIATE GOODS DEMAND FOR PRODUCTION,
        TCORP0(I) CORPORATE INCOME TAX,
        TCFEE0(I)  FEES PAID BY BUSINESS;
QE0(IP) = SAM(IP,"ROW");
QLDY0(L,IP) = SAM(L,IP);
QLADY0(IP) = SAM("LAND",IP);
QKIDY0(K,IP) = SAM(K,IP);
QADY0(JP,IP) = SAM(JP,IP);
QY0(IP) = SUM(Z,SAM(IP,Z))-SAM("ROW",IP)-SAM("LOCSTX",IP)-SAM("COSTX",IP);
TCORP0(IP) = SAM("CORPTAX",IP)/QY0(IP);
```

```
 TCFEE0(IP) = SAM("FEES",IP)/QY0(IP);
DISPLAY QY0, QE0, QLDY0, QLADY0, QKIDY0, QADY0;
PARAMETER     QHS0(HD) PRODUCTION OF IMPUTED HOUSING SERVICES,
              QLADHS0(HD) LAND DEMAND FOR HOUSING SERVICES,
              QKHDHS0(K,HD) CAPITAL DEMAND FOR HOUSING SERVICES,
              QADHS0(JP,HD) INTERMEDIATE GOODS DEMAND FOR HOUSING SERVICES;
 QHS0(HD) = SUM(Z,SAM(Z,HD));
 QLADHS0(HD) = SAM("LAND",HD);
 QKHDHS0(K,HD) = SAM(K,HD);
 QADHS0(JP,HD) = SAM(JP,HD);
DISPLAY QHS0, QLADHS0, QKHDHS0, QADHS0;
PARAMETER     QA0(IP)  PRODUCTION OF ARMINGTON AGGREGATES,
              QMDA0(IP) IMPORTS FOR AGGREGATION,
              QYDA0(IP) DOMESTIC OUTPUT FOR AGGREGATION,
              TLV0(I) LOCAL SALES TAXES,
              TSV0(I) STATE SALES TAXES;
 QMDA0(IP) = SAM("ROW",IP);
 QYDA0(IP) = QY0(IP)-QE0(IP);
 QA0(IP) = QMDA0(IP)+QYDA0(IP)+SAM("LOCSTX",IP)+SAM("COSTX",IP);
 TLV0(IP) = SAM("LOCSTX",IP)/(QA0(IP));
 TSV0(IP) = SAM("COSTX",IP)/(QA0(IP));
DISPLAY QA0, QMDA0, QYDA0;
PARAMETER     QKI0   COMMERCIAL CAPITAL,
```

QKH0   RESIDENTIAL CAPITAL,

QKDK0 DEMAND FOR INVESTMENT CAPITAL;

QKI0 = SUM(K,SUM(IP,SAM(K,IP)));

QKH0 = SUM(K,SUM(HD,SAM(K,HD)));

QKDK0 = SUM(K,SUM(I,SAM(K,I)));

DISPLAY QKI0, QKH0, QKDK0;

PARAMETER

QLASH0(H) ENDOWMENT OF LAND BY DOMESTIC HOUSEHOLDS,

QLEISSH0(L,H) ENDOWMENT OF LEISURE OR LABOR BY DOMESTIC HOUSEHOLDS,

LEISSUMSUP(H) TOTAL ENDOWMENT OF LEISURE OR LABOR BY HOUSEHOLDS,

QREMSH0(H) ENDOWMENT OF REMITTANCES BY DOMESTIC HOUSEHOLDS,

QSOCSH0(H) ENDOWMENT OF EXOGENOUS GOVERNMENT TRANSFERS BY DOMESTIC HOUSEHOLDS,

HH0(H) NUMBER OF HOUSEHOLDS,

INVD0(IP) INTERMEDIATES FOR CAPITAL PRODUCTION,

INV0 NET INVESTMENT,

QK0 CAPITAL STOCK,

QKAP0(K) CAPITAL STOCK BY TYPE,

KPROP(H),

KPROPF,

```
            SPEND(FSL)  GOVERNMENT SPENDING PROPORTIONS;
 SPEND(FSL) = SUM(Z,SAM(Z,FSL));
 QLASH0(H) = SAM(H,"LAND");
 QLEISSH0(L,H) = WORK1(L,H)*2;
 LEISSUMSUP(H) = SUM(L,QLEISSH0(L,H));
 QREMSH0(H) = SAM(H,"ROW");
 QSOCSH0(H) = SUM(GY,SAM(H,GY));
 HH0(H) = 1;
 QK0 = (SUM(K,(SUM(H,QKSH0(K,H))))+(sum(K,QKSF0(K))));
 QKAP0(K) = ((SUM(H,QKSH0(K,H)))+QKSF0(K));
 KPROP(H) = (sum(K,QKSH0(K,H)))/QK0;
 KPROPF = -SUM(K,SAM(K,"ROW"))/QK0;
 INVD0(IP) = SUM(H,INVESD0(IP,H));
 INV0 = SUM(IP,INVD0(IP));
DISPLAY QKSH0, QLASH0, LEISSUMSUP, QLEISSH0, QREMSH0, QSOCSH0, KPROP,
KPROPF;
PARAMETER
        TOTKAP(K),
        KAPPER(K),
        DEPRECIATION(K),
        QKENDOW0(K);
 TOTKAP(K)=(SUM(Z,SAM(K,Z))-SAM(K,"ROW"));
 KAPPER(K)=TOTKAP(K)/QK0;
```

```
 QKENDOW0(K) = QKSF0(K)+SUM(H,QKSH0(K,H));

 DEPRECIATION(K) = DEPRECIATE(K)*QKENDOW0(K);

DISPLAY TOTKAP, KAPPER, QKENDOW0,QKIDY0, DEPRECIATION;

VARIABLES BOP  BALANCE OF PAYMENTS;

PARAMETER PRODU  PRODUCTIVITY PARAMETER;

PARAMETER DEP DEPRECIATION;

PRODU = 1;

DEP = 0.1;

DISPLAY QKSH0, INVESOUT0, INVESD9;

SET T /1*10/;

SET TAFTER(T) /8*10/

SET TFIRST(T)

   TLAST(T);

TFIRST(T) = YES$(ORD(T) EQ 1);

TLAST(T)  = YES$(ORD(T) EQ CARD(T));

SCALAR         GRO     GROWTH RATE    /0.03/

               REN     INTEREST RATE  /0.03/

               DEL     DEPRECIATION RATE     /0.07/

PARAMETER       QREF(T) REFERENCE QUANTITY PATH,

               IREF(T) REFERENCE INVESTMENT PATH,

               PREF(T) REFERENCE PRICE PATH,

               SHOCK(T) shock to sector of interest,

               SHOCK2  second shock to sector,
```

SHOCK3(K),

TOTALDEP,

DEMCH(T),

newpk0(k),

kapprop(k,ip),

imdkapprop(k,ip),

newkapsum(ip),

newkapprop(k,ip),

newkapspend(k,ip),

newqkidy0(k,ip),

newkapdemand(k),

newtotkap,

newkapper(k),

newtotaldep,

kdemsum(ip),

hkdemsum(hd),

hkapprop(k,hd),

himdkapprop(k,hd),

hnewkapsum(hd),

hnewkapprop(k,hd),

hnewkapspend(k,hd),

hnewqkhdhs0(k,hd),

hnewkapdemand(k),

necessaryi(k),

necessaryi1,

necessaryi2,

newqksh0(k,h),

newqksf0(k),

sumispend,

sumkown(k),

ishareh(ip,k,h),

isharef(ip,k),

kshareh(k,h),

ksharef(k),

vacrate(k),

kscalar(k),

vacscalar(k),

DIFFK(K),

sumkendow(k),

kproph1(k,h),

kendow1(k,h),

krev(h),

oldkrev(h),

newkstock(k),

oldkbill(ip),

newkbill(ip),

```
        oldfork,
        newfork,
        dollval(k),
        newrpbill(ip),
        tki1(ip),
        newkappersum;
QREF(T) = (1+GRO)**(ORD(T)-1);
IREF(T) = (1+GRO)**(ORD(T));
PREF(T) = (1/(1+REN))**(ORD(T)-1);
SHOCK(T)=EPS;
SHOCK2=0;
SHOCK3(K)=0;
TOTALDEP = SUM(K,(KAPPER(K)*DEPRECIATE(K)));
**** contortions in GAMS to set non-unity capital prices to reflect
**** differences in depreciation rates without changing total
**** capital consumption by sector
newpk0(k)= (depreciate(k)+gro)*10 ;
kdemsum(ip) = sum(k,qkidy0(k,ip));
kapprop(k,ip) = qkidy0(k,ip)/(kdemsum(ip));
imdkapprop(k,ip) = newpk0(k)*kapprop(k,ip);
newkapsum(ip) = sum(k,imdkapprop(k,ip));
newkapprop(k,ip) = imdkapprop(k,ip)/newkapsum(ip);
newkapspend(k,ip) = kdemsum(ip)*newkapprop(k,ip);
```

```
newqkidy0(k,ip) = newkapspend(k,ip)/newpk0(k);

newkapdemand(k) = sum(ip,newqkidy0(k,ip));

hkdemsum(hd) = sum(k,qkhdhs0(k,hd));

hkapprop(k,hd) = qkhdhs0(k,hd)/hkdemsum(hd);

himdkapprop(k,hd) = newpk0(k)*hkapprop(k,hd);

hnewkapsum(hd) = sum(k,himdkapprop(k,hd));

hnewkapprop(k,hd) = himdkapprop(k,hd)/hnewkapsum(hd);

hnewkapspend(k,hd) = hkdemsum(hd)*hnewkapprop(k,hd);

hnewqkhdhs0(k,hd) = hnewkapspend(k,hd)/newpk0(k);

hnewkapdemand(k) = sum(hd,hnewqkhdhs0(k,hd));

**** checks to see if this is working properly and what aggregate depreciation

**** is going to be as well as how much investment spending would be needed

**** to keep the economy on the balanced growth path

newtotkap = sum(k,newkapdemand(k))+sum(k,hnewkapdemand(k));

newkstock(k) = newkapdemand(k)+hnewkapdemand(k);

newkapper(k) = (newkapdemand(k)+hnewkapdemand(k))/newtotkap;

newkappersum = sum(k,newkapper(k));

newtotaldep = sum(k,(newkapper(k)*depreciate(k)));

necessaryi(k) = (newkapdemand(k)+hnewkapdemand(k))*(depreciate(k)+gro)*10;

necessaryi1 = sum(k,necessaryi(k));

necessaryi2 = necessaryi1/(1+gro);

**** changes to capital endowments to reflect the above

sumkendow(k) = sum(h,qksh0(k,h))+qksf0(k);
```

```
kproph1(k,h) = qksh0(k,h)/sumkendow(k);

kendow1(k,h) = kproph1(k,h)*(newkapdemand(k)+hnewkapdemand(k));

krev(h) = sum(k,(newpk0(k)*kendow1(k,h)));

oldkrev(h) = sum(k,qksh0(k,h));

newQKSH0(K,H) = kendow1(k,h);

newQKSF0(K) = newkstock(k)-sum(h,kendow1(k,h));

sumispend = sum(ip,invd0(ip));

sumkown(k) = sum(h,(newqksh0(k,h)))+newqksf0(k);

ishareh(ip,k,h) = (invd0(ip)/sumispend)*(newqksh0(k,h)/newkstock(k));

isharef(ip,k) = (invd0(ip)/sumispend)*(newqksf0(k)/newkstock(k));

kshareh(k,h) = newqksh0(k,h)/newkstock(k);

ksharef(k) = newqksf0(k)/newkstock(k);

DIFFK(K) = SUMKOWN(K)-NEWKAPDEMAND(K)-HNEWKAPDEMAND(K);

oldkbill(ip) = sum(k,(qkidy0(k,ip)));

newkbill(ip) = sum(k,(newqkidy0(k,ip)*newpk0(k)));

newrpbill(ip) = sum(rp,(newqkidy0(rp,ip)*newpk0(rp)));

oldfork = sum(k,qksf0(k));

newfork = sum(k,(newqksf0(k)*newpk0(k)));

dollval(k) = newpk0(k)*newkstock(k);

PARAMETER TKI0(I)   PROPERTY TAXES ON COMMERCIAL CAPITAL;

 TKI0(IP)=SAM("CNPRP",IP)/((sum(RP,SAM(RP,IP)))+sum(LA,SAM(LA,IP)));

 tki1(ip) = sam("CNPRP",ip)/(newrpbill(ip)+sam("LAND",ip));

PARAMETER QSAVING0(H)   HOUSEHOLD SAVINGS,
```

```
COINREV  COLORADO INCOME TAX REVENUE ON INCOME SAVED;
* QUANTITY OF DOMESTIC SAVINGS *
 QSAVING0(H) = INVESD9(H)-INVESOUT0(H);
* ADJUSTED COLORADO INCOME TAX RATE *
 TCOPIT1(H)= SAM("COPIT",H)/(SUM(IP,QADH0(IP,H))+QSAVING0(H));
* ADJUSTED US INCOME TAX RATE *
 TUSPIT1(H)= SAM("USPIT",H)/(SUM(IP,QADH0(IP,H))+QSAVING0(H));
* TOTAL UTILITY OUTPUT/CONSUMPTION WITH ADJUSTED INCOME TAX RATES *
 QW1(H) =
((SUM(HD,QHSDH0(HD,H)))*(1+TKH0(H)))+((SUM(IP,QADH0(IP,H)))*(1+TUSPIT1(H)+T
COPIT1(H)+THFEE0(H)));
 COINREV = SUM(H,(TCOPIT1(H)*QSAVING0(H)));
DISPLAY TOTALDEP, newtotaldep, newkappersum, necessaryi1, necessaryi2, invesd3,
ishareh, DIFFK, krev, oldkrev, oldkbill, newkbill, oldfork, newfork, dollval,
newkstock, newpk0, tuspit1;
PARAMETER DEM(K,IP,T) DEMAND SCALAR FOR COMMERCIAL PROPERTY
USAGE;
 DEM(K,IP,T)$SAM(K,IP) = SAM(K,IP)/SAM(K,IP);
$ONTEXT
$MODEL: COLORADO
$COMMODITIES:
P_L(L,T)          !   WAGE INDEX
P_LA(T)           !   LAND RENT INDEX
```

P_K(K,T) ! FINANCIAL CAPITAL RETURN INDEX

P_W(H,T) ! WELFARE PRICE INDEX

P_LS(L,H,T)$WORK(L,H) ! LEISURE PRICE INDEX

P_GC(FG,T) ! GOVERNMENT CONSUMPTION PRICE

P_A(IP,T) ! ARMINGTON AGGREGATE PRICE

P_Y(IP,T) ! SECTORAL PRODUCTION PRICE

P_H(HD,T) ! HOUSING PRICE

P_FX(T) ! PRICE OF FOREIGN EXCHANGE

$SECTORS:

A_GOVT(FG,T) ! GOVERNMENT EXPENDITURE

A_YARM(IP,T) ! PRODUCTION OF ARMINGTON AGGREGATES

A_LS(H,T) ! LABOR SUPPLY

A_W(H,T) ! WELFARE INDEX

A_Y(IP,T) ! SECTORAL PRODUCTION

A_H(HD,T) ! HOUSING SERVICES

$CONSUMERS:

I_GOVT0(T) ! STATE AND LOCAL GOVERNMENT REVENUE

I_GOVT1(T)

I_GOVT2(T)

I_GOVT3(T)

I_GOVT4(T)

LOC_GOVT1(T)

LOC_GOVT2(T)

```
LOC_GOVT3(T)
F_GOVT(T)          !   FEDERAL GOVERNMENT REVENUE
RA(H,T)            !   HOUSEHOLD INCOME
RAF(T)             !   OUT-OF-STATE HOLDERS OF LAND AND CAPITAL
IMPACT(T)
IMPACT_2(T)
EXPORTS(IP,T)
$AUXILIARY:
LAS(T)             !   ENDOGENOUS SUPPLY OF DEVELOPABLE LAND
MIG(H,T)           !   ENDOGENOUS HOUSEHOLD MIGRATION
LSUP(H,T)          !   ENDOGENOUS LABOR SUPPLY
INVEST(K,T)        !   ENDOGENOUS INVESTMENT
OWN(K,T)           !   DESIRE TO OWN CAPITAL
EXPDEM(IP,T)
COSAVINGSTAX(T)    !   COLORADO INCOME TAX ON SAVINGS
SAVING(H,T)        !   ENDOGENOUS SAVINGS WITH CONSTANT SAVINGS RATE
$PROD:A_LS(H,T) s:100
*Labor Supply
O: P_L(L,T)        Q: QLABSUP0(L,H)  p: (1-TLS1(L)) A: F_GOVT(T) T: TLS1(L)
I: P_LS(L,H,T)$WORK(L,H)      Q: WORK1(L,H)
$PROD:A_W(H,T)  s:1
*  Welfare produced using leisure, goods and services
O: P_W(H,T)        Q: QW1(H)
```

* Income taxes proportional to factor use to generate HH specific welfare indices

I: P_A(IP,T)   Q: QADH0(IP,H) P: (1+TCOPIT1(H)+TUSPIT1(H)+THFEE0(H)) A: I_GOVT1(T)

T: TCOPIT1(H) A: F_GOVT(T) T: TUSPIT1(H) A: I_GOVT2(T) T: THFEE0(H)

I: P_H(HD,T)   Q: QHSDH0(HD,H) P: (1+TKH0(H)) A: LOC_GOVT2(T) T: TKH0(H)

$PROD:A_GOVT(FG,T) s:1   int:0

*Production of government services

O: P_GC(FG,T)   Q: QGC0(FG)

I: P_L(L,T)   Q: QLDG0(L,FG) P: (1+TLDG0(L,FG)) A: F_GOVT(T) T: TLDG0(L,FG)

I: P_A(JP,T)   Q: QADG0(JP,FG)   int:

$PROD:A_Y(IP,T)   s:1 kl: 0.4 int:0

*Domestic production of goods and services

*kl nest to reflect Raval (2011) complementarity between capital and labor

O: P_Y(IP,T)   Q: (PRODU*QY0(IP)) P: (1-TCORP0(IP)-TCFEE0(IP)) A: I_GOVT3(T) T: TCORP0(IP) A: I_GOVT2(T) T: TCFEE0(IP)

I: P_L(L,T)   Q: QLDY0(L,IP) P: (1+TLDI0(L,IP)) A: F_GOVT(T) T: TLDI0(L,IP) kl:

I: P_LA(T)   Q: QLADY0(IP)   P: (1+TKI1(IP)) A: LOC_GOVT1(T) T: TKI1(IP)

I: P_K(K,T)   Q: (DEM(K,IP,T)*newQKIDY0(K,IP)) P: (newpk0(K)*(1+TKI1(K))) A: LOC_GOVT1(T) T: TKI1(K) kl:

I: P_A(JP,T)   Q: QADY0(JP,IP) int:

$PROD:A_H(HD,T)   s:1 int:0

*Domestic production of housing services

O: P_H(HD,T)   Q: QHS0(HD)

I: P_LA(T)   Q: QLADHS0(HD)

I: P_K(K,T)   Q: hnewQKHDHS0(K,HD) P: newpk0(k)

I: P_A(JP,T)   Q: QADHS0(JP,HD) int:

$PROD:A_YARM(IP,T)   s:1

*Production of Armington aggregates using imports

O: P_A(IP,T)   Q: QA0(IP) P: (1-TSV0(IP)-TLV0(IP)) A: I_GOVT4(T) T: TSV0(IP) A: LOC_GOVT3(T) T: TLV0(IP)

I: P_FX(T)   Q: QMDA0(IP)

I: P_Y(IP,T)   Q: (QY0(IP)-QE0(IP))

$DEMAND:EXPORTS(IP,T)

*Export demand as independent block - no substitution between exports BUT each is given a -1.0 price elasticity via EXPDEM

D: P_Y(IP,T)   Q: QE0(IP)

E: P_FX(T)   Q: (QE0(IP)*QREF(T)) R: EXPDEM(IP,T)

$DEMAND:RA(H,T)

* Utility Maximization

D: P_W(H,T)   Q: (QW1(H)*QREF(T))

* Land Endowment

E: P_LA(T)   Q: (QLASH0(H)*QREF(T)) R: LAS(T)

* Time Endowment (used to generate Labor)

E: P_LS(L,H,T)$WORK(L,H)   Q: (WORK1(L,H)*QREF(T))   R: LSUP(H,T)

E: P_LS(L,H,T)$WORK(L,H)   Q: (WORK1(L,H)*QREF(T))   R: MIG(H,T)

* Remittances

E: P_FX(T)   Q: (QREMSH0(H)*QREF(T))

* Outflow of savings

E: P_FX(T)   Q: (-QSAVING0(H)*QREF(T))   R: SAVING(H,T)

* US income taxes on savings outflows

E: P_FX(T)   Q: (-QSAVING0(H)*QREF(T)*TUSPIT1(H))   R: SAVING(H,T)

* CO income taxes on savings outflows

E: P_FX(T)   Q: (-QSAVING0(H)*QREF(T)*TCOPIT1(H))   R: SAVING(H,T)

* Social Security Payments

E: P_FX(T)   Q: (QSOCSH0(H)*QREF(T))

* Per Period Capital Endowment

E: P_K(K,T)   Q: (kscalar(k)*kshareh(k,h)) R: OWN(K,T)

* Borrowing to finance baseline investment

E: P_FX(T)   Q: (SUM(K,QKSH0(K,H))*QREF(T))

* Capital supply shocks for simulations

*E: P_K(K,T)   Q: SHOCK3(K)

* Construction/Investment Spending

E: P_A(IP,T)   Q: (-ishareh(IP,"KAP",H))   R: INVEST("KAP",T)

$DEMAND:RAF(T)

* Demand for "foreign exchange"

D: P_FX(T)   Q: (KLAOUT0*QREF(T))

* Out-of-state ownership of capital

E: P_K(K,T)   Q: (kscalar(k)*ksharef(k))   R: OWN(K,T)

* Out-of-state ownership of land

E: P_LA(T)   Q: (QLASF0*QREF(T)) R: LAS(T)

* Construction/Investment Spending

E: P_A(IP,T)   Q: (-isharef(IP,"KAP"))   R: INVEST("KAP",T)

$DEMAND:IMPACT_2(T)

*SIMULATED SHOCK TO CAPITAL STOCK

D: P_FX(T)   Q: 1

E: P_K(K,T)   Q: SHOCK3(K)

$DEMAND:IMPACT(T)

*SIMULATED SHOCK TO CONSTRUCTION SECTOR DEMAND

D: P_Y("Const",T)   Q: 1

E: P_FX(T)   Q: SHOCK(T)

$DEMAND:I_GOVT0(T)

*FUNDING OF FEDERAL GOVERNMENT SERVICES

D: P_GC("FED",T)   Q: (FEDPROD0*QREF(T))

E: P_FX(T)   Q: (FEDPROD0*QREF(T))

$DEMAND:I_GOVT1(T)

*COLORADO PERSONAL INCOME TAX

D: P_GC(FSL,T)   Q: (SPEND(FSL)*QREF(T))

E: P_FX(T)   Q: (COINREV*QREF(T)) R: COSAVINGSTAX(T)

$DEMAND:I_GOVT2(T)

*COLORADO GOVERNMENT FEES-FOR-SERVICE

D: P_GC(FSL,T)   Q: (SPEND(FSL)*QREF(T))

$DEMAND:I_GOVT3(T)

*COLORADO CORPORATE INCOME TAX

D: P_GC(FSL,T)   Q: (SPEND(FSL)*QREF(T))

$DEMAND:I_GOVT4(T)

*COLORADO SALES TAX

D: P_GC(FSL,T)   Q: (SPEND(FSL)*QREF(T))

$DEMAND:LOC_GOVT1(T)

*BUSINESS PROPERTY TAX

D: P_GC(FSL,T)   Q: (SPEND(FSL)*QREF(T))

$DEMAND:LOC_GOVT2(T)

*RESIDENTIAL PROPERTY TAX

D: P_GC(FSL,T)   Q: (SPEND(FSL)*QREF(T))

$DEMAND:LOC_GOVT3(T)

*LOCAL SALES TAX

D: P_GC(FSL,T)   Q: (SPEND(FSL)*QREF(T))

$DEMAND:F_GOVT(T)

*OUTFLOW OF FEDERAL TAXES

D: P_FX(T)   Q: (1*QREF(T))

$REPORT:

  V: EMP(L,T,H)   O: P_L(L,T) PROD:A_LS(H,T)

  V: OUTP(IP,T)   O: P_Y(IP,T) PROD:A_Y(IP,T)

  V: HOUTP(HD,T)   O: P_Y(HD,T) PROD:A_Y(HD,T)

  V: GOUTP(FG,T)   O: P_GC(FG,T) PROD:A_GOVT(FG,T)

* ELASTICITIES OF INVESTMENT SUPPLY, LAND SUPPLY AND MIGRATION SET TO TWO AND A HALF

$CONSTRAINT:LAS(T)

LAS(T) =E= ((LAS(T-1)+1$TFIRST(T))+(((P_LA(T))-P_LA(T-1)-1$TFIRST(T))*2.5));

$CONSTRAINT:LSUP(H,T)

(LSUP(H,T)-1) =E= (0.3*((SUM(L,(P_L(L,T)*WORKPROP(L,H)))/P_W(H,T))-1));

$CONSTRAINT:MIG(H,T)

(MIG(H,T)) =E= (MIG(H,T-1))+(0.1*((SUM(L,(P_L(L,T)*WORKPROP(L,H)))/P_W(H,T))-1));

$CONSTRAINT:OWN(K,T)

OWN(K,T) =E= ((1-DEPRECIATE(K))*OWN(K,T-1))+SUMKOWN(K)$TFIRST(T)+(INVEST(K,T-1)/10);

$CONSTRAINT:INVEST(K,T)

INVEST(K,T) =E= (1+(((P_K(K,T)/NEWPK0(K))-1)*1.0))*QREF(T)*SUMKOWN(K)*(DEPRECIATE(K)+GRO)*10;

$CONSTRAINT:EXPDEM(IP,T)

EXPDEM(IP,T) =E= (1/P_Y(IP,T));

$CONSTRAINT:SAVING(H,T)

SAVING(H,T) =E= P_W(H,T)*(A_W(H,T)/qref(t));

$CONSTRAINT:COSAVINGSTAX(T)

COSAVINGSTAX(T) =E= SUM(H,(QSAVING0(H)*SAVING(H,T)))/SUM(H,QSAVING0(H));

$OFFTEXT

```
$SYSINCLUDE mpsgeset COLORADO

P_FX.FX(T)=1;

P_K.L(K,T)=newpk0(k);

P_K.LO(K,T)=eps;

LSUP.L(H,T)=1;

MIG.L(H,T)=0;

MIG.LO(H,T)=-100;

INVEST.L(K,T)=newkstock(k)*qref(t)*10*(depreciate(k)*gro);

INVEST.LO(K,T)=0;

LAS.L(T)=1;

LAS.LO(T)=0;

P_L.L(L,T)=1;

P_LA.L(T)=1;

P_W.L(H,T)=1;

P_Y.L(IP,T)=1;

P_A.L(IP,T)=1;

A_W.L(H,T)=1;

A_Y.L(IP,T)=1;

OWN.L(K,T)=newkstock(k)*qref(t);

OWN.LO(K,T)=((1-DEPRECIATE(K))**(ORD(T)));

SET RUN(SM) /BASE,TODAY,SIMM1/;

PARAMETER SUMMARY(*,SM)   SOLUTION SUMMARY;

TABLE TAXCHANGE(SM,*) INDICATORS FOR TAX RATE SIMULATIONS
```

```
          S
BASE         0
TODAY        0
SIMM1        1;
IF (RUN("BASE"), COLORADO.ITERLIM=0;);
FILE RESULTS /C:\Users\Chris\Documents\Disser\Disser\cofix.txt/;
LOOP(SM$RUN(SM),
    IF (TAXCHANGE(SM,"S"),
       ;
ELSE
    );
$INCLUDE COLORADO.GEN
COLORADO.OPTFILE = 0;
OPTION SYSOUT=ON;
SOLVE COLORADO USING MCP;
    COLORADO.ITERLIM = 5000;
    COLORADO.WORKFACTOR=3.0;
    SUMMARY("STATUS",SM) = COLORADO.MODELSTAT;
    SUMMARY("ITERS",SM) = COLORADO.ITERUSD;
    SUMMARY("CPU",SM) = COLORADO.RESUSD;
    SUMMARY("CONTROL",SM) = COLORADO.OBJVAL;
PUT RESULTS;
    );
```

```
DISPLAY SUMMARY;

SET SUMMARY1  /STATUS, ITERS, CPU, CONTROL /

PUT 'COLORADO      ';

 LOOP(SM, PUT '     ',SM.TL);

 PUT /;

LOOP(SUMMARY1, PUT '          ';

       PUT SUMMARY1.TL,

       LOOP(SM, PUT SUMMARY(SUMMARY1,SM) );

       PUT / );
```

Appendix B

CO-RE Model in GAMS MPSGE

```
$TITLE COLORADO
*-------------------------------------------------------------------------------
* 1.1 CONTROLS PLACED ON OUTPUT GENERATION
*----------------------------------------------------------------------------------------------------------
$OFFSYMLIST OFFSYMXREF
*----------------------------------------------------------------------------------------------------------
* 1.2 SET UP FILE FOR SOLUTION VALUES
*----------------------------------------------------------------------------------------------------------
*----------------------------------------------------------------------------------------------------------
* 2. SET DEFINITION
*----------------------------------------------------------------------------------------------------------
* 2.1 EXPLICIT SET DECLARATION
*----------------------------------------------------------------------------------------------------------
SETS  Z  ALL ACCOUNTS IN SOCIAL ACCOUNTING MATRIX /
 Agric
 Mining
Coal
Elec
NatGas
```

Utilities

Const

Manuf

WHTR

Retail

TransWare

Info

FinIns

RealEst

HGSER

Manage

Admin

Educ

unijc

HealthCare

Arts

LodgeRest

OtherServ

PubAdm

HS1

HS2

HS3

HS4

HS5

HS6

L1

L2

L3

L4

L5

LAND

SingleResSF

MultiResSF

TechK

OtherK

MachineryK

GridK

AutoK

OtherTransK

OfficeSF

MedicalSF

WarehouseSF

MobileSF

RetailSF

ManufacturingSF

InfrastructureSF

ChurchSF

SchoolSF

RecreationSF

HotelSF

FarmSF

HH1

HH2

HH3

HH4

HH5

HH6

HH7

INVES

USSOCL1

USSOCL2

USSOCL3

USSOCL4

USSOCL5

USPIT

COPIT

CORPTAX

CNPRP

FEES

COSTX

LOCSTX

CYGF

SUBS

FED

STED

STHEALTH

STJUST

STADM

CDOT

ROW /

F(Z) FACTORS /

L1,L2,L3,L4,L5,LAND,SingleResSF,MultiResSF,TechK,OtherK,MachineryK,GridK,AutoK,

OtherTransK,OfficeSF,MedicalSF,WarehouseSF,MobileSF,RetailSF,ManufacturingSF,

InfrastructureSF,ChurchSF,SchoolSF,RecreationSF,HotelSF,FarmSF/

L(F) LABOR /L1,L2,L3,L4,L5/

LA(F) LAND /LAND/

K(F) CAPITAL

/SingleResSF,MultiResSF,TechK,OtherK,MachineryK,GridK,AutoK,

OtherTransK,OfficeSF,MedicalSF,WarehouseSF,MobileSF,RetailSF,ManufacturingSF,

InfrastructureSF,ChurchSF,SchoolSF,RecreationSF,HotelSF,FarmSF/

PP(K) PERSONAL PROPERTY

/TechK,OtherK,MachineryK,GridK,AutoK,OtherTransK/

RP(K) REAL PROPERTY /OfficeSF,MedicalSF,WarehouseSF,MobileSF,RetailSF,ManufacturingSF,InfrastructureSF,

ChurchSF,SchoolSF,RecreationSF,HotelSF,FarmSF/

PPORH(K) PERSONAL PROPERTY AND HOUSING /TechK,OtherK,MachineryK,GridK,AutoK,OtherTransK,SingleResSF,MultiResSF/

G(Z) GOVERNMENTS / USSOCL1, USSOCL2, USSOCL3,USSOCL4, USSOCL5, USPIT, COPIT, CORPTAX,CNPRP,FEES,

COSTX,LOCSTX,

CYGF,SUBS,FED,STED,STHEALTH,STJUST,STADM,CDOT/

GN(G) ENDOGENOUS GOVERNMENTS / FED,STED,STHEALTH,STJUST,STADM,CDOT /

*GOVP(I) ENDOGENOUS GOVERNMENTS / FED,STED,STHEALTH,STJUST,STADM,CDOT /

GNL(G) lOCAL ENDOGENOUS GOVERNMENTS / STED,STHEALTH,STJUST,STADM,CDOT/

GX(G) EXOGENOUS GOVERMENTS / USSOCL1, USSOCL2, USSOCL3,USSOCL4,USSOCL5,USPIT, COPIT, CORPTAX,CNPRP,FEES,COSTX,LOCSTX/

GS(G) SALES OR EXCISE TAXES / FEES,COSTX,LOCSTX,corptax /

*GK(G) USE TAX (KTAX) / CYUSE/

GL(G) LAND TAXES / CNPRP/

GF(G) FACTOR TAXES / USSOCL1, USSOCL2, USSOCL3,USSOCL4,USSOCL5, CNPRP/

GI(G) INCOME TAX UNITS / USPIT,copit /

GH(G) HOUSEHOLD TAX UNITS / CNPRP,fees /

GY(G) EXOGNOUS TRANSFER PMT / USSOCL1, USSOCL2, USSOCL3, USSOCL4, USSOCL5, USPIT, COPIT, CORPTAX,CNPRP,FEES,COSTX,LOCSTX, FED/

GTA(G) EXOGNOUS TRANSFER PMT / USSOCL1, USSOCL2,USSOCL3,USSOCL4,USSOCL5, USPIT, COPIT, CORPTAX,CNPRP,FEES,COSTX,LOCSTX, CYGF,FED/

GT(G) ENDOGENOUS TRANSFER PMT / CYGF, FED /

H(Z) HOUSEHOLDS / HH1, HH2, HH3, HH4, HH5, HH6,HH7 /

WORK(L,H) WORKERS /L1.(HH1,HH2,HH3,HH4,HH5,HH6,HH7)

L2.(HH2,HH3,HH4,HH5,HH6,HH7)

L3.(HH5,HH6,HH7)

L4.(HH6,HH7)

L5.(HH7)/

IG(Z) I+G SECTORS / Agric, Mining,Coal,Elec,NatGas, Utilities, Const,Manuf, WHTR, Retail,TransWare, Info,FinIns,RealEst,HGSER,Manage,

Admin,Educ,unijc,HealthCare,

Arts,LodgeRest,OtherServ,PubAdm,HS1,HS2,HS3,HS4,HS5,HS6,

FED,STED,STHEALTH,STJUST,STADM,CDOT/

I(IG) INDUSTRY SECTORS / Agric, Mining,Coal,Elec,NatGas,

Utilities, Const,Manuf, WHTR, Retail,TransWare, Info,FinIns,RealEst,HGSER,Manage, Admin,Educ,unijc,HealthCare,

Arts,LodgeRest,OtherServ,PubAdm,HS1,HS2,HS3,HS4,HS5,HS6/

IG2(IG) ENDOGENOUS GOVERNMENTS /

FED,STED,STHEALTH,STJUST,STADM,CDOT /

IP(I) PRODUCTION SECTORS /Agric, Mining,Coal,Elec,NatGas, Utilities, Const,Manuf, WHTR, Retail,TransWare,

Info,FinIns,RealEst,HGSER,Manage,Admin,Educ,unijc,HealthCare,

Arts,LodgeRest,OtherServ,PubAdm/

OFFUSE(IP) OFFICE-USING SECTORS /FinIns,Retail,HGSER,Manage,Admin/

PRIVS(IP) PRIVATE CAPITAL-USING SECTORS /Agric, Mining,Coal,Elec,NatGas, Utilities, Const,Manuf, WHTR, Retail,TransWare,

Info,FinIns,RealEst,HGSER,Manage,Admin,Educ,unijc,HealthCare,

Arts,LodgeRest,OtherServ/

FG(IG) PRODUCTION GOV. /FED,STED,STHEALTH,STJUST,STADM,CDOT/

FSL(FG) STATE AND LOCAL GOV. /STED,STHEALTH,STJUST,STADM,CDOT/

FEDR(FG) FEDERAL GOV. /FED/

HD(I) HOUSING SERV.DEMAND /HS1, HS2, HS3, HS4, HS5, HS6/

SF(HD) DETACHED HOUSING /HS1,HS2,HS3,HS4,HS5/

MUF(HD) ATTACHED HOUSING /HS6/

SM SIMMLOOP

/BASE,TODAY,SIMM1,SIMM2,SIMM3,SIMM4,SIMM5,SIMM6,SIMM7/

R1H REPORT 1 FOR SCALARS / GFREV, SFREV, PIT,

DGF, DSF, DDRE, PDRE, SPI,COMM,COMMO,

GN, NKI, HH, W, W1, W2, W3, R,RL, L, K, HN,HW, GFSAV, LD,

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 /

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* 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

*---

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* 3.1 SOCIAL ACCOUNTING MATRIX, CAPITAL COEFFICIENT MATRIX AND
PARAMETERS
*-----------------------------------------------------------------
TABLE SAM(Z,Z1) SOCIAL ACCOUNTING MATRIX
$ONDELIM
$INCLUDE c:\Users\Chris\Documents\Dissertation Related Stuff\NIPAsam2.csv
$OFFDELIM
*------------------------------------------------------------------------------------------------------------
* 3.2 PARAMETER DECLARATION
*------------------------------------------------------------------------------------------------------------
PARAMETERS
* PARAMETERS CALCULATED FROM SOCIAL ACCOUNTING MATRIX AND TABLE
DATA
HH0(H)      DOF    HHDS    NUMBER OF HOUSEHOLDS
HN0(H)      DOF    HHDS    NUMBER OF NONWORKING HOUSEHOLDS
HW0(H)      DOF    HHDS    NUMBER OF WORKING HOUSEHOLDS;
*------------------------------------------------------------------------------------------------------------
* 3.3 CALCULATIONS OF PARAMETERS AND INITIAL VALUES
*------------------------------------------------------------------------------------------------------------
OPTION DECIMALS=8 ;
TABLE MISCH(H,*) MISC.  HH DATA
         HH0                HW0
HH1      122862             121827
```

```
HH2     175378          171415

HH3     385109          366882

HH4     182306          171916

HH5     365070          339473

HH6     250286          235032

HH7     405588          376157;

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

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

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

PARAMETER TKI0(I)   PROPERTY TAXES ON COMMERCIAL CAPITAL;

TKI0(IP)=SAM("CNPRP",IP)/((sum(RP,SAM(RP,IP)))+sum(LA,SAM(LA,IP)));

PARAMETER TKH0(H) PROPERTY TAXES ON RESIDENTIAL CAPITAL;

TKH0(H)=(SAM("CNPRP",H)/(SUM(HD,SAM(HD,H))));

DISPLAY TKI0, TKH0;

PARAMETER TLDI0(L,I)  PRIVATE EMPLOYER SHARE OF PAYROLL TAXES;

  TLDI0("L1",IP)= SAM("USSOCL1",IP)/SAM("L1",IP);

  TLDI0("L2",IP)= SAM("USSOCL2",IP)/SAM("L2",IP);

  TLDI0("L3",IP)= SAM("USSOCL3",IP)/SAM("L3",IP);

  TLDI0("L4",IP)= SAM("USSOCL4",IP)/SAM("L4",IP);

  TLDI0("L5",IP)= SAM("USSOCL5",IP)/SAM("L5",IP);

PARAMETER TLDG0(L,FG)  PUBLIC EMPLOYER SHARE OF PAYROLL TAXES;

  TLDG0("L1",FG) = SAM("USSOCL1",FG)/SAM("L1",FG);

  TLDG0("L2",FG) = SAM("USSOCL2",FG)/SAM("L2",FG);
```

```
  TLDG0("L3",FG) = SAM("USSOCL3",FG)/SAM("L3",FG);
  TLDG0("L4",FG) = SAM("USSOCL4",FG)/SAM("L4",FG);
  TLDG0("L5",FG) = SAM("USSOCL5",FG)/SAM("L5",FG);
PARAMETER LI0(L);
 LI0(L)=SUM(H,SAM(H,L));
PARAMETER TLS0(L)   EMPLOYEE SHARE OF PAYROLL TAXES;
 TLS0("L1") = SAM("USSOCL1","L1")/(LI0("L1")+SAM("USSOCL1","L1"));
 TLS0("L2") = SAM("USSOCL2","L2")/(LI0("L2")+SAM("USSOCL2","L2"));
 TLS0("L3") = SAM("USSOCL3","L3")/(LI0("L3")+SAM("USSOCL3","L3"));
 TLS0("L4") = SAM("USSOCL4","L4")/(LI0("L4")+SAM("USSOCL4","L4"));
 TLS0("L5") = SAM("USSOCL5","L5")/(LI0("L5")+SAM("USSOCL5","L5"));
PARAMETER TLS1(L) PAYROLL TAX RATE FOR MPSGE;
 TLS1(L) = TLS0(L)
TABLE WORK0(L,H)
         HH1          HH2          HH3          HH4          HH5
L1       1963.200402   883.467607    848.743351    751.908112    1156.110615
L2       0             2285.337821   4077.302229   5991.492537   7193.962546
L3       0             0             0             0             7027.453123
L4       0             0             0             0             0
L5       0             0             0             0             0
+        HH6          HH7
L1       1039.999790   1113.363917
L2       9054.106853   7075.077710
```

```
L3       5759.216302   8730.033725

L4       7918.629220   12364.851540

L5       18.394169     33887.143330;

PARAMETER DEPRECIATE(K);

DEPRECIATE("SingleResSF")      =0.030;

DEPRECIATE("MultiResSF")       =0.030;

DEPRECIATE("TechK")            =0.433;

DEPRECIATE("OtherK")           =0.144;

DEPRECIATE("MachineryK")       =0.375;

DEPRECIATE("GridK")            =0.050;

DEPRECIATE("AutoK")            =0.198;

DEPRECIATE("OtherTransK")      =0.071;

DEPRECIATE("OfficeSF")         =0.024;

DEPRECIATE("MedicalSF")        =0.020;

DEPRECIATE("WarehouseSF")      =0.022;

DEPRECIATE("MobileSF")         =0.048;

DEPRECIATE("RetailSF")         =0.026;

DEPRECIATE("ManufacturingSF")  =0.031;

DEPRECIATE("InfrastructureSF") =0.037;

DEPRECIATE("ChurchSF")         =0.019;

DEPRECIATE("SchoolSF")         =0.019;

DEPRECIATE("RecreationSF")     =0.030;

DEPRECIATE("HotelSF")          =0.028;
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```
DEPRECIATE("FarmSF")          =0.116;
PARAMETER KLAOUT0 NON-RESIDENT OWNERSHIP OF LAND AND CAPITAL,
        QKSF0(K)  NON-RESIDENT OWNERSHIP OF CAPITAL,
        QLASF0 NON-RESIDENT OWNERSHIP OF LAND;
 QKSF0(K) = -SAM(K,"ROW");
 QLASF0 = -SAM("LAND","ROW");
 KLAOUT0 = SUM(K,QKSF0(K)) + QLASF0;
PARAMETER WORK1(L,H)  WORKERS BY HOUSEHOLD BY LABOR GROUP,
        LABGRPSHARE(L,H),
        QFICA(L,H),
        WORKPROP(L,H),
        WRKSUM(H),
        QLABSUP0(L,H);
  WORK1(L,H) = WORK0(L,H)$WORK(L,H);
  LABGRPSHARE(L,H) = WORK1(L,H)/LI0(L);
  QFICA("L1",H) = LABGRPSHARE("L1",H)*(SAM("USSOCL1","L1"));
  QFICA("L2",H) = LABGRPSHARE("L2",H)*(SAM("USSOCL2","L2"));
  QFICA("L3",H) = LABGRPSHARE("L3",H)*(SAM("USSOCL3","L3"));
  QFICA("L4",H) = LABGRPSHARE("L4",H)*(SAM("USSOCL4","L4"));
  QFICA("L5",H) = LABGRPSHARE("L5",H)*(SAM("USSOCL5","L5"));
  QLABSUP0(L,H) = WORK1(L,H)+QFICA(L,H);
  WRKSUM(H) = SUM(L,WORK1(L,H));
  WORKPROP(L,H) = WORK1(L,H)/WRKSUM(H);
```

```
DISPLAY LABGRPSHARE;
PARAMETER FEDPROD0 FEDERAL GOVERNMENT EXPENDITURES AT LOCAL LEVEL;
FEDPROD0 = (SUM(Z,SAM(Z,"FED")));
DISPLAY QKSF0, QLASF0, KLAOUT0, FEDPROD0;
PARAMETER INVESOUT1,
        INVESOUT2(H),
        INVESOUT3,
        INVESOUT4(H),
        INVESD1(H),
        INVESD2(I),
        INVESD3;
INVESOUT1 = SAM("INVES","ROW");
 INVESOUT2(H) = SAM("INVES",H);
 INVESOUT3 = (SUM(H,INVESOUT2(H)));
 INVESOUT4(H) = INVESOUT2(H)/INVESOUT3;
 INVESD1(H)= SAM("INVES",H);
INVESD2(I) = SAM(I,"INVES");
INVESD3 = (SUM(I,INVESD2(I)));
PARAMETER INVESOUT0(H),
        INVESD0(I,H);
 INVESOUT0(H)$(SAM("INVES",H) ne 0) = INVESOUT1*INVESOUT4(H);
 INVESD0(I,H)$INVESD1(H) = (INVESD2(I)/INVESD3)*(INVESD1(H)+INVESOUT0(H));
```

```
DISPLAY INVESD0;

DISPLAY INVESOUT0;

PARAMETER    QLS0(L,H) QUANTITY OF LABOR SUPPLIED BY HH,

             QDLEI0(L,H) LEISURE CONSUMPTION BY HOUSEHOLD,

             QADH0(IP,H) HOUSEHOLD ARMINGTON CONSUMPTION DEMAND,

             QHSDH0(HD,H) HOUSEHOLD HOUSING DEMAND,

             INVESD9(H);

QDLEI0(L,H) = WORK1(L,H);

QADH0(IP,H) = SAM(IP,H);

 QHSDH0(HD,H) = SAM(HD,H);

 INVESD9(H) = SUM(IP,INVESD0(IP,H));

PARAMETER TUSPIT0(H) US PERSONAL INCOME TAX,

          TCOPIT0(H) COLORADO PERSONAL INCOME TAX,

          TCOPIT1(H),

          TUSPIT1(H),

          THFEE0(H) FEES PAID BY HOUSEHOLDS TO STATE AND LOCAL
GOVERNMENT,

          QW0(H) UTILITY BY HOUSEHOLD GROUP,

          QW1(H) UTILITY BY HOUSEHOLD WITHOUT LEISURE,

          HSDSUM(H),

          ADSUM(H),

          LEISUM(H),

          QKSH0(K,H),
```

```
        CONSUMPTION0(H),
        INVESTMENT0(H),
        WORKSUM(H);
QKSH0("SingleResSF",H)=SAM(H,"SingleResSF");
QKSH0("MultiResSF",H)=SAM(H,"MultiResSF");
QKSH0("TechK",H)=SAM(H,"TechK");
QKSH0("OtherK",H)=SAM(H,"OtherK");
QKSH0("MachineryK",H)=SAM(H,"MachineryK");
QKSH0("GridK",H)=SAM(H,"GridK");
QKSH0("AutoK",H)=SAM(H,"AutoK");
QKSH0("OtherTransK",H)=SAM(H,"OtherTransK");
QKSH0("OfficeSF",H)=SAM(H,"OfficeSF");
QKSH0("MedicalSF",H)=SAM(H,"MedicalSF");
QKSH0("WarehouseSF",H)=SAM(H,"WarehouseSF");
QKSH0("RetailSF",H)=SAM(H,"RetailSF");
QKSH0("MobileSF",H)=SAM(H,"MobileSF");
QKSH0("ManufacturingSF",H)=SAM(H,"ManufacturingSF");
QKSH0("InfrastructureSF",H)=SAM(H,"InfrastructureSF");
QKSH0("ChurchSF",H)=SAM(H,"ChurchSF");
QKSH0("SchoolSF",H)=SAM(H,"SchoolSF");
QKSH0("RecreationSF",H)=SAM(H,"RecreationSF");
QKSH0("HotelSF",H)=SAM(H,"HotelSF");
QKSH0("FarmSF",H)=SAM(H,"FarmSF");
```

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CONSUMPTION0(H) = SUM(IP,QADH0(IP,H));
 INVESTMENT0(H) = SUM(K,QKSH0(K,H));
TCOPIT0(H)= SAM("COPIT",H)/(CONSUMPTION0(H));
 TUSPIT0(H)= SAM("USPIT",H)/(CONSUMPTION0(H));
 THFEE0(H) = SAM("FEES",H)/(SUM(IP,QADH0(IP,H)));
 HSDSUM(H) = SUM(HD,QHSDH0(HD,H))*(1+TKH0(H));
 ADSUM(H) = SUM(IP,QADH0(IP,H))*(1+TUSPIT0(H)+TCOPIT0(H)+THFEE0(H));
 LEISUM(H) = SUM(L,QDLEI0(L,H));
 WORKSUM(H) = SUM(L,WORK1(L,H));
DISPLAY QDLEI0, QADH0, QHSDH0, HSDSUM, ADSUM, LEISUM, WORKSUM,
TUSPIT0, TCOPIT0, CONSUMPTION0, INVESTMENT0;
PARAMETER    QGC0(FG)  GOVERNMENT CONSUMPTION,
*GOVERNMENT OUTPUT CALCULATED WITHOUT TAX EXPENDITURES
            QLDG0(L,FG),
            QADG0(JP,FG),
            QGCDG0(FG),
            QFXDG0;
 QGC0(FG) = (SUM(Z,SAM(Z,FG))-(SAM("SUBS",FG)));
 QLDG0(L,FG) = SAM(L,FG);
 QADG0(JP,FG) = SAM(JP,FG);
 QGCDG0(FG) = SUM(Z,SAM(Z,FG));
 QFXDG0 = SUM(Z,SAM("FED",Z))-(SAM("FED","ROW"))-(SAM("SUBS","FED"));
```

DISPLAY QGC0, QLDG0, QADG0, QGCDG0, QFXDG0;

PARAMETER QY0(I) DOMESTIC PRODUCTION OF GOODS AND SERVICES FOR DOMESTIC CONSUMPTION,

QE0(IP) DOMESTIC PRODUCTION OF GOODS AND SERVICES FOR EXPORT,

QLDY0(L,I) LABOR DEMAND FOR PRODUCTION OF GOODS AND SERVICES,

QLADY0(I) LAND DEMAND FOR PRODUCTION OF GOODS AND SERVICES,

QKIDY0(K,I) COMMERCIAL AND INDUSTRIAL CAPITAL DEMAND FOR PRODUCTION OF GOODS AND SERVICES,

QADY0(JP,I) INTERMEDIATE GOODS DEMAND FOR PRODUCTION,

TCORP0(I) CORPORATE INCOME TAX,

TCFEE0(I) FEES PAID BY BUSINESS;

QE0(IP) = SAM(IP,"ROW");

QLDY0(L,IP) = SAM(L,IP);

QLADY0(IP) = SAM("LAND",IP);

QKIDY0(K,IP) = SAM(K,IP);

QADY0(JP,IP) = SAM(JP,IP);

QY0(IP) = SUM(Z,SAM(IP,Z))-SAM("ROW",IP)-SAM("LOCSTX",IP)-SAM("COSTX",IP);

TCORP0(IP) = SAM("CORPTAX",IP)/QY0(IP);

TCFEE0(IP) = SAM("FEES",IP)/QY0(IP);

DISPLAY QY0, QE0, QLDY0, QLADY0, QKIDY0, QADY0;

PARAMETER QHS0(HD) PRODUCTION OF IMPUTED HOUSING SERVICES,

QLADHS0(HD) LAND DEMAND FOR HOUSING SERVICES,

QKHDHS0(K,HD) CAPITAL DEMAND FOR HOUSING SERVICES,

```
            QADHS0(JP,HD) INTERMEDIATE GOODS DEMAND FOR HOUSING SERVICES;
 QHS0(HD) = SUM(Z,SAM(Z,HD));
 QLADHS0(HD) = SAM("LAND",HD);
 QKHDHS0(K,HD) = SAM(K,HD);
 QADHS0(JP,HD) = SAM(JP,HD);
DISPLAY QHS0, QLADHS0, QKHDHS0, QADHS0;
PARAMETER    QA0(IP)  PRODUCTION OF ARMINGTON AGGREGATES,
            QMDA0(IP) IMPORTS FOR AGGREGATION,
            QYDA0(IP) DOMESTIC OUTPUT FOR AGGREGATION,
            TLV0(I) LOCAL SALES TAXES,
            TSV0(I) STATE SALES TAXES;
 QMDA0(IP) = SAM("ROW",IP);
QYDA0(IP) = QY0(IP)-QE0(IP);
 QA0(IP) = QMDA0(IP)+QYDA0(IP)+SAM("LOCSTX",IP)+SAM("COSTX",IP);
TLV0(IP) = SAM("LOCSTX",IP)/(QA0(IP));
TSV0(IP) = SAM("COSTX",IP)/(QA0(IP));
DISPLAY QA0, QMDA0, QYDA0;
PARAMETER    QKI0   COMMERCIAL CAPITAL,
            QKH0   RESIDENTIAL CAPITAL,
            QKDK0  DEMAND FOR INVESTMENT CAPITAL;
 QKI0 = SUM(K,SUM(IP,SAM(K,IP)));
 QKH0 = SUM(K,SUM(HD,SAM(K,HD)));
 QKDK0 = SUM(K,SUM(I,SAM(K,I)));
```

DISPLAY QKI0, QKH0, QKDK0;

PARAMETER

QLASH0(H) ENDOWMENT OF LAND BY DOMESTIC HOUSEHOLDS,

QLEISSH0(L,H) ENDOWMENT OF LEISURE OR LABOR BY DOMESTIC HOUSEHOLDS,

LEISSUMSUP(H) TOTAL ENDOWMENT OF LEISURE OR LABOR BY HOUSEHOLDS,

QREMSH0(H) ENDOWMENT OF REMITTANCES BY DOMESTIC HOUSEHOLDS,

QSOCSH0(H) ENDOWMENT OF EXOGENOUS GOVERNMENT TRANSFERS BY DOMESTIC HOUSEHOLDS,

HH0(H) NUMBER OF HOUSEHOLDS,

INVD0(IP) INTERMEDIATES FOR CAPITAL PRODUCTION,

INV0 NET INVESTMENT,

QK0 CAPITAL STOCK,

QKAP0(K) CAPITAL STOCK BY TYPE,

KPROP(H),

KPROPF,

SPEND(FSL) GOVERNMENT SPENDING PROPORTIONS;

SPEND(FSL) = SUM(Z,SAM(Z,FSL));

QLASH0(H) = SAM(H,"LAND");

QLEISSH0(L,H) = WORK1(L,H)*2;

LEISSUMSUP(H) = SUM(L,QLEISSH0(L,H));

```
QREMSH0(H) = SAM(H,"ROW");
 QSOCSH0(H) = SUM(GY,SAM(H,GY));
 HH0(H) = 1;
 QK0 = (SUM(K,(SUM(H,QKSH0(K,H))))+(sum(K,QKSF0(K))));
 QKAP0(K) = ((SUM(H,QKSH0(K,H)))+QKSF0(K));
 KPROP(H) = (sum(K,QKSH0(K,H)))/QK0;
 KPROPF = -SUM(K,SAM(K,"ROW"))/QK0;
 INVD0(IP) = SUM(H,INVESD0(IP,H));
 INV0 = SUM(IP,INVD0(IP));
DISPLAY QKSH0, QLASH0, LEISSUMSUP, QLEISSH0, QREMSH0, QSOCSH0, KPROP,
KPROPF;
PARAMETER
        TOTKAP(K),
        KAPPER(K),
        DEPRECIATION(K),
        QKENDOW0(K);
TOTKAP(K)=(SUM(Z,SAM(K,Z))-SAM(K,"ROW"));
 KAPPER(K)=TOTKAP(K)/QK0;
QKENDOW0(K) = QKSF0(K)+SUM(H,QKSH0(K,H));
 DEPRECIATION(K) = DEPRECIATE(K)*QKENDOW0(K);
DISPLAY TOTKAP, KAPPER, QKENDOW0,QKIDY0, DEPRECIATION;
VARIABLES BOP  BALANCE OF PAYMENTS;
PARAMETER PRODU  PRODUCTIVITY PARAMETER;
```

```
PARAMETER DEP DEPRECIATION;

PRODU = 1;

DEP = 0.1;

DISPLAY QKSH0, INVESOUT0, INVESD9;

SET T /1*30/;

SET TNOTFIRST(T) /2*30/;

SET TAFTER(T) /10*30/

SET TFIRST(T)

   TLAST(T);

TFIRST(T) = YES$(ORD(T) EQ 1);

TLAST(T)  = YES$(ORD(T) EQ CARD(T));

SCALAR          GRO     GROWTH RATE    /0.03/

             REN     INTEREST RATE  /0.03/

             DEL     DEPRECIATION RATE     /0.07/

PARAMETER       QREF(T) REFERENCE QUANTITY PATH,

             IREF(T) REFERENCE INVESTMENT PATH,

             PREF(T) REFERENCE PRICE PATH,

             SHOCK(T) shock to sector of interest,

             SHOCK2  second shock to sector,

             SHOCK3(K),

             TOTALDEP,

             DEMCH(T),

             newpk0(k),
```

kapprop(k,ip),

imdkapprop(k,ip),

newkapsum(ip),

newkapprop(k,ip),

newkapspend(k,ip),

newqkidy0(k,ip),

newkapdemand(k),

newtotkap,

newkapper(k),

newtotaldep,

kdemsum(ip),

hkdemsum(hd),

hkapprop(k,hd),

himdkapprop(k,hd),

hnewkapsum(hd),

hnewkapprop(k,hd),

hnewkapspend(k,hd),

hnewqkhdhs0(k,hd),

hnewkapdemand(k),

necessaryi(k),

necessaryi1,

necessaryi2,

newqksh0(k,h),

newqksf0(k),

sumispend,

sumkown(k),

ishareh(ip,k,h),

isharef(ip,k),

kshareh(k,h),

ksharef(k),

vacrate(k),

kscalar(k),

vacscalar(k),

DIFFK(K),

sumkendow(k),

kproph1(k,h),

kendow1(k,h),

krev(h),

oldkrev(h),

newkstock(k),

oldkbill(ip),

newkbill(ip),

oldfork,

newfork,

dollval(k),

newrpbill(ip),

```
        tki1(ip),
        newqkidy1(rp,ip,t),
        kapproph(h,t),
        kappropf(t),
        newkappersum;
QREF(T) = (1+GRO)**(ORD(T)-1);
IREF(T) = (1+GRO)**(ORD(T));
PREF(T) = (1/(1+REN))**(ORD(T)-1);
SHOCK(T)=EPS;
SHOCK2=0;
SHOCK3(K)=0;
DEMCH("1")=1;
DEMCH("2")=0.917004;
DEMCH("3")=0.840896;
DEMCH("4")=0.771105;
DEMCH("5")=0.707107;
DEMCH("6")=0.648420;
DEMCH("7")=0.594604;
DEMCH("8")=0.545254;
DEMCH("9")=0.5;
DEMCH(TAFTER)=0.5;
TOTALDEP = SUM(K,(KAPPER(K)*DEPRECIATE(K)));
**** set non-unity capital prices to reflect
```

```
**** differences in depreciation rates without changing total

**** capital consumption by sector

newpk0(k)= (depreciate(k)+gro)*10 ;

kdemsum(ip) = sum(k,qkidy0(k,ip));

kapprop(k,ip) = qkidy0(k,ip)/(kdemsum(ip));

imdkapprop(k,ip) = newpk0(k)*kapprop(k,ip);

newkapsum(ip) = sum(k,imdkapprop(k,ip));

newkapprop(k,ip) = imdkapprop(k,ip)/newkapsum(ip);

newkapspend(k,ip) = kdemsum(ip)*newkapprop(k,ip);

newqkidy0(k,ip) = newkapspend(k,ip)/newpk0(k);

newqkidy1(rp,ip,t) = newqkidy0(rp,ip);

newkapdemand(k) = sum(ip,newqkidy0(k,ip));

hkdemsum(hd) = sum(k,qkhdhs0(k,hd));

hkapprop(k,hd) = qkhdhs0(k,hd)/hkdemsum(hd);

himdkapprop(k,hd) = newpk0(k)*hkapprop(k,hd);

hnewkapsum(hd) = sum(k,himdkapprop(k,hd));

hnewkapprop(k,hd) = himdkapprop(k,hd)/hnewkapsum(hd);

hnewkapspend(k,hd) = hkdemsum(hd)*hnewkapprop(k,hd);

hnewqkhdhs0(k,hd) = hnewkapspend(k,hd)/newpk0(k);

hnewkapdemand(k) = sum(hd,hnewqkhdhs0(k,hd));

newtotkap = sum(k,newkapdemand(k))+sum(k,hnewkapdemand(k));

newkstock(k) = newkapdemand(k)+hnewkapdemand(k);

newkapper(k) = (newkapdemand(k)+hnewkapdemand(k))/newtotkap;
```

```
newkappersum = sum(k,newkapper(k));

newtotaldep = sum(k,(newkapper(k)*depreciate(k)));

necessaryi(k) = (newkapdemand(k)+hnewkapdemand(k))*(depreciate(k)+gro)*10;

necessaryi1 = sum(k,necessaryi(k));

necessaryi2 = necessaryi1/(1+gro);

**** changes to capital endowments to reflect the above

sumkendow(k) = sum(h,qksh0(k,h))+qksf0(k);

kproph1(k,h) = qksh0(k,h)/sumkendow(k);

kendow1(k,h) = kproph1(k,h)*(newkapdemand(k)+hnewkapdemand(k));

krev(h) = sum(k,(newpk0(k)*kendow1(k,h)));

oldkrev(h) = sum(k,qksh0(k,h));

newQKSH0(K,H) = kendow1(k,h);

newQKSF0(K) = newkstock(k)-sum(h,kendow1(k,h));

sumispend = sum(ip,invd0(ip));

sumkown(k) = sum(h,(newqksh0(k,h)))+newqksf0(k);

ishareh(ip,k,h) = (invd0(ip)/sumispend)*(newqksh0(k,h)/newkstock(k));

isharef(ip,k) = (invd0(ip)/sumispend)*(newqksf0(k)/newkstock(k));

kshareh(k,h) = newqksh0(k,h)/newkstock(k);

ksharef(k) = newqksf0(k)/newkstock(k);

VACRATE(K) = 0.1615385;

kscalar(k) = 1/(1-vacrate(k));

vacscalar(k) = vacrate(k)/(1-vacrate(k));

DIFFK(K) = SUMKOWN(K)-NEWKAPDEMAND(K)-HNEWKAPDEMAND(K);
```

```
oldkbill(ip) = sum(k,(qkidy0(k,ip)));

newkbill(ip) = sum(k,(newqkidy0(k,ip)*newpk0(k)));

newrpbill(ip) = sum(rp,(newqkidy0(rp,ip)*newpk0(rp)));

oldfork = sum(k,qksf0(k));

newfork = sum(k,(newqksf0(k)*newpk0(k)));

dollval(k) = newpk0(k)*newkstock(k);

tki1(ip) = sam("CNPRP",ip)/(newrpbill(ip)+sam("LAND",ip));

kapproph(h,t) = sum(k,newqksh0(k,h))/sum(k,newkstock(k));

kappropf(t) = sum(k,newqksf0(k))/sum(k,newkstock(k));

PARAMETER TKI0(I)   PROPERTY TAXES ON COMMERCIAL CAPITAL,

        TOTRP(IP) TOTAL REAL PROPERTY USE BY SECTOR;

 TKI0(IP)=SAM("CNPRP",IP)/((sum(RP,SAM(RP,IP)))+sum(LA,SAM(LA,IP)));

        TOTRP(IP) = SUM(RP,newQKIDY0(RP,IP));

DISPLAY TOTRP, newqkidy0;

PARAMETER QSAVING0(H)   HOUSEHOLD SAVINGS,

        BASEINV(K),

        BASEI(K,H),

        BASEKUSING1(RP),

        BASEKUSEPROP(RP,IP),

        BASEKUSEL(RP),

        COINREV;

 QSAVING0(H) = INVESD9(H)-INVESOUT0(H);

TCOPIT1(H)= SAM("COPIT",H)/(SUM(IP,QADH0(IP,H))+QSAVING0(H));
```

TUSPIT1(H)= SAM("USPIT",H)/(SUM(IP,QADH0(IP,H))+QSAVING0(H));

QW1(H) = ((SUM(HD,QHSDH0(HD,H)))*(1+TKH0(H)))+((SUM(IP,QADH0(IP,H)))*(1+TUSPIT1(H)+TCOPIT1(H)+THFEE0(H)));

COINREV = SUM(H,(TCOPIT1(H)*QSAVING0(H)));

BASEINV(K) = SUMKOWN(K)*(GRO+DEPRECIATE(K))*10;

BASEI(K,H) = BASEINV(K)*kshareh(K,H);

DISPLAY TOTALDEP, newtotaldep, newkappersum, necessaryi1, necessaryi2, invesd3, ishareh, DIFFK, krev, oldkrev, oldkbill, newkbill, oldfork, newfork, dollval, newkstock, newpk0, tuspit1;

PARAMETER DEM(K,IP,T) DEMAND SCALAR FOR COMMERCIAL PROPERTY USAGE,

basekusing(ip),

BASEKUSEPROP1(RP,IP),

BASEKUSEL1(RP),

KRATL1(RP),

KRATK(RP) RATIO OF CAPITAL STOCK FOR EACH TYPE TO OFFICE STOCK,

KRATL(RP) RATIO OF "CAPITAL USING LABOR" FOR EACH TYPE TO OFFICE LABOR;

DEM(K,IP,T)$SAM(K,IP) = SAM(K,IP)/SAM(K,IP);

BASEKUSING1(RP) = SUM(IP,newQKIDY0(RP,IP));

BASEKUSING(IP) = SUM(RP,newQKIDY0(RP,IP));

BASEKUSEPROP(RP,IP)$BASEKUSING(IP) = (newQKIDY0(RP,IP))/BASEKUSING(IP);

```
 BASEKUSEPROP1(RP,IP) = NEWQKIDY0(RP,IP)/BASEKUSING1(RP);
 BASEKUSEL(RP) = sum(ip,sum(l,QLDY0(L,IP))*BASEKUSEPROP(RP,IP));
 BASEKUSEL1(RP)                                                  =
SUM(PRIVS,SUM(L,QLDY0(L,PRIVS))*BASEKUSEPROP1(RP,PRIVS));
 KRATK(RP) = BASEKUSING1(RP)/BASEKUSING1("officesf");
 KRATL(RP) = BASEKUSEL("OFFICESF")/BASEKUSEL(RP);
 KRATL1(RP) = BASEKUSEL1("OFFICESF")/BASEKUSEL1(RP);
DISPLAY basekusing, basekuseprop1, basekusel1, KRATK, KRATL;
parameter absbump(t);
absbump("1") = 15.11010378;
absbump("2") = 10.08651311;
absbump("3") = 6.688426142;
absbump("4") = 4.388564861;
absbump("5") = 2.830649458;
absbump("6") = 1.773941801;
absbump("7") = 1.055774012;
absbump("8") = 0.566229398;
absbump("9") = 0.231034601;
absbump("10") = 0;
*NEED TO FIX INVESTMENT IN THE CAPITAL PRODUCTION BLOCK AND IN THE
BASELINE
*DEMAND FOR GOODS AND SERVICES FROM INVES
$ONTEXT
```

```
$MODEL: COLORADO

$COMMODITIES:

P_L(L,T)          !    WAGE INDEX

P_LI(L,IP,T)        !    PRIVATE SECTOR WAGE INDEX

P_LG(L,FG,T)        !    PUBLIC SECTOR WAGE INDEX

P_LA(T)           !    LAND RENT INDEX

P_K(K,T)          !    FINANCIAL CAPITAL RETURN INDEX

P_KR(RP,T)          !    REAL PROPERTY RENTS

P_W(H,T)          !    WELFARE PRICE INDEX

P_LS(L,H,T)$WORK(L,H)        !    LEISURE PRICE INDEX

P_GC(FG,T)          !    GOVERNMENT CONSUMPTION PRICE

P_A(IP,T)          !    ARMINGTON AGGREGATE PRICE

P_Y(IP,T)          !    SECTORAL PRODUCTION PRICE

P_H(HD,T)          !    HOUSING PRICE

P_FX(T)           !    PRICE OF FOREIGN EXCHANGE

PTRAN(H,T)

PTRANF(T)

$SECTORS:

A_GOVT(FG,T)        !    GOVERNMENT EXPENDITURE

A_YARM(IP,T)        !    PRODUCTION OF ARMINGTON AGGREGATES

A_LS(H,T)          !    LABOR SUPPLY

A_LS2(L,IP,T)       !    SECTORAL LABOR SUPPLY

A_LS3(L,FG,T)       !    GOVERNMENT LABOR SUPPLY
```

```
A_K(RP,T)          !    REAL PROPERTY RENTAL ACTIVITY
A_W(H,T)           !    WELFARE INDEX
A_Y(IP,T)          !    SECTORAL PRODUCTION
A_H(HD,T)          !    HOUSING SERVICES
$CONSUMERS:
I_GOVT0(T)         !    STATE AND LOCAL GOVERNMENT REVENUE
I_GOVT1(T)
I_GOVT2(T)
I_GOVT3(T)
I_GOVT4(T)
LOC_GOVT1(T)
LOC_GOVT2(T)
LOC_GOVT3(T)
F_GOVT(T)          !    FEDERAL GOVERNMENT REVENUE
RA(H,T)            !    HOUSEHOLD INCOME
RAF(T)             !    OUT-OF-STATE HOLDERS OF LAND AND CAPITAL
IMPACT(T)
IMPACT_2(T)
EXPORTS(IP,T)
REDIST(T)
$AUXILIARY:
CCI(T)             !    CONSTRUCTION COST INDEX
KUSEPROP(RP,PRIVS,T)    !    PROPORTION OF DESIRED CAPITAL USE BY SECTOR
```

KUSING(PRIVS,T)

KUSEL(RP,T) ! LABOR USE BY CAPITAL TYPE

ABSORPTION(RP,T) ! ABSORPTION OF CAPITAL STOCK

OCC(RP,T)

CONSTRUCTION(RP,T)

LAS(T) ! ENDOGENOUS SUPPLY OF DEVELOPABLE LAND

MIG(H,T) ! ENDOGENOUS HOUSEHOLD MIGRATION

LSUP(H,T) ! ENDOGENOUS LABOR SUPPLY

INVEST(PPORH,T) ! ENDOGENOUS INVESTMENT

OWN(K,T) ! DESIRE TO OWN CAPITAL

EXPDEM(IP,T)

VACANCY(RP,T) ! VACANT CAPITAL

COSAVINGSTAX(T) ! COLORADO INCOME TAX ON SAVINGS

SAVING(H,T) ! ENDOGENOUS SAVINGS WITH CONSTANT SAVINGS RATE

DOMINV(H,T)

INVDIFF(H,T)

SLUGP_K(RP,T)

SLUGP_K1(RP,T)

SLUGP(T)

TKE(RP,IP,T)$newqkidy1(rp,ip,t)

$PROD:A_LS(H,T) s:5

*Labor Supply

O: P_L(L,T) Q: QLABSUP0(L,H) p: (1-TLS1(L)) A: F_GOVT(T) T: TLS1(L)

```
I: P_LS(L,H,T)$WORK(L,H)       Q: WORK1(L,H)

$PROD:A_LS2(L,IP,T) s:0

O: P_LI(L,IP,T)      Q: QLDY0(L,IP)

I: P_L(L,T)          Q: QLDY0(L,IP)

$PROD:A_LS3(L,FG,T) s:0

O: P_LG(L,FG,T)      Q: QLDG0(L,FG)

I: P_L(L,T)          Q: QLDG0(L,FG)

$PROD:A_K(RP,T) S:0

O: P_KR(RP,T)        Q: BASEKUSING1(RP)

I: P_K(RP,T)         Q: BASEKUSING1(RP)

$PROD:A_W(H,T)  s:1

*  Welfare produced using leisure, goods and services

O: P_W(H,T)           Q: QW1(H)

*  Income taxes proportional to factor use to generate HH specific welfare indices

I:  P_A(IP,T)                  Q:  QADH0(IP,H)  P:  (1+TCOPIT1(H)+TUSPIT1(H)+THFEE0(H))  A:

I_GOVT1(T) T: TCOPIT1(H) A: F_GOVT(T) T: TUSPIT1(H) A: I_GOVT2(T) T: THFEE0(H)

I: P_H(HD,T)         Q: QHSDH0(HD,H) P: (1+TKH0(H)) A: LOC_GOVT2(T) T: TKH0(H)

$PROD:A_GOVT(FG,T)  s:1     int:0

*Production of government services

O: P_GC(FG,T)        Q: QGC0(FG)

I:  P_LG(L,FG,T)                     Q:  QLDG0(L,FG)  P:  (1+TLDG0(L,FG))  A:  F_GOVT(T)  T:

TLDG0(L,FG)

I: P_A(JP,T)           Q: QADG0(JP,FG)   int:
```

$PROD:A_Y(IP,T)   s:0.5

*Domestic production of goods and services

*kl nest to reflect Raval (2011) complementarity between capital and labor

O: P_Y(IP,T)   Q: (PRODU*QY0(IP)) P: (1-TCORP0(IP)-TCFEE0(IP)) A: I_GOVT3(T) T: TCORP0(IP) A: I_GOVT2(T) T: TCFEE0(IP)

I: P_LI(L,IP,T)   Q: QLDY0(L,IP) P: (1+TLDI0(L,IP)) A: F_GOVT(T) T: TLDI0(L,IP)

I: P_LA(T)   Q: QLADY0(IP)   P: (1+TKI1(IP)) A: LOC_GOVT1(T) T: TKI1(IP)

I: P_KR(RP,T)   Q: (DEM(RP,IP,T)*newQKIDY0(RP,IP)) P: (newpk0(rp)*(1+TKI1(IP))) A: LOC_GOVT1(T) T: TKI1(IP) A: REDIST(T) N:SLUGP_K(RP,T)

I: P_K(PP,T)   Q: (DEM(PP,IP,T)*newQKIDY0(PP,IP)) P: newpk0(pp)

I: P_A(JP,T)   Q: QADY0(JP,IP)

$PROD:A_H(HD,T)   s:1 int:0

*Domestic production of housing services

O: P_H(HD,T)   Q: QHS0(HD)

I: P_LA(T)   Q: QLADHS0(HD)

I: P_K(K,T)   Q: hnewQKHDHS0(K,HD) P: newpk0(k)

I: P_A(JP,T)   Q: QADHS0(JP,HD) int:

$PROD:A_YARM(IP,T)   s:1

*Production of Armington aggregates using imports

O: P_A(IP,T)   Q: QA0(IP) P: (1-TSV0(IP)-TLV0(IP)) A: I_GOVT4(T) T: TSV0(IP) A: LOC_GOVT3(T) T: TLV0(IP)

I: P_FX(T)   Q: QMDA0(IP)

I: P_Y(IP,T)   Q: (QY0(IP)-QE0(IP))

$DEMAND:EXPORTS(IP,T)

*Export demand as independent block - no substitution between exports BUT each is given a -1.0 price elasticity via EXPDEM

D: P_Y(IP,T)   Q: QE0(IP)

E: P_FX(T)   Q: (QE0(IP)*QREF(T)) R: EXPDEM(IP,T)

$DEMAND:RA(H,T)

* Utility Maximization

D: P_W(H,T)   Q: (QW1(H)*QREF(T))

* Land Endowment

E: P_LA(T)   Q: (QLASH0(H)*QREF(T)) R: LAS(T)

* Time Endowment (used to generate Labor and Leisure)

E: P_LS(L,H,T)$WORK(L,H)   Q: (WORK1(L,H)*QREF(T))   R: LSUP(H,T)

E: P_LS(L,H,T)$WORK(L,H)   Q: (WORK1(L,H)*QREF(T))   R: MIG(H,T)

* Remittances

E: P_FX(T)   Q: (QREMSH0(H)*QREF(T))

* Outflow of savings

*E: P_FX(T)   Q: (-QSAVING0(H)*QREF(T))   R: SAVING(H,T)

E: P_FX(T)   Q: (-1)   R: SAVING(H,T)

* US income taxes on savings outflows

E: P_FX(T)   Q: (-TUSPIT1(H))   R: SAVING(H,T)

* CO income taxes on savings outflows

E: P_FX(T)   Q: (-TCOPIT1(H))   R: SAVING(H,T)

* Social Security Payments

E: P_FX(T) Q: (QSOCSH0(H)*QREF(T))

* Per Period Capital Endowment

E: P_K(K,T) Q: kshareh(k,h) R: OWN(K,T)

E: P_K(RP,T) Q: -kshareh(rp,h) R: VACANCY(RP,T)

* Borrowing to finance baseline investment

E: P_FX(T) Q: (SUM(K,QKSH0(K,H))*QREF(T))

* Capital supply shocks for simulations

*E: P_K(K,T) Q: SHOCK3(K)

* Construction/Investment Spending

E: P_A(IP,T) Q: (-ishareh(IP,"SingleResSF",H)) R: INVEST("SingleResSF",T)

E: P_A(IP,T) Q: (-ishareh(IP,"MultiResSF",H)) R: INVEST("MultiResSF",T)

E: P_A(IP,T) Q: (-ishareh(IP,"TechK",H)) R: INVEST("TechK",T)

E: P_A(IP,T) Q: (-ishareh(IP,"MachineryK",H)) R: INVEST("MachineryK",T)

E: P_A(IP,T) Q: (-ishareh(IP,"OtherK",H)) R: INVEST("OtherK",T)

E: P_A(IP,T) Q: (-ishareh(IP,"GridK",H)) R: INVEST("GridK",T)

E: P_A(IP,T) Q: (-ishareh(IP,"AutoK",H)) R: INVEST("AutoK",T)

E: P_A(IP,T) Q: (-ishareh(IP,"OtherTransK",H)) R: INVEST("OtherTransK",T)

E: P_A(IP,T) Q: (-ishareh(IP,"OfficeSF",H)*10) R: CONSTRUCTION("OfficeSF",T)

E: P_A(IP,T) Q: (-ishareh(IP,"MedicalSF",H)*10) R: CONSTRUCTION("MedicalSF",T)

E: P_A(IP,T) Q: (-ishareh(IP,"WarehouseSF",H)*10) R: CONSTRUCTION("WarehouseSF",T)

E: P_A(IP,T) Q: (-ishareh(IP,"MobileSF",H)*10) R: CONSTRUCTION("MobileSF",T)

E: P_A(IP,T) Q: (-ishareh(IP,"RetailSF",H)*10) R: CONSTRUCTION("RetailSF",T)

E: P_A(IP,T) Q: (-ishareh(IP,"ManufacturingSF",H)*10) R: CONSTRUCTION("ManufacturingSF",T)

E: P_A(IP,T) Q: (-ishareh(IP,"InfrastructureSF",H)*10) R: CONSTRUCTION("InfrastructureSF",T)

E: P_A(IP,T) Q: (-ishareh(IP,"ChurchSF",H)*10) R: CONSTRUCTION("ChurchSF",T)

E: P_A(IP,T) Q: (-ishareh(IP,"SchoolSF",H)*10) R: CONSTRUCTION("SchoolSF",T)

E: P_A(IP,T) Q: (-ishareh(IP,"RecreationSF",H)*10) R: CONSTRUCTION("RecreationSF",T)

E: P_A(IP,T) Q: (-ishareh(IP,"HotelSF",H)*10) R: CONSTRUCTION("HotelSF",T)

E: P_A(IP,T) Q: (-ishareh(IP,"FarmSF",H)*10) R: CONSTRUCTION("FarmSF",T)

E: PTRAN(H,T) Q: kapproph(h,t) R:SLUGP(T)

$DEMAND:RAF(T)

* Demand for "foreign exchange"

D: P_FX(T) Q: (KLAOUT0*QREF(T))

* Out-of-state ownership of capital

E: P_K(K,T) Q: ksharef(k) R: OWN(K,T)

E: P_K(RP,T) Q: -ksharef(rp) R: VACANCY(RP,T)

* Out-of-state ownership of land

E: P_LA(T) Q: (QLASF0*QREF(T)) R: LAS(T)

* Construction/Investment Spending

E: P_A(IP,T) Q: (-isharef(IP,"SingleResSF")) R: INVEST("SingleResSF",T)

E: P_A(IP,T) Q: (-isharef(IP,"MultiResSF")) R: INVEST("MultiResSF",T)

E: P_A(IP,T) Q: (-isharef(IP,"TechK")) R: INVEST("TechK",T)

E: P_A(IP,T) Q: (-isharef(IP,"MachineryK")) R: INVEST("MachineryK",T)

E: P_A(IP,T) Q: (-isharef(IP,"OtherK")) R: INVEST("OtherK",T)

E: P_A(IP,T) Q: (-isharef(IP,"GridK")) R: INVEST("GridK",T)

E: P_A(IP,T) Q: (-isharef(IP,"AutoK")) R: INVEST("AutoK",T)

E: P_A(IP,T) Q: (-isharef(IP,"OtherTransK")) R: INVEST("OtherTransK",T)

E: P_A(IP,T) Q: (-isharef(IP,"OfficeSF")*10) R: CONSTRUCTION("OfficeSF",T)

E: P_A(IP,T) Q: (-isharef(IP,"MedicalSF")*10) R: CONSTRUCTION("MedicalSF",T)

E: P_A(IP,T) Q: (-isharef(IP,"WarehouseSF")*10) R: CONSTRUCTION("WarehouseSF",T)

E: P_A(IP,T) Q: (-isharef(IP,"MobileSF")*10) R: CONSTRUCTION("MobileSF",T)

E: P_A(IP,T) Q: (-isharef(IP,"RetailSF")*10) R: CONSTRUCTION("RetailSF",T)

E: P_A(IP,T) Q: (-isharef(IP,"ManufacturingSF")*10) R: CONSTRUCTION("ManufacturingSF",T)

E: P_A(IP,T) Q: (-isharef(IP,"InfrastructureSF")*10) R: CONSTRUCTION("InfrastructureSF",T)

E: P_A(IP,T) Q: (-isharef(IP,"ChurchSF")*10) R: CONSTRUCTION("ChurchSF",T)

E: P_A(IP,T) Q: (-isharef(IP,"SchoolSF")*10) R: CONSTRUCTION("SchoolSF",T)

E: P_A(IP,T) Q: (-isharef(IP,"RecreationSF")*10) R: CONSTRUCTION("RecreationSF",T)

E: P_A(IP,T) Q: (-isharef(IP,"HotelSF")*10) R: CONSTRUCTION("HotelSF",T)

E: P_A(IP,T) Q: (-isharef(IP,"FarmSF")*10) R: CONSTRUCTION("FarmSF",T)

E: PTRANF(T) Q: kappropf(t) R: SLUGP(T)

$DEMAND:IMPACT_2(T)

```
D: P_FX(T)          Q: 1

E: P_K(K,T)         Q: SHOCK3(K)

$DEMAND:IMPACT(T)

D: P_Y("Const",T)    Q: 1

E: P_FX(T)          Q: SHOCK(T)

$DEMAND:I_GOVT0(T)

D: P_GC("FED",T)     Q: (FEDPROD0*QREF(T))

E: P_FX(T)           Q: (FEDPROD0*QREF(T))

$DEMAND:I_GOVT1(T)

*COLORADO PERSONAL INCOME TAX

D: P_GC(FSL,T)       Q: (SPEND(FSL)*QREF(T))

E: P_FX(T)          Q: (COINREV)  R: COSAVINGSTAX(T)

$DEMAND:I_GOVT2(T)

*COLORADO GOVERNMENT FEES-FOR-SERVICE

D: P_GC(FSL,T)       Q: (SPEND(FSL)*QREF(T))

$DEMAND:I_GOVT3(T)

*COLORADO CORPORATE INCOME TAX

D: P_GC(FSL,T)       Q: (SPEND(FSL)*QREF(T))

$DEMAND:I_GOVT4(T)

*COLORADO SALES TAX

D: P_GC(FSL,T)       Q: (SPEND(FSL)*QREF(T))

$DEMAND:LOC_GOVT1(T)

*BUSINESS PROPERTY TAX
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D: P_GC(FSL,T)       Q: (SPEND(FSL)*QREF(T))

$DEMAND:LOC_GOVT2(T)

*RESIDENTIAL PROPERTY TAX

D: P_GC(FSL,T)       Q: (SPEND(FSL)*QREF(T))

$DEMAND:LOC_GOVT3(T)

*LOCAL SALES TAX

D: P_GC(FSL,T)       Q: (SPEND(FSL)*QREF(T))

$DEMAND:F_GOVT(T)

D: P_FX(T)           Q: (1*QREF(T))

$DEMAND:REDIST(T)

D: P_FX(T)

E: PTRAN(H,T)        Q: -kapproph(h,t) R: SLUGP(T)

E: PTRANF(T)         Q: -kappropf(t)        R: SLUGP(T)

e: P_FX(T)           Q: 100000

$REPORT:

  V: EMP(L,T,H)    O: P_L(L,T)  PROD:A_LS(H,T)

  V: OUTP(IP,T)    O: P_Y(IP,T)  PROD:A_Y(IP,T)

  V: HOUTP(HD,T)   O: P_Y(HD,T)  PROD:A_Y(HD,T)

  V: GOUTP(FG,T)   O: P_GC(FG,T)  PROD:A_GOVT(FG,T)

$CONSTRAINT:CCI(T)

        CCI(T) =G= sum(IP,P_A(IP,T)*(invd0(ip)/sumispend));

$CONSTRAINT: KUSING(PRIVS,T)

        KUSING(PRIVS,T) =E= SUM(RP,(DEM(RP,PRIVS,T)*NEWQKIDY0(RP,PRIVS)));
```

```
$CONSTRAINT: KUSEPROP(RP,PRIVS,T)
          KUSEPROP(RP,PRIVS,T)                                                    =E=
(DEM(RP,PRIVS,T)*NEWQKIDY0(RP,PRIVS))/BASEKUSING(PRIVS);
$CONSTRAINT:KUSEL(RP,T)
         KUSEL(RP,T)                                                              =G=
(sum(PRIVS,sum(L,A_LS2(L,PRIVS,T)*QLDY0(L,PRIVS))*KUSEPROP(RP,PRIVS,T)))/BA
SEKUSEL(RP);
$CONSTRAINT:ABSORPTION(RP,T)
          ABSORPTION(RP,T)                                                        =E=
(KRATK(RP)*0.32421*(1.0925333/1.03)*((0.13232*BASEKUSEL1(RP)*KRATL1(RP)*KUS
EL(RP,T))                                                                          -
(0.016996606*KRATL1(RP)*BASEKUSEL1(RP)*KUSEL(RP,T)*(((SLUGP_K(RP,T-
1))/newPK0(RP))+1$TFIRST(T))))
                         -                                      0.32421*((A_K(RP,T-
1)*BASEKUSING1(RP))+((1/1.03)*BASEKUSING1(RP)$TFIRST(T))));
$CONSTRAINT:OCC(RP,T)
          OCC(RP,T) =g= (occ(rp,t-1)+0.970874*basekusing1(rp)$tfirst(t))+absorption(rp,t);
$CONSTRAINT:CONSTRUCTION(RP,T)
        CONSTRUCTION(RP,T) =G=
                    ((DEPRECIATE(RP))*(OWN(RP,t-
1)+((BASEKUSING1(RP)$TFIRST(T))*(1+vacrate(rp))/1.03)))+
                    ((BASEKUSING1(RP)*(1+vacrate(rp)))/37058.69364)*QREF(T)*
                    ((7361.031162*(((SLUGP_K(RP,T-1))/newPK0(RP))+1$TFIRST(T)))
```

```
- 3549.275 - 1731.235743*(CCI(T-1)+1$TFIRST(T))
- (6197.538*((VACANCY(RP,T-1)/((A_K(RP,T-1)*BASEKUSING1(RP))+1$TFIRST(T))+0.1615385$TFIRST(T)))
));
$CONSTRAINT:LAS(T)
LAS(T) =G= ((LAS(T-1)+1$TFIRST(T))+(((P_LA(T))-P_LA(T-1)-1$TFIRST(T))*2.5));
$CONSTRAINT:LSUP(H,T)
(LSUP(H,T)-1) =G= (0.3*((SUM(L,(P_L(L,T)*WORKPROP(L,H)))/P_W(H,T))-1));
$CONSTRAINT:MIG(H,T)
(MIG(H,T)) =E= (MIG(H,T-1))+(0.1*((SUM(L,(P_L(L,T)*WORKPROP(L,H)))/P_W(H,T))-1));
$CONSTRAINT:OWN(RP,T)
OWN(RP,T) =G= ((1-DEPRECIATE(RP))*OWN(RP,T-1))+((1+VACRATE(RP))*(1-DEPRECIATE(RP))*0.970874*SUMKOWN(RP)$TFIRST(T))+CONSTRUCTION(RP,T);
$CONSTRAINT:OWN(PPORH,T)
OWN(PPORH,T) =G= ((1-DEPRECIATE(PPORH))*OWN(PPORH,T-1))+SUMKOWN(PPORH)$TFIRST(T)+(INVEST(PPORH,T-1)/10);
$CONSTRAINT:INVEST(PPORH,T)
INVEST(PPORH,T) =E= (1+(((P_K(PPORH,T)/NEWPK0(PPORH))-1)*1.0))*(SUMKOWN(PPORH)$TFIRST(T)+(1.03*OWN(PPORH,T-1)))*(DEPRECIATE(PPORH)+GRO)*10;
$CONSTRAINT:VACANCY(RP,T)
```

VACANCY(RP,T) =G= (0.1615385$TFIRST(T)*newkstock(rp)) + VACANCY(RP,T-1) + CONSTRUCTION(RP,T) - (OWN(RP,T-1)*DEPRECIATE(RP)) - (1-.970874)$TFIRST(T)*NEWKSTOCK(RP) - ABSORPTION(RP,T);

$CONSTRAINT:EXPDEM(IP,T)

EXPDEM(IP,T) =G= (1/P_Y(IP,T));

$CONSTRAINT:DOMINV(H,T)

DOMINV(H,T) =G= (sum(PPORH,(kshareh(PPORH,h)*invest(PPORH,t)))+(10*SUM(RP,(KSHAREH(RP,H)*CONSTRUCTION(RP,T)))));

$CONSTRAINT:INVDIFF(H,T)

INVDIFF(H,T) =E= DOMINV(H,T)-(sum(K,BASEI(K,H))*qref(t));

$CONSTRAINT:SAVING(H,T)

SAVING(H,T) =E= ((P_W(H,T)*A_W(H,T)*QSAVING0(H))-INVDIFF(H,T));

$CONSTRAINT:COSAVINGSTAX(T)

COSAVINGSTAX(T) =E= SUM(H,(SAVING(H,T)))/SUM(H,QSAVING0(H));

$CONSTRAINT:SLUGP_K(RP,T)

SLUGP_K(RP,T) =E= (NEWPK0(RP)*(1/1.195493626)*

(0.5726503+(0.6098741*1.044888*((SLUGP_K(RP,T-1)/newPK0(RP))+1$TFIRST(T)))

+(6.056216*((ABSORPTION(RP,T-1)/(OCC(RP,T-1)+1$TFIRST(T)))+0.03$TFIRST(T)))

-(1.21197*((VACANCY(RP,T-1)/(OCC(RP,T-1)+1$TFIRST(T)))+0.1615385$TFIRST(T)))));

```
$CONSTRAINT:SLUGP_K1(RP,T)
        SLUGP_K1(RP,T) =E=  (SLUGP_K(RP,T)/P_KR(RP,T))-1;
$CONSTRAINT:SLUGP(T)
         SLUGP(T)                                               =E=
(sum(rp,(SLUGP_K1(RP,T)*A_K(RP,T)*BASEKUSING1(RP)*P_KR(RP,T))));
$CONSTRAINT:TKE(RP,IP,T)$newqkidy1(rp,ip,t)
        TKE(RP,IP,T)$newqkidy1(rp,ip,t) =e= 0;
$OFFTEXT
$SYSINCLUDE mpsgeset COLORADO
A_LS.L(H,T) = qref(t);
A_LS.LO(H,T) = 0;
A_LS2.L(L,IP,T) = qref(t);
A_LS2.LO(L,IP,T) = 0;
A_LS3.L(L,FG,T) = qref(t);
A_LS3.LO(L,FG,T) = 0;
A_K.L(RP,T) = QREF(T);
A_K.LO(RP,T) = 0;
A_W.L(H,T) = qref(t);
A_W.LO(H,T) = 0;
A_GOVT.L(FG,T) = qref(t);
A_GOVT.LO(FG,T) = 0;
A_Y.L(IP,T) = qref(t);
A_Y.LO(IP,T) = 0.01;
```

```
A_YARM.L(IP,T) = qref(t);

A_YARM.LO(IP,T) = 0;

A_H.L(HD,T) = qref(t);

A_H.LO(HD,T) = 0;

P_L.L(L,T) = 1;

P_L.LO(L,T) = 0;

P_LI.L(L,IP,T) = 1;

P_LI.LO(L,IP,T) = 0;

P_LG.L(L,FG,T) = 1;

P_LG.LO(L,FG,T) = 0;

P_L.L(L,T)=1;

P_L.LO(L,T) = 0;

P_LA.L(T)=1;

P_LA.LO(T) = 0;

P_LS.L(L,H,T)$WORK(L,H) = 1;

P_LS.LO(L,H,T)$WORK(L,H) = 0;

P_W.L(H,T)=1;

P_W.LO(H,T)=0;

P_Y.L(IP,T)=1;

P_Y.LO(IP,T)=0;

P_A.L(IP,T)=1;

P_A.LO(IP,T)=0;

P_GC.L(FG,T) = 1;
```

```
P_GC.LO(FG,T)=0;

P_H.L(HD,T) = 1;

P_H.LO(HD,T) = 0;

P_FX.FX(T)=1;

P_K.L(K,T)=newpk0(k);

P_K.LO(K,T)=0;

P_KR.L(RP,T)=newpk0(rp);

P_KR.LO(RP,T)=0;

PTRAN.fx(H,T)= 1;

PTRANF.fx(T) = 1;

CCI.L(T) = 1;

CCI.LO(T) = 0;

KUSING.L(PRIVS,T) = BASEKUSING(PRIVS);

KUSING.LO(PRIVS,T) = 0;

KUSEPROP.L(RP,PRIVS,T) = BASEKUSEPROP(RP,PRIVS);

KUSEPROP.LO(RP,PRIVS,T) = 0;

KUSEL.L(RP,T) = qref(t);

KUSEL.LO(RP,T) = 0;

ABSORPTION.L(RP,T) = ((0.03*NEWKSTOCK(RP)/1.03)*QREF(T));

ABSORPTION.LO(RP,T) = -10000;

OCC.L(RP,T) = newkstock(rp)*qref(t);

OCC.LO(RP,T) = 1;

CONSTRUCTION.L(RP,T) = ((.054/1.03)*BASEKUSING1(RP)*QREF(T));
```

```
CONSTRUCTION.LO(RP,T) = 0;

LAS.L(T)=1;

LAS.LO(T)=0;

MIG.L(H,T)=0;

MIG.LO(H,T)=-100;

LSUP.L(H,T)=1;

LSUP.LO(H,T) = 0;

I_GOVT0.L(T) = 6548.670*QREF(T);

INVEST.L(PPORH,T)=newkstock(PPORH)*qref(t)*10*(depreciate(PPORH)+gro);

INVEST.LO(PPORH,T)=(-newkstock(PPORH)*qref(t)*10*(depreciate(PPORH)));

OWN.L(RP,T)=NEWKSTOCK(RP)*QREF(T)*(1+VACRATE(RP));

OWN.L(PPORH,T)=NEWKSTOCK(PPORH)*QREF(T);

OWN.LO(K,T)=(OWN.L(K,T-1)*(((1-DEPRECIATE(K))**(ORD(T)))));

VACANCY.L(RP,t)=VACRATE(RP)*NEWKSTOCK(RP)*QREF(t);

VACANCY.LO(RP,T) = 0;

EXPDEM.L(IP,T) = 1;

EXPDEM.LO(IP,T) = 0;

DOMINV.L(H,T)=sum(k,basei(k,h))*qref(t);

DOMINV.LO(H,T) = 0;

INVDIFF.L(H,T)=0;

INVDIFF.LO(H,T)=-100000;

SAVING.L(H,T)=(QSAVING0(H)*QREF(T));

SAVING.LO(H,T)=-100000;
```

```
COSAVINGSTAX.L(T)=QREF(T);

COSAVINGSTAX.LO(T)=0;

SLUGP_K.UP(RP,T) = 10;

SLUGP_K.L(RP,T) = newPK0(RP);

SLUGP_K.LO(RP,T) = 0.2*newPK0(RP);

SLUGP_K1.L(RP,T) = 0;

SLUGP_K1.LO(RP,T) = -100;

SLUGP.L(T) = 0;

SLUGP.LO(T) = -100000;

TKE.L(RP,IP,T) = 0;

TKE.LO(RP,IP,T) = -1;

SET RUN(SM) /BASE,TODAY,SIMM1/;

PARAMETER SUMMARY(*,SM)   SOLUTION SUMMARY;

TABLE TAXCHANGE(SM,*) INDICATORS FOR TAX RATE SIMULATIONS

               S

BASE         0

TODAY         0

SIMM1         1;

IF (RUN("BASE"), COLORADO.ITERLIM=0;);

FILE RESULTS /C:\Users\Chris\Documents\Disser\Disser\cofix.txt/;

LOOP(SM$RUN(SM),

*       IF (TAXCHANGE(SM,"S"),

*          TSV0(IP) = 0.6*(SAM("COSTX",IP)/(QA0(IP)));
```

```
*       ELSE
*          TSV0(IP) = SAM("COSTX",IP)/(QA0(IP));
*       IF (TAXCHANGE(SM,"L"),
*          TLS1(L) = 0.5*(TLS0(L));
*       ELSE
*          TLS1(L) = TLS0(L));
*       IF (TAXCHANGE(SM,"S"),
*           SHOCK(T)=100;
*       ELSE
*           SHOCK(T)=EPS);
      IF (TAXCHANGE(SM,"S"),
*          DEM("OFFICESF",IP,T)$TNOTFIRST(T)=0.5;
*          TKI0(IP) = 0.5*(SAM("CNPRP",IP)/SAM("KAP",IP));
*          TKH0(H) = 0.5*(SAM("CNPRP",H)/(SUM(HD,SAM(HD,H))));
*       ELSE
*           DEM("OFFICESF",IP,T)=1;
*       IF (TAXCHANGE(SM,"L"),
*          DEM("OFFICESF",OFFUSE,T)$TNOTFIRST(T)=0.5;
*       ELSE
*          DEM("OFFICESF",OFFUSE,T)=1;
*
*       IF (TAXCHANGE(SM,"K"),
*          DEM("OFFICESF",IP,T)=DEMCH(T);
```

```
*       ELSE
*          DEM("OFFICESF",IP,T)=1;
*
*       IF (TAXCHANGE(SM,"Y"),
         DEM("OFFICESF",OFFUSE,T)=DEMCH(T);
*       ELSE
*          DEM("OFFICESF",OFFUSE,T)=1);
*       ELSE
*          TKI0(IP) = SAM("CNPRP",IP)/SAM("KAP",IP);
*          TKH0(H) = SAM("CNPRP",H)/(SUM(HD,SAM(HD,H))));
*        IF (TAXCHANGE(SM,"Y"),
*           SHOCK3("OfficeSF")=10;
*           SHOCK2=15;
        ELSE
*           SHOCK3("OfficeSF")=0;
*           SHOCK2=0);
*       IF (TAXCHANGE(SM,"Y"),
*          PRODU = 1.1;
*       ELSE
*          PRODU = 1);
*       IF (TAXCHANGE(SM,"I"),
*          TUSPIT0(H) = 0.5*(SAM("USPIT",H)/SUM(IP,QADH0(IP,H)));
*       ELSE
```

```
*          TUSPIT0(H) = SAM("USPIT",H)/SUM(IP,QADH0(IP,H)));
*       IF (TAXCHANGE(SM,"IN"),
*          TCOPIT0(H) = 1.2867*(SAM("COPIT",H)/SUM(IP,QADH0(IP,H)));
*       ELSE
*         TCOPIT0(H) = SAM("COPIT",H)/SUM(IP,QADH0(IP,H));
*       IF (TAXCHANGE(SM,"CO2"),
*          TSV0(IP) = 0.6*(SAM("COSTX",IP)/(QA0(IP)));
*          TCOPIT0(H) = 1.2867*(SAM("COPIT",H)/SUM(IP,QADH0(IP,H)));
*       ELSE
*       TSV0(IP) = SAM("COSTX",IP)/(QA0(IP));
*       TCOPIT0(H) = SAM("COPIT",H)/SUM(IP,QADH0(IP,H))));
      );
$INCLUDE COLORADO.GEN
COLORADO.OPTFILE = 0;
OPTION SYSOUT=ON;
SOLVE COLORADO USING MCP;
      COLORADO.RESLIM = 30000;
      COLORADO.ITERLIM = 100000;
      COLORADO.WORKFACTOR=100.0;
      SUMMARY("STATUS",SM) = COLORADO.MODELSTAT;
      SUMMARY("ITERS",SM) = COLORADO.ITERUSD;
      SUMMARY("CPU",SM) = COLORADO.RESUSD;
      SUMMARY("CONTROL",SM) = COLORADO.OBJVAL;
```

* CHANGE IN WELFARE ACTIVITY BY HOUSEHOLD GROUP *

SUMMARY("PCHANGE2",SM) = (((P_KR.L("officesf","2"))*(1+SLUGP_K1.L("officesf","2"))/(newPK0("officesf")*(1)))-1);

SUMMARY("PCHANGE3",SM) = (((P_KR.L("officesf","3"))*(1+SLUGP_K1.L("officesf","3"))/(newPK0("officesf")*(1)))-1);

SUMMARY("PCHANGE4",SM) = (((P_KR.L("officesf","4"))*(1+SLUGP_K1.L("officesf","4"))/(newPK0("officesf")*(1)))-1);

SUMMARY("PCHANGE5",SM) = (((P_KR.L("officesf","5"))*(1+SLUGP_K1.L("officesf","5"))/(newPK0("officesf")*(1)))-1);

SUMMARY("PCHANGE6",SM) = (((P_KR.L("officesf","6"))*(1+SLUGP_K1.L("officesf","6"))/(newPK0("officesf")*(1)))-1);

SUMMARY("PCHANGE7",SM) = (((P_KR.L("officesf","7"))*(1+SLUGP_K1.L("officesf","7"))/(newPK0("officesf")*(1)))-1);

SUMMARY("PCHANGE8",SM) = (((P_KR.L("officesf","8"))*(1+SLUGP_K1.L("officesf","8"))/(newPK0("officesf")*(1)))-1);

SUMMARY("PCHANGE9",SM) = (((P_KR.L("officesf","9"))*(1+SLUGP_K1.L("officesf","9"))/(newPK0("officesf")*(1)))-1);

SUMMARY("PCHANGE10",SM) = (((P_KR.L("officesf","10"))*(1+SLUGP_K1.L("officesf","10"))/(newPK0("officesf")*(1)))-1);

SUMMARY("PCHANGE11",SM) = (((P_KR.L("officesf","11"))*(1+SLUGP_K1.L("officesf","11"))/(newPK0("officesf")*(1)))-1);

SUMMARY("PCHANGE12",SM) = (((P_KR.L("officesf","12"))*(1+SLUGP_K1.L("officesf","12"))/(newPK0("officesf")*(1)))-1);

```
SUMMARY("PCHANGE13",SM) =
(((P_KR.L("officesf","13"))*(1+SLUGP_K1.L("officesf","13"))/(newPK0("officesf")*(1)))-1);
SUMMARY("PCHANGE14",SM) =
(((P_KR.L("officesf","14"))*(1+SLUGP_K1.L("officesf","14"))/(newPK0("officesf")*(1)))-1);
SUMMARY("PCHANGE15",SM) =
(((P_KR.L("officesf","15"))*(1+SLUGP_K1.L("officesf","15"))/(newPK0("officesf")*(1)))-1);
SUMMARY("PCHANGE16",SM) =
(((P_KR.L("officesf","16"))*(1+SLUGP_K1.L("officesf","16"))/(newPK0("officesf")*(1)))-1);
SUMMARY("PCHANGE17",SM) =
(((P_KR.L("officesf","17"))*(1+SLUGP_K1.L("officesf","17"))/(newPK0("officesf")*(1)))-1);
SUMMARY("PCHANGE18",SM) =
(((P_KR.L("officesf","18"))*(1+SLUGP_K1.L("officesf","18"))/(newPK0("officesf")*(1)))-1);
SUMMARY("PCHANGE19",SM) =
(((P_KR.L("officesf","19"))*(1+SLUGP_K1.L("officesf","19"))/(newPK0("officesf")*(1)))-1);
SUMMARY("PCHANGE20",SM) =
(((P_KR.L("officesf","20"))*(1+SLUGP_K1.L("officesf","20"))/(newPK0("officesf")*(1)))-1);
SUMMARY("OFFVAC1",SM) =
VACANCY.L("officesf","1")/(A_K.L("officesf","1")*BASEKUSING1("officesf"));
SUMMARY("OFFVAC2",SM) =
VACANCY.L("officesf","2")/(A_K.L("officesf","2")*BASEKUSING1("officesf"));
SUMMARY("OFFVAC3",SM) =
VACANCY.L("officesf","3")/(A_K.L("officesf","3")*BASEKUSING1("officesf"));
```

SUMMARY("OFFVAC4",SM) =
VACANCY.L("officesf","4")/(A_K.L("officesf","4")*BASEKUSING1("officesf"));

SUMMARY("OFFVAC5",SM) =
VACANCY.L("officesf","5")/(A_K.L("officesf","5")*BASEKUSING1("officesf"));

SUMMARY("OFFVAC6",SM) =
VACANCY.L("officesf","6")/(A_K.L("officesf","6")*BASEKUSING1("officesf"));

SUMMARY("OFFVAC7",SM) =
VACANCY.L("officesf","7")/(A_K.L("officesf","7")*BASEKUSING1("officesf"));

SUMMARY("OFFVAC8",SM) =
VACANCY.L("officesf","8")/(A_K.L("officesf","8")*BASEKUSING1("officesf"));

SUMMARY("OFFVAC9",SM) =
VACANCY.L("officesf","9")/(A_K.L("officesf","9")*BASEKUSING1("officesf"));

SUMMARY("OFFVAC10",SM) =
VACANCY.L("officesf","10")/(A_K.L("officesf","10")*BASEKUSING1("officesf"));

SUMMARY("OFFVAC11",SM) =
VACANCY.L("officesf","11")/(A_K.L("officesf","11")*BASEKUSING1("officesf"));

SUMMARY("OFFVAC12",SM) =
VACANCY.L("officesf","12")/(A_K.L("officesf","12")*BASEKUSING1("officesf"));

SUMMARY("OFFVAC13",SM) =
VACANCY.L("officesf","13")/(A_K.L("officesf","13")*BASEKUSING1("officesf"));

SUMMARY("OFFVAC14",SM) =
VACANCY.L("officesf","14")/(A_K.L("officesf","14")*BASEKUSING1("officesf"));

SUMMARY("OFFVAC15",SM) =
VACANCY.L("officesf","15")/(A_K.L("officesf","15")*BASEKUSING1("officesf"));

SUMMARY("OFFVAC16",SM) =
VACANCY.L("officesf","16")/(A_K.L("officesf","16")*BASEKUSING1("officesf"));

SUMMARY("OFFVAC17",SM) =
VACANCY.L("officesf","17")/(A_K.L("officesf","17")*BASEKUSING1("officesf"));

SUMMARY("OFFVAC18",SM) =
VACANCY.L("officesf","18")/(A_K.L("officesf","18")*BASEKUSING1("officesf"));

SUMMARY("OFFVAC19",SM) =
VACANCY.L("officesf","19")/(A_K.L("officesf","19")*BASEKUSING1("officesf"));

SUMMARY("OFFVAC20",SM) =
VACANCY.L("officesf","20")/(A_K.L("officesf","20")*BASEKUSING1("officesf"));

SUMMARY("OFFVAC21",SM) =
VACANCY.L("officesf","21")/(A_K.L("officesf","21")*BASEKUSING1("officesf"));

SUMMARY("OFFVAC22",SM) =
VACANCY.L("officesf","22")/(A_K.L("officesf","22")*BASEKUSING1("officesf"));

SUMMARY("OFFVAC23",SM) =
VACANCY.L("officesf","23")/(A_K.L("officesf","23")*BASEKUSING1("officesf"));

SUMMARY("OFFVAC24",SM) =
VACANCY.L("officesf","24")/(A_K.L("officesf","24")*BASEKUSING1("officesf"));

SUMMARY("OFFVAC25",SM) =
VACANCY.L("officesf","25")/(A_K.L("officesf","25")*BASEKUSING1("officesf"));

SUMMARY("OFFVAC26",SM) = VACANCY.L("officesf","26")/(A_K.L("officesf","26")*BASEKUSING1("officesf"));

SUMMARY("OFFVAC27",SM) = VACANCY.L("officesf","27")/(A_K.L("officesf","27")*BASEKUSING1("officesf"));

SUMMARY("OFFVAC28",SM) = VACANCY.L("officesf","28")/(A_K.L("officesf","28")*BASEKUSING1("officesf"));

SUMMARY("OFFVAC29",SM) = VACANCY.L("officesf","29")/(A_K.L("officesf","29")*BASEKUSING1("officesf"));

SUMMARY("OFFVAC30",SM) = VACANCY.L("officesf","30")/(A_K.L("officesf","30")*BASEKUSING1("officesf"));

SUMMARY("JOB1",SM) = 1067266*((SUM(H,EMP.L("L1","1",H))/SUM(H,QLABSUP0("L1",H)))-QREF("1"))+(924461*((SUM(H,EMP.L("L2","1",H))/SUM(H,QLABSUP0("L2",H)))-QREF("1")))+(339147*((SUM(H,EMP.L("L3","1",H))/SUM(H,QLABSUP0("L3",H)))-QREF("1")))+(230429*((SUM(H,EMP.L("L4","1",H))/SUM(H,QLABSUP0("L4",H)))-QREF("1")))+(180543*((SUM(H,EMP.L("L5","1",H))/SUM(H,QLABSUP0("L5",H)))-QREF("1")));

SUMMARY("JOB2",SM) = 1067266*((SUM(H,EMP.L("L1","2",H))/SUM(H,QLABSUP0("L1",H)))-QREF("2"))+(924461*((SUM(H,EMP.L("L2","2",H))/SUM(H,QLABSUP0("L2",H)))-QREF("2")))+(339147*((SUM(H,EMP.L("L3","2",H))/SUM(H,QLABSUP0("L3",H)))-QREF("2")))+(230429*((SUM(H,EMP.L("L4","2",H))/SUM(H,QLABSUP0("L4",H)))-

QREF("2")))+(180543*((SUM(H,EMP.L("L5","2",H))/SUM(H,QLABSUP0("L5",H)))-
QREF("2")));

SUMMARY("JOB3",SM) =
1067266*((SUM(H,EMP.L("L1","3",H))/SUM(H,QLABSUP0("L1",H)))-
QREF("3"))+(924461*((SUM(H,EMP.L("L2","3",H))/SUM(H,QLABSUP0("L2",H)))-
QREF("3")))+(339147*((SUM(H,EMP.L("L3","3",H))/SUM(H,QLABSUP0("L3",H)))-
QREF("3")))+(230429*((SUM(H,EMP.L("L4","3",H))/SUM(H,QLABSUP0("L4",H)))-
QREF("3")))+(180543*((SUM(H,EMP.L("L5","3",H))/SUM(H,QLABSUP0("L5",H)))-
QREF("3")));

SUMMARY("JOB4",SM) =
1067266*((SUM(H,EMP.L("L1","4",H))/SUM(H,QLABSUP0("L1",H)))-
QREF("4"))+(924461*((SUM(H,EMP.L("L2","4",H))/SUM(H,QLABSUP0("L2",H)))-
QREF("4")))+(339147*((SUM(H,EMP.L("L3","4",H))/SUM(H,QLABSUP0("L3",H)))-
QREF("4")))+(230429*((SUM(H,EMP.L("L4","4",H))/SUM(H,QLABSUP0("L4",H)))-
QREF("4")))+(180543*((SUM(H,EMP.L("L5","4",H))/SUM(H,QLABSUP0("L5",H)))-
QREF("4")));

SUMMARY("JOB5",SM) =
1067266*((SUM(H,EMP.L("L1","5",H))/SUM(H,QLABSUP0("L1",H)))-
QREF("5"))+(924461*((SUM(H,EMP.L("L2","5",H))/SUM(H,QLABSUP0("L2",H)))-
QREF("5")))+(339147*((SUM(H,EMP.L("L3","5",H))/SUM(H,QLABSUP0("L3",H)))-
QREF("5")))+(230429*((SUM(H,EMP.L("L4","5",H))/SUM(H,QLABSUP0("L4",H)))-
QREF("5")))+(180543*((SUM(H,EMP.L("L5","5",H))/SUM(H,QLABSUP0("L5",H)))-
QREF("5")));

SUMMARY("JOB6",SM) =
1067266*((SUM(H,EMP.L("L1","6",H))/SUM(H,QLABSUP0("L1",H)))-
QREF("6"))+(924461*((SUM(H,EMP.L("L2","6",H))/SUM(H,QLABSUP0("L2",H)))-
QREF("6")))+(339147*((SUM(H,EMP.L("L3","6",H))/SUM(H,QLABSUP0("L3",H)))-
QREF("6")))+(230429*((SUM(H,EMP.L("L4","6",H))/SUM(H,QLABSUP0("L4",H)))-
QREF("6")))+(180543*((SUM(H,EMP.L("L5","6",H))/SUM(H,QLABSUP0("L5",H)))-
QREF("6")));

SUMMARY("JOB7",SM) =
1067266*((SUM(H,EMP.L("L1","7",H))/SUM(H,QLABSUP0("L1",H)))-
QREF("7"))+(924461*((SUM(H,EMP.L("L2","7",H))/SUM(H,QLABSUP0("L2",H)))-
QREF("7")))+(339147*((SUM(H,EMP.L("L3","7",H))/SUM(H,QLABSUP0("L3",H)))-
QREF("7")))+(230429*((SUM(H,EMP.L("L4","7",H))/SUM(H,QLABSUP0("L4",H)))-
QREF("7")))+(180543*((SUM(H,EMP.L("L5","7",H))/SUM(H,QLABSUP0("L5",H)))-
QREF("7")));

SUMMARY("JOB8",SM) =
1067266*((SUM(H,EMP.L("L1","8",H))/SUM(H,QLABSUP0("L1",H)))-
QREF("8"))+(924461*((SUM(H,EMP.L("L2","8",H))/SUM(H,QLABSUP0("L2",H)))-
QREF("8")))+(339147*((SUM(H,EMP.L("L3","8",H))/SUM(H,QLABSUP0("L3",H)))-
QREF("8")))+(230429*((SUM(H,EMP.L("L4","8",H))/SUM(H,QLABSUP0("L4",H)))-
QREF("8")))+(180543*((SUM(H,EMP.L("L5","8",H))/SUM(H,QLABSUP0("L5",H)))-
QREF("8")));

SUMMARY("JOB9",SM) =
1067266*((SUM(H,EMP.L("L1","9",H))/SUM(H,QLABSUP0("L1",H)))-

QREF("9"))+(924461*((SUM(H,EMP.L("L2","9",H))/SUM(H,QLABSUP0("L2",H)))-

QREF("9")))+(339147*((SUM(H,EMP.L("L3","9",H))/SUM(H,QLABSUP0("L3",H)))-

QREF("9")))+(230429*((SUM(H,EMP.L("L4","9",H))/SUM(H,QLABSUP0("L4",H)))-

QREF("9")))+(180543*((SUM(H,EMP.L("L5","9",H))/SUM(H,QLABSUP0("L5",H)))-

QREF("9")));

SUMMARY("JOB10",SM) =

1067266*((SUM(H,EMP.L("L1","10",H))/SUM(H,QLABSUP0("L1",H)))-

QREF("10"))+(924461*((SUM(H,EMP.L("L2","10",H))/SUM(H,QLABSUP0("L2",H)))-

QREF("10")))+(339147*((SUM(H,EMP.L("L3","10",H))/SUM(H,QLABSUP0("L3",H)))-

QREF("10")))+(230429*((SUM(H,EMP.L("L4","10",H))/SUM(H,QLABSUP0("L4",H)))-

QREF("10")))+(180543*((SUM(H,EMP.L("L5","10",H))/SUM(H,QLABSUP0("L5",H)))-

QREF("10")));

SUMMARY("JOB11",SM) =

1067266*((SUM(H,EMP.L("L1","11",H))/SUM(H,QLABSUP0("L1",H)))-

QREF("11"))+(924461*((SUM(H,EMP.L("L2","11",H))/SUM(H,QLABSUP0("L2",H)))-

QREF("11")))+(339147*((SUM(H,EMP.L("L3","11",H))/SUM(H,QLABSUP0("L3",H)))-

QREF("11")))+(230429*((SUM(H,EMP.L("L4","11",H))/SUM(H,QLABSUP0("L4",H)))-

QREF("11")))+(180543*((SUM(H,EMP.L("L5","11",H))/SUM(H,QLABSUP0("L5",H)))-

QREF("11")));

SUMMARY("JOB12",SM) =

1067266*((SUM(H,EMP.L("L1","12",H))/SUM(H,QLABSUP0("L1",H)))-

QREF("12"))+(924461*((SUM(H,EMP.L("L2","12",H))/SUM(H,QLABSUP0("L2",H)))-

QREF("12")))+(339147*((SUM(H,EMP.L("L3","12",H))/SUM(H,QLABSUP0("L3",H)))-

QREF("12")))+(230429*((SUM(H,EMP.L("L4","12",H))/SUM(H,QLABSUP0("L4",H)))-QREF("12")))+(180543*((SUM(H,EMP.L("L5","12",H))/SUM(H,QLABSUP0("L5",H)))-QREF("12")));

SUMMARY("JOB13",SM) = 1067266*((SUM(H,EMP.L("L1","13",H))/SUM(H,QLABSUP0("L1",H)))-QREF("13"))+(924461*((SUM(H,EMP.L("L2","13",H))/SUM(H,QLABSUP0("L2",H)))-QREF("13")))+(339147*((SUM(H,EMP.L("L3","13",H))/SUM(H,QLABSUP0("L3",H)))-QREF("13")))+(230429*((SUM(H,EMP.L("L4","13",H))/SUM(H,QLABSUP0("L4",H)))-QREF("13")))+(180543*((SUM(H,EMP.L("L5","13",H))/SUM(H,QLABSUP0("L5",H)))-QREF("13")));

SUMMARY("JOB14",SM) = 1067266*((SUM(H,EMP.L("L1","14",H))/SUM(H,QLABSUP0("L1",H)))-QREF("14"))+(924461*((SUM(H,EMP.L("L2","14",H))/SUM(H,QLABSUP0("L2",H)))-QREF("14")))+(339147*((SUM(H,EMP.L("L3","14",H))/SUM(H,QLABSUP0("L3",H)))-QREF("14")))+(230429*((SUM(H,EMP.L("L4","14",H))/SUM(H,QLABSUP0("L4",H)))-QREF("14")))+(180543*((SUM(H,EMP.L("L5","14",H))/SUM(H,QLABSUP0("L5",H)))-QREF("14")));

SUMMARY("JOB15",SM) = 1067266*((SUM(H,EMP.L("L1","15",H))/SUM(H,QLABSUP0("L1",H)))-QREF("15"))+(924461*((SUM(H,EMP.L("L2","15",H))/SUM(H,QLABSUP0("L2",H)))-QREF("15")))+(339147*((SUM(H,EMP.L("L3","15",H))/SUM(H,QLABSUP0("L3",H)))-QREF("15")))+(230429*((SUM(H,EMP.L("L4","15",H))/SUM(H,QLABSUP0("L4",H)))-

QREF("15")))+(180543*((SUM(H,EMP.L("L5","15",H))/SUM(H,QLABSUP0("L5",H)))-QREF("15")));

SUMMARY("JOB16",SM) = 1067266*((SUM(H,EMP.L("L1","16",H))/SUM(H,QLABSUP0("L1",H)))-QREF("16"))+(924461*((SUM(H,EMP.L("L2","16",H))/SUM(H,QLABSUP0("L2",H)))-QREF("16")))+(339147*((SUM(H,EMP.L("L3","16",H))/SUM(H,QLABSUP0("L3",H)))-QREF("16")))+(230429*((SUM(H,EMP.L("L4","16",H))/SUM(H,QLABSUP0("L4",H)))-QREF("16")))+(180543*((SUM(H,EMP.L("L5","16",H))/SUM(H,QLABSUP0("L5",H)))-QREF("16")));

SUMMARY("JOB17",SM) = 1067266*((SUM(H,EMP.L("L1","17",H))/SUM(H,QLABSUP0("L1",H)))-QREF("17"))+(924461*((SUM(H,EMP.L("L2","17",H))/SUM(H,QLABSUP0("L2",H)))-QREF("17")))+(339147*((SUM(H,EMP.L("L3","17",H))/SUM(H,QLABSUP0("L3",H)))-QREF("17")))+(230429*((SUM(H,EMP.L("L4","17",H))/SUM(H,QLABSUP0("L4",H)))-QREF("17")))+(180543*((SUM(H,EMP.L("L5","17",H))/SUM(H,QLABSUP0("L5",H)))-QREF("17")));

SUMMARY("JOB18",SM) = 1067266*((SUM(H,EMP.L("L1","18",H))/SUM(H,QLABSUP0("L1",H)))-QREF("18"))+(924461*((SUM(H,EMP.L("L2","18",H))/SUM(H,QLABSUP0("L2",H)))-QREF("18")))+(339147*((SUM(H,EMP.L("L3","18",H))/SUM(H,QLABSUP0("L3",H)))-QREF("18")))+(230429*((SUM(H,EMP.L("L4","18",H))/SUM(H,QLABSUP0("L4",H)))-QREF("18")))+(180543*((SUM(H,EMP.L("L5","18",H))/SUM(H,QLABSUP0("L5",H)))-QREF("18")));

SUMMARY("JOB19",SM) = 1067266*((SUM(H,EMP.L("L1","19",H))/SUM(H,QLABSUP0("L1",H)))-QREF("19"))+(924461*((SUM(H,EMP.L("L2","19",H))/SUM(H,QLABSUP0("L2",H)))-QREF("19")))+(339147*((SUM(H,EMP.L("L3","19",H))/SUM(H,QLABSUP0("L3",H)))-QREF("19")))+(230429*((SUM(H,EMP.L("L4","19",H))/SUM(H,QLABSUP0("L4",H)))-QREF("19")))+(180543*((SUM(H,EMP.L("L5","19",H))/SUM(H,QLABSUP0("L5",H)))-QREF("19")));

SUMMARY("JOB20",SM) = 1067266*((SUM(H,EMP.L("L1","20",H))/SUM(H,QLABSUP0("L1",H)))-QREF("20"))+(924461*((SUM(H,EMP.L("L2","20",H))/SUM(H,QLABSUP0("L2",H)))-QREF("20")))+(339147*((SUM(H,EMP.L("L3","20",H))/SUM(H,QLABSUP0("L3",H)))-QREF("20")))+(230429*((SUM(H,EMP.L("L4","20",H))/SUM(H,QLABSUP0("L4",H)))-QREF("20")))+(180543*((SUM(H,EMP.L("L5","20",H))/SUM(H,QLABSUP0("L5",H)))-QREF("20")));

SUMMARY("OFFRENT1",SM) = 100*(P_K.L("OfficeSF","1")*(1+SLUGP_K1.L("OfficeSF","1")));

SUMMARY("OFFRENT2",SM) = 100*(P_K.L("OfficeSF","2")*(1+SLUGP_K1.L("OfficeSF","2")));

SUMMARY("OFFRENT3",SM) = 100*(P_K.L("OfficeSF","3")*(1+SLUGP_K1.L("OfficeSF","3")));

SUMMARY("OFFRENT4",SM) = 100*(P_K.L("OfficeSF","4")*(1+SLUGP_K1.L("OfficeSF","4")));

SUMMARY("OFFRENT5",SM) =
100*(P_K.L("OfficeSF","5")*(1+SLUGP_K1.L("OfficeSF","5")));

SUMMARY("OFFRENT6",SM) =
100*(P_K.L("OfficeSF","6")*(1+SLUGP_K1.L("OfficeSF","6")));

SUMMARY("OFFRENT7",SM) =
100*(P_K.L("OfficeSF","7")*(1+SLUGP_K1.L("OfficeSF","7")));

SUMMARY("OFFRENT8",SM) =
100*(P_K.L("OfficeSF","8")*(1+SLUGP_K1.L("OfficeSF","8")));

SUMMARY("OFFRENT9",SM) =
100*(P_K.L("OfficeSF","9")*(1+SLUGP_K1.L("OfficeSF","9")));

SUMMARY("OFFRENT10",SM) =
100*(P_K.L("OfficeSF","10")*(1+SLUGP_K1.L("OfficeSF","10")));

SUMMARY("OFFRENT11",SM) =
100*(P_K.L("OfficeSF","11")*(1+SLUGP_K1.L("OfficeSF","11")));

SUMMARY("OFFRENT12",SM) =
100*(P_K.L("OfficeSF","12")*(1+SLUGP_K1.L("OfficeSF","12")));

SUMMARY("OFFRENT13",SM) =
100*(P_K.L("OfficeSF","13")*(1+SLUGP_K1.L("OfficeSF","13")));

SUMMARY("OFFRENT14",SM) =
100*(P_K.L("OfficeSF","14")*(1+SLUGP_K1.L("OfficeSF","14")));

SUMMARY("OFFRENT15",SM) =
100*(P_K.L("OfficeSF","15")*(1+SLUGP_K1.L("OfficeSF","15")));

SUMMARY("OFFRENT16",SM) =
100*(P_K.L("OfficeSF","16")*(1+SLUGP_K1.L("OfficeSF","16")));

SUMMARY("OFFRENT17",SM) =
100*(P_K.L("OfficeSF","17")*(1+SLUGP_K1.L("OfficeSF","17")));

SUMMARY("OFFRENT18",SM) =
100*(P_K.L("OfficeSF","18")*(1+SLUGP_K1.L("OfficeSF","18")));

SUMMARY("OFFRENT19",SM) =
100*(P_K.L("OfficeSF","19")*(1+SLUGP_K1.L("OfficeSF","19")));

SUMMARY("OFFRENT20",SM) =
100*(P_K.L("OfficeSF","20")*(1+SLUGP_K1.L("OfficeSF","20")));

SUMMARY("OFFRENT21",SM) =
100*(P_K.L("OfficeSF","21")*(1+SLUGP_K1.L("OfficeSF","21")));

SUMMARY("OFFRENT22",SM) =
100*(P_K.L("OfficeSF","22")*(1+SLUGP_K1.L("OfficeSF","22")));

SUMMARY("OFFRENT23",SM) =
100*(P_K.L("OfficeSF","23")*(1+SLUGP_K1.L("OfficeSF","23")));

SUMMARY("OFFRENT24",SM) =
100*(P_K.L("OfficeSF","24")*(1+SLUGP_K1.L("OfficeSF","24")));

SUMMARY("OFFRENT25",SM) =
100*(P_K.L("OfficeSF","25")*(1+SLUGP_K1.L("OfficeSF","25")));

SUMMARY("OFFRENT26",SM) =
100*(P_K.L("OfficeSF","26")*(1+SLUGP_K1.L("OfficeSF","26")));

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	SUMMARY("OFFRENT27",SM)                                                    =
100*(P_K.L("OfficeSF","27")*(1+SLUGP_K1.L("OfficeSF","27")));
	SUMMARY("OFFRENT28",SM)                                                    =
100*(P_K.L("OfficeSF","28")*(1+SLUGP_K1.L("OfficeSF","28")));
	SUMMARY("OFFRENT29",SM)                                                    =
100*(P_K.L("OfficeSF","29")*(1+SLUGP_K1.L("OfficeSF","29")));
	SUMMARY("OFFRENT30",SM)                                                    =
100*(P_K.L("OfficeSF","30")*(1+SLUGP_K1.L("OfficeSF","30")));
SUMMARY("SLUG3",SM) = 100*SLUGP_K.L("OfficeSF","3");
	SUMMARY("totINV1",SM) = sum(RP,CONSTRUCTION.L(RP,"1"))*10;
	SUMMARY("totINV2",SM) = sum(RP,CONSTRUCTION.L(RP,"2"))*10;
	SUMMARY("totINV3",SM) = sum(RP,CONSTRUCTION.L(RP,"3"))*10;
	SUMMARY("totINV4",SM) = sum(RP,CONSTRUCTION.L(RP,"4"))*10;
	SUMMARY("totINV5",SM) = sum(RP,CONSTRUCTION.L(RP,"5"))*10;
	SUMMARY("totINV6",SM) = sum(RP,CONSTRUCTION.L(RP,"6"))*10;
	SUMMARY("totINV7",SM) = sum(RP,CONSTRUCTION.L(RP,"7"))*10;
	SUMMARY("totINV8",SM) = sum(RP,CONSTRUCTION.L(RP,"8"))*10;
	SUMMARY("totINV9",SM) = sum(RP,CONSTRUCTION.L(RP,"9"))*10;
	SUMMARY("totINV10",SM) = sum(RP,CONSTRUCTION.L(RP,"10"))*10;
	SUMMARY("totINV11",SM) = sum(RP,CONSTRUCTION.L(RP,"11"))*10;
	SUMMARY("totINV12",SM) = sum(RP,CONSTRUCTION.L(RP,"12"))*10;
	SUMMARY("totINV13",SM) = sum(RP,CONSTRUCTION.L(RP,"13"))*10;
	SUMMARY("totINV14",SM) = sum(RP,CONSTRUCTION.L(RP,"14"))*10;
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SUMMARY("totINV15",SM) = sum(RP,CONSTRUCTION.L(RP,"15"))*10;
SUMMARY("totINV16",SM) = sum(RP,CONSTRUCTION.L(RP,"16"))*10;
SUMMARY("totINV17",SM) = sum(RP,CONSTRUCTION.L(RP,"17"))*10;
SUMMARY("totINV18",SM) = sum(RP,CONSTRUCTION.L(RP,"18"))*10;
SUMMARY("totINV19",SM) = sum(RP,CONSTRUCTION.L(RP,"19"))*10;
SUMMARY("totINV20",SM) = sum(RP,CONSTRUCTION.L(RP,"20"))*10;
SUMMARY("PtotINV1",SM) = sum(PPORH,INVEST.L(PPORH,"1"));
SUMMARY("PtotINV2",SM) = sum(PPORH,INVEST.L(PPORH,"2"));
SUMMARY("PtotINV3",SM) = sum(PPORH,INVEST.L(PPORH,"3"));
SUMMARY("PtotINV4",SM) = sum(PPORH,INVEST.L(PPORH,"4"));
SUMMARY("PtotINV5",SM) = sum(PPORH,INVEST.L(PPORH,"5"));
SUMMARY("PtotINV6",SM) = sum(PPORH,INVEST.L(PPORH,"6"));
SUMMARY("PtotINV7",SM) = sum(PPORH,INVEST.L(PPORH,"7"));
SUMMARY("PtotINV8",SM) = sum(PPORH,INVEST.L(PPORH,"8"));
SUMMARY("PtotINV9",SM) = sum(PPORH,INVEST.L(PPORH,"9"));
SUMMARY("PtotINV10",SM) = sum(PPORH,INVEST.L(PPORH,"10"));
SUMMARY("PtotINV11",SM) = sum(PPORH,INVEST.L(PPORH,"11"));
SUMMARY("PtotINV12",SM) = sum(PPORH,INVEST.L(PPORH,"12"));
SUMMARY("PtotINV13",SM) = sum(PPORH,INVEST.L(PPORH,"13"));
SUMMARY("PtotINV14",SM) = sum(PPORH,INVEST.L(PPORH,"14"));
SUMMARY("PtotINV15",SM) = sum(PPORH,INVEST.L(PPORH,"15"));
SUMMARY("PtotINV16",SM) = sum(PPORH,INVEST.L(PPORH,"16"));
SUMMARY("PtotINV17",SM) = sum(PPORH,INVEST.L(PPORH,"17"));
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SUMMARY("PtotINV18",SM) = sum(PPORH,INVEST.L(PPORH,"18"));
SUMMARY("PtotINV19",SM) = sum(PPORH,INVEST.L(PPORH,"19"));
SUMMARY("PtotINV20",SM) = sum(PPORH,INVEST.L(PPORH,"20"));
SUMMARY("COTOT1",SM) =
(I_GOVT1.L("1")+I_GOVT2.L("1")+I_GOVT3.L("1")+I_GOVT4.L("1"));
SUMMARY("COTOT2",SM) =
(I_GOVT1.L("2")+I_GOVT2.L("2")+I_GOVT3.L("2")+I_GOVT4.L("2"));
SUMMARY("COTOT3",SM) =
(I_GOVT1.L("3")+I_GOVT2.L("3")+I_GOVT3.L("3")+I_GOVT4.L("3"));
SUMMARY("COTOT4",SM) =
(I_GOVT1.L("4")+I_GOVT2.L("4")+I_GOVT3.L("4")+I_GOVT4.L("4"));
SUMMARY("COTOT5",SM) =
(I_GOVT1.L("5")+I_GOVT2.L("5")+I_GOVT3.L("5")+I_GOVT4.L("5"));
SUMMARY("COTOT6",SM) =
(I_GOVT1.L("6")+I_GOVT2.L("6")+I_GOVT3.L("6")+I_GOVT4.L("6"));
SUMMARY("COTOT7",SM) =
(I_GOVT1.L("7")+I_GOVT2.L("7")+I_GOVT3.L("7")+I_GOVT4.L("7"));
SUMMARY("COTOT8",SM) =
(I_GOVT1.L("8")+I_GOVT2.L("8")+I_GOVT3.L("8")+I_GOVT4.L("8"));
SUMMARY("COTOT9",SM) =
(I_GOVT1.L("9")+I_GOVT2.L("9")+I_GOVT3.L("9")+I_GOVT4.L("9"));
SUMMARY("COTOT10",SM) =
(I_GOVT1.L("10")+I_GOVT2.L("10")+I_GOVT3.L("10")+I_GOVT4.L("10"));
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SUMMARY("COTOT11",SM) =
(I_GOVT1.L("11")+I_GOVT2.L("11")+I_GOVT3.L("11")+I_GOVT4.L("11"));
SUMMARY("COTOT12",SM) =
(I_GOVT1.L("12")+I_GOVT2.L("12")+I_GOVT3.L("12")+I_GOVT4.L("12"));
SUMMARY("COTOT13",SM) =
(I_GOVT1.L("13")+I_GOVT2.L("13")+I_GOVT3.L("13")+I_GOVT4.L("13"));
SUMMARY("COTOT14",SM) =
(I_GOVT1.L("14")+I_GOVT2.L("14")+I_GOVT3.L("14")+I_GOVT4.L("14"));
SUMMARY("COTOT15",SM) =
(I_GOVT1.L("15")+I_GOVT2.L("15")+I_GOVT3.L("15")+I_GOVT4.L("15"));
SUMMARY("COTOT16",SM) =
(I_GOVT1.L("16")+I_GOVT2.L("16")+I_GOVT3.L("16")+I_GOVT4.L("16"));
SUMMARY("COTOT17",SM) =
(I_GOVT1.L("17")+I_GOVT2.L("17")+I_GOVT3.L("17")+I_GOVT4.L("17"));
SUMMARY("COTOT18",SM) =
(I_GOVT1.L("18")+I_GOVT2.L("18")+I_GOVT3.L("18")+I_GOVT4.L("18"));
SUMMARY("COTOT19",SM) =
(I_GOVT1.L("19")+I_GOVT2.L("19")+I_GOVT3.L("19")+I_GOVT4.L("19"));
SUMMARY("COTOT20",SM) =
(I_GOVT1.L("20")+I_GOVT2.L("20")+I_GOVT3.L("20")+I_GOVT4.L("20"));
SUMMARY("LOCSALES1",SM) = LOC_GOVT3.L("1");
SUMMARY("LOCSALES2",SM) = LOC_GOVT3.L("2");
SUMMARY("LOCSALES3",SM) = LOC_GOVT3.L("3");
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SUMMARY("LOCSALES4",SM) = LOC_GOVT3.L("4");
SUMMARY("LOCSALES5",SM) = LOC_GOVT3.L("5");
SUMMARY("LOCSALES6",SM) = LOC_GOVT3.L("6");
SUMMARY("LOCSALES7",SM) = LOC_GOVT3.L("7");
SUMMARY("LOCSALES8",SM) = LOC_GOVT3.L("8");
SUMMARY("LOCSALES9",SM) = LOC_GOVT3.L("9");
SUMMARY("LOCSALES10",SM) = LOC_GOVT3.L("10");
SUMMARY("LOCSALES11",SM) = LOC_GOVT3.L("11");
SUMMARY("LOCSALES12",SM) = LOC_GOVT3.L("12");
SUMMARY("LOCSALES13",SM) = LOC_GOVT3.L("13");
SUMMARY("LOCSALES14",SM) = LOC_GOVT3.L("14");
SUMMARY("LOCSALES15",SM) = LOC_GOVT3.L("15");
SUMMARY("LOCSALES16",SM) = LOC_GOVT3.L("16");
SUMMARY("LOCSALES17",SM) = LOC_GOVT3.L("17");
SUMMARY("LOCSALES18",SM) = LOC_GOVT3.L("18");
SUMMARY("LOCSALES19",SM) = LOC_GOVT3.L("19");
SUMMARY("LOCSALES20",SM) = LOC_GOVT3.L("20");
SUMMARY("PRPTXTOT1",SM) =
(LOC_GOVT1.L("1")+LOC_GOVT2.L("1"))/QREF("1");
SUMMARY("PRPTXTOT2",SM) =
(LOC_GOVT1.L("2")+LOC_GOVT2.L("2"))/QREF("2");
SUMMARY("PRPTXTOT3",SM) =
(LOC_GOVT1.L("3")+LOC_GOVT2.L("3"))/QREF("3");
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```
	SUMMARY("PRPTXTOT4",SM)                                    =
(LOC_GOVT1.L("4")+LOC_GOVT2.L("4"))/QREF("4");
	SUMMARY("PRPTXTOT5",SM)                                    =
(LOC_GOVT1.L("5")+LOC_GOVT2.L("5"))/QREF("5");
	SUMMARY("PRPTXTOT6",SM)                                    =
(LOC_GOVT1.L("6")+LOC_GOVT2.L("6"))/QREF("6");
	SUMMARY("PRPTXTOT7",SM)                                    =
(LOC_GOVT1.L("7")+LOC_GOVT2.L("7"))/QREF("7");
	SUMMARY("PRPTXTOT8",SM)                                    =
(LOC_GOVT1.L("8")+LOC_GOVT2.L("8"))/QREF("8");
	SUMMARY("PRPTXTOT9",SM)                                    =
(LOC_GOVT1.L("9")+LOC_GOVT2.L("9"))/QREF("9");
	SUMMARY("PRPTXTOT10",SM)                                   =
(LOC_GOVT1.L("10")+LOC_GOVT2.L("10"))/QREF("10");
	SUMMARY("PRPTXTOT11",SM)                                   =
(LOC_GOVT1.L("11")+LOC_GOVT2.L("11"))/QREF("11");
	SUMMARY("PRPTXTOT12",SM)                                   =
(LOC_GOVT1.L("12")+LOC_GOVT2.L("12"))/QREF("12");
	SUMMARY("PRPTXTOT13",SM)                                   =
(LOC_GOVT1.L("13")+LOC_GOVT2.L("13"))/QREF("13");
	SUMMARY("PRPTXTOT14",SM)                                   =
(LOC_GOVT1.L("14")+LOC_GOVT2.L("14"))/QREF("14");
```

```
SUMMARY("PRPTXTOT15",SM) =
(LOC_GOVT1.L("15")+LOC_GOVT2.L("15"))/QREF("15");
SUMMARY("PRPTXTOT16",SM) =
(LOC_GOVT1.L("16")+LOC_GOVT2.L("16"))/QREF("16");
SUMMARY("PRPTXTOT17",SM) =
(LOC_GOVT1.L("17")+LOC_GOVT2.L("17"))/QREF("17");
SUMMARY("PRPTXTOT18",SM) =
(LOC_GOVT1.L("18")+LOC_GOVT2.L("18"))/QREF("18");
SUMMARY("PRPTXTOT19",SM) =
(LOC_GOVT1.L("19")+LOC_GOVT2.L("19"))/QREF("19");
SUMMARY("PRPTXTOT20",SM) =
(LOC_GOVT1.L("20")+LOC_GOVT2.L("20"))/QREF("20");
SUMMARY("DOMOUT1",SM) =
(SUM(IP,OUTP.L(IP,"1"))+SUM(FG,GOUTP.L(FG,"1")));
SUMMARY("DOMOUT2",SM) =
(SUM(IP,OUTP.L(IP,"2"))+SUM(FG,GOUTP.L(FG,"2")));
SUMMARY("DOMOUT3",SM) =
(SUM(IP,OUTP.L(IP,"3"))+SUM(FG,GOUTP.L(FG,"3")));
SUMMARY("DOMOUT4",SM) =
(SUM(IP,OUTP.L(IP,"4"))+SUM(FG,GOUTP.L(FG,"4")));
SUMMARY("DOMOUT5",SM) =
(SUM(IP,OUTP.L(IP,"5"))+SUM(FG,GOUTP.L(FG,"5")));
```

```
SUMMARY("DOMOUT6",SM) =
(SUM(IP,OUTP.L(IP,"6"))+SUM(FG,GOUTP.L(FG,"6")));
SUMMARY("DOMOUT7",SM) =
(SUM(IP,OUTP.L(IP,"7"))+SUM(FG,GOUTP.L(FG,"7")));
SUMMARY("DOMOUT8",SM) =
(SUM(IP,OUTP.L(IP,"8"))+SUM(FG,GOUTP.L(FG,"8")));
SUMMARY("DOMOUT9",SM) =
(SUM(IP,OUTP.L(IP,"9"))+SUM(FG,GOUTP.L(FG,"9")));
SUMMARY("DOMOUT10",SM) =
(SUM(IP,OUTP.L(IP,"10"))+SUM(FG,GOUTP.L(FG,"10")));
SUMMARY("DOMOUT11",SM) =
(SUM(IP,OUTP.L(IP,"11"))+SUM(FG,GOUTP.L(FG,"11")));
SUMMARY("DOMOUT12",SM) =
(SUM(IP,OUTP.L(IP,"12"))+SUM(FG,GOUTP.L(FG,"12")));
SUMMARY("DOMOUT13",SM) =
(SUM(IP,OUTP.L(IP,"13"))+SUM(FG,GOUTP.L(FG,"13")));
SUMMARY("DOMOUT14",SM) =
(SUM(IP,OUTP.L(IP,"14"))+SUM(FG,GOUTP.L(FG,"14")));
SUMMARY("DOMOUT15",SM) =
(SUM(IP,OUTP.L(IP,"15"))+SUM(FG,GOUTP.L(FG,"15")));
SUMMARY("DOMOUT16",SM) =
(SUM(IP,OUTP.L(IP,"16"))+SUM(FG,GOUTP.L(FG,"16")));
```

```
    SUMMARY("DOMOUT17",SM)                                         =
(SUM(IP,OUTP.L(IP,"17"))+SUM(FG,GOUTP.L(FG,"17")));
    SUMMARY("DOMOUT18",SM)                                         =
(SUM(IP,OUTP.L(IP,"18"))+SUM(FG,GOUTP.L(FG,"18")));
    SUMMARY("DOMOUT19",SM)                                         =
(SUM(IP,OUTP.L(IP,"19"))+SUM(FG,GOUTP.L(FG,"19")));
    SUMMARY("DOMOUT20",SM)                                         =
(SUM(IP,OUTP.L(IP,"20"))+SUM(FG,GOUTP.L(FG,"20")));
PUT RESULTS;
    );
DISPLAY SUMMARY;
SET SUMMARY1  /STATUS, ITERS, CPU, CONTROL /
PUT 'COLORADO      ';
 LOOP(SM, PUT '     ',SM.TL);
 PUT /;
LOOP(SUMMARY1, PUT '           ';
    PUT SUMMARY1.TL,
    LOOP(SM, PUT SUMMARY(SUMMARY1,SM) );
    PUT / );
```

Appendix C

CO-E Model in GAMS MPSGE

```
$TITLE COLORADO
*----------------------------------------------------------------------------------------------------------------
$OFFSYMLIST OFFSYMXREF
SETS  Z  ALL ACCOUNTS IN SOCIAL ACCOUNTING MATRIX /
Agric
 Mining
Coal
IOU
COOP
MUNI
GENcoal
GENgas
GENpeak
GENwind
RESpv
COMMpv
UTILpv
GENhydro
NatGas
```

Utilities

Const

Manuf

WHTR

Retail

TransWare

Info

FinIns

RealEst

HGSER

Manage

Admin

Educ

unijc

HealthCare

Arts

LodgeRest

OtherServ

PubAdm

HS1

HS2

HS3

HS4

HS5

HS6

L1

L2

L3

L4

L5

LAND

KAP

Kcoal

Kgas

Kwind

Kpv

Khydro

HH1

HH2

HH3

HH4

HH5

HH6

HH7

INVES

USSOCL1

USSOCL2

USSOCL3

USSOCL4

USSOCL5

USPIT

COPIT

CORPTAX

CNPRP

FEES

COSTX

LOCSTX

CYGF

SUBS

FED

STED

STHEALTH

STJUST

STADM

CDOT

ROW /

F(Z) FACTORS /L1,L2,L3,L4,L5,LAND,KAP,Kcoal,Kgas,Kwind,Kpv,Khydro/

L(F) LABOR /L1,L2,L3,L4,L5/

LA(F) LAND /LAND/

K(F) CAPITAL /KAP,Kcoal,Kgas,Kwind,Kpv,Khydro/

G(Z) GOVERNMENTS / USSOCL1, USSOCL2, USSOCL3,USSOCL4, USSOCL5, USPIT, COPIT, CORPTAX,CNPRP,FEES,

COSTX,LOCSTX,

CYGF,SUBS,FED,STED,STHEALTH,STJUST,STADM,CDOT/

GN(G) ENDOGENOUS GOVERNMENTS / FED,STED,STHEALTH,STJUST,STADM,CDOT /

GNL(G) lOCAL ENDOGENOUS GOVERNMENTS / STED,STHEALTH,STJUST,STADM,CDOT/

GX(G) EXOGENOUS GOVERMENTS / USSOCL1, USSOCL2, USSOCL3,USSOCL4,USSOCL5,USPIT, COPIT, CORPTAX,CNPRP,FEES,COSTX,LOCSTX/

GS(G) SALES OR EXCISE TAXES / FEES,COSTX,LOCSTX,corptax /

GL(G) LAND TAXES / CNPRP/

GF(G) FACTOR TAXES / USSOCL1, USSOCL2, USSOCL3,USSOCL4,USSOCL5, CNPRP/

GI(G) INCOME TAX UNITS / USPIT,copit /

GH(G) HOUSEHOLD TAX UNITS / CNPRP,fees /

GY(G) EXOGNOUS TRANSFER PMT / USSOCL1, USSOCL2, USSOCL3, USSOCL4, USSOCL5, USPIT, COPIT, CORPTAX,CNPRP,FEES,COSTX,LOCSTX, FED/

GTA(G) EXOGNOUS TRANSFER PMT / USSOCL1, USSOCL2,USSOCL3,USSOCL4,USSOCL5, USPIT, COPIT, CORPTAX,CNPRP,FEES,COSTX,LOCSTX, CYGF,FED/

GT(G) ENDOGENOUS TRANSFER PMT / CYGF, FED /

H(Z) HOUSEHOLDS / HH1, HH2, HH3, HH4, HH5, HH6,HH7 /

WORK(L,H) WORKERS /L1.(HH1,HH2,HH3,HH4,HH5,HH6,HH7)

L2.(HH2,HH3,HH4,HH5,HH6,HH7)

L3.(HH5,HH6,HH7)

L4.(HH6,HH7)

L5.(HH7)/

IG(Z) I+G SECTORS / Agric, Mining,Coal,IOU, COOP, MUNI, GENcoal,GENgas,GENpeak,GENwind,RESpv,COMMpv,UTILpv,GENhydro,NatGas, Utilities, Const,Manuf, WHTR, Retail,TransWare, Info,FinIns,RealEst,HGSER,Manage,

Admin,Educ,unijc,HealthCare,

Arts,LodgeRest,OtherServ,PubAdm,HS1,HS2,HS3,HS4,HS5,HS6,

FED,STED,STHEALTH,STJUST,STADM,CDOT/

I(IG) INDUSTRY SECTORS / Agric, Mining,Coal,IOU, COOP, MUNI, GENcoal,GENgas,GENpeak,GENwind,RESpv,COMMpv,UTILpv,GENhydro,NatGas,

Utilities, Const,Manuf, WHTR, Retail,TransWare, Info,FinIns,RealEst,HGSER,Manage,

Admin,Educ,unijc,HealthCare,

Arts,LodgeRest,OtherServ,PubAdm,HS1,HS2,HS3,HS4,HS5,HS6/

IG2(IG) ENDOGENOUS GOVERNMENTS / FED,STED,STHEALTH,STJUST,STADM,CDOT /

IP(I) PRODUCTION SECTORS /Agric, Mining,Coal,NatGas, Utilities, Const,Manuf, WHTR, Retail,TransWare,

Info,FinIns,RealEst,HGSER,Manage,Admin,Educ,unijc,HealthCare, Arts,LodgeRest,OtherServ,PubAdm/

GR(I) TRANSMISSION SECTORS /IOU,COOP,MUNI/

NONEL(I) NON-ELECTRICITY PRODUCTION /Agric, Mining,Coal,NatGas, Utilities, Const,Manuf, WHTR, Retail,TransWare,

Info,FinIns,RealEst,HGSER,Manage,Admin,Educ,unijc,HealthCare, Arts,LodgeRest,OtherServ,PubAdm/

IE(I) ENERGY SECTORS /GENcoal,GENgas,GENpeak,GENwind,RESpv,COMMpv,UTILpv,GENhydro/

IEU(IE) UTILITY-SCALE GENERATION SECTORS /GENcoal,GENgas,GENpeak,GENwind,UTILpv,GENhydro/

IER(IE) RETAIL GENERATION SECTORS /RESpv,COMMpv/

FG(IG) PRODUCTION GOV. /FED,STED,STHEALTH,STJUST,STADM,CDOT/

FSL(FG) STATE AND LOCAL GOV. /STED,STHEALTH,STJUST,STADM,CDOT/

FEDR(FG) FEDERAL GOV. /FED/

HD(I) HOUSING SERV.DEMAND /HS1, HS2, HS3, HS4, HS5, HS6/

SF(HD) DETACHED HOUSING /HS1,HS2,HS3,HS4,HS5/

MUF(HD) ATTACHED HOUSING /HS6/

SM SIMMLOOP /BASE,TODAY,SIMM1,SIMM2,SIMM3,SIMM4,SIMM5,SIMM6,SIMM7

R1H REPORT 1 FOR SCALARS / GFREV, SFREV, PIT,

```
                    DGF, DSF, DDRE, PDRE, SPI,COMM,COMMO,
                    GN, NKI, HH, W, W1, W2, W3, R,RL, L, K, HN,HW, GFSAV, LD,
                     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 c:\Users\Chris\Documents\Dissertation Related Stuff\NREL\GASsam4.csv
$OFFDELIM
*-----------------------------------------------------------------------------------------------------
* 3.2 PARAMETER DECLARATION
*-----------------------------------------------------------------------------------------------------
PARAMETERS
* PARAMETERS CALCULATED FROM SOCIAL ACCOUNTING MATRIX AND TABLE DATA
HH0(H)     DOF    HHDS    NUMBER OF HOUSEHOLDS
HN0(H)     DOF    HHDS    NUMBER OF NONWORKING HOUSEHOLDS
HW0(H)     DOF    HHDS    NUMBER OF WORKING HOUSEHOLDS;
*-----------------------------------------------------------------------------------------------------
* 3.3 CALCULATIONS OF PARAMETERS AND INITIAL VALUES
*-----------------------------------------------------------------------------------------------------
OPTION DECIMALS=8
*DISPLAY SD7;
TABLE MISCH(H,*) MISC.  HH DATA
        HH0             HW0
```

HH1	122862	121827
HH2	175378	171415
HH3	385109	366882
HH4	182306	171916
HH5	365070	339473
HH6	250286	235032
HH7	405588	376157;

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

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

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

TABLE GRIDPERY(z,GR) ELECTRICITY CONSUMPTION PERCENTAGES BY UTILITY TYPE

	IOU	COOP	MUNI
Agric	0	0.614786468	0.385213532
Mining	0	0.614786468	0.385213532
Coal	0	0.614786468	0.385213532
GENcoal	1	0	0
GENpeak	1	0	0
GENgas	1	0	0
GENwind	1	0	0
RESpv	1	0	0
COMMpv	1	0	0
UTILpv	1	0	0

GENhydro	1	0	0
NatGas	0	0.614786468	0.385213532
Utilities	0.542309998	0.281381620	0.176308383
Const	0.542309998	0.281381620	0.176308383
Manuf	0.806421054	0.119009716	0.074569229
WHTR	0.835149877	0.101347625	0.063502498
Retail	0.572797005	0.262638620	0.164564375
TransWare	0.169759825	0.510420424	0.319819750
Info	0.938863151	0.037586108	0.023550742
FinIns	0.850960623	0.091627392	0.057411985
RealEst	0.662742918	0.207341090	0.129915992
HGSER	0.783790504	0.132922672	0.083286824
Manage	0.783790504	0.132922672	0.083286824
Admin	0.746092747	0.156098743	0.097808510
Educ	0.844711348	0.095469362	0.059819290
unijc	0.844711348	0.095469362	0.059819290
HealthCare	0.645647515	0.217851113	0.136501373
Arts	0.208089086	0.486856113	0.305054800
LodgeRest	0.396264618	0.371168343	0.232567039
OtherServ	0.613142285	0.237834888	0.149022827
PubAdm	0.625974279	0.229945952	0.144079769
FED	0.625974279	0.229945952	0.144079769
STED	0.625974279	0.229945952	0.144079769

```
STHEALTH        0.625974279       0.229945952         0.144079769
STJUST          0.625974279       0.229945952         0.144079769
STADM           0.625974279       0.229945952         0.144079769
CDOT            0.625974279       0.229945952         0.144079769;
TABLE GRIDPERH(H,GR)
        IOU             COOP            MUNI
HH1     0.549496030     0.276963744     0.173540226
HH2     0.502173914     0.306056741     0.191769345
HH3     0.550469388     0.276365337     0.173165275
HH4     0.581317181     0.257400532     0.161282288
HH5     0.624341317     0.230949875     0.144708808
HH6     0.666251325     0.205184169     0.128564506
HH7     0.763849551     0.145182101     0.090968349;
PARAMETER PGRID(GR) RELATIVE ELECTRICITY PRICES BY UTILITY TYPE,
        UTTYPE(GR) SHARE OF TOTAL ELECTRICITY OUTPUT BY UTILITY TYPE,
        UTTYPE1(GR) SHARE OF ELECTRICITY OUTPUT SCALED TO BALANCE GRID
SECTORS IN SAM,
        VAGRID(GR) VALUE ADDED SHARE FOR TRANSMISSION UTILITIES,
        VAGRID1(GR),
        VAGRID2(GR),
        PRODGRID(GR) RELATIVE FACTOR PRODUCTIVITY BY BY ;
 PGRID("IOU") = 1;
 PGRID("COOP") = 1.11;
```

```
 PGRID("MUNI") = 0.824444;
* SHARES OF ELECTRICITY GENERATED (NOT ELECTRICITY REVENUES) FOR
EACH GRID SECTOR *
 UTTYPE("IOU") = 0.626901;
 UTTYPE("COOP") = 0.229376;
 UTTYPE("MUNI") = 0.143723;
 UTTYPE1("IOU") = 0.626885996;
 UTTYPE1("COOP") = 0.229303426;
 UTTYPE1("MUNI") = 0.143810577;
*DISPLAY PRODGRID, VAGRID, VAGRID1, VAGRID2;
PARAMETER TKI0(I)   PROPERTY TAXES ON COMMERCIAL CAPITAL;
 TKI0(IP)=SAM("CNPRP",IP)/((sum(K,SAM(K,IP)))+sum(LA,SAM(LA,IP)));
*** ADDED PROPERTY TAX RATES ON UTILITIES AND GENERATORS 2/8/14 ***
 TKI0(GR)=SAM("CNPRP",GR)/((sum(K,SAM(K,GR)))+sum(LA,SAM(LA,GR)));
 TKI0(IE)=SAM("CNPRP",IE)/((SUM(K,SAM(K,IE)))+SUM(LA,SAM(LA,IE)));
PARAMETER TKH0(H) PROPERTY TAXES ON RESIDENTIAL CAPITAL;
 TKH0(H)=(SAM("CNPRP",H)/(SUM(HD,SAM(HD,H))));
DISPLAY TKI0, TKH0;
PARAMETER TLDI0(L,I)  PRIVATE EMPLOYER SHARE OF PAYROLL TAXES;
  TLDI0("L1",I)$SAM("L1",I)= SAM("USSOCL1",I)/SAM("L1",I);
  TLDI0("L2",I)$SAM("L2",I)= SAM("USSOCL2",I)/SAM("L2",I);
  TLDI0("L3",I)$SAM("L3",I)= SAM("USSOCL3",I)/SAM("L3",I);
  TLDI0("L4",I)$SAM("L4",I)= SAM("USSOCL4",I)/SAM("L4",I);
```

```
  TLDI0("L5",I)$SAM("L5",I)= SAM("USSOCL5",I)/SAM("L5",I);
PARAMETER TLDG0(L,FG)  PUBLIC EMPLOYER SHARE OF PAYROLL TAXES;
  TLDG0("L1",FG) = SAM("USSOCL1",FG)/SAM("L1",FG);
  TLDG0("L2",FG) = SAM("USSOCL2",FG)/SAM("L2",FG);
  TLDG0("L3",FG) = SAM("USSOCL3",FG)/SAM("L3",FG);
  TLDG0("L4",FG) = SAM("USSOCL4",FG)/SAM("L4",FG);
  TLDG0("L5",FG) = SAM("USSOCL5",FG)/SAM("L5",FG);
PARAMETER LI0(L);
 LI0(L)=SUM(H,SAM(H,L));
PARAMETER TLS0(L)   EMPLOYEE SHARE OF PAYROLL TAXES;
 TLS0("L1") = SAM("USSOCL1","L1")/(LI0("L1")+SAM("USSOCL1","L1"));
 TLS0("L2") = SAM("USSOCL2","L2")/(LI0("L2")+SAM("USSOCL2","L2"));
 TLS0("L3") = SAM("USSOCL3","L3")/(LI0("L3")+SAM("USSOCL3","L3"));
 TLS0("L4") = SAM("USSOCL4","L4")/(LI0("L4")+SAM("USSOCL4","L4"));
 TLS0("L5") = SAM("USSOCL5","L5")/(LI0("L5")+SAM("USSOCL5","L5"));
PARAMETER TLS1(L) PAYROLL TAX RATE FOR MPSGE;
 TLS1(L) = TLS0(L)
TABLE WORK0(L,H)
        HH1         HH2         HH3         HH4         HH5
L1      1963.200402   883.467607   848.743351   751.908112   1156.110615
L2      0           2285.337821   4077.302229   5991.492537   7193.962546
L3      0           0           0           0           7027.453123
L4      0           0           0           0           0
```

```
L5        0             0             0             0             0

+         HH6           HH7

L1        1039.999790   1113.363917

L2        9054.106853   7075.077710

L3        5759.216302   8730.033725

L4        7918.629220   12364.851540

L5        18.394169     33887.143330;

PARAMETER DEPRECIATE(K);

DEPRECIATE("KAP")    = 0.070;

DEPRECIATE("Kcoal")  = 0.070;

DEPRECIATE("Kgas")   = 0.070;

DEPRECIATE("Kwind")  = 0.070;

DEPRECIATE("Kpv")    = 0.070;

DEPRECIATE("Khydro") = 0.070;

PARAMETER KLAOUT0 NON-RESIDENT OWNERSHIP OF LAND AND CAPITAL,

        QKSF0(K)  NON-RESIDENT OWNERSHIP OF CAPITAL,

        QLASF0 NON-RESIDENT OWNERSHIP OF LAND;

 QKSF0(K) = -SAM(K,"ROW");

 QLASF0 = -SAM("LAND","ROW");

 KLAOUT0 = SUM(K,QKSF0(K)) + QLASF0;

PARAMETER WORK1(L,H)  WORKERS BY HOUSEHOLD BY LABOR GROUP,

        LABGRPSHARE(L,H),

        QFICA(L,H),
```

```
        WORKPROP(L,H),
        WRKSUM(H),
        QLABSUP0(L,H);
  WORK1(L,H) = WORK0(L,H)$WORK(L,H);
  LABGRPSHARE(L,H) = WORK1(L,H)/LI0(L);
  QFICA("L1",H) = LABGRPSHARE("L1",H)*(SAM("USSOCL1","L1"));
  QFICA("L2",H) = LABGRPSHARE("L2",H)*(SAM("USSOCL2","L2"));
  QFICA("L3",H) = LABGRPSHARE("L3",H)*(SAM("USSOCL3","L3"));
  QFICA("L4",H) = LABGRPSHARE("L4",H)*(SAM("USSOCL4","L4"));
  QFICA("L5",H) = LABGRPSHARE("L5",H)*(SAM("USSOCL5","L5"));
  QLABSUP0(L,H) = WORK1(L,H)+QFICA(L,H);
  WRKSUM(H) = SUM(L,WORK1(L,H));
  WORKPROP(L,H) = WORK1(L,H)/WRKSUM(H);
DISPLAY LABGRPSHARE;
PARAMETER FEDPROD0 FEDERAL GOVERNMENT EXPENDITURES AT LOCAL
LEVEL;
 FEDPROD0 = (SUM(Z,SAM(Z,"FED"))-SAM("SUBS","FED"));
DISPLAY QKSF0, QLASF0, KLAOUT0, FEDPROD0;
***  INVESTMENT EQUATION AND VALUE DECLARATIONS ***
PARAMETER INVESOUT1,
        INVESOUT2(H),
        INVESOUT3,
        INVESOUT4(H),
```

```
        INVESD1(H),
        INVESD2(I),
        INVESD3,
        INVESOUT0(H),
        INVESD0(I,H),
        INVESDGR0(GR,H),
        INVESDGR1(GR,H),
        INVDGR0(GR),
        INVD0(I) INTERMEDIATES FOR CAPITAL PRODUCTION,
        INV0 NET INVESTMENT,
        INVESD9(H) TOTAL HOUSEHOLD INVESTMENT,
        QSAVING0(H) TOTAL HOUSEHOLD SAVING;
*** TOTAL OUTFLOW OF SAVINGS FROM REGION
 INVESOUT1 = SAM("INVES","ROW");
*** LOCAL HOUSEHOLD SPENDING ON INVESTMENT WITHIN REGION, AS COMPONENT OF LOCAL SAVING
 INVESOUT2(H) = SAM("INVES",H);
*** SUM OF ALL LOCAL HOUSEHOLD SPENDING ON INVESTMENT WITHIN REGION, AS COMPONENT OF LOCAL SAVING
 INVESOUT3 = (SUM(H,INVESOUT2(H)));
*** EACH HOUSEHOLD'S SHARE OF TOTAL LOCAL HOUSEHOLD SPENDING ON INVESTMENT WITHIN REGION
 INVESOUT4(H) = INVESOUT2(H)/INVESOUT3;
```

*** TOTALLY UNNECESSARY REDECLARATION OF INVESOUT2(H)

INVESD1(H)= SAM("INVES",H);

*** AMOUNT OF INVESTMENT SPENDING ON EACH INDUSTRY SECTOR (IN OLDER VERSIONS, MAY HAVE CORRESPONDED TO

*** INVESTMENT IN SECTOR-SPECIFIC CAPITAL, HERE CORRESPONDS TO INGREDIENTS IN PRODUCTION OF ALL CAPITAL

INVESD2(I) = SAM(I,"INVES");

*** SUM OF ALL INVESTMENT SPENDING ON INDUSTRY SECTORS' OUTPUT - IMPORTED COMPONENT IS DEFINED ELSEWHERE

INVESD3 = (SUM(I,INVESD2(I)));

*** AMOUNT OF OUTFLOW OF SAVINGS FROM REGION ATTRIBUTABLE TO EACH HOUSEHOLD GROUP, IF NON-ZERO

INVESOUT0(H)$(SAM("INVES",H) ne 0) = INVESOUT1*INVESOUT4(H);

*** AMOUNT OF INVESTMENT SPENDING ON EACH INDUSTRY BY EACH LOCAL HOUSEHOLD GROUP

INVESD0(I,H)$INVESD1(H) = (SAM(I,"INVES")/INVESD3)*(INVESD1(H)+INVESOUT0(H));

*** SUM OF ALL INVESTMENT SPENDING ON EACH INDUSTRY, SHOULD EQUAL INVESD2(I) IF EQUATIONS ARE SET UP PROPERLY

INVD0(IP) = SUM(H,INVESD0(IP,H));

INVD0(GR) = SUM(H,INVESD0(GR,H));

*** SUM OF ALL INVESTMENT SPENDING ON ALL INDUSTRIES, SHOULD EQUAL INVESD3 IF EQUATIONS ARE SET UP PROPERLY

INV0 = SUM(I,INVD0(I));

*** SUM OF ALL DOMESTIC INVESTMENT SPENDING BY EACH LOCAL HOUSEHOLD GROUP

INVESD9(H) = SUM(I,INVESD0(I,H));

*** TOTAL AMOUNT OF THEIR INCOME THAT HOUSEHOLDS DO NOT SPEND - INCLUDES BOTH DOMESTIC INVESTMENT AND OUTFLOWS

QSAVING0(H) = INVESD9(H)-INVESOUT0(H);

DISPLAY INVESOUT0;

PARAMETER QLS0(L,H) QUANTITY OF LABOR SUPPLIED BY HH,

QDLEI0(L,H) LEISURE CONSUMPTION BY HOUSEHOLD,

QADH0(I,H) HOUSEHOLD ARMINGTON CONSUMPTION DEMAND,

QHSDH0(HD,H) HOUSEHOLD HOUSING DEMAND;

QDLEI0(L,H) = WORK1(L,H);

QADH0(IP,H) = SAM(IP,H);

QADH0(GR,H) = SAM(GR,H)/PGRID(GR);

QHSDH0(HD,H) = SAM(HD,H);

PARAMETER TUSPIT0(H) US PERSONAL INCOME TAX,

TCOPIT0(H) COLORADO PERSONAL INCOME TAX,

TCOPIT1(H),

TUSPIT1(H),

THFEE0(H) FEES PAID BY HOUSEHOLDS TO STATE AND LOCAL GOVERNMENT,

QW0(H) UTILITY BY HOUSEHOLD GROUP,

```
        QW1(H) UTILITY BY HOUSEHOLD WITHOUT LEISURE,
        HSDSUM(H),
        ADSUM(H),
        LEISUM(H),
        QKSH0(K,H),
        CONSUMPTION0(H),
        INVESTMENT0(H),
        WORKSUM(H);
QKSH0("KAP",H)=SAM(H,"KAP");
 QKSH0("Kcoal",H)=SAM(H,"Kcoal");
 QKSH0("Kgas",H)=SAM(H,"Kgas");
 QKSH0("Kwind",H)=SAM(H,"Kwind");
 QKSH0("Kpv",H)=SAM(H,"Kpv");
 QKSH0("Khydro",H)=SAM(H,"Khydro");
*** TOTAL BASELINE CONSUMPTION SPENDING (NOT Q) FOR EACH HH GROUP,
DOES NOT INCLUDE HOUSING ***
 CONSUMPTION0(H) = SUM(IP,QADH0(IP,H))+SUM(GR,SAM(GR,H));;
*** ACTUALLY REFERS TO THE TOTAL INITIAL CAPITAL ENDOWMENT FOR EACH
HH GROUP
 INVESTMENT0(H) = SUM(K,QKSH0(K,H));
*** STATE INCOME TAX RATE FOR EACH HOUSEHOLD ***
 TCOPIT0(H)= SAM("COPIT",H)/(CONSUMPTION0(H));
*** FEDERAL INCOME TAX RATE FOR EACH HOUSEHOLD ***
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 TUSPIT0(H)= SAM("USPIT",H)/(CONSUMPTION0(H));
*** "USER FEE" TAX RATE FOR EACH HOUSEHOLD GROUP ***
 THFEE0(H) = SAM("FEES",H)/(CONSUMPTION0(H));
*** TOTAL SPENDING ON HOUSING BY EACH HOUSEHOLD GROUP, INCLUDES
EXPLICIT AND IMPLICIT COSTS ***
 HSDSUM(H) = SUM(HD,QHSDH0(HD,H))*(1+TKH0(H));
*** TOTAL CONSUMPTION SPENDING, INCLUDING INCOME TAXES AND FEES
(WHICH ARE TREATED AS HH-SPECIFIC CONSUMPTION TAXES ***
 ADSUM(H) = SUM(IP,QADH0(IP,H))*(1+TUSPIT0(H)+TCOPIT0(H)+THFEE0(H));
*** TOTAL SUPPLY OF LABOR/LEISURE FOR EACH HOUSEHOLD GROUP ***
 LEISUM(H) = SUM(L,QDLEI0(L,H));
 WORKSUM(H) = SUM(L,WORK1(L,H));
PARAMETER    QGC0(FG)  GOVERNMENT CONSUMPTION,
*GOVERNMENT OUTPUT CALCULATED WITHOUT TAX EXPENDITURES
            QLDG0(L,FG) GOVERNMENT LABOR DEMAND,
            QADG0(JP,FG) GOVERNMENT INTERMEDIATE GOODS DEMAND,
            QADGGR0(GR,FG) GOVERNMENT ELECTRICITY DEMAND,
            QGCDG0(FG) TOTAL GOVERNMENT CONSUMPTION,
            QFXDG0  GOVERNMENT "FOREIGN EXCHANGE" OUTFLOWS;
 QGC0(FG) = (SUM(Z,SAM(Z,FG))-(SAM("SUBS",FG)));
 QLDG0(L,FG) = SAM(L,FG);
 QADG0(JP,FG) = SAM(JP,FG);
 QADGGR0(GR,FG) = SAM(GR,FG)/PGRID(GR);
```

QGCDG0(FG) = SUM(Z,SAM(Z,FG));

QFXDG0 = SUM(Z,SAM("FED",Z))-(SAM("FED","ROW"))-(SAM("SUBS","FED"));

DISPLAY QGC0, QLDG0, QADG0, QGCDG0, QFXDG0;

PARAMETER QY0(I) DOMESTIC PRODUCTION OF GOODS AND SERVICES FOR DOMESTIC CONSUMPTION,

QE0(I) DOMESTIC PRODUCTION OF GOODS AND SERVICES FOR EXPORT,

QEGR0(GR),

QLDY0(L,I) LABOR DEMAND FOR PRODUCTION OF GOODS AND SERVICES,

QLDGR0(L,GR),

QLADY0(I) LAND DEMAND FOR PRODUCTION OF GOODS AND SERVICES,

QLADGR0(GR),

QKIDY0(K,I) COMMERCIAL AND INDUSTRIAL CAPITAL DEMAND FOR PRODUCTION OF GOODS AND SERVICES,

QKIDGR0(K,GR),

QADY0(JP,I) INTERMEDIATE GOODS DEMAND FOR PRODUCTION,

QADGR0(GR,I) ELECTRICITY DEMAND BY FIRMS,

QADGR1(IP,GR) INTERMEDIATE GOODS DEMAND BY TRANSMISSION UTILITIES,

TCORP0(I) CORPORATE INCOME TAX,

TCORPGR0(GR) CORPORATE INCOME TAX ON ELECTRIC UTILITIES,

SUB0(IE),

SUBS0(IE),

QGR0(GR),

TCFEEGR0(GR) FEES PAID BY ELECTRIC UTILITIES,

TCFEE0(I) FEES PAID BY BUSINESS;

QE0(I) = SAM(I,"ROW");

QLDY0(L,I) = SAM(L,I);

QLADY0(I) = SAM("LAND",I);

QKIDY0(K,I) = SAM(K,I);

*** DEMAND FOR NON-ELECTRIC INTERMEDIATE INPUTS BY INDUSTRIES ***

QADY0(JP,I) = SAM(JP,I);

*** DEMAND FOR RETAIL ELECTRICITY BY INDUSTRIES AS AN INTERMEDIATE INPUT (DOES NOT INCLUDE WHOLESALE ELECTRICITY) ***

QADGR0(GR,I) = SAM(GR,I);

* TOTAL SPENDING ON IP BY Z, MINUS IMPORTS OF IP, MINUS SALES TAXES PAID ON IP *

QY0(I) = SUM(Z,SAM(I,Z))-SAM("ROW",I)-SAM("LOCSTX",I)-SAM("COSTX",I);

*** FEDERAL PRODUCTION SUBSIDIES FOR RENEWABLE ENERGY PRODUCERS

SUB0(IE)= SAM(IE,"SUBS");

*** TOTAL ELECTRICITY OUTPUT FOR ALL GRID SECTORS ***

QY0(IE) = SUM(Z,SAM(IE,Z))-SAM("ROW",IE)-SAM("LOCSTX",IE)-SAM("COSTX",IE);

*** FEDERAL PRODUCTION SUBSIDY RATE FOR RENEWABLE ENERGY PRODUCERS

SUBS0(IE)= SAM(IE,"SUBS")/QY0(IE);

*** CORPORATE INCOME TAX RATE FOR EACH INDUSTRY

TCORP0(I) = SAM("CORPTAX",I)/QY0(I);

```
*** "FEE-FOR-SERVICE" TAX RATE FOR EACH INDUSTRY
 TCFEE0(I) = SAM("FEES",I)/QY0(I)
*DISPLAY  QY0,  QE0,  QLDY0,  QLADY0,  QKIDY0,  QADY0,  QGR0,  qldgr0,  qladgr0,
qkidgr0, qadgr1;
PARAMETER     QHS0(HD) PRODUCTION OF IMPUTED HOUSING SERVICES,
              QLADHS0(HD) LAND DEMAND FOR HOUSING SERVICES,
              QKHDHS0(K,HD) CAPITAL DEMAND FOR HOUSING SERVICES,
              QADHS0(JP,HD) INTERMEDIATE GOODS DEMAND FOR HOUSING SERVICES;
 QHS0(HD) = SUM(Z,SAM(Z,HD));
 QLADHS0(HD) = SAM("LAND",HD);
 QKHDHS0(K,HD) = SAM(K,HD);
 QADHS0(JP,HD) = SAM(JP,HD);
DISPLAY QHS0, QLADHS0, QKHDHS0, QADHS0;
PARAMETER     QA0(IP)  PRODUCTION OF ARMINGTON AGGREGATES,
              QAGR0(GR) PRODUCTION OF ARMINGTON ELECTRICITY AGGREGATES,
              QMDA0(IP) IMPORTS FOR AGGREGATION,
              QMDE0(IE) IMPORTS BY GENERATORS,
              QMDAGR0(GR),
              QYDA0(IP) DOMESTIC OUTPUT FOR AGGREGATION,
              QYDAGR0(GR),
              P0(IE) DOMESTIC ELECTRICITY PRICE BY TYPE,
              ELECPRICE(IE),
              QYE1(IE) DOMESTIC ELECTRICITY INPUTS,
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QYE0(IE) DOMESTIC ELECTRICITY OUTPUT,
SUBS0(IE),
ELECIN0(IE,GR),
ELECIN1(IE,GR),
AFTERSUBPE0(IE),
PELEC0(GR),
PELEC1(GR),
subrate(ie),
TLVGR0(GR),
TSVGR0(GR),
QGENOUTGR0(GR),
TLV0(I) LOCAL SALES TAXES,
TSV0(I) STATE SALES TAXES;
QMDA0(IP) = SAM("ROW",IP);
QMDAGR0(GR) = SAM("ROW",GR);
QMDE0(IE) = SAM("ROW",IE);
QYDA0(IP) = QY0(IP)-QE0(IP);
QYDAGR0(GR) = QY0(GR) - QE0(GR);
QA0(IP)   = QMDA0(IP)+QYDA0(IP)+SAM("LOCSTX",IP)+SAM("COSTX",IP);
QAGR0(GR) =
QMDAGR0(GR)+QYDAGR0(GR)+SAM("LOCSTX",GR)+SAM("COSTX",GR);
*** TOTAL REVENUES/EXPENDITURES FOR GENERATORS IN THE SAM ***
QYE1(IE)  = QMDE0(IE)+QY0(IE)+SAM("LOCSTX",IE)+SAM("COSTX",IE)-SUB0(IE);
```

```
*** RECALCULATED FEDERAL PRODUCTION SUBSIDY RATE ***
 subrate(ie) = -sub0(ie)/qye1(ie);
*** NON-UNITARY PRICES FOR WHOLESALE ELECTRICITY, BASED ON LCOE FIGURES FROM EIA
 P0("GENcoal")    = 1.001;
 P0("GENgas")     = 0.671;
 P0("GENpeak")    = 2.000;
 P0("GENwind")    = 0.866/(1-subrate("GENwind"));
 P0("UTILpv")     = 1.443;
 P0("RESpv")      = 1.443*1.44;
 P0("COMMpv")     = 1.443*1.44;
 P0("GENhydro")   = 0.903;
*** REAL OUTPUT FOR EACH GENERATION SECTOR ***
 QYE0(IE)  = QYE1(IE)/P0(IE);
 ELECIN0(IE,GR) = SAM(IE,GR);
 AFTERSUBPE0(IE) = P0(IE)*(1-SUBRATE(IE));
 ELECIN1(IE,GR) = ELECIN0(IE,GR)/P0(IE);
PELEC0(GR) = SUM(IE,ELECIN0(IE,GR))/SUM(IE,ELECIN1(IE,GR));
 PELEC1(GR) = (sum(ie,elecin0(ie,gr))-elecin0("GENwind",gr))/(sum(ie,elecin1(ie,gr))-elecin0("GENwind",gr));
 QGENOUTGR0(GR) = SUM(IE,ELECIN1(IE,GR));
 TLV0(IP)  = SAM("LOCSTX",IP)/(QA0(IP));
```

TLV0(IE) = SAM("LOCSTX",IE)/(QY0(IE)+QMDE0(IE)+SAM("LOCSTX",IE)+SAM("COSTX",IE));

TSV0(IP) = SAM("COSTX",IP)/(QA0(IP));

TSV0(IE) = SAM("COSTX",IE)/(QY0(IE)+QMDE0(IE)+SAM("LOCSTX",IE)+SAM("COSTX",IE));

TSVGR0(GR) = SAM("COSTX",GR)/QAGR0(GR);

TLVGR0(GR) = SAM("LOCSTX",GR)/QAGR0(GR);

ELECPRICE(IE) = P0(IE);

DISPLAY QA0, QMDA0, QYDA0, ELECPRICE, p0, pelec0, pelec1;

PARAMETER QKI0 COMMERCIAL CAPITAL,

QKH0 RESIDENTIAL CAPITAL,

QKDK0 DEMAND FOR INVESTMENT CAPITAL;

QKI0 = SUM(K,SUM(IP,SAM(K,IP)));

QKH0 = SUM(K,SUM(HD,SAM(K,HD)));

QKDK0 = SUM(K,SUM(I,SAM(K,I)));

DISPLAY QKI0, QKH0, QKDK0;

PARAMETER

QLASH0(H) ENDOWMENT OF LAND BY DOMESTIC HOUSEHOLDS,

QLEISSH0(L,H) ENDOWMENT OF LEISURE OR LABOR BY DOMESTIC HOUSEHOLDS,

LEISSUMSUP(H) TOTAL ENDOWMENT OF LEISURE OR LABOR BY HOUSEHOLDS,

QREMSH0(H) ENDOWMENT OF REMITTANCES BY DOMESTIC HOUSEHOLDS,

QSOCSH0(H) ENDOWMENT OF EXOGENOUS GOVERNMENT TRANSFERS BY DOMESTIC HOUSEHOLDS,

HH0(H) NUMBER OF HOUSEHOLDS,

QK0 CAPITAL STOCK,

QKAP0(K) CAPITAL STOCK BY TYPE,

KPROP(H),

KPROPF,

SPEND(FSL) GOVERNMENT SPENDING PROPORTIONS;

SPEND(FSL) = SUM(Z,SAM(Z,FSL));

QLASH0(H) = SAM(H,"LAND");

QLEISSH0(L,H) = WORK1(L,H)*2;

LEISSUMSUP(H) = SUM(L,QLEISSH0(L,H));

QREMSH0(H) = SAM(H,"ROW");

QSOCSH0(H) = SUM(GY,SAM(H,GY));

HH0(H) = 1;

QK0 = (SUM(K,(SUM(H,QKSH0(K,H))))+(sum(K,QKSF0(K))));

QKAP0(K) = ((SUM(H,QKSH0(K,H)))+QKSF0(K));

KPROP(H) = (sum(K,QKSH0(K,H)))/QK0;

KPROPF = -SUM(K,SAM(K,"ROW"))/QK0;

PARAMETER

QKSH1(K,H),

```
        QKSH2(K,H),
        QKSH3(K,H),
        QKSF1(K),
        QKSF2(K),
        QKSF3(K),
        KPROP(H),
        KPROPF,
        SIMWIND1,
        SIMWIND2,
        SIMWIND3,
        WINDBOOST;
WINDBOOST = 1.270572;
SIMWIND1 = (1.575954+WINDBOOST);
SIMWIND2 = (3.151909+WINDBOOST);
SIMWIND3 = (4.727863+WINDBOOST);
QKSH1("Kcoal",H) = (0.8*SAM(H,"Kcoal"));
QKSH2("Kcoal",H) = (0.6*SAM(H,"Kcoal"));
QKSH3("Kcoal",H) = (0.4*SAM(H,"Kcoal"));
QKSH1("Kwind",H) = ((SIMWIND1)*SAM(H,"Kwind"));
QKSH2("Kwind",H) = ((SIMWIND2)*SAM(H,"Kwind"));
QKSH3("Kwind",H) = ((SIMWIND3)*SAM(H,"Kwind"));
QKSF1("Kcoal") = (-SAM("Kcoal","ROW")*0.8);
QKSF2("Kcoal") = (-SAM("Kcoal","ROW")*0.6);
```

```
 QKSF3("Kcoal") = (-SAM("Kcoal","ROW")*0.4);

 QKSF1("Kwind") = ((SIMWIND1)*(-SAM("Kwind","ROW")));

 QKSF2("Kwind") = ((SIMWIND2)*(-SAM("Kwind","ROW")));

 QKSF3("Kwind") = ((SIMWIND3)*(-SAM("Kwind","ROW")));

DISPLAY QKSH0, QLASH0, LEISSUMSUP, QLEISSH0, QREMSH0, QSOCSH0, KPROP,
KPROPF, QMDAGR0;

PARAMETER  QEDY0(IP),

        QGENIN0(IE),

        QGENOUT0,

        TOTKAP(K),

        QSUBSIDY0,

        KAPPER(K),

        SUB1(IE),

        SIMWIND,

        QKIDY1(K,IE),

        INTERMITTENCY,

        P1(IE),

        IMT(K),

        IELAS(K) THE ELASTICITY OF INVESTMENT SUPPLY,

        subrate(ie),

        HIGHINTER,

        QKIDY2(K,IE),

        P2(IE),
```

```
        QNMDY0(IER,IP),
        QNMDH0(IER,H),
        QNMDGR0(IER,GR),
        QKENDOW0(K);
 QLDY0(L,IE)= SAM(L,IE);
 QLADY0(IE)= SAM("LAND",IE);
 QKIDY0(K,IE)= SAM(K,IE);
 TOTKAP(K)=(SUM(Z,SAM(K,Z))-SAM(K,"ROW"));
 KAPPER(K)=TOTKAP(K)/QK0;
* ADDING KGAS COST TO GENWIND TO REFLECT ADDITIONAL COSTS IMPOSED
BY INTERMITTENCY
 QKIDY1("Kgas","GENwind") =
((QYE0("GENwind")*0.25)*(SAM("Kgas","GENgas")/QYE0("GENgas")));
 INTERMITTENCY = QKIDY1("Kgas","GENwind");
 HIGHINTER = (P0("GENwind")*QYE0("GENwind")*0.66);
 QKIDY2("Kgas","GENwind") = (P0("GENwind")*QYE0("GENwind")*0.66);
 P1(IE) = P0(IE)*((QYE1(IE)+SUM(K,QKIDY1(K,IE)))/QYE1(IE));
 P2(IE) = P0(IE)*((QYE1(IE)+SUM(K,QKIDY2(K,IE)))/QYE1(IE));
 QNMDY0(IER,IP) = SAM(IER,IP)/P0("COMMpv");
 QNMDH0(IER,H) = SAM(IER,H)/P0("RESpv");
 QNMDGR0(IER,GR) = SAM(IER,GR)/P0(IER);
*-----------------------------------------------------------------------------
 QADY0(JP,IE)= SAM(JP,IE);
```

```
 QEDY0(IP)= SUM(IE,SAM(IE,IP));
 TCORP0(IE)=SAM("CORPTAX",IE)/(QY0(IE)+QMDE0(IE));
 TCFEE0(IE)=SAM("FEES",IE)/(QY0(IE)+QMDE0(IE));
 TKI0(IE)=SAM("CNPRP",IE)/(SUM(K,SAM(K,IE)));
TLDI0("L5",IE)= SAM("USSOCL5",IE)/SAM("L5",IE);
 SUB1(IE) = SUB0(IE)/P0(IE);
QGENIN0(IE) = QYE0(IE);
QGENOUT0 = sum(IEU,QYE1(IEU))+SUM(IER,QNMDGR0(IER,"IOU"));
 QSUBSIDY0 = SUM(IE,SUB0(IE));
 QKENDOW0(K) = QKSF0(K)+SUM(H,QKSH0(K,H));
 IMT(K) = 0;
 SIMWIND = 0;
 IELAS(K) = 10;
 IELAS("KAP") = 1;
DISPLAY TOTKAP, KAPPER, QKENDOW0,QKIDY0, QGENOUT0;
DISPLAY QKSH0, INVESOUT0, INVESD9, subrate, qye0, qye1;
SET T /1*20/;
SET TAFTER(T) /8*20/
SET TFIRST(T)
   TLAST(T);
TFIRST(T) = YES$(ORD(T) EQ 1);
TLAST(T)  = YES$(ORD(T) EQ CARD(T));
SCALAR          GRO     GROWTH RATE    /0.03/
```

```
        REN     INTEREST RATE  /0.03/
        DEL     DEPRECIATION RATE     /0.07/
PARAMETER       QREF(T) REFERENCE QUANTITY PATH,
        IREF(T) REFERENCE INVESTMENT PATH,
        PREF(T) REFERENCE PRICE PATH,
        SHOCK(T) shock to sector of interest,
        SHOCK2  second shock to sector,
        SHOCK3(K),
        COALDROP(T),
        COALPER(T),
        GASPER(T),
        WIPER(T),
        SIME(IE,T),
        GASCAPADD(T),
        GASCAPIN(T),
        DEMCH(T);
QREF(T) = (1+GRO)**(ORD(T)-1);
IREF(T) = (1+GRO)**(ORD(T));
PREF(T) = (1/(1+REN))**(ORD(T)-1);
SHOCK(T)=EPS;
SHOCK2=0;
SHOCK3(K)=0;
DEMCH("1")=0.917004;
```

```
DEMCH("2")=0.840896;
DEMCH("3")=0.771105;
DEMCH("4")=0.707107;
DEMCH("5")=0.648420;
DEMCH("6")=0.594604;
DEMCH("7")=0.545254;
DEMCH("8")=0.5;
DEMCH(TAFTER)=0.5;
COALDROP(T)= (0.97**ORD(T));
COALPER(T) = (QYE0("GENcoal")/SUM(IE,QYE0(IE)))*((COALDROP(T-
1)+1$TFIRST(T))/QREF(T));
GASPER(T) =
(QYE0("GENgas")/SUM(IE,QYE0(IE)))+(QYE0("GENcoal")/SUM(IE,QYE0(IE))-
COALPER(T));
GASCAPADD(T) = (QKIDY0("Kgas","GENgas")/QYE0("GENgas"))*(QYE0("GENcoal")*(1-
COALDROP(T-1)-1$TFIRST(T)));
GASCAPIN(T) = 10*(GASCAPADD(T)-GASCAPADD(T-1));
WIPER(T) =
(QYE0("GENwind")/SUM(IE,QYE0(IE)))+(QYE0("GENcoal")/SUM(IE,QYE0(IE))-
COALPER(T));
SIME(IE,T) = 1;
PARAMETER  TCOPIT1(H)  CO INCOME TAX RATE,
        TUSPIT1(H)  US INCOME TAX RATE,
```

```
COINREV     COLORADO INCOME TAX REVENUES FROM TAXES ON SAVING;
 TCOPIT1(H)=
SAM("COPIT",H)/(SUM(IP,QADH0(IP,H))+QSAVING0(H)+SUM(GR,(QADH0(GR,H))));
 TUSPIT1(H)=
SAM("USPIT",H)/(SUM(IP,QADH0(IP,H))+QSAVING0(H)+SUM(GR,(QADH0(GR,H))));
QW1(H)                                                                  =
((SUM(HD,QHSDH0(HD,H)))*(1+TKH0(H)))+((SUM(IP,QADH0(IP,H))+SUM(GR,QADH0(
GR,H)))*(1+TUSPIT1(H)+TCOPIT1(H)+THFEE0(H)));
 COINREV = SUM(H,(TCOPIT1(H)*QSAVING0(H)));
PARAMETER GASPER1(T),
    SWITCHH(K,H,T),
    SWITCHF(K,T),
    SWITCHH1(K,H,T),
    SWITCHF1(K,T),
    EARLYRETH(K,H),
    EARLYRETF(K),
    EARLYRETH1(K,H),
    EARLYRETF1(K),
    CAPREQ(K,IEU),
    EFRACN(GR,T),
    EFRACR(GR,T),
    EFRACS(GR,T),
    QYRENEW(GR,T),
```

```
        QYNONRENEW(GR,T),
        QYSOLAR(GR,T),
        COMPPEAK,
        COMPPEAK0(GR),
        GASPRODUCTIVITY,
        EFRACH(GR,T),
        SIMK(IE,T),
        PRODSHOCK(IP,T);
PRODSHOCK(IP,T) = 1;
 SWITCHH(K,H,T) = 0;
 SWITCHF(K,T) = 0;
 EARLYRETH(K,H) = 0;
 EARLYRETF(K) = 0;
 EARLYRETH1(K,H) = QKSH0(K,H)*0.101;
 EARLYRETF1(K) = QKSF0(K)*0.101;
 CAPREQ(K,IEU) = 0;
 SWITCHH1(K,H,T) = QKSH0(K,H)*0.08486253;
QYNONRENEW(GR,T)                                                  =
(ELECIN1("GENgas",GR)+ELECIN1("GENcoal",GR)+ELECIN1("GENpeak",GR));
 QYSOLAR(GR,T) = (ELECIN1("UTILpv",GR)+SUM(IER,QNMDGR0(IER,GR)));
 COMPPEAK = (0.045/(P0("GENpeak")-PELEC1("IOU")));
 COMPPEAK0(GR) = COMPPEAK*ELECIN1("GENwind",GR);
 QYRENEW(GR,T) = (ELECIN1("GENwind",GR)+COMPPEAK0(GR));
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```
 QYNONRENEW(GR,T) =
(ELECIN1("GENgas",GR)+ELECIN1("GENcoal",GR)+ELECIN1("GENpeak",GR)-
COMPPEAK0(GR));
 EFRACN(GR,T) =
(ELECIN1("GENgas",GR)+ELECIN1("GENcoal",GR)+ELECIN1("GENpeak",GR)-
COMPPEAK0(GR))/QGENOUTGR0(GR);
 EFRACR(GR,T) =
(ELECIN1("GENwind",GR)+ELECIN1("UTILpv",GR)+COMPPEAK0(GR)+SUM(IER,QNM
DGR0(IER,GR)))/QGENOUTGR0(GR);
 EFRACH(GR,T) = (ELECIN1("GENhydro",GR))/QGENOUTGR0(GR);
 SIMK(IE,T) = (1-0.04)**(ORD(T)-1);
 GASPRODUCTIVITY = 1;
DISPLAY GASCAPADD, GASCAPIN, EFRACN, EFRACR, EFRACS, qyrenew, qynonrenew,
qysolar, elecin1, elecin0;
PARAMETER DEM(K,IP,T) DEMAND SCALAR FOR COMMERCIAL PROPERTY
USAGE;
 DEM(K,IP,T)$SAM(K,IP) = SAM(K,IP)/SAM(K,IP);
DISPLAY EFRACR, EFRACS, EFRACN, EFRACH, QYE0, PELEC0, COMPPEAK,
COMPPEAK0;
*NEED TO FIX INVESTMENT IN THE CAPITAL PRODUCTION BLOCK AND IN THE
BASELINE
*DEMAND FOR GOODS AND SERVICES FROM INVES
$ONTEXT
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```
$MODEL: COLORADO

$COMMODITIES:

P_L(L,T)            !    WAGE INDEX

P_LA(T)             !    LAND RENT INDEX

P_K(K,T)            !    FINANCIAL CAPITAL RETURN INDEX

P_KFS(T)            !    COAL K FUEL-SWITCHING

P_W(H,T)            !    WELFARE PRICE INDEX

P_LS(L,H,T)$WORK(L,H)       !    LEISURE PRICE INDEX

P_GC(FG,T)          !    GOVERNMENT CONSUMPTION PRICE

P_A(IP,T)           !    ARMINGTON AGGREGATE PRICE

P_AGR(GR,T)         !    ARMINGTON AGGREGATE PRICE FOR ELECTRICITY

P_Y(IP,T)           !    SECTORAL PRODUCTION PRICE

P_H(HD,T)           !    HOUSING PRICE

P_FX(T)             !    PRICE OF FOREIGN EXCHANGE

P_FOR(IP,T)$QMDA0(IP)       !    PRICE OF IMPORTS

P_E(GR,T)           !    BULK ELECTRICITY PRICE

P_GE(IE,T)          !    ELECTRICITY PRODUCER PRICE

P_GRID(GR,T)        !    ELECTRICITY CONSUMER PRICE

P_RENEW(GR,T)

P_NONRENEW(GR,T)

P_SOLAR(GR,T)

P_CARVE(GR,T)

P_HYDRO(GR,T)
```

$SECTORS:

A_GOVT(FG,T) ! GOVERNMENT EXPENDITURE

A_YARM(IP,T) ! PRODUCTION OF ARMINGTON AGGREGATES

A_GRARM(GR,T) ! PRODUCTION OF ARMINGTON AGGREGATES FOR ELECTRICITY

A_LS(H,T) ! LABOR SUPPLY

A_W(H,T) ! WELFARE INDEX

A_Y(IP,T) ! SECTORAL PRODUCTION

A_H(HD,T) ! HOUSING SERVICES

A_ELEC(GR,T) ! WHOLESALE ELECTRICITY BUNDLING

A_GEN(IEU,T) ! UTILITY ELECTRICITY GENERATION

A_DGEN(IER,T) ! RETAIL ELECTRICITY GENERATION

A_GENHYBRID(T) ! ELECTRICITY GENERATION - FUEL-SWITCHING

A_GRID(GR,T) ! ELECTRICITY TRANSMISSION UTILITIES

A_FUELSWITCH(T) ! FUEL-SWITCHING PLANTS TO GAS

A_ELECN(GR,T)

A_ELECR(GR,T)

A_ELECS(GR,T)

A_ELECC(GR,T)

A_ELECH(GR,T

$CONSUMERS:

I_GOVT0(T) ! FEDERAL GOVERNMENT TAX OUTFLOWS

I_GOVT1(T) ! STATE PERSONAL INCOME TAX

```
I_GOVT2(T)          !    STATE FEES FOR GOVERNMENT SERVICES
I_GOVT3(T)          !    STATE CORPORATE INCOME TAX
I_GOVT4(T)          !    STATE SALES TAX
LOC_GOVT1(T)        !    COMMERCIAL PROPERTY TAXES
LOC_GOVT2(T)        !    RESIDENTIAL PROPERTY TAXES
LOC_GOVT3(T)        !    LOCAL SALES TAXES
F_GOVT1(T)          !    FEDERAL GOVERNMENT EXPENDITURES
F_GOVT2(T)
RA(H,T)             !    HOUSEHOLD INCOME
RAF(T)              !    OUT-OF-STATE HOLDERS OF LAND AND CAPITAL
IMPACT(T)
IMPACT_2(T)
EXPORTS(IP,T)       !    OUT-OF-STATE DEMAND
IMPORTS(IP,T)$QMDA0(IP)
$AUXILIARY:
LAS(T)              !    ENDOGENOUS SUPPLY OF DEVELOPABLE LAND
MIG(H,T)            !    ENDOGENOUS HOUSEHOLD MIGRATION
LSUP(H,T)           !    ENDOGENOUS LABOR SUPPLY
INVEST(K,T)         !    ENDOGENOUS INVESTMENT
OWN(K,T)            !    DESIRE TO OWN CAPITAL
EXPDEM(IP,T)        !    EXPORT DEMAND
EXPDEMGR(GR,T)      !    GRID EXPORT DEMAND
SAVING(H,T)         !    ENDOGENOUS SAVING
```

COSAVINGSTAX(T) ! STATE TAXES ON SAVING

IMPSUP(IP,T)$QMDA0(IP)

$PROD:A_LS(H,T) s:100

*Labor Supply

O: P_L(L,T) Q: QLABSUP0(L,H) p: (1-TLS1(L)) A: F_GOVT2(T) T: TLS1(L)

I: P_LS(L,H,T)$WORK(L,H) Q: WORK1(L,H)

$PROD:A_W(H,T) s:0.1 none:1

* Welfare produced using goods and services

O: P_W(H,T) Q: QW1(H)

* Income taxes proportional to factor use to generate HH specific welfare indices

I: P_A(NONEL,T) Q: QADH0(NONEL,H) P: (1+TCOPIT1(H)+TUSPIT1(H)+THFEE0(H)) A: I_GOVT1(T) T: TCOPIT1(H) A: F_GOVT1(T) T: TUSPIT1(H) A: I_GOVT2(T) T: THFEE0(H) none:

I: P_AGR(GR,T) Q: (QADH0(GR,H)) P: (PGRID(GR)*(1+TCOPIT1(H)+TUSPIT1(H)+THFEE0(H))) A: I_GOVT1(T) T: TCOPIT1(H) A: F_GOVT1(T) T: TUSPIT1(H) A: I_GOVT2(T) T: THFEE0(H)

I: P_H(HD,T) Q: QHSDH0(HD,H) P: (1+TKH0(H)) A: LOC_GOVT2(T) T: TKH0(H) none:

I: P_GE(IER,T) Q: QNMDH0(IER,H) P: P0(IER)

$PROD:A_GOVT(FG,T) s:1 int:0

*Production of government services

O: P_GC(FG,T) Q: QGC0(FG)

I: P_L(L,T) Q: QLDG0(L,FG) P: (1+TLDG0(L,FG)) A: F_GOVT2(T) T: TLDG0(L,FG)

I: P_A(JP,T)   Q: QADG0(JP,FG)   int:

I: P_AGR(GR,T)   Q: QADGGR0(GR,FG) P: PGRID(GR)

$PROD:A_Y(IP,T)   s:1 kl: 0.4 int:0

*Domestic production of goods and services

*kl nest to reflect Raval (2011) complementarity between capital and labor

O: P_Y(IP,T)   Q: (PRODSHOCK(IP,T)*QY0(IP))   P: (1-TCORP0(IP)-TCFEE0(IP)) A: I_GOVT3(T) T: TCORP0(IP) A: I_GOVT2(T) T: TCFEE0(IP)

I: P_L(L,T)   Q: QLDY0(L,IP) P: (1+TLDI0(L,IP)) A: F_GOVT2(T) T: TLDI0(L,IP) kl:

I: P_LA(T)   Q: QLADY0(IP)   P: (1+TKI0(IP)) A: LOC_GOVT1(T) T: TKI0(IP)

I: P_K(K,T)   Q: (DEM(K,IP,T)*QKIDY0(K,IP)) P:(1+TKI0(IP))   A: LOC_GOVT1(T) T: TKI0(IP)

I: P_A(JP,T)   Q: QADY0(JP,IP) int:

I: P_AGR(GR,T)   Q: (QADGR0(GR,IP)/PGRID(GR)) P: PGRID(GR)

I: P_GE(IER,T)   Q: QNMDY0(IER,IP) P:P0(IER)

$PROD:A_GRID(GR,T) S:1 KL: 0.4 INT:0

* DOMESTIC TRANSMISSION OF ELECTRICITY BY UTILITY TYPE - REPLACES "GRID" AS AN ELEMENT OF SET "IP" *

O: P_GRID(GR,T)   Q: (QY0(GR)/PGRID(GR))   P: (PGRID(GR)*(1-TCORP0(GR)-TCFEE0(GR))) A: I_GOVT3(T) T: TCORP0(GR) A: I_GOVT2(T) T: TCFEE0(GR)

I: P_L(L,T)   Q: QLDY0(L,GR)   P: (1+TLDI0(L,GR)) A: F_GOVT2(T) T: TLDI0(L,GR) kl:

I: P_LA(T)   Q: QLADY0(GR)   P: (1+TKI0(GR)) A: LOC_GOVT1(T) T: TKI0(GR)

I: P_K(K,T)   Q: QKIDY0(K,GR)   P:(1+TKI0(GR))   A: LOC_GOVT1(T) T: TKI0(GR)

I: P_A(JP,T) Q: QADY0(JP,GR)

I: P_E(GR,T) Q: QGENOUTGR0(GR) P: PELEC0(GR) int:

$PROD:A_GEN(IEU,T) s:1

O: P_GE(IEU,T) Q: QYE0(IEU) P: (P0(IEU)*(1-TCORP0(IEU))*(1-TCFEE0(IEU))*(1-subrate(ieU))) A: F_GOVT1(T) T: subrate(ieU) A: I_GOVT3(T) T: (TCORP0(IEU)*(1-subrate(ieU))) A: I_GOVT2(T) T: (TCFEE0(IEU)*(1-subrate(ieU))*(1+tcorp0(ieU)))

I: P_L(L,T) Q: QLDY0(L,IEU) P: (1+TLDI0(L,IEU)) A: F_GOVT2(T) T: TLDI0(L,IEU)

I: P_LA(T) Q: QLADY0(IEU)

I: P_K(K,T) Q: (CAPREQ(K,IEU)+QKIDY0(K,IEU)) P: (1+TKI0(IEU)) A: LOC_GOVT1(T) T: TKI0(IEU)

I: P_A(JP,T) Q: QADY0(JP,IEU)

I: P_AGR(GR,T) Q: QADGR0(GR,IEU) P: PGRID(GR)

I: P_FX(T) Q: QMDE0(IEU)

$PROD:A_GENHYBRID(T) S:1

O: P_GE("GENcoal",T) Q: QYE0("GENcoal") P: (P0("GENcoal")*(1-TCORP0("GENcoal"))*(1-TCFEE0("GENcoal"))) A: I_GOVT3(T) T: (TCORP0("GENcoal")) A: I_GOVT2(T) T: (TCFEE0("GENcoal")*(1+tcorp0("GENcoal")))

I: P_L(L,T) Q: QLDY0(L,"GENcoal") P: (1+TLDI0(L,"GENcoal")) A: F_GOVT2(T) T: TLDI0(L,"GENcoal")

I: P_LA(T) Q: QLADY0("GENcoal")

I: P_KFS(T) Q: QKIDY0("Kcoal","GENcoal") P: (1+TKI0("GENcoal")) A: LOC_GOVT1(T) T: TKI0("GENcoal")

I: P_A(JP,T) Q: (6.2*QADY0(JP,"GENgas"))

I: P_AGR(GR,T) Q: (QADGR0(GR,"GENcoal")*GRIDPERY("GENcoal",GR)) P: PGRID(GR)

I: P_FX(T) Q: (6.2*QMDE0("GENgas"))

$PROD:A_DGEN(IER,T) S:1

O: P_GE(IER,T) Q: QYE0(IER) P: (P0(IER)*(1-TCORP0(IER))*(1-TCFEE0(IER))*(1-subrate(ieR))) A: F_GOVT1(T) T: subrate(ieR) A: I_GOVT3(T) T: (TCORP0(IER)*(1-subrate(ieR))) A: I_GOVT2(T) T: (TCFEE0(IER)*(1-subrate(ieR))*(1+tcorp0(ieR)))

I: P_L(L,T) Q: QLDY0(L,IER) P: (1+TLDI0(L,IER)) A: F_GOVT2(T) T: TLDI0(L,IER)

I: P_LA(T) Q: QLADY0(IER)

I: P_K(K,T) Q: QKIDY0(K,IER) P: (1+TKI0(IER)) A: LOC_GOVT1(T) T: TKI0(IER)

I: P_A(JP,T) Q: QADY0(JP,IER)

I: P_AGR(GR,T) Q: QADGR0(GR,IER) P: PGRID(GR)

I: P_FX(T) Q: QMDE0(IER)

$PROD:A_FUELSWITCH(T) S:1

O: P_KFS(T) Q: 1

I: P_K("Kcoal",T) Q: 1

$PROD:A_ELEC(GR,T) s:0

* INTERMEDIATE ELECTRICITY AGGREGATION, INTO BUNDLES FOR EACH UTILITY TYPE *

O: P_E(GR,T) Q: 1

I: P_CARVE(GR,T) Q: EFRACR(GR,T)

I: P_NONRENEW(GR,T) Q: EFRACN(GR,T)

I: P_HYDRO(GR,T) Q: EFRACH(GR,T)

$PROD:A_ELECR(GR,T) S:0

O: P_RENEW(GR,T) Q: QYRENEW(GR,T)

I: P_GE("GENwind",T) Q: (ELECIN1("GENwind",GR)*SIME("GENwind",T)) P:P0("GENwind")

I: P_GE("GENpeak",T) Q: (COMPPEAK0(GR)*SIME("GENwind",T)) P:P0("GENpeak")

$PROD:A_ELECH(GR,T)

O: P_HYDRO(GR,T) Q: ELECIN1("GENhydro",GR)

I: P_GE("GENhydro",T) Q: (ELECIN1("GENhydro",GR)*SIME("GENhydro",T)) P:P0("GENhydro")

$PROD:A_ELECS(GR,T) S:0 RET:1

O: P_SOLAR(GR,T) Q: QYSOLAR(GR,T)

I: P_GE("UTILpv",T) Q: (ELECIN1("UTILpv",GR)*SIME("UTILpv",T)) P:P0("UTILpv")

I: P_GE(IER,T) Q: (QNMDGR0(IER,GR)*SIME(IER,T)) P: P0(IER) RET:

$PROD:A_ELECN(GR,T) S:1 B:10

O: P_NONRENEW(GR,T) Q: QYNONRENEW(GR,T)

I: P_GE("GENcoal",T) Q: (ELECIN1("GENcoal",GR)*SIME("GENcoal",T)*SIMK("GENcoal",T)) P:P0("GENcoal")

I: P_GE("GENgas",T) Q: ((ELECIN1("GENgas",GR)*SIME("GENgas",T))+((1-SIMK("GENcoal",T))*ELECIN1("GENcoal",GR))) P:P0("GENgas")

I: P_GE("GENpeak",T) Q: ((ELECIN1("GENpeak",GR)-COMPPEAK0(GR))*SIME("GENpeak",T)) P:P0("GENpeak")

$PROD:A_ELECC(GR,T) S:0

O: P_CARVE(GR,T) Q: EFRACR(GR,T)

I: P_RENEW(GR,T) Q: (EFRACR(GR,T)-EFRACS(GR,T))

I: P_SOLAR(GR,T) Q: EFRACS(GR,T)

$PROD:A_H(HD,T) s:1 int:0

*Domestic production of housing services

O: P_H(HD,T) Q: QHS0(HD)

I: P_LA(T) Q: QLADHS0(HD)

I: P_K(K,T) Q: QKHDHS0(K,HD)

I: P_A(JP,T) Q: QADHS0(JP,HD) int:

$PROD:A_YARM(IP,T) s:1

*Production of Armington aggregates using imports

O: P_A(IP,T) Q: QA0(IP) P: (1-TSV0(IP)-TLV0(IP)) A: I_GOVT4(T) T: TSV0(IP) A: LOC_GOVT3(T) T: TLV0(IP)

I: P_Y(IP,T) Q: (QY0(IP)-QE0(IP))

I: P_FOR(IP,T) Q: QMDA0(IP)

$PROD:A_GRARM(GR,T) S:1

O: P_AGR(GR,T) Q: (QAGR0(GR)) P: (PGRID(GR)*(1-TSVGR0(GR)-TLVGR0(GR))) A: I_GOVT4(T) T: TSVGR0(GR) A: LOC_GOVT3(T) T: TLVGR0(GR)

$DEMAND:IMPORTS(IP,T)$QMDA0(IP)

D: P_FX(T) Q: 1

E: P_FOR(IP,T)$QMDA0(IP) Q: (QMDA0(ip)*QREF(T)) R: IMPSUP(IP,T)

IMPSUPGR(GR,T) P: PGRID(GR)

$DEMAND:EXPORTS(IP,T)

*Export demand as independent block - no substitution between exports BUT each is given a -1.0 price elasticity via EXPDEM

D: P_Y(IP,T) Q: QE0(IP)

E: P_FX(T) Q: (QE0(IP)*QREF(T)) R: EXPDEM(IP,T)

$DEMAND:RA(H,T)

* Utility Maximization (demand for "welfare")

D: P_W(H,T) Q: (QW1(H)*QREF(T))

* Land Endowment

E: P_LA(T) Q: (QLASH0(H)*QREF(T)) R: LAS(T)

* Time Endowment (used to generate Labor and Leisure) - local

E: P_LS(L,H,T)$WORK(L,H) Q: (WORK1(L,H)*QREF(T)) R: LSUP(H,T)

* Additions to labor supply due to in-migration

E: P_LS(L,H,T)$WORK(L,H) Q: (WORK1(L,H)*QREF(T)) R: MIG(H,T)

* Remittances

E: P_FX(T) Q: (QREMSH0(H)*QREF(T))

* Savings

E: P_FX(T) Q: (-QSAVING0(H)*QREF(T)) R: SAVING(H,T)

* US Income Taxes on Savings

E: P_FX(T) Q: (-QSAVING0(H)*QREF(T)*TUSPIT1(H)) R: SAVING(H,T)

* CO Income Taxes on Savings

E: P_FX(T) Q: (-QSAVING0(H)*QREF(T)*TCOPIT1(H)) R: SAVING(H,T)

* Social Security Payments

E: P_FX(T) Q: (QSOCSH0(H)*QREF(T))

* Per Period Capital Endowment

E: P_K(K,T) Q: (QKSH0(K,H)-SWITCHH(K,H,T)-EARLYRETH(K,H)) R: OWN(K,T)

E: P_KFS(T) Q: SWITCHH("Kcoal",H,T)

* SAM Income Balancing Transfers

E: P_FX(T) Q: (SUM(K,QKSH0(K,H))*QREF(T))

*E: P_K(K,T) Q: SHOCK3(K)

* state income taxes on savings and investment

* federal income taxes on savings and investment

* Construction/Investment Spending

E: P_A(IP,T) Q: (-KPROP(H)*INVD0(IP)*KAPPER("KAP")) R: INVEST("KAP",T)

E: P_A(IP,T) Q: (-KPROP(H)*INVD0(IP)*KAPPER("Kcoal")) R: INVEST("Kcoal",T)

E: P_A(IP,T) Q: (-KPROP(H)*INVD0(IP)*KAPPER("Kgas")) R: INVEST("Kgas",T)

E: P_A(IP,T) Q: (-KPROP(H)*INVD0(IP)*KAPPER("Kwind")) R: INVEST("Kwind",T)

E: P_A(IP,T) Q: (-KPROP(H)*INVD0(IP)*KAPPER("Kpv")) R: INVEST("Kpv",T)

E: P_A(IP,T) Q: (-KPROP(H)*INVD0(IP)*KAPPER("Khydro")) R: INVEST("Khydro",T)

E: P_AGR(GR,T) Q: (-KPROP(H)*INVD0(GR)*KAPPER("KAP")) R: INVEST("KAP",T)

E: P_AGR(GR,T) Q: (-KPROP(H)*INVD0(GR)*KAPPER("Kcoal")) R: INVEST("Kcoal",T)

E: P_AGR(GR,T) Q: (-KPROP(H)*INVD0(GR)*KAPPER("Kgas")) R: INVEST("Kgas",T)

E: P_AGR(GR,T) Q: (-KPROP(H)*INVD0(GR)*KAPPER("Kwind")) R: INVEST("Kwind",T)

E: P_AGR(GR,T) Q: (-KPROP(H)*INVD0(GR)*KAPPER("Kpv")) R: INVEST("Kpv",T)

E: P_AGR(GR,T) Q: (-KPROP(H)*INVD0(GR)*KAPPER("Khydro")) R: INVEST("Khydro",T)

$DEMAND:RAF(T)

* Demand for "foreign exchange"

D: P_FX(T) Q: (KLAOUT0*QREF(T))

* Out-of-state ownership of capital

E: P_K(K,T) Q: (QKSF0(K)-SWITCHF(K,T)-EARLYRETF(K)) R: OWN(K,T)

E: P_KFS(T) Q: SWITCHF("Kcoal",T)

* Exogenous capital supplies

* Out-of-state ownership of land

E: P_LA(T) Q: (QLASF0*QREF(T)) R: LAS(T)

E: P_K("Kgas",T) Q: IMT("Kgas")

* Construction/Investment Spending

E: P_A(IP,T) Q: (-KPROPF*INVD0(IP)*KAPPER("KAP")) R: INVEST("KAP",T)

E: P_A(IP,T) Q: (-KPROPF*INVD0(IP)*KAPPER("Kcoal")) R: INVEST("Kcoal",T)

E: P_A(IP,T) Q: (-KPROPF*INVD0(IP)*KAPPER("Kgas")) R: INVEST("Kgas",T)

E: P_A(IP,T) Q: (-KPROPF*INVD0(IP)*KAPPER("Kwind")) R: INVEST("Kwind",T)

E: P_A(IP,T) Q: (-KPROPF*INVD0(IP)*KAPPER("Kpv")) R: INVEST("Kpv",T)

E: P_A(IP,T) Q: (-KPROPF*INVD0(IP)*KAPPER("Khydro")) R: INVEST("Khydro",T)

E: P_AGR(GR,T) Q: (-KPROPF*INVD0(GR)*KAPPER("KAP")) R: INVEST("KAP",T)

E: P_AGR(GR,T) Q: (-KPROPF*INVD0(GR)*KAPPER("Kcoal")) R: INVEST("Kcoal",T)

E: P_AGR(GR,T) Q: (-KPROPF*INVD0(GR)*KAPPER("Kgas")) R: INVEST("Kgas",T)

E: P_AGR(GR,T) Q: (-KPROPF*INVD0(GR)*KAPPER("Kwind")) R: INVEST("Kwind",T)

E: P_AGR(GR,T) Q: (-KPROPF*INVD0(GR)*KAPPER("Kpv")) R: INVEST("Kpv",T)

E: P_AGR(GR,T) Q: (-KPROPF*INVD0(GR)*KAPPER("Khydro")) R: INVEST("Khydro",T)

E: P_FX(T) Q: 10000

$DEMAND:IMPACT_2(T)

D: P_FX(T) Q: 1

E: P_K(K,T) Q: SHOCK3(K)

$DEMAND:IMPACT(T)

D: P_Y("Const",T) Q: 1

E: P_FX(T) Q: SHOCK(T)

$DEMAND:I_GOVT0(T)

D: P_GC("FED",T) Q: (FEDPROD0*QREF(T))

E: P_FX(T) Q: (FEDPROD0*QREF(T))

$DEMAND:I_GOVT1(T)

*COLORADO PERSONAL INCOME TAX

D: P_GC(FSL,T)   Q: (SPEND(FSL)*QREF(T))

E: P_FX(T)   Q: (COINREV*QREF(T))   R: COSAVINGSTAX(T)

$DEMAND:I_GOVT2(T)

*COLORADO GOVERNMENT FEES-FOR-SERVICE

D: P_GC(FSL,T)   Q: (SPEND(FSL)*QREF(T))

$DEMAND:I_GOVT3(T)

*COLORADO CORPORATE INCOME TAX

D: P_GC(FSL,T)   Q: (SPEND(FSL)*QREF(T))

$DEMAND:I_GOVT4(T)

*COLORADO SALES TAX

D: P_GC(FSL,T)   Q: (SPEND(FSL)*QREF(T))

$DEMAND:LOC_GOVT1(T)

*BUSINESS PROPERTY TAX

D: P_GC(FSL,T)   Q: (SPEND(FSL)*QREF(T))

$DEMAND:LOC_GOVT2(T)

*RESIDENTIAL PROPERTY TAX

D: P_GC(FSL,T)   Q: (SPEND(FSL)*QREF(T))

$DEMAND:LOC_GOVT3(T)

*LOCAL SALES TAX

D: P_GC(FSL,T)   Q: (SPEND(FSL)*QREF(T))

$DEMAND:F_GOVT1(T)

D: P_FX(T)   Q: (1*QREF(T))

$DEMAND:F_GOVT2(T)

```
D: P_FX(T)          Q: (1*QREF(T))
$REPORT:
  V: EMP(L,T,H)    O: P_L(L,T)  PROD:A_LS(H,T)
  V: EMPYIN(L,IP,T)   I: P_L(L,T)  PROD:A_Y(IP,T)
  V: EMPGIN(L,FG,T)   I: P_L(L,T)  PROD:A_GOVT(FG,T)
  V: OUTP(IP,T)    O: P_Y(IP,T)  PROD:A_Y(IP,T)
  V: HOUTP(HD,T)   O: P_Y(HD,T)  PROD:A_Y(HD,T)
  V: GOUTP(FG,T)   O: P_GC(FG,T)  PROD:A_GOVT(FG,T)
  V: GINGR(FG,T)   I: P_AGR("IOU",T) PROD: A_GOVT(FG,T)
  V: GROUTP(GR,T)  O: P_GRID(GR,T) PROD: A_GRID(GR,T)
$CONSTRAINT:LAS(T)
        LAS(T) =E= ((LAS(T-1)+1$TFIRST(T))+(((P_LA(T))-P_LA(T-1)-1$TFIRST(T))*2.5));
$CONSTRAINT:LSUP(H,T)
 (LSUP(H,T)-1) =E= (0.3*((SUM(L,(P_L(L,T)*WORKPROP(L,H)))/P_W(H,T))-1));
$CONSTRAINT:MIG(H,T)
 (MIG(H,T))   =E=   (MIG(H,T-1))+(0.1*((SUM(L,(P_L(L,T)*WORKPROP(L,H)))/P_W(H,T))-
1));
$CONSTRAINT:OWN(K,T)
          OWN(K,T)                =E=                ((1-DEPRECIATE(K))*(OWN(K,T-
1)+1$TFIRST(T)))+((0.7*(INVEST(K,T)/(1+QREF(T)-QREF(T-1)-
1$TFIRST(T)))+0.3*INVEST(K,T-1))/10);
$CONSTRAINT:INVEST(K,T)
         INVEST(K,T) =E= QREF(T)*(1+((P_K(K,T)-1)*IELAS(K)));
```

```
$CONSTRAINT:EXPDEM(IP,T)

        EXPDEM(IP,T) =E= (1/P_Y(IP,T));

$CONSTRAINT:EXPDEMGR(GR,T)

        EXPDEMGR(GR,T) =E= (PGRID(GR)/P_GRID(GR,T));

$CONSTRAINT:IMPSUP(IP,T)$QMDA0(IP)

        IMPSUP(IP,T)$QMDA0(IP)                                     =E=

PRODSHOCK(IP,T)*(1+(10*((P_FOR(IP,T)$QMDA0(IP)/P_Y(IP,T))-1)));

$CONSTRAINT:SAVING(H,T)

        SAVING(H,T) =E= P_W(H,T)*(A_W(H,T)/qref(t));

$CONSTRAINT:COSAVINGSTAX(T)

        COSAVINGSTAX(T)                                            =E=

SUM(H,(QSAVING0(H)*SAVING(H,T)))/SUM(H,QSAVING0(H));

$OFFTEXT

$SYSINCLUDE mpsgeset COLORADO

P_FX.FX(T)=1;

P_K.L(K,T)=1;

P_K.LO(K,T)=eps;

LSUP.L(H,T)=1;

MIG.L(H,T)=0;

MIG.LO(H,T)=-100;

INVEST.L(K,T)=QREF(T);

INVEST.LO(K,T)=0;

LAS.L(T)=1;
```

```
LAS.LO(T)=0;
P_L.L(L,T)=1;
P_LA.L(T)=1;
P_W.L(H,T)=1;
P_Y.L(IP,T)=1;
P_A.L(IP,T)=1;
A_W.L(H,T)=1;
A_Y.L(IP,T)=1;
A_ELEC.L(GR,T) = QGENOUT0*UTTYPE(GR);
A_ELECC.L(GR,T) = QGENOUT0*UTTYPE(GR);
OWN.L(K,T)=QREF(T);
P_GRID.L(GR,T) = PGRID(GR);
P_E.L(GR,T) = PELEC0(GR);
INVEST.FX("Kcoal",T)=0.6;
*                                                    P0("GENwind")=        ((0.866/(1-
subrate("GENwind")))*((QYE1("GENwind")+SUM(K,QKIDY2(K,"GENwind")))/QYE1("GEN
wind")));
*       QKIDY0("Kgas","GENwind")=QKIDY2("Kgas","GENwind");
*       IMT("Kgas")= HIGHINTER;
SET RUN(SM) /BASE, TODAY, SIMM1/;
PARAMETER SUMMARY(*,SM)   SOLUTION SUMMARY;
TABLE TAXCHANGE(SM,*) INDICATORS FOR TAX RATE SIMULATIONS
          S
```

```
BASE        0
TODAY       0
SIMM1       1;
IF (RUN("BASE"), COLORADO.ITERLIM=0;);
FILE RESULTS /C:\Users\Chris\Documents\Disser\Disser\cofix.txt/;
LOOP(SM$RUN(SM),
IF (TAXCHANGE(SM,"S"),
PRODSHOCK("NATGAS",T) = 0.5;
*** INVESTOR-OWNED UTILITIES RENEWABLE PORTFOLIO STANDARD ***
ELSE
    );
$INCLUDE COLORADO.GEN
COLORADO.OPTFILE = 0;
OPTION SYSOUT=ON;
SOLVE COLORADO USING MCP;
    COLORADO.ITERLIM = 5000;
    COLORADO.WORKFACTOR=3.0;
    SUMMARY("STATUS",SM) = COLORADO.MODELSTAT;
    SUMMARY("ITERS",SM) = COLORADO.ITERUSD;
    SUMMARY("CPU",SM) = COLORADO.RESUSD;
    SUMMARY("CONTROL",SM) = COLORADO.OBJVAL;
    summary("p_el_1",sm) = P_GRID.L("IOU","1");
    summary("p_el_2",sm) = P_GRID.L("IOU","2");
```

```
    summary("p_el_3",sm) = P_GRID.L("IOU","3");
    summary("p_el_4",sm) = P_GRID.L("IOU","4");
    summary("p_el_5",sm) = P_GRID.L("IOU","5");
    summary("p_el_6",sm) = P_GRID.L("IOU","6");
    summary("p_el_7",sm) = P_GRID.L("IOU","7");
    summary("p_el_8",sm) = P_GRID.L("IOU","8");
    summary("p_el_9",sm) = P_GRID.L("IOU","9");
    summary("p_el_10",sm) = P_GRID.L("IOU","10");
    summary("p_el_11",sm) = P_GRID.L("IOU","11");
    summary("p_el_12",sm) = P_GRID.L("IOU","12");
    summary("p_el_13",sm) = P_GRID.L("IOU","13");
    summary("p_el_14",sm) = P_GRID.L("IOU","14");
    summary("p_el_15",sm) = P_GRID.L("IOU","15");
    summary("p_el_16",sm) = P_GRID.L("IOU","16");
    summary("p_el_17",sm) = P_GRID.L("IOU","17");
    summary("p_el_18",sm) = P_GRID.L("IOU","18");
    summary("p_el_19",sm) = P_GRID.L("IOU","19");
    summary("p_el_20",sm) = P_GRID.L("IOU","20");
PUT RESULTS;
    );
DISPLAY SUMMARY;
SET SUMMARY1  /STATUS, ITERS, CPU, CONTROL, DWH1, DWH2, DWH3,
DWH4, DWH5, DWH6, DWH7, EMP1, EMP2, EMP3, EMP4, EMP5, COPIT, COFEE,
```

```
COCORP, COSALES, COTOT, LOCBP, LOCRP, LOCSALES, LOCTOT, SNLTOT, FREE1,
FREE2, FREE3, FREE4, FREE5, INVST, W1, W2, W3, W4, W5, DOMOUT,
HOUSE1, HOUSE2, HOUSE3, HOUSE4, HOUSE5, HOUSE6, HOUSE7, CONS1, CONS2,
CONS3,
CONS4, CONS5, CONS6, CONS7/
PUT 'COLORADO      ';
 LOOP(SM, PUT '     ',SM.TL);
 PUT /;
LOOP(SUMMARY1, PUT '          ';
     PUT SUMMARY1.TL,
     LOOP(SM, PUT SUMMARY(SUMMARY1,SM) );
     PUT / );
```

Appendix D

CO-D Model in GAMS MPSGE

```
$TITLE COLORADO
*-----------------------------------------------------------------------------------
* 1.1 CONTROLS PLACED ON OUTPUT GENERATION
*-------------------------------------------------------------------------------------------------------------
$OFFSYMLIST OFFSYMXREF
*OPTIONS SYSOUT=OFF, SOLPRINT=OFF, LIMROW=0, LIMCOL=0;
*-------------------------------------------------------------------------------------------------------------
* 2. SET DEFINITION
*-------------------------------------------------------------------------------------------------------------
* 2.1 EXPLICIT SET DECLARATION
*-------------------------------------------------------------------------------------------------------------
SETS  Z  ALL ACCOUNTS IN SOCIAL ACCOUNTING MATRIX /
 Agric
 Mining
 Utilities
 Const
Manuf
 WHTR
 Retail
```

TransWare

Info

FinIns

RealEst

HGSER

Manage

Admin

Educ

StateUG

StateG

PrivateUG

PrivateG

HealthCare

Arts

LodgeRest

OtherServ

HS1

HS2

HS3

HS4

HS5

HS6

EMPHI

OLHI

POHI

L1

L2

L3

HK1

HK2

HK3

KAP

HH1

HH2

HH3

HH4

HH5

HH6

HH7

HH8

HH9

HH10

HH11

HH12

HH13

INVES

PENFUND

HINS

MEDICARE

MEDICAID

USSOC

USPIT

COPIT

CORPTAX

CNPRP

FEES

COSTX

LOCSTX

CYGF

SUBS

FED

STED

STHEALTH

STJUST

STADM

CDOT

ROW /

F(Z) FACTORS / L1,L2,L3,HK1,HK2,HK3,KAP/

L(F) LABOR /L1,L2,L3,HK1,HK2,HK3/

K(F) CAPITAL /KAP/

RP(K) REAL PROPERTY /KAP/

PPORH(K) PERSONAL PROPERTY AND HOUSING /KAP/

G(Z) GOVERNMENTS / USSOC, USPIT, COPIT, CORPTAX,CNPRP,FEES,

COSTX,LOCSTX,

CYGF,SUBS,FED,STED,STHEALTH,STJUST,STADM,CDOT/

GN(G) GOVERNMENT SERVICES / FED,STED,STHEALTH,STJUST,STADM,CDOT /

GNL(G) lOCAL ENDOGENOUS GOVERNMENTS / STED,STHEALTH,STJUST,STADM,CDOT/

GX(G) EXOGENOUS GOVERMENTS / USSOC,USPIT, COPIT, CORPTAX,CNPRP,FEES,COSTX,LOCSTX/

GS(G) SALES OR EXCISE TAXES / FEES,COSTX,LOCSTX,corptax /

GF(G) FACTOR TAXES / USSOC, CNPRP/

GI(G) INCOME TAX UNITS / USPIT,copit /

GH(G) HOUSEHOLD TAX UNITS / CNPRP,fees /

GY(G) EXOGNOUS TRANSFER PMT / USSOC, USPIT, COPIT, CORPTAX,CNPRP,FEES,COSTX,LOCSTX, FED/

GTA(G) EXOGNOUS TRANSFER PMT / USSOC, USPIT, COPIT, CORPTAX,CNPRP,FEES,COSTX,LOCSTX, CYGF,FED/

GT(G) ENDOGENOUS TRANSFER PMT / CYGF, FED /

H(Z) HOUSEHOLDS / HH1, HH2, HH3, HH4, HH5, HH6,HH7, HH8,HH9,HH10,HH11,HH12,HH13 /

GQ(H) GROUP QUARTERS /HH13/

NONGQ(H) NON GROUP QUARTERS /HH1, HH2, HH3, HH4, HH5, HH6,HH7, HH8,HH9,HH10,HH11,HH12/

WORK(L,H) WORKERS /L1.(HH1, HH2, HH3, HH4, HH5, HH6,HH7, HH8,HH9,HH10,HH11,HH12,HH13)

L2.(HH1, HH2, HH3, HH4, HH5, HH6,HH7, HH8,HH9,HH10,HH11,HH12,HH13)

L3.(HH1, HH2, HH3, HH4, HH5, HH6,HH7, HH8,HH9,HH10,HH11,HH12,HH13)

HK1.(HH1, HH2, HH3, HH4, HH5, HH6,HH7, HH8,HH9,HH10,HH11,HH12)

HK2.(HH1, HH2, HH3, HH4, HH5, HH6,HH7, HH8,HH9,HH10,HH11,HH12)

HK3.(HH3, HH4, HH5, HH6,HH7, HH8,HH9,HH10,HH11,HH12)/

IG(Z) I+G SECTORS / Agric,Mining, Utilities, Const,Manuf, WHTR, Retail,TransWare, Info,FinIns,RealEst,HGSER,Manage,

Admin,Educ,StateUG,StateG,PrivateUG,PrivateG,HealthCare, Arts,LodgeRest,OtherServ,HS1,HS2,HS3,HS4,HS5,HS6,

FED,STED,STHEALTH,STJUST,STADM,CDOT/

I(IG) INDUSTRY SECTORS / Agric, Mining,

Utilities, Const,Manuf, WHTR, Retail,TransWare, Info,FinIns,RealEst,HGSER,Manage,

Admin,Educ,StateUG,StateG,PrivateG,PrivateUG,HealthCare, Arts,LodgeRest,OtherServ,HS1,HS2,HS3,HS4,HS5,HS6/

IG2(IG) ENDOGENOUS GOVERNMENTS / FED,STED,STHEALTH,STJUST,STADM,CDOT /

IP(I) PRODUCTION SECTORS /Agric, Mining, Utilities, Const,Manuf, WHTR, Retail,TransWare,

Info,FinIns,RealEst,HGSER,Manage,Admin,Educ,StateUG,StateG,PrivateUG,PrivateG,HealthCare, Arts,LodgeRest,OtherServ/

NED(IP) Non-University Sectors /Agric, Mining, Utilities, Const,Manuf, WHTR, Retail,TransWare,

Info,FinIns,RealEst,HGSER,Manage,Admin,Educ,HealthCare,

Arts,LodgeRest,OtherServ/

HED(IP) University Sectors /StateUG,StateG,PrivateUG,PrivateG/

OFFUSE(IP) OFFICE-USING SECTORS /FinIns,Retail,HGSER,Manage,Admin/

PRIVS(IP) PRIVATE CAPITAL-USING SECTORS /Agric, Mining, Utilities, Const,Manuf, WHTR,Retail,TransWare,

Info,FinIns,RealEst,HGSER,Manage,Admin,Educ,StateUG,StateG,PrivateUG,PrivateG,HealthCare, Arts,LodgeRest,OtherServ/

FG(IG) PRODUCTION GOV. /FED,STED,STHEALTH,STJUST,STADM,CDOT/

FSL(FG) STATE AND LOCAL GOV. /STED,STHEALTH,STJUST,STADM,CDOT/

FEDR(FG) FEDERAL GOV. /FED/

HD(I) HOUSING SERV.DEMAND /HS1, HS2, HS3, HS4, HS5, HS6/

SF(HD) DETACHED HOUSING /HS1,HS2,HS3,HS4,HS5/

MUF(HD) ATTACHED HOUSING /HS6/

```
SM        SIMMLOOP                /BASE,TODAY,SIMM1/

R1H       REPORT 1 FOR SCALARS     / GFREV, SFREV, PIT,

                         DGF, DSF, DDRE, PDRE, SPI,COMM,COMMO,

                         GN, NKI, HH, W, W1, W2, W3, R,RL, L, K, HN,HW, GFSAV, LD,

                          HC,SSC, 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 c:\Users\Chris\Documents\Dissertation Related Stuff\DEMSAM3.csv

$OFFDELIM

PARAMETERS

* PARAMETERS CALCULATED FROM SOCIAL ACCOUNTING MATRIX AND TABLE DATA

HH0(H)     DOF    HHDS    NUMBER OF HOUSEHOLDS

HN0(H)     DOF    HHDS    NUMBER OF NONWORKING HOUSEHOLDS

HW0(H)     DOF    HHDS    NUMBER OF WORKING HOUSEHOLDS;

OPTION DECIMALS=8 ;

TABLE MISCH(H,*) MISC.  HH DATA

          HH0        HSCALAR

HH1     20457      21.33159541

HH2     111607     23.09269605

HH3     166815     22.31937383

HH4     173596     21.62920508

HH5     185305     21.01678575
```

```
HH6     193606    20.66673783
HH7     220490    20.03179795
HH8     223168    19.83715556
HH9     202255    19.47756163
HH10     164574    19.50159972
HH11     115349    18.82941561
HH12     242151    17.72701318
HH13     142780    20.87732125;
SET PEEPS /1*15/
SET TEEN(PEEPS) /4/
SET ADULT1(PEEPS) /5/
SET ADULT2(PEEPS) /6/
SET ADULT3(PEEPS) /7/
SET LAB(L) /L1,L2,L3/
SET HUMANK(L) /HK1,HK2,HK3/
SET GED(LAB) /L1/
SET BA(LAB) /L2/
SET PHD(LAB) /L3/
SET KGED(HUMANK) /HK1/
SET KBA(HUMANK) /HK2/
SET KPHD(HUMANK)/HK2/
PARAMETER NEWB(LAB);
NEWB("L1") = 1.0;
```

```
NEWB("L2") = 0.0;

NEWB("L3") = 0.0;

TABLE KNEWB(HUMANK,PEEPS)

        1     2     3     4     5     6     7     8     9     10     11     12     13     14
15
HK1     0     0     0     0     1     0     0     0     0     0     0     0     0     0
0
HK2     0     0     0     0     0     1     0     0     0     0     0     0     0     0
0
HK3     0     0     0     0     0     0     1     0     0     0     0     0     0     0
0 ;

PARAMETER HH0(H),
        HSCALAR(H);

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

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

TABLE ATTAINMENT(LAB,PEEPS)

*     1          2          3          4          5          6          7          8          9
10         11         12         13         14         15
*L1      0.000000      0.000000      0.000000      0.126997      0.113417      0.096693
0.090304      0.088595      0.096180      0.113430      0.107026      0.082502      0.049102
0.020504      0.015249
```

*L2 0.000000 0.000000 0.000000 0.002710 0.082783 0.123128

0.126820 0.132663 0.123342 0.130624 0.121449 0.089218 0.045340

0.014631 0.007291

*L3 0.000000 0.000000 0.000000 0.000016 0.010733 0.079980

0.122574 0.145796 0.129122 0.134417 0.141941 0.119131 0.078138

0.025458 0.012693;

1 2 3 4 5 6 7 8 9

10 11 12 13 14 15

L1 0.000000 0.000000 0.000000 0.988014 0.696581 0.523138

0.474557 0.449233 0.491480 0.519639 0.513554 0.514424 0.529647

0.592070 0.684117

L2 0.000000 0.000000 0.000000 0.011958 0.288322 0.377769

0.377933 0.381469 0.357421 0.339345 0.330474 0.315469 0.277339

0.239583 0.185478

L3 0.000000 0.000000 0.000000 0.000028 0.015096 0.099094

0.147509 0.169297 0.151100 0.141015 0.155972 0.170107 0.193014

0.168346 0.130405

TABLE EFFECTIVELABOR(H,PEEPS)

1 2 3 4 5 6 7 8 9

10 11 12 13 14 15

HH1 0 0 0 27847.5498 5380.734297 815.5427492 209.056649

397.4294512 418.2400512 355.4913682 209.1517139 209.056649

34.872382 13.96671711 0

HH2 0 0 0 7898.440005 145884.2567 16291.46874 3343.555862

864.2477836 834.9189715 992.7043431 963.4079748 363.9656594

85.61607723 21.40401931 21.40401931

HH3 0 0 0 2200.099588 20499.38175 216660.9728 21151.86565

5858.272509 1667.261814 1154.267016 1111.403896 983.2883626

406.0187303 106.8657054 85.58350038

HH4 0 0 0 4555.50743 5969.37213 27946.95135 238927.1657

24734.04187 6598.129552 2152.698263 1156.981406 1203.384027

1110.648886 231.2404735 115.7747634

HH5 0 0 0 18192.73729 4001.703625 8368.043427 27511.71122

245312.6389 23903.96246 7518.64941 2596.00834 1342.099923

1230.36539 447.2106112 111.8977282

HH6 0 0 0 36516.97197 11568.36215 3555.535831 7828.109942

29764.98941 246122.5826 22923.06598 7157.505864 2146.808168

1409.634894 498.7126178 585.0574287

HH7 0 0 0 47163.19732 25242.01091 6484.434717 3645.107219

9294.118829 29525.94291 279761.5557 24907.22544 7165.322809

1686.283162 673.8460355 736.9500917

HH8 0 0 0 31849.7923 23976.09101 10767.87946 4638.434466

3584.596671 9075.928964 34316.92002 273114.5546 20331.55104

4830.337741 994.7830388 745.6912885

HH9 0 0 0 11420.23565 13981.66571 9070.632428 5338.215616 3894.207958 3843.169882 9999.808297 27644.68857 214253.8046 11999.69869 2203.865611 806.8534429

HH10 0 0 0 3558.276964 4880.150701 4075.720393 3367.469754 3522.349917 1874.423567 2721.890067 7402.404961 17134.64625 124137.755 4956.594793 1277.466486

HH11 0 0 0 1148.181905 1168.877892 927.0038079 1006.565857 1539.759978 1947.355173 1526.925876 1599.349314 3129.487255 7274.495869 45173.83423 1888.305946

HH12 0 0 0 933.9063809 1195.167223 927.0238132 715.9841799 985.0988733 2144.060755 3201.594688 2965.954468 2309.771688 2173.755514 3126.756427 30996.88372

HH13 0 0 0 24266.48176 11827.06158 6940.324782 4388.284144 4036.173703 3260.162463 2827.775334 1896.272814 868.2828784 529.6821201 164.358574 354.859359;

TABLE LABORAGEHOUSE(LAB,PEEPS,H)

HH1 HH2 HH3 HH4 HH5 HH6 HH7 HH8 HH9 HH10 HH11 HH12 HH13

L1.1 0.000000000 0.000000000 0.000000000 0.000000000 0.000000000 0.000000000 0.000000000 0.000000000 0.000000000 0.000000000 0.000000000 0.000000000 0.000000000

L1.2 0.000000000 0.000000000 0.000000000 0.000000000 0.000000000

0.000000000 0.000000000 0.000000000 0.000000000 0.000000000

0.000000000 0.000000000 0.000000000

L1.3 0.000000000 0.000000000 0.000000000 0.000000000 0.000000000

0.000000000 0.000000000 0.000000000 0.000000000 0.000000000

0.000000000 0.000000000 0.000000000

L1.4 0.125855786 0.035649487 0.010235693 0.020978450 0.084327067

0.167973316 0.217459804 0.146634435 0.052477045 0.016367512

0.005341775 0.004252063 0.112447566

L1.5 0.024612800 0.476560946 0.065540388 0.023610681 0.017813581

0.051788228 0.106125430 0.092606805 0.052511232 0.018999767

0.005024335 0.005399261 0.059406546

L1.6 0.004087778 0.065524902 0.620885600 0.087604993 0.029088689

0.014690145 0.031377523 0.046535275 0.036530675 0.015679120

0.003999069 0.004721067 0.039275166

L1.7 0.001367802 0.015544526 0.074209382 0.685515206 0.084665984

0.027632715 0.014320165 0.021934884 0.026076680 0.014359831

0.004432226 0.003390587 0.026550012

L1.8 0.001673025 0.004567753 0.023219346 0.082503978 0.678619168

0.089986026 0.031859475 0.013939262 0.018709025 0.017004567

0.007427449 0.004712719 0.025778209

L1.9 0.002054787 0.004470510 0.007741765 0.023012390 0.075100253

0.698508878 0.095539465 0.032036461 0.016163956 0.007930929

0.009239849 0.010187052 0.018013704

L1.10 0.001524510 0.004125109 0.004339184 0.007467821 0.023515864

0.066673862 0.724375750 0.096800107 0.030132519 0.008910364

0.005741433 0.013202119 0.013191356

L1.11 0.000807867 0.004490106 0.004480912 0.004850931 0.007649632

0.022358828 0.078654185 0.743052211 0.083203387 0.022539767

0.006338527 0.012743736 0.008829912

L1.12 0.001497156 0.002145983 0.005201002 0.006458497 0.007042500

0.008841126 0.028033119 0.073065277 0.768576374 0.069227881

0.013156297 0.011875958 0.004878831

L1.13 0.000251553 0.001030198 0.004369375 0.009738614 0.011294988

0.010424495 0.010382564 0.029134814 0.078687879 0.767420555

0.054572399 0.017346413 0.005346154

L1.14 0.000000000 0.000616772 0.001846527 0.006663360 0.010948372

0.009985715 0.013948026 0.019679066 0.035680856 0.081845218

0.750714135 0.063804347 0.004267607

L1.15 0.000000000 0.000829308 0.002482831 0.003583807 0.003463793

0.018461763 0.022016080 0.022451217 0.021739252 0.032514367

0.050270112 0.813006351 0.009181120

L2.1 0.000000000 0.000000000 0.000000000 0.000000000 0.000000000
0.000000000 0.000000000 0.000000000 0.000000000 0.000000000
0.000000000 0.000000000 0.000000000

L2.2 0.000000000 0.000000000 0.000000000 0.000000000 0.000000000
0.000000000 0.000000000 0.000000000 0.000000000 0.000000000
0.000000000 0.000000000 0.000000000

L2.3 0.000000000 0.000000000 0.000000000 0.000000000 0.000000000
0.000000000 0.000000000 0.000000000 0.000000000 0.000000000
0.000000000 0.000000000 0.000000000

L2.4 0.305839366 0.090642906 0.000000000 0.017804905 0.025812988
0.158426991 0.162043385 0.127475560 0.054053457 0.015445575
0.000000000 0.005334454 0.037120414

L2.5 0.007905423 0.655064239 0.092350470 0.015156784 0.006761177
0.019929321 0.058095099 0.072778855 0.046898982 0.015339750
0.002572609 0.001921219 0.005226071

L2.6 0.001240176 0.043896726 0.759740918 0.089361433 0.024243908
0.006791300 0.010701094 0.023676437 0.022310041 0.011220021
0.002306185 0.000998124 0.003513637

L2.7 0.000000000 0.006868312 0.061688230 0.782170451 0.084590020
0.023344853 0.008657960 0.009194857 0.008808614 0.008472622
0.002398976 0.001425097 0.002380008

L2.8 0.001151038 0.001178477 0.015624844 0.068206025 0.771374820
0.089777603 0.025823061 0.008464321 0.005935862 0.006416445
0.002981308 0.001852767 0.001213430

L2.9 0.000707442 0.000905383 0.002529880 0.018389017 0.070903766
0.779460426 0.084569923 0.023110103 0.007572245 0.003733514
0.002959947 0.003282230 0.001876125

L2.10 0.000501005 0.001367861 0.002047589 0.004063900 0.016782458
0.057960360 0.788973757 0.090428424 0.023693591 0.005021013
0.002794947 0.004593554 0.001771542

L2.11 0.000538852 0.001287294 0.002202270 0.001788095 0.007680960
0.017492099 0.065455837 0.802792294 0.071625158 0.020107560
0.002755579 0.004285791 0.001988211

L2.12 0.000000000 0.000751002 0.002248391 0.002434056 0.002875333
0.007852640 0.026582969 0.084955693 0.799501665 0.055837951
0.009889130 0.005266860 0.001804310

L2.13 0.000000000 0.000000000 0.000491590 0.005854022 0.003600535
0.007975310 0.012592926 0.033815616 0.075935235 0.805449951
0.041826742 0.010682842 0.001775231

L2.14 0.000000000 0.000000000 0.003046765 0.000000000 0.003187902
0.006178649 0.012007409 0.008855563 0.041305265 0.078208629
0.797799459 0.049410358 0.000000000

L2.15 0.000000000 0.000000000 0.000000000 0.000000000 0.000000000

0.012399523 0.021084765 0.011847763 0.020095226 0.036366863

0.047294295 0.839871485 0.011040080

L3.1 0.000000000 0.000000000 0.000000000 0.000000000 0.000000000

0.000000000 0.000000000 0.000000000 0.000000000 0.000000000

0.000000000 0.000000000 0.000000000

L3.2 0.000000000 0.000000000 0.000000000 0.000000000 0.000000000

0.000000000 0.000000000 0.000000000 0.000000000 0.000000000

0.000000000 0.000000000 0.000000000

L3.3 0.000000000 0.000000000 0.000000000 0.000000000 0.000000000

0.000000000 0.000000000 0.000000000 0.000000000 0.000000000

0.000000000 0.000000000 0.000000000

L3.4 0.000000000 0.000000000 0.000000000 0.000000000 0.000000000

0.000000000 0.000000000 0.000000000 0.000000000 0.000000000

0.000000000 1.000000000 0.000000000

L3.5 0.006714527 0.566264805 0.139557288 0.055956107 0.010816453

0.010481982 0.061111142 0.100155494 0.042129249 0.003398743

0.000000000 0.001460122 0.001954089

L3.6 0.000000000 0.012272131 0.815041230 0.098372055 0.023950895

0.011253467 0.002733708 0.011424749 0.014699752 0.005929453

0.000000000 0.001175691 0.003146868

L3.7 0.000000000 0.002771871 0.048429437 0.819747908 0.089979866

0.016062692 0.008472852 0.003508097 0.005902562 0.002976153

0.000781570 0.000511430 0.000855561

L3.8 0.000000000 0.000517860 0.006849354 0.065086802 0.802265772

0.085655398 0.021744804 0.007373321 0.005892854 0.002752323

0.000821352 0.000752446 0.000287715

L3.9 0.000000000 0.000000000 0.002148288 0.013488985 0.065635910

0.802049170 0.079161598 0.022478759 0.006303620 0.002825219

0.001854832 0.001941972 0.002111648

L3.10 0.000000000 0.000561702 0.001238205 0.004021356 0.017274179

0.054823564 0.801915512 0.084374224 0.023884965 0.007327648

0.001425422 0.001748892 0.001404331

L3.11 0.000000000 0.000000000 0.000781709 0.001269391 0.005725448

0.019419411 0.055068311 0.816810850 0.076776326 0.017733480

0.002362248 0.002870708 0.001182118

L3.12 0.000000000 0.000000000 0.001397078 0.002016592 0.002436326

0.005194176 0.021106079 0.061812445 0.833160766 0.058181174

0.009649896 0.004341238 0.000704231

L3.13 0.000461167 0.000000000 0.000710005 0.001537270 0.004457370

0.006479306 0.009094003 0.030954935 0.071180564 0.835687563

0.030344403 0.008824993 0.000268421

L3.14 0.001415449 0.000000000 0.000000000 0.000000000 0.002280150

0.006628928 0.002147078 0.019001852 0.039076444 0.103171429

0.802469397 0.022161555 0.001647718

L3.15 0.000000000 0.000000000 0.004370735 0.004731657 0.004573204

0.004431790 0.004306306 0.016938327 0.021374733 0.037361767

0.052831700 0.840817879 0.008261902;

TABLE HKAGEHOUSE(HUMANK,PEEPS,H)

HH1 HH2 HH3 HH4 HH5 HH6

HH7 HH8 HH9 HH10 HH11 HH12 HH13

HK1.1 0.000000000 0.000000000 0.000000000 0.000000000 0.000000000

0.000000000 0.000000000 0.000000000 0.000000000 0.000000000

0.000000000 0.000000000 0.000000000

HK1.2 0.000000000 0.000000000 0.000000000 0.000000000 0.000000000

0.000000000 0.000000000 0.000000000 0.000000000 0.000000000

0.000000000 0.000000000 0.000000000

HK1.3 0.000000000 0.000000000 0.000000000 0.000000000 0.000000000

0.000000000 0.000000000 0.000000000 0.000000000 0.000000000

0.000000000 0.000000000 0.000000000

HK1.4 0.125855786 0.035649487 0.010235693 0.020978450 0.084327067

0.167973316 0.217459804 0.146634435 0.052477045 0.016367512

0.005341775 0.004252063 0.112447566

HK1.5 0.024612800 0.476560946 0.065540388 0.023610681 0.017813581

0.051788228 0.106125430 0.092606805 0.052511232 0.018999767

0.005024335 0.005399261 0.059406546

HK1.6 0.004087778 0.065524902 0.620885600 0.087604993 0.029088689

0.014690145 0.031377523 0.046535275 0.036530675 0.015679120

0.003999069 0.004721067 0.039275166

HK1.7 0.001367802 0.015544526 0.074209382 0.685515206 0.084665984

0.027632715 0.014320165 0.021934884 0.026076680 0.014359831

0.004432226 0.003390587 0.026550012

HK1.8 0.001673025 0.004567753 0.023219346 0.082503978 0.678619168

0.089986026 0.031859475 0.013939262 0.018709025 0.017004567

0.007427449 0.004712719 0.025778209

HK1.9 0.002054787 0.004470510 0.007741765 0.023012390 0.075100253

0.698508878 0.095539465 0.032036461 0.016163956 0.007930929

0.009239849 0.010187052 0.018013704

HK1.10 0.001524510 0.004125109 0.004339184 0.007467821

0.023515864 0.066673862 0.724375750 0.096800107 0.030132519

0.008910364 0.005741433 0.013202119 0.013191356

HK1.11 0.000807867 0.004490106 0.004480912 0.004850931

0.007649632 0.022358828 0.078654185 0.743052211 0.083203387

0.022539767 0.006338527 0.012743736 0.008829912

HK1.12 0.001497156 0.002145983 0.005201002 0.006458497

0.007042500 0.008841126 0.028033119 0.073065277 0.768576374

0.069227881 0.013156297 0.011875958 0.004878831

HK1.13 0.000251553 0.001030198 0.004369375 0.009738614

0.011294988 0.010424495 0.010382564 0.029134814 0.078687879

0.767420555 0.054572399 0.017346413 0.005346154

HK1.14 0.000000000 0.000616772 0.001846527 0.006663360

0.010948372 0.009985715 0.013948026 0.019679066 0.035680856

0.081845218 0.750714135 0.063804347 0.004267607

HK1.15 0.000000000 0.000829308 0.002482831 0.003583807

0.003463793 0.018461763 0.022016080 0.022451217 0.021739252

0.032514367 0.050270112 0.813006351 0.009181120

HK2.1 0.000000000 0.000000000 0.000000000 0.000000000 0.000000000

0.000000000 0.000000000 0.000000000 0.000000000 0.000000000

0.000000000 0.000000000 0.000000000

HK2.2 0.000000000 0.000000000 0.000000000 0.000000000 0.000000000

0.000000000 0.000000000 0.000000000 0.000000000 0.000000000

0.000000000 0.000000000 0.000000000

HK2.3 0.000000000 0.000000000 0.000000000 0.000000000 0.000000000

0.000000000 0.000000000 0.000000000 0.000000000 0.000000000

0.000000000 0.000000000 0.000000000

HK2.4 0.305839366 0.090642906 0.000000000 0.017804905 0.025812988

0.158426991 0.162043385 0.127475560 0.054053457 0.015445575

0.000000000 0.005334454 0.037120414

HK2.5 0.007905423 0.655064239 0.092350470 0.015156784 0.006761177

0.019929321 0.058095099 0.072778855 0.046898982 0.015339750

0.002572609 0.001921219 0.005226071

HK2.6 0.001240176 0.043896726 0.759740918 0.089361433 0.024243908

0.006791300 0.010701094 0.023676437 0.022310041 0.011220021

0.002306185 0.000998124 0.003513637

HK2.7 0.000000000 0.006868312 0.061688230 0.782170451 0.084590020

0.023344853 0.008657960 0.009194857 0.008808614 0.008472622

0.002398976 0.001425097 0.002380008

HK2.8 0.001151038 0.001178477 0.015624844 0.068206025 0.771374820

0.089777603 0.025823061 0.008464321 0.005935862 0.006416445

0.002981308 0.001852767 0.001213430

HK2.9 0.000707442 0.000905383 0.002529880 0.018389017 0.070903766

0.779460426 0.084569923 0.023110103 0.007572245 0.003733514

0.002959947 0.003282230 0.001876125

HK2.10 0.000501005 0.001367861 0.002047589 0.004063900

0.016782458 0.057960360 0.788973757 0.090428424 0.023693591

0.005021013 0.002794947 0.004593554 0.001771542

HK2.11 0.000538852 0.001287294 0.002202270 0.001788095
0.007680960 0.017492099 0.065455837 0.802792294 0.071625158
0.020107560 0.002755579 0.004285791 0.001988211

HK2.12 0.000000000 0.000751002 0.002248391 0.002434056
0.002875333 0.007852640 0.026582969 0.084955693 0.799501665
0.055837951 0.009889130 0.005266860 0.001804310

HK2.13 0.000000000 0.000000000 0.000491590 0.005854022
0.003600535 0.007975310 0.012592926 0.033815616 0.075935235
0.805449951 0.041826742 0.010682842 0.001775231

HK2.14 0.000000000 0.000000000 0.003046765 0.000000000
0.003187902 0.006178649 0.012007409 0.008855563 0.041305265
0.078208629 0.797799459 0.049410358 0.000000000

HK2.15 0.000000000 0.000000000 0.000000000 0.000000000
0.000000000 0.012399523 0.021084765 0.011847763 0.020095226
0.036366863 0.047294295 0.839871485 0.011040080

HK3.1 0.000000000 0.000000000 0.000000000 0.000000000 0.000000000
0.000000000 0.000000000 0.000000000 0.000000000 0.000000000
0.000000000 0.000000000 0.000000000

HK3.2 0.000000000 0.000000000 0.000000000 0.000000000 0.000000000
0.000000000 0.000000000 0.000000000 0.000000000 0.000000000
0.000000000 0.000000000 0.000000000

HK3.3 0.000000000 0.000000000 0.000000000 0.000000000 0.000000000
0.000000000 0.000000000 0.000000000 0.000000000 0.000000000
0.000000000 0.000000000 0.000000000

HK3.4 0.000000000 0.000000000 0.000000000 0.000000000 0.000000000
0.000000000 0.000000000 0.000000000 0.000000000 0.000000000
0.000000000 1.000000000 0.000000000

HK3.5 0.006714527 0.566264805 0.139557288 0.055956107 0.010816453
0.010481982 0.061111142 0.100155494 0.042129249 0.003398743
0.000000000 0.001460122 0.001954089

HK3.6 0.000000000 0.012272131 0.815041230 0.098372055 0.023950895
0.011253467 0.002733708 0.011424749 0.014699752 0.005929453
0.000000000 0.001175691 0.003146868

HK3.7 0.000000000 0.002771871 0.048429437 0.819747908 0.089979866
0.016062692 0.008472852 0.003508097 0.005902562 0.002976153
0.000781570 0.000511430 0.000855561

HK3.8 0.000000000 0.000517860 0.006849354 0.065086802 0.802265772
0.085655398 0.021744804 0.007373321 0.005892854 0.002752323
0.000821352 0.000752446 0.000287715

HK3.9 0.000000000 0.000000000 0.002148288 0.013488985 0.065635910
0.802049170 0.079161598 0.022478759 0.006303620 0.002825219
0.001854832 0.001941972 0.002111648

HK3.10 0.000000000 0.000561702 0.001238205 0.004021356
0.017274179 0.054823564 0.801915512 0.084374224 0.023884965
0.007327648 0.001425422 0.001748892 0.001404331
HK3.11 0.000000000 0.000000000 0.000781709 0.001269391
0.005725448 0.019419411 0.055068311 0.816810850 0.076776326
0.017733480 0.002362248 0.002870708 0.001182118
HK3.12 0.000000000 0.000000000 0.001397078 0.002016592
0.002436326 0.005194176 0.021106079 0.061812445 0.833160766
0.058181174 0.009649896 0.004341238 0.000704231
HK3.13 0.000461167 0.000000000 0.000710005 0.001537270
0.004457370 0.006479306 0.009094003 0.030954935 0.071180564
0.835687563 0.030344403 0.008824993 0.000268421
HK3.14 0.001415449 0.000000000 0.000000000 0.000000000
0.002280150 0.006628928 0.002147078 0.019001852 0.039076444
0.103171429 0.802469397 0.022161555 0.001647718
HK3.15 0.000000000 0.000000000 0.004370735 0.004731657
0.004573204 0.004431790 0.004306306 0.016938327 0.021374733
0.037361767 0.052831700 0.840817879 0.008261902;

TABLE LENDOWMENT(H,LAB)

	L1	L2	L3
HH1	33908.988462	1926.236495	55.866868
HH2	115688.724355	58950.273296	2926.392464
HH3	135338.164965	107690.184528	28856.931855

```
HH4     148618.252339    119060.924031    47022.719521
HH5     161521.103048    123825.811649    55190.113656
HH6     199648.693799    119844.979816    50583.663222
HH7     253911.770716    130341.520708    52032.703744
HH8     234637.592343    127714.624242    55874.344051
HH9     173276.623416    93035.216085     48145.006988
HH10     98684.217716    49033.686925     31191.244216
HH11     42034.939545    16371.874474     9923.329087
HH12     36746.638377    9644.657336      5284.662018
HH13     58499.489441    2356.213449      504.016623    ;
*SET                                                          PEEPS
/AGE1,AGE2,AGE3,AGE4,AGE5,AGE6,AGE7,AGE8,AGE9,AGE10,AGE11,AGE12,AGE13,
AGE14,AGE15/
PARAMETER TOTALAGEWORKING(PEEPS),
     TOTFTE(LAB),
     PFTE0(LAB),
     LENDOWMENT1(H,HUMANK),
     TOTALEDAGEWORKING(LAB,PEEPS);
TOTALAGEWORKING(PEEPS)=SUM(H,EFFECTIVELABOR(H,PEEPS));
TOTALEDAGEWORKING(LAB,PEEPS)=
TOTALAGEWORKING(PEEPS)*ATTAINMENT(LAB,PEEPS);
PFTE0("L1")=0.012;
PFTE0("L2")=0.027;
```

```
PFTE0("L3")=0.050;

TOTFTE(LAB)= (SUM(H,SAM(H,LAB)))/PFTE0(LAB);

LENDOWMENT1(H,"HK1") = SAM(H,"HK1")/PFTE0("L1");

LENDOWMENT1(H,"HK2") = SAM(H,"HK2")/PFTE0("L2");

LENDOWMENT1(H,"HK3") = SAM(H,"HK3")/PFTE0("L3");

DISPLAY TOTFTE, TOTALEDAGEWORKING;

TABLE TOTALAGEHK(HUMANK,PEEPS)

        1       2       3       4       5       6       7       8       9

10      11      12      13      14      15

HK1     0.000000    0.000000    0.000000    0.000000    981.587062    2386.391910

2695.061533     3142.709116     3829.063118     4821.895051     4733.251753

3352.201170     1692.488018     476.364292      263.279485

HK2     0.000000    0.000000    0.000000    0.000000    0.000000    1587.818708

2711.720286     3946.407750     4262.653418     4730.682521     4239.548176

2915.535702     1187.018958     252.597211      37.369825

HK3     0.000000    0.000000    0.000000    0.000000    0.000000    0.000000

837.805957      2159.525278     2244.716422     2740.613977     2433.894843

1661.290456     839.638554      5.964151        0.000000;

PARAMETER HKPAYMENTS(H,HUMANK),

        HKPAYMENTS0(H,HUMANK),

        HKPAYMENTS2(HUMANK,PEEPS,H),

        HKPAYRATIO(H,HUMANK);
```

```
HKPAYMENTS0(H,HUMANK) = SAM(H,HUMANK);

HKPAYMENTS(H,HUMANK)=

SUM(PEEPS,(HKAGEHOUSE(HUMANK,PEEPS,H)*TOTALAGEHK(HUMANK,PEEPS)));

HKPAYRATIO(H,HUMANK)$HKPAYMENTS(H,HUMANK)                              =

HKPAYMENTS0(H,HUMANK)/HKPAYMENTS(H,HUMANK);

DISPLAY TOTALEDAGEWORKING;

SET BABY(PEEPS)

   ELDERLY(PEEPS);

BABY(PEEPS) = YES$(ORD(PEEPS) EQ 1);

ELDERLY(PEEPS)  = YES$(ORD(PEEPS) EQ CARD(PEEPS));

TABLE PARTCHANGE(PEEPS,*)

        PARTICIPATION

5        1.333860147

6        1.024778978

7        1.069682750

8        0.993950594

9        0.982295908

10       0.994285173

11       0.970150935

12       0.871192412

13       0.723617821

14       0.546199232

15       0.311986870;
```

TABLE EXPERIENCE(PEEPS,HUMANK)

	HK1	HK2	HK3
1	0.000000	0.000000	0.000000
2	0.000000	0.000000	0.000000
3	0.000000	0.000000	0.000000
4	0.000000	0.000000	0.000000
5	0.000000	0.000000	0.000000
6	2.927579	0.000000	0.000000
7	1.292049	1.827576	0.000000
8	1.175954	1.377666	2.126361
9	1.098383	1.137014	1.110600
10	1.081074	1.044383	1.140189
11	1.040830	0.955094	0.808818
12	0.916063	0.855202	0.748803
13	0.842920	0.713878	0.657755
14	0.604910	0.610763	0.017914
15	0.738480	0.245212	0.000000;

TABLE STUDENTPERCENT(PEEPS,*)

	GPROP	UGPROP
1	0.00000000	0.00000000
2	0.00000000	0.00000000
3	0.00000000	0.00007304
4	0.00056057	0.33889352

```
5          0.19307467        0.31671744

6          0.25861854        0.11579243

7          0.14034477        0.06837356

8          0.12133679        0.05185013

9          0.08855182        0.03699667

10         0.07425148        0.03044019

11         0.05828954        0.01921244

12         0.03659289        0.01144005

13         0.01676830        0.00414541

14         0.00567163        0.00227526

15         0.00593901        0.00378986;

PARAMETER PARTICIPATION(PEEPS),

          GPROP(PEEPS),

          UGPROP(PEEPS);

PARTICIPATION(PEEPS)=PARTCHANGE(PEEPS,'PARTICIPATION');

GPROP(PEEPS) = STUDENTPERCENT(PEEPS,"GPROP");

UGPROP(PEEPS) = STUDENTPERCENT(PEEPS,"UGPROP");

TABLE POP0(H,PEEPS)

          1              2              3              4              5              6              7

8            9             10             11             12             13             14             15

HH1       5162.246090       277.310740       639.947862       31037.471324       5866.188738

895.927007              234.647550             405.300313             490.626694              426.631908

213.315954        234.647550        63.994786         42.663191         42.663191
```

HH2 38934.285537 6258.120629 1039.171322 9698.932340

164096.698117 18220.137182 3810.294848 1062.264018 1039.171322

1547.210635 1154.634802 600.410097 277.112353 184.741568

230.926960

HH3 81554.991972 38210.767996 9195.582018 3258.628579

23100.551913 233951.676478 22810.400054 6361.021541 1874.827402

1406.120551 1584.675542 1383.801177 714.219963 290.151860

401.748729

HH4 102717.094941 67980.591577 39019.085971 8976.120110

6229.211064 28485.663095 233811.706952 24397.743334 6510.390730

2119.662098 1470.785946 1492.415151 1557.302766 432.584102

670.505358

HH5 83730.874447 86231.871952 66223.891913 30915.691845

4077.256436 8616.882159 29360.449699 244173.016899 24190.320404

7587.059657 2711.165362 1765.410003 1933.544289 1113.889645

1387.107860

HH6 39783.470325 71031.577925 84216.956661 58590.201751

12007.374680 3823.346499 8349.362084 32508.778608 249385.525406

23849.415457 7274.691716 2438.675064 2046.007045 1653.339026

2914.010034

HH7 19330.685019 36077.268102 68689.035159 69730.688653

25360.256201 6730.684110 4006.359589 9975.835377 32511.608068

284852.166803 25760.892160 7612.083220 2103.338784 1722.734623

4346.900154

HH8 9501.997511 14282.752000 33623.978667 46121.386667

24558.398578 11307.178667 5098.148978 3927.756800 9779.717689

36936.783644 284603.670756 22138.265600 5871.798044 1785.344000

5217.171911

HH9 6349.685092 7440.428544 11530.716487 17705.103525

15737.869800 10225.719857 6544.460709 4616.182107 4655.137230

11900.790158 33774.091872 257941.348710 16263.763964 3544.916217

5317.374326

HH10 3490.786349 3393.278351 5694.467117 7313.099893

6669.547103 5577.457519 4836.396729 5031.412727 2944.741557

4017.329541 11154.915037 28121.306790 209525.187344 10920.895841

6591.540704

HH11 1713.476820 1939.429807 2692.606432 2862.071172

2184.212210 1713.476820 1995.918054 3050.365328 4123.642018

3201.000653 3332.806562 6872.736696 21201.921972 142726.970291

11034.037545

HH12 1613.158199 1985.425476 2659.051977 3244.043411

2605.870937 2038.606515 1879.063397 2375.419766 4945.836676

7977.155930 7675.796706 6505.813836 8101.245022 19535.168521

320185.312006

```
HH13    125.263927    62.631964    1565.799093    38330.761807
18789.589121    13236.221670    9144.266706    8163.032607    7119.166545
6346.705659    5219.330311    3799.672467    2672.297119    2296.505337
25908.755666;
PARAMETER TOTPOP0(PEEPS),
     TOTPOP1(H),
     POPRATIO(H,PEEPS);
TOTPOP0(PEEPS)=SUM(H,POP0(H,PEEPS));
TOTPOP1(H)=SUM(PEEPS,POP0(H,PEEPS));
POPRATIO(H,PEEPS) = POP0(H,PEEPS)/TOTPOP0(PEEPS);
DISPLAY TOTPOP0, TOTPOP1, POPRATIO;
TABLE FERT(PEEPS,*)
    FERTILITY
1    0
2    0
3    0.001887623
4    0.093732425
5    0.2308338
6    0.292421746
7    0.253225806
8    0.134465462
9    0.038787024
10    0.014806494
```

```
11      0
12      0
13      0
14      0
15      0;
PARAMETER FERTILITY(PEEPS);
FERTILITY(PEEPS)=FERT(PEEPS,'FERTILITY');
TABLE MORT(PEEPS,*)
          MORTALITY
1       0.007555
2       0.000656
3       0.000909
4       0.003107
5       0.004409
6       0.004643
7       0.004643
8       0.008439
9       0.008439
10      0.017351
11      0.017351
12      0.036105
13      0.036105
14      0.091685
```

```
15       0.271364  ;

PARAMETER MORTALITY(PEEPS);

MORTALITY(PEEPS)=MORT(PEEPS,'MORTALITY');

PARAMETER MOVEOUT(PEEPS);

MOVEOUT("4")=0.2338;

MOVEOUT("5")=0.5676;

MOVEOUT("6")=0.5930;

MOVEOUT("7")=0.3948;

TABLE GROWUP(H,PEEPS)

         4            5            6            7

HH1      0.000000     0.000000     0.000146     0.000070

HH2      0.377236     0.028634     0.002925     0.000702

HH3      0.108893     0.739900     0.057701     0.011581

HH4      0.037853     0.107768     0.766564     0.071734

HH5      0.000000     0.029988     0.096314     0.758756

HH6      0.000000     0.000000     0.029984     0.098056

HH7      0.000000     0.000000     0.000000     0.028357

HH8      0.000000     0.000000     0.000000     0.000000

HH9      0.000000     0.000000     0.000000     0.000000

HH10     0.000000     0.000000     0.000000     0.000000

HH11     0.000000     0.000000     0.000000     0.000000

HH12     0.000000     0.000000     0.000000     0.000000

HH13     0.476018     0.093711     0.046365     0.030743;
```

```
TABLE INCO(H,*)

          INCOME

HH1       714.453000

HH2       5667.977000

HH3       13670.400000

HH4       18614.237000

HH5       24619.298000

HH6       27053.154000

HH7       33133.374000

HH8       34440.811000

HH9       31381.192000

HH10       25010.045000

HH11       16922.520000

HH12       27206.729000

HH13       2362.542000;

PARAMETER INCOME(H);

INCOME(H) = INCO(H,"INCOME");

PARAMETER TKI0(I)   PROPERTY TAXES ON COMMERCIAL CAPITAL;

 TKI0(IP)=SAM("CNPRP",IP)/(sum(K,SAM(K,IP)));

PARAMETER TKH0(H) PROPERTY TAXES ON RESIDENTIAL CAPITAL;

 TKH0(NONGQ)=(SAM("CNPRP",NONGQ)/(SUM(HD,SAM(HD,NONGQ))));

DISPLAY TKI0, TKH0;

PARAMETER
```

```
TOTL0(IG)  TOTAL LABOR INPUT,

LABORSHARE(L,H),

SUPPORTSHARE(H,L),

TOTALLABH(H),

TOTALLAB1(H),

TLDI0(I)  PRIVATE EMPLOYER SHARE OF PAYROLL TAXES;

*** ALL LABOR GROUPS FACE THE SAME PAYROLL TAX RATE ***

TOTL0(IG) =SUM(L,SAM(L,IG));

TLDI0(IP) = SAM("USSOC",IP)/TOTL0(IP);

LABORSHARE(L,H)=SAM(H,L)/SUM(IG,SAM(L,IG));

TOTALLABH(H) = SUM(L,SAM(H,L));

TOTALLAB1(H)                                                                 =

SUM(LAB,LENDOWMENT(H,LAB))+SUM(HUMANK,LENDOWMENT1(H,HUMANK));

SUPPORTSHARE(H,LAB) = LENDOWMENT(H,LAB)/TOTALLAB1(H);

SUPPORTSHARE(H,HUMANK) = LENDOWMENT1(H,HUMANK)/TOTALLAB1(H);

DISPLAY LABORSHARE, SUPPORTSHARE;

PARAMETER TLDG0(FG)  PUBLIC EMPLOYER SHARE OF PAYROLL TAXES;

TLDG0(FG) = SAM("USSOC",FG)/TOTL0(FG);

PARAMETER LI0(L),

          LI1(H);

 LI0(L)=SUM(H,SAM(H,L));

 LI1(H)=SUM(L,SAM(H,L));

PARAMETER TLS0(H)   EMPLOYEE SHARE OF PAYROLL TAXES;
```

```
TLS0(H) = SAM("USSOC",H)/(LI1(H)+SAM("USSOC",H));

PARAMETER TLS1(H) PAYROLL TAX RATE FOR MPSGE;

 TLS1(H) = TLS0(H);

TABLE WORK0(L,H)

         HH1            HH2            HH3            HH4            HH5            HH6

L1       415.7563194     1499.825711     1699.290509     1670.395515     1825.134223
2289.175509

L2        53.1415079     1719.563044     3042.327670     3010.918029     3148.177700
3091.825555

L3         2.8540755      158.077875     1509.684723     2202.133614     2598.457294
2416.638296

HK1       10.8320979      927.583795     2259.911692     2736.556330     3078.232295
3555.260018

HK2        1.6156414       34.419823     1598.240105     2600.830903     3850.062324
4065.129525

HK3                0               0        8.058368      743.118156     1850.434321
1999.406582

+

         HH7            HH8            HH9            HH10           HH11           HH12
HH13

L1       2904.141107     2702.628227     2021.78923     1164.179072      487.633942
400.8336663     778.3434129
```

```
L2          3354.286712          3309.877059          2442.450614         1301.514926          427.3310249
236.7096133         70.5368932
L3          2479.705080          2681.574769          2340.646964         1533.181402          479.6557472
240.1886886         27.94169817
HK1         4558.238481          4485.46611           3355.499281         1932.150978          809.3105441
665.2508872         0
HK2         4589.544509          3916.122286          2889.81588          1539.903603          505.6020271
280.0659286         0
HK3         2361.988755          2196.952698          1917.638368         1256.100354          392.9709514
196.7810832         0            ;
TABLE MIGPR(L,*)
            MIGPROP
L1          0.982015
L2          1.021322
L3          0.992985
HK1         0.982015
HK2         1.021322
HK3         0.992985;
TABLE MIGPR1(H,*)
            MIGPROP
HH1         2.884355
HH2         3.100802
HH3         1.896107
```

```
HH4        1.298309

HH5        1.040013

HH6        0.885812

HH7        0.703994

HH8        0.700576

HH9        0.676899

HH10       0.585955

HH11       0.417514

HH12       0.296809

HH13       3.074998 ;

TABLE MIGPR2(PEEPS,LAB)

        L1        L2        L3

1      0.849     0.950     1.202

2      0.683     0.764     0.967

3      0.570     0.638     0.807

4      1.489     1.665     2.108

5      2.250     2.515     3.185

6      1.675     1.873     2.372

7      1.115     1.246     1.578

8      0.795     0.889     1.125

9      0.624     0.697     0.883

10     0.464     0.518     0.657

11     0.421     0.470     0.596
```

```
12      0.421       0.471       0.596

13      0.406       0.454       0.574

14      0.301       0.337       0.427

15      0.281       0.314       0.397;

TABLE LFP(PEEPS,*)

        BALFP             PHDLFP

1       0               0

2       0               0

3       0               0

4       0.819444444      1

5       0.920254777      0.918918919

6       0.898949212      0.933649289

7       0.852910053      0.910622368

8       0.837205524      0.897142857

9       0.834035383      0.8835673

10      0.827947061      0.87293666

11      0.811668537      0.851236749

12      0.733417448      0.77267951

13      0.568107973      0.612992126

14      0.323761964      0.374840358

15      0.115035318      0.169928826;

PARAMETER MIGPROP(L),

          BALFP(PEEPS),
```

```
        PHDLFP(PEEPS),
        MIGPROP1(H);
MIGPROP(L)=MIGPR(L,"MIGPROP");
MIGPROP1(H)=MIGPR1(H,"MIGPROP");
BALFP(PEEPS)=LFP(PEEPS,"BALFP");
PHDLFP(PEEPS)=LFP(PEEPS,"PHDLFP");
PARAMETER DEPRECIATE(K);
DEPRECIATE(K) = 0.098486322;
DISPLAY WORK0;
PARAMETER KLAOUT0 NON-RESIDENT OWNERSHIP OF LAND AND CAPITAL,
        QKSF0(K)  NON-RESIDENT OWNERSHIP OF CAPITAL;
 QKSF0(K) = -SAM(K,"ROW");
 KLAOUT0 = SUM(K,QKSF0(K));
PARAMETER WORK1(L,H)  WORKERS BY HOUSEHOLD BY LABOR GROUP,
        LABGRPSHARE(L,H),
        LABGRPSHARE1(L,H),
        QFICA(L,H),
        WORKPROP(L,H),
        WRKSUM(H),
        QLABSUP0(L,H);
  WORK1(L,H) = WORK0(L,H)$WORK(L,H);
  LABGRPSHARE1(L,H)$LI1(H) = WORK1(L,H)$LI1(H)/LI1(H)$LI1(H);
  QFICA(L,H) = LABGRPSHARE1(L,H)*SAM("USSOC",H);
```

```
  QLABSUP0(L,H) = WORK1(L,H)+QFICA(L,H);
  WRKSUM(H) = SUM(L,WORK1(L,H));
  WORKPROP(L,H) = WORK1(L,H)/WRKSUM(H);
DISPLAY LABGRPSHARE1, QFICA, WORK1, QLABSUP0;
PARAMETER FEDPROD0 FEDERAL GOVERNMENT EXPENDITURES AT LOCAL LEVEL;
 FEDPROD0 = (SUM(Z,SAM(Z,"FED")));
DISPLAY QKSF0, KLAOUT0, FEDPROD0;
PARAMETER INVESOUT1,
        INVESOUT2(H),
        INVESOUT3,
        INVESOUT4(H),
        INVESD1(H),
        INVESD2(I),
        INVESD3;
* INVESTMENT FLOW INTO OR OUT OF COLORADO, CURRENTLY POSITIVE
 INVESOUT1 = SAM("INVES","ROW");
* HOUSEHOLD SAVING
 INVESOUT2(H) = SAM("INVES",H);
* TOTAL HOUSHOLD SAVING - SOME OF WHICH MIGHT FLOW OUT
 INVESOUT3 = (SUM(H,INVESOUT2(H)));
* THE FRACTION OF TOTAL HOUSHOLD INVESTMENT CARRIED OUT BY EACH HOUSHOLD GROUP
```

```
 INVESOUT4(H) = INVESOUT2(H)/INVESOUT3;
* SAME AS INVESTOUT2(H), TOTAL HOUSHEOLD SAVING
 INVESD1(H)= SAM("INVES",H);
* INVESTMENT SPENDING ON DIFFERENT INGREDIENTS OF CAPITAL
 INVESD2(I) = SAM(I,"INVES");
* TOTAL INVESTMENT SPENDING ON ALL INGREDIENTS OF CAPITAL
 INVESD3 = (SUM(I,INVESD2(I)));
PARAMETER INVESOUT0(H),
        INVD0(IP),
        INV0,
        INVESD0(I,H);
* MONEY FLOWING INTO/OUT OF COLORADO FOR INVESTMENT ALLOCATED TO
HOUSEHOLDS
INVESOUT0(H)$(SAM("INVES",H) ne 0) = INVESOUT1*INVESOUT4(H);
* TOTAL INVESTMENT SPENDING ON EACH INGREDIENT BY EACH HOUSEHOLD,
AFTER TAKING AWAY WHAT FLOWS OUT
 INVESD0(I,H)$INVESD1(H) = (INVESD2(I)/INVESD3)*(INVESD1(H)+INVESOUT0(H));
* TOTAL INVESTMENT SPENDING ON EACH INGREDIENT BY ALL HOUSEHOLDS
 INVD0(IP) = SUM(H,INVESD0(IP,H));
* TOTAL INVESTMENT SPENDING
 INV0 = SUM(IP,INVD0(IP));
DISPLAY INVESD0;
DISPLAY INVESOUT0;
```

PARAMETER QLS0(L,H) QUANTITY OF LABOR SUPPLIED BY HH,

QDLEI0(L,H) LEISURE CONSUMPTION BY HOUSEHOLD,

QADH0(IP,H) HOUSEHOLD ARMINGTON CONSUMPTION DEMAND,

QHSDH0(HD,H) HOUSEHOLD HOUSING DEMAND,

HEDSPEND(HED) TOTAL HIGHER EDUCATION SPENDING BY DOMESTIC HOUSEHOLDS,

HEDSPENDPROP(HED,H),

OUTPROP(HED) PROPORTION OF DOMESTIC SPENDING ON HIGHER ED THAT GOES OUT OF STATE,

EDSUB0(HED) SUBSIDY RATE ON PUBLIC HIGHER EDUCATION,

EDSUB1(HED,H) SUBSIDY RATE ON PUBLIC HIGHER EDUCATION BY HOUSEHOLD,

EDSUB(HED),

EDSPEND(H),

INCOME1(H),

INVESD9(H);

QDLEI0(L,H) = WORK1(L,H);

QADH0(IP,H) = SAM(IP,H);

HEDSPEND(HED) = SUM(H,SAM(HED,H));

HEDSPENDPROP(HED,H) = SAM(HED,H)/HEDSPEND(HED);

OUTPROP(HED) = SAM("ROW",HED)/HEDSPEND(HED);

QADH0(HED,H) = (SAM(HED,H)*(1-OUTPROP(HED))) + (SAM(HED,"CYGF")*HEDSPENDPROP(HED,H));

```
 EDSUB1(HED,H)            = ((SAM(HED,H)*(1-OUTPROP(HED)))/QADH0(HED,H))-1;
 EDSUB(HED) = EDSUB1(HED,"HH6");
 EDSUB0(HED) = EDSUB1(HED,"HH6");
 EDSPEND(H) = SUM(HED,(QADH0(HED,H)*(1-EDSUB0(HED))));
 INCOME1(H) = INCOME(H)-EDSPEND(H);
QADH0("HealthCare",H)                                                    =
SAM("HEALTHCARE",H)+SAM(H,"HINS")+SAM(H,"MEDICAID")+SAM(H,"MEDICARE
");
 QHSDH0(HD,H) = SAM(HD,H);
* TOTAL INVESTMENT SPENDING BY EACH HOUSEHOLD GROUP
 INVESD9(H) = SUM(IP,INVESD0(IP,H));
DISPLAY EDSUB0, EDSUB1;
SCALARS EDPELAS,
        EDIELAS,
        EDWELAS,
        EDCELAS;
EDPELAS = 0.25;
EDIELAS = 1;
EDWELAS = 0.77;
EDCELAS = 1;
PARAMETER TUSPIT0(H) US PERSONAL INCOME TAX,
          TCOPIT0(H) COLORADO PERSONAL INCOME TAX,
          TCOPIT1(H),
```

TUSPIT1(H),

THFEE0(H) FEES PAID BY HOUSEHOLDS TO STATE AND LOCAL GOVERNMENT,

QW0(H) UTILITY BY HOUSEHOLD GROUP,

QW1(H) UTILITY BY HOUSEHOLD WITHOUT LEISURE,

HSDSUM(H),

ADSUM(H),

LEISUM(H),

QKSH0(K,H),

CONSUMPTION0(H),

INVESTMENT0(H),

WORKSUM(H);

QKSH0(K,H) = SAM(H,"KAP");

CONSUMPTION0(H) = SUM(NED,QADH0(NED,H));

INVESTMENT0(H) = SUM(K,QKSH0(K,H));

TCOPIT0(H)= SAM("COPIT",H)/(CONSUMPTION0(H));

TUSPIT0(H)= SAM("USPIT",H)/(CONSUMPTION0(H));

THFEE0(H) = SAM("FEES",H)/(SUM(IP,QADH0(IP,H)));

HSDSUM(H) = SUM(HD,QHSDH0(HD,H))*(1+TKH0(H));

LEISUM(H) = SUM(L,QDLEI0(L,H));

WORKSUM(H) = SUM(L,WORK1(L,H));

DISPLAY QDLEI0, QADH0, QHSDH0, HSDSUM, LEISUM, WORKSUM, TUSPIT0, TCOPIT0, CONSUMPTION0, INVESTMENT0;

```
PARAMETER    QGC0(FG)  GOVERNMENT CONSUMPTION,
*GOVERNMENT OUTPUT CALCULATED WITHOUT TAX EXPENDITURES
            QLDG0(L,FG),
            QADG0(JP,FG),
            QGCDG0(FG),
            QFXDG0;
 QGC0(FG) = (SUM(Z,SAM(Z,FG))-(SAM("SUBS",FG)));
 QLDG0(L,FG) = SAM(L,FG);
 QADG0(JP,FG) = SAM(JP,FG);
 QGCDG0(FG) = SUM(Z,SAM(Z,FG));
 QFXDG0 = SUM(Z,SAM("FED",Z))-(SAM("FED","ROW"))-(SAM("SUBS","FED"));
DISPLAY QGC0, QLDG0, QADG0, QGCDG0, QFXDG0;
PARAMETER      QY0(I)   DOMESTIC PRODUCTION OF GOODS AND SERVICES FOR
DOMESTIC CONSUMPTION,
            QE0(IP)  DOMESTIC PRODUCTION OF GOODS AND SERVICES FOR EXPORT,
            QLDY0(L,I)  LABOR DEMAND FOR PRODUCTION OF GOODS AND SERVICES,
            QLADY0(I)   LAND DEMAND FOR PRODUCTION OF GOODS AND SERVICES,
            QKIDY0(K,I)      COMMERCIAL  AND  INDUSTRIAL  CAPITAL  DEMAND  FOR
PRODUCTION OF GOODS AND SERVICES,
            QADY0(JP,I)  INTERMEDIATE GOODS DEMAND FOR PRODUCTION,
            TCORP0(I) CORPORATE INCOME TAX,
            TCFEE0(I)  FEES PAID BY BUSINESS;
 QE0(IP) = SAM(IP,"ROW");
```

```
 QLDY0(L,IP) = SAM(L,IP);
 QKIDY0(K,IP) = SAM(K,IP);
 QADY0(JP,IP) = SAM(JP,IP);
 QY0(IP) = SUM(Z,SAM(IP,Z))-SAM("ROW",IP)-SAM("LOCSTX",IP)-SAM("COSTX",IP);
 TCORP0(IP) = SAM("CORPTAX",IP)/QY0(IP);
 TCFEE0(IP) = SAM("FEES",IP)/QY0(IP);
DISPLAY QY0, QE0, QLDY0, QKIDY0, QADY0;
PARAMETER     QHS0(HD) PRODUCTION OF IMPUTED HOUSING SERVICES,
              QLADHS0(HD) LAND DEMAND FOR HOUSING SERVICES,
              QKHDHS0(K,HD) CAPITAL DEMAND FOR HOUSING SERVICES,
              QADHS0(JP,HD) INTERMEDIATE GOODS DEMAND FOR HOUSING SERVICES;
 QHS0(HD) = SUM(Z,SAM(Z,HD));
 QKHDHS0(K,HD) = SAM(K,HD);
 QADHS0(JP,HD) = SAM(JP,HD);
DISPLAY QHS0, QKHDHS0, QADHS0;
PARAMETER     QA0(IP)  PRODUCTION OF ARMINGTON AGGREGATES,
              QMDA0(IP) IMPORTS FOR AGGREGATION,
              QYDA0(IP) DOMESTIC OUTPUT FOR AGGREGATION,
              TLV0(I) LOCAL SALES TAXES,
              TSV0(I) STATE SALES TAXES;
 QMDA0(IP) = SAM("ROW",IP);
 QYDA0(IP) = QY0(IP)-QE0(IP);
 QA0(IP) = QMDA0(IP)+QYDA0(IP)+SAM("LOCSTX",IP)+SAM("COSTX",IP);
```

```
 TLV0(IP) = SAM("LOCSTX",IP)/(QA0(IP));
 TSV0(IP) = SAM("COSTX",IP)/(QA0(IP));
DISPLAY QA0, QMDA0, QYDA0;
PARAMETER    QKI0   COMMERCIAL CAPITAL,
             QKH0   RESIDENTIAL CAPITAL,
             QKDK0  DEMAND FOR INVESTMENT CAPITAL;
 QKI0 = SUM(K,SUM(IP,SAM(K,IP)));
 QKH0 = SUM(K,SUM(HD,SAM(K,HD)));
 QKDK0 = SUM(K,SUM(I,SAM(K,I)));
DISPLAY QKI0, QKH0, QKDK0;
PARAMETER
             QLEISSH0(L,H) ENDOWMENT OF LEISURE OR LABOR BY DOMESTIC
HOUSEHOLDS,
             LEISSUMSUP(H) TOTAL ENDOWMENT OF LEISURE OR LABOR BY
HOUSEHOLDS,
             QREMSH0(H) ENDOWMENT OF REMITTANCES BY DOMESTIC
HOUSEHOLDS,
             QSOCSH0(H) ENDOWMENT OF EXOGENOUS GOVERNMENT TRANSFERS BY
DOMESTIC HOUSEHOLDS,
             HH0(H) NUMBER OF HOUSEHOLDS,
             QK0 CAPITAL STOCK,
             QKAP0(K) CAPITAL STOCK BY TYPE,
             KPROP(H),
```

```
            KPROPF,
            SPEND(FSL)  GOVERNMENT SPENDING PROPORTIONS;
 SPEND(FSL) = SUM(Z,SAM(Z,FSL));
 QLEISSH0(L,H) = WORK1(L,H)*2;
 LEISSUMSUP(H) = SUM(L,QLEISSH0(L,H));
 QREMSH0(H) = SAM(H,"ROW");
 QSOCSH0(H) = SUM(GY,SAM(H,GY));
 HH0(H) = 1;
 QK0 = (SUM(K,(SUM(H,QKSH0(K,H))))+(sum(K,QKSF0(K))));
 QKAP0(K) = ((SUM(H,QKSH0(K,H)))+QKSF0(K));
 KPROP(H) = (sum(K,QKSH0(K,H)))/QK0;
 KPROPF = -SUM(K,SAM(K,"ROW"))/QK0;
DISPLAY QKSH0, LEISSUMSUP, QLEISSH0, QREMSH0, QSOCSH0, KPROP, KPROPF,
SPEND;
PARAMETER
        TOTKAP(K),
        KAPPER(K),
        DEPRECIATION(K),
        QKENDOW0(K);
 TOTKAP(K)=(SUM(Z,SAM(K,Z))-SAM(K,"ROW"));
 KAPPER(K)=TOTKAP(K)/QK0;
 QKENDOW0(K) = QKSF0(K)+SUM(H,QKSH0(K,H));
 DEPRECIATION(K) = DEPRECIATE(K)*QKENDOW0(K);
```

```
DISPLAY TOTKAP, KAPPER, QKENDOW0,QKIDY0, DEPRECIATION;

VARIABLES BOP  BALANCE OF PAYMENTS;

PARAMETER PRODU  PRODUCTIVITY PARAMETER;

PRODU = 1;

DISPLAY QKSH0, INVESOUT0, INVESD9;

SET T /1*10/;

SET TNOTFIRST(T) /2*10/;

SET TFIRST(T)

   TLAST(T);

TFIRST(T) = YES$(ORD(T) EQ 1);

TLAST(T)  =YES$(ORD(T) EQ CARD(T));

SCALAR          GRO     FIVE YEAR GROWTH RATE    /0.077284/

             REN     INTEREST RATE  /0.015/

             TFPGRO  TOTAL FACTOR PRODUCTIVITY GROWTH RATE /0/

             DEL     ANNUAL DEPRECIATION RATE     /0.0205225

PARAMETER       QREF(T) REFERENCE QUANTITY PATH,

             IREF(T) REFERENCE INVESTMENT PATH,

             PREF(T) REFERENCE PRICE PATH,

             SHOCK(T) shock to sector of interest,

             SHOCK2  second shock to sector,

             SHOCK3(K),

             TOTALDEP,

             DEMCH(T),
```

newpk0(k),

kapprop(k,ip),

imdkapprop(k,ip),

newkapsum(ip),

newkapprop(k,ip),

newkapspend(k,ip),

newqkidy0(k,ip),

NEWQKIDG0(K,FG),

newkapdemand(k),

newtotkap,

newkapper(k),

newtotaldep,

kdemsum(ip),

hkdemsum(hd),

hkapprop(k,hd),

himdkapprop(k,hd),

hnewkapsum(hd),

hnewkapprop(k,hd),

hnewkapspend(k,hd),

hnewqkhdhs0(k,hd),

hnewkapdemand(k),

necessaryi(k),

necessaryi1,

necessaryi2,

newqksh0(k,h),

newqksf0(k),

sumispend,

sumkown(k),

ishareh(ip,k,h),

isharef(ip,k),

kshareh(k,h),

ksharef(k),

vacrate(k),

kscalar(k),

vacscalar(k),

DIFFK(K),

sumkendow(k),

kproph1(k,h),

kendow1(k,h),

krev(h),

oldkrev(h),

newkstock(k),

oldkbill(ip),

newkbill(ip),

oldfork,

newfork,

```
        dollval(k),
        newrpbill(ip),
        tki1(ip),
        newqkidy1(rp,ip,t),
        kapproph(h,t),
        kapropf(t),
        TFP(t),
        newkappersum;
QREF(T) = (1+GRO)**(ORD(T)-1);
TFP(T) = (1+TFPGRO)**(ORD(T)-1);
IREF(T) = (1+GRO)**(ORD(T));
PREF(T) = (1/(1+REN))**(ORD(T)-1);
SHOCK(T)=EPS;
SHOCK2=0;
SHOCK3(K)=0;
TOTALDEP = SUM(K,(KAPPER(K)*DEPRECIATE(K)));
newpk0(k)= (depreciate(k)+gro)*10 ;
kdemsum(ip) = sum(k,qkidy0(k,ip));
kapprop(k,ip) = qkidy0(k,ip)/(kdemsum(ip));
imdkapprop(k,ip) = newpk0(k)*kapprop(k,ip);
newkapsum(ip) = sum(k,imdkapprop(k,ip));
newkapprop(k,ip) = imdkapprop(k,ip)/newkapsum(ip);
newkapspend(k,ip) = kdemsum(ip)*newkapprop(k,ip);
```

```
newqkidy0(k,ip) = newkapspend(k,ip)/newpk0(k);

NEWQKIDG0(K,FG) = SAM("KAP",FG);

newqkidy1(rp,ip,t) = newqkidy0(rp,ip);

newkapdemand(k) = sum(ip,newqkidy0(k,ip));

hkdemsum(hd) = sum(k,qkhdhs0(k,hd));

hkapprop(k,hd) = qkhdhs0(k,hd)/hkdemsum(hd);

himdkapprop(k,hd) = newpk0(k)*hkapprop(k,hd);

hnewkapsum(hd) = sum(k,himdkapprop(k,hd));

hnewkapprop(k,hd) = himdkapprop(k,hd)/hnewkapsum(hd);

hnewkapspend(k,hd) = hkdemsum(hd)*hnewkapprop(k,hd);

hnewqkhdhs0(k,hd) = hnewkapspend(k,hd)/newpk0(k);

hnewkapdemand(k) = sum(hd,hnewqkhdhs0(k,hd));

newtotkap = sum(k,newkapdemand(k))+sum(k,hnewkapdemand(k));

newkstock(k) = newkapdemand(k)+hnewkapdemand(k);

newkapper(k) = (newkapdemand(k)+hnewkapdemand(k))/newtotkap;

newkappersum = sum(k,newkapper(k));

newtotaldep = sum(k,(newkapper(k)*depreciate(k)));

necessaryi(k) = (newkapdemand(k)+hnewkapdemand(k))*(depreciate(k)+gro)*10;

necessaryi1 = sum(k,necessaryi(k));

necessaryi2 = necessaryi1/(1+gro);

**** changes to capital endowments to reflect the above

sumkendow(k) = sum(h,qksh0(k,h))+qksf0(k);

kproph1(k,h) = qksh0(k,h)/sumkendow(k);
```

```
kendow1(k,h) = kproph1(k,h)*(newkapdemand(k)+hnewkapdemand(k));

krev(h) = sum(k,(newpk0(k)*kendow1(k,h)));

oldkrev(h) = sum(k,qksh0(k,h));

newQKSH0(K,H) = kendow1(k,h);

newQKSF0(K) = newkstock(k)-sum(h,kendow1(k,h));

sumispend = sum(ip,invd0(ip));

sumkown(k) = sum(h,(newqksh0(k,h)))+newqksf0(k);

ishareh(ip,k,h) = (invd0(ip)/sumispend)*(newqksh0(k,h)/newkstock(k));

isharef(ip,k) = (invd0(ip)/sumispend)*(newqksf0(k)/newkstock(k));

kshareh(k,h) = newqksh0(k,h)/newkstock(k);

ksharef(k) = newqksf0(k)/newkstock(k);

VACRATE(K) = 0.1615385;

kscalar(k) = 1/(1-vacrate(k));

vacscalar(k) = vacrate(k)/(1-vacrate(k));

DIFFK(K) = SUMKOWN(K)-NEWKAPDEMAND(K)-HNEWKAPDEMAND(K);

oldkbill(ip) = sum(k,(qkidy0(k,ip)));

newkbill(ip) = sum(k,(newqkidy0(k,ip)*newpk0(k)));

newrpbill(ip) = sum(rp,(newqkidy0(rp,ip)*newpk0(rp)));

oldfork = sum(k,qksf0(k));

newfork = sum(k,(newqksf0(k)*newpk0(k)));

dollval(k) = newpk0(k)*newkstock(k);

tki1(ip) = sam("CNPRP",ip)/(newrpbill(ip));

kapproph(h,t) = sum(k,newqksh0(k,h))/sum(k,newkstock(k));
```

```
kappropf(t) = sum(k,newqksf0(k))/sum(k,newkstock(k));

PARAMETER TKI0(I)   PROPERTY TAXES ON COMMERCIAL CAPITAL,

        IELAS(K)  ELASTICITY OF INVESTMENT SUPPLY,

        TOTRP(IP) TOTAL REAL PROPERTY USE BY SECTOR;

 TKI0(IP)=SAM("CNPRP",IP)/(sum(RP,SAM(RP,IP)));

        IELAS(K) = 5;

        TOTRP(IP) = SUM(RP,newQKIDY0(RP,IP));

DISPLAY TOTRP, newqkidy0, NEWQKIDG0,hnewQKHDHS0;

PARAMETER QSAVING0(H)   HOUSEHOLD SAVINGS,

        BASEINV(K),

        BASEI(K,H),

        BASEKUSING1(RP),

        BASEKUSEPROP(RP,IP),

        BASEKUSEL(RP),

        TOTED0,

        EDPER(H),

        OUTOFSTATE(HED,H),

        COINREV;

* AMOUNT OF DOMESTIC SAVINGS

 TOTED0 = SUM(H,SAM("STATEUG",H));

 EDPER(H) = SAM("STATEUG",H)/TOTED0;

 OUTOFSTATE(HED,H) = SAM("ROW",HED)*EDPER(H);

 QSAVING0(H) = INVESD9(H)-INVESOUT0(H);
```

```
TCOPIT1(H)= SAM("COPIT",H)/(SUM(NED,QADH0(NED,H))+QSAVING0(H));
 TUSPIT1(H)= SAM("USPIT",H)/(SUM(NED,QADH0(NED,H))+QSAVING0(H));
*                                        QW1(H)                                        =
((SUM(HD,QHSDH0(HD,H)))*(1+TKH0(H)))+((SUM(NED,QADH0(NED,H)))*(1+TUSPIT1(
H)+TCOPIT1(H)+THFEE0(H)))+(SUM(HED,QADH0(HED,H)*(1+EDSUB0(HED)))))+SUM(
HED,OUTOFSTATE(HED,H));
 QW1(H)                                                                                =
((SUM(HD,QHSDH0(HD,H)))*(1+TKH0(H)))+((SUM(NED,QADH0(NED,H)))*(1+TUSPIT1(
H)+TCOPIT1(H)+THFEE0(H)));
 COINREV = SUM(H,(TCOPIT1(H)*QSAVING0(H)));
 BASEINV(K)       = SUMKOWN(K)*(GRO+DEPRECIATE(K))*10;
 BASEI(K,H) = BASEINV(K)*kshareh(K,H);
 ADSUM(H)                                                                              =
SUM(NED,QADH0(NED,H))*(1+TUSPIT0(H)+TCOPIT0(H)+THFEE0(H))+SUM(HED,QAD
H0(HED,H)*(1+EDSUB(HED)))+SUM(HED,OUTOFSTATE(HED,H));
DISPLAY QSAVING0,tuspit1, TCOPIT1, TOTALDEP, newtotaldep, newkappersum,
necessaryi1, necessaryi2, invesd3, ishareh, DIFFK, krev, oldkrev, oldkbill, newkbill, oldfork,
newfork, dollval, newkstock, newpk0, tuspit1, edsub;
PARAMETER DEM(K,IP,T) DEMAND SCALAR FOR COMMERCIAL PROPERTY
USAGE,
        basekusing(ip),
        BASEKUSEPROP1(RP,IP),
        BASEKUSEL1(RP),
```

KRATL1(RP),

KRATK(RP) RATIO OF CAPITAL STOCK FOR EACH TYPE TO OFFICE STOCK,

PRODSHOCK(IP,T) PRODUCTIVITY SHOCK,

POPGRO0(PEEPS,T),

POP1(PEEPS,T),

SKILLSB(LAB,PEEPS,T),

SKILLS0(LAB,PEEPS,T),

MELAS MIGRATION ELASTICITY PARAMETER,

KRATL(RP) RATIO OF "CAPITAL USING LABOR" FOR EACH TYPE TO OFFICE LABOR;

DEM(K,IP,T)$SAM(K,IP) = SAM(K,IP)/SAM(K,IP);

BASEKUSING1(RP) = SUM(IP,newQKIDY0(RP,IP));

BASEKUSING(IP) = SUM(RP,newQKIDY0(RP,IP));

BASEKUSEPROP(RP,IP)$BASEKUSING(IP) = (newQKIDY0(RP,IP))/BASEKUSING(IP);

BASEKUSEPROP1(RP,IP) = NEWQKIDY0(RP,IP)/BASEKUSING1(RP);

BASEKUSEL(RP) = sum(ip,sum(l,QLDY0(L,IP))*BASEKUSEPROP(RP,IP));

BASEKUSEL1(RP) = SUM(PRIVS,SUM(L,QLDY0(L,PRIVS))*BASEKUSEPROP1(RP,PRIVS));

PRODSHOCK(IP,T) = 1;

POPGRO0(PEEPS,T) = 0 + (SUM(H,(0.030309165*MIGPROP1(H)*POPRATIO(H,PEEPS)*TOTPOP0(PEEPS))))$TNOTFIRST(T);

POP1(PEEPS,T) = TOTPOP0(PEEPS)+POPGRO0(PEEPS,T);

```
 MELAS = 0.5;
 SKILLSB(LAB,PEEPS,T) =
TOTALEDAGEWORKING(LAB,PEEPS)*((1+0.030309165)**(ORD(T)-1));
 SKILLS0(LAB,PEEPS,T) =
(1+0.030309165$TNOTFIRST(T))*(TOTALEDAGEWORKING(LAB,PEEPS)$TFIRST(T)
                     + (214600.4*UGPROP(PEEPS-1))*1$BA(LAB)$UGPROP(PEEPS-1)
                     - (214600.4*UGPROP(PEEPS-1))*1$GED(LAB)$UGPROP(PEEPS-1)
                     + (38259.6*GPROP(PEEPS-1))*1$PHD(LAB)$GPROP(PEEPS-1)
                     - (38259.6*GPROP(PEEPS-1))*1$BA(LAB)$GPROP(PEEPS-1)
                     + NEWB(LAB)*0.66*POP1(PEEPS,T-1)$TEEN(PEEPS)
                     + PARTICIPATION(PEEPS)*SKILLSB(LAB,PEEPS-1,T-
1)$TNOTFIRST(T)
                     + PARTICIPATION("15")*SKILLSB(LAB,"15",T-
1)$ELDERLY(PEEPS));
DISPLAY basekusing, basekuseprop1, basekusel1;
$ONTEXT
$MODEL: COLORADO
$COMMODITIES:
P_L(L,T)          !    WAGE INDEX
P_K(K,T)          !    FINANCIAL CAPITAL RETURN INDEX
P_W(H,T)          !    WELFARE PRICE INDEX
P_GC(FG,T)        !    GOVERNMENT CONSUMPTION PRICE
P_A(NED,T)        !    ARMINGTON AGGREGATE PRICE
```

P_Y(IP,T) ! SECTORAL PRODUCTION PRICE

P_H(HD,T) ! HOUSING PRICE

P_FX(T) ! PRICE OF FOREIGN EXCHANGE

P_INS(T) ! PRICE OF INSURANCE

P_FOR(IP,T)$QMDA0(IP)

$SECTORS:

A_GOVT(FG,T) ! GOVERNMENT EXPENDITURE

A_YARM(NED,T) ! PRODUCTION OF ARMINGTON AGGREGATES

A_W(H,T) ! WELFARE INDEX

A_Y(IP,T) ! SECTORAL PRODUCTION

A_H(HD,T) ! HOUSING SERVICES

A_INS(T) ! PRODUCTION OF INSURANCE

$CONSUMERS:

I_GOVT0(T) ! STATE AND LOCAL GOVERNMENT REVENUE

I_GOVT1(T)

I_GOVT2(T)

I_GOVT3(T)

I_GOVT4(T)

I_GOVT5(T)

LOC_GOVT1(T)

LOC_GOVT2(T)

LOC_GOVT3(T)

F_GOVT(T) ! FEDERAL GOVERNMENT REVENUE

RA(H,T) ! HOUSEHOLD INCOME

RAF(T) ! OUT-OF-STATE HOLDERS OF LAND AND CAPITAL

IMPACT(T)

IMPACT_2(T)

EXPORTS(IP,T)

IMPORTS(IP,T)$QMDA0(IP)

MEDICAID(T)

MEDICARE(T)

$AUXILIARY:

CCI(T) ! CONSTRUCTION COST INDEX

MIG(L,H,T) ! ENDOGENOUS MIGRATION

LSUP(LAB,H,T) ! ENDOGENOUS LABOR SUPPLY

HKSUP(HUMANK,H,T)$HKPAYMENTS0(H,HUMANK) ! ENDOGENOUS HUMAN CAPITAL SUPPLY

INVEST(K,T) ! ENDOGENOUS INVESTMENT

OWN(K,T) ! DESIRE TO OWN CAPITAL

EXPDEM(IP,T) ! DEMAND FOR EXPORTS

COSAVINGSTAX(T) ! COLORADO INCOME TAX ON SAVINGS

SAVING(H,T) ! ENDOGENOUS SAVINGS WITH CONSTANT SAVINGS RATE

IMPSUP(IP,T)$QMDA0(IP) ! SUPPLY OF IMPORTS

EMPLOYHEALTH(T) ! EMPLOYER HEALTH BENEFITS

HCOST(T) ! HEALTH CARE COST INDEX

POP(PEEPS,T) ! TOTAL POPULATION BY AGE GROUP

BABIES(T) ! TOTAL FERTILITY

HPOP(PEEPS,H,T) ! TOTAL POPULATION BY AGE AND HOUSEHOLD GROUP

SKILLS(LAB,PEEPS,T) ! TOTAL LABOR SUPPLY BY AGE GROUP

KSKILLS(HUMANK,PEEPS,T) ! TOTAL HUMAN CAPITAL SUPPLY BY AGE GROUP

HSKILLS(LAB,PEEPS,H,T) ! TOTAL LABOR SUPPLY BY AGE AND HOUSEHOLD GROUP

HKSKILLS(HUMANK,PEEPS,H,T) ! TOTAL HUMAN CAPITAL SUPPLY BY AGE AND HOUSEHOLD GROUP

BACHDEGREE(T) ! NUMBER OF BACHELORS DEGREES AWARDED

GRADDEGREE(T) ! NUMBER OF GRADUATE DEGREES AWARDED

NEWBA(PEEPS,T)$UGPROP(PEEPS) ! NEW BACHELORS DEGREE INDEX, BY AGE GROUP

NEWPHD(PEEPS,T)$GPROP(PEEPS) ! NEW GRADUATE DEGREE INDEX, BY AGE GROUP

BASELSUP(LAB,H,T) ! BASE LABOR SUPPLY, AFTER MIGRATION AND DEMOGRAPHIC SHIFTS

BASEHKSUP(HUMANK,H,T)$HKPAYMENTS0(H,HUMANK) ! BASE HUMAN CAPITAL SUPPLY, AFTER MIGRATION AND DEMOGRAPHIC SHIFTS

HMEMBERS(H,T) ! INDEX OF TOTAL POPULATION IN EACH HOUSEHOLD GROUP

WORKMIG(L,T) ! LABOR NET MIGRATION

POPMIG(PEEPS,T) ! POPULATION NET MIGRATION

HMIG(H,T) ! HOUSEHOLD NET MIGRATION

EDDEMAND1(H,T)

EDDEMAND2(H,T)

EDDEMAND3(H,T)

EDDEMAND4(H,T)

EDDEMAND5(H,T)

EDDEMAND6(H,T)

EDDEMAND7(H,T)

EDDEMAND8(H,T)

STATEUGSUBS(H,T)

STATEGSUBS(H,T)

EDSUBBILL(T)

$PROD:A_W(H,T) s:2

* Welfare produced using leisure, goods and services

O: P_W(H,T) Q: QW1(H)

* Income taxes proportional to factor use to generate HH specific welfare indices

I: P_A(NED,T) Q: QADH0(NED,H) P: (1+TCOPIT1(H)+TUSPIT1(H)+THFEE0(H)) A: I_GOVT1(T) T: TCOPIT1(H) A: F_GOVT(T) T: TUSPIT1(H) A: I_GOVT2(T) T: THFEE0(H)

*I: P_Y(HED,T) Q: QADH0(HED,H) P: (1+EDSUB(HED)) A: I_GOVT5(T) T: EDSUB(HED)

*I: P_FOR(HED,T) Q: OUTOFSTATE(HED,H)

I: P_H(HD,T) Q: QHSDH0(HD,H) P: (1+TKH0(H)) A: LOC_GOVT2(T) T: TKH0(H)

$PROD:A_GOVT(FG,T) s:2   int:0

*Production of government services

O: P_GC(FG,T)   Q: (TFP(T)*QGC0(FG))

I: P_L(L,T)   Q: QLDG0(L,FG) P: (1+TLDG0(FG)) A: F_GOVT(T) T: TLDG0(FG)

I: P_K(K,T)   Q: NEWQKIDG0(K,FG)

I: P_FX(T)   Q: SAM("PENFUND",FG)

I: P_INS(T)   Q: SAM("HINS",FG)

I: P_A(JP,T)   Q: QADG0(JP,FG)   int:

$PROD:A_Y(NED,T)   s:2

*Domestic production of goods and services

*kl nest to reflect Raval (2011) complementarity between capital and labor

O: P_Y(NED,T)   Q: (TFP(T)*PRODU*QY0(NED))   P: (1-TCORP0(NED)-TCFEE0(NED)) A: I_GOVT3(T) T: TCORP0(NED) A: I_GOVT2(T) T: TCFEE0(NED)

I: P_L(L,T)   Q: QLDY0(L,NED) P: (1+TLDI0(NED)) A: F_GOVT(T) T: TLDI0(NED)

I: P_FX(T)   Q: SAM("PENFUND",NED)

I: P_INS(T)   Q: SAM("HINS",NED)

I: P_K(K,T)   Q: (DEM(K,NED,T)*QKIDY0(K,NED)) P: ((1+TKI1(NED))) A: LOC_GOVT1(T) T: TKI1(NED)

I: P_A(JP,T)   Q: QADY0(JP,NED)

$PROD:A_Y(HED,T)   s:2

*Domestic production of goods and services

*kl nest to reflect Raval (2011) complementarity between capital and labor

O: P_Y(HED,T) Q: (TFP(T)*PRODU*QY0(HED)) P: (1-TCORP0(HED)-TCFEE0(HED)) A: I_GOVT3(T) T: TCORP0(HED) A: I_GOVT2(T) T: TCFEE0(HED)

I: P_L(L,T) Q: QLDY0(L,HED) P: (1+TLDI0(HED)) A: F_GOVT(T) T: TLDI0(HED)

I: P_FX(T) Q: SAM("PENFUND",HED)

I: P_INS(T) Q: SAM("HINS",HED)

I: P_K(K,T) Q: (DEM(K,HED,T)*QKIDY0(K,HED)) P: (1+TKI1(HED)) A: LOC_GOVT1(T) T: TKI1(HED)

I: P_A(JP,T) Q: QADY0(JP,HED)

$PROD:A_H(HD,T) s:0

*Domestic production of housing services

O: P_H(HD,T) Q: (TFP(T)*QHS0(HD))

I: P_K(K,T) Q: QKHDHS0(K,HD) P: 1

I: P_A(JP,T) Q: QADHS0(JP,HD)

$PROD:A_YARM(NED,T) s:0

*Production of Armington aggregates using imports

O: P_A(NED,T) Q: QA0(NED) P: (1-TSV0(NED)-TLV0(NED)) A: I_GOVT4(T) T: TSV0(NED) A: LOC_GOVT3(T) T: TLV0(NED)

I: P_FOR(NED,T) Q: QMDA0(NED)

I: P_Y(NED,T) Q: (QY0(NED)-QE0(NED))

$PROD:A_INS(T)

O: P_INS(T) Q: (SUM(IG,SAM("HINS",IG)))

I: P_A("HEALTHCARE",T) Q: (SUM(IG,SAM("HINS",IG)))

$DEMAND:IMPORTS(IP,T)$QMDA0(IP)

D: P_FX(T)   Q: 1

E: P_FOR(IP,T)$QMDA0(IP)   Q: (QMDA0(IP)*QREF(T)) R: IMPSUP(IP,T)

$DEMAND:EXPORTS(IP,T)

*Export demand as independent block - no substitution between exports BUT each is given a -1.0 price elasticity via EXPDEM

D: P_Y(IP,T)   Q: QE0(IP)

E: P_FX(T)   Q: (QE0(IP)*QREF(T)) R: EXPDEM(IP,T)

$DEMAND:MEDICAID(T)

D: P_A("HEALTHCARE",T) Q: SAM("MEDICAID","ROW")

E: P_FX(T)   Q: SAM("MEDICAID","ROW")   R: HCOST(T)

$DEMAND:MEDICARE(T)

D: P_A("HEALTHCARE",T) Q: SAM("MEDICARE","ROW")

E: P_FX(T)   Q: SAM("MEDICARE","ROW")   R: HCOST(T)

$DEMAND:RA(H,T)

* Utility Maximization

D: P_W(H,T)   Q: (QW1(H)*QREF(T))

* Time Endowment (used to generate Labor and Leisure)

E: P_L(LAB,T)$WORK(LAB,H)   Q: (QLABSUP0(LAB,H))   R: LSUP(LAB,H,T)

E: P_FX(T)   Q: -QFICA("L1",H)   R: LSUP("L1",H,T)

E: P_FX(T)   Q: -QFICA("L2",H)   R: LSUP("L2",H,T)

E: P_FX(T)   Q: -QFICA("L3",H)   R: LSUP("L3",H,T)

* Human Capital Endowment

E: P_L(HUMANK,T)$WORK(HUMANK,H) Q: (QLABSUP0(HUMANK,H)) R: HKSUP(HUMANK,H,T)

E: P_FX(T) Q: -QFICA("HK1",H) R: HKSUP("HK1",H,T)

E: P_FX(T) Q: -QFICA("HK2",H) R: HKSUP("HK2",H,T)

E: P_FX(T) Q: -QFICA("HK3",H) R: HKSUP("HK3",H,T)

* Remittances

E: P_FX(T) Q: (QREMSH0(H)) R:HMEMBERS(H,T)

* Pension Fund

E: P_FX(T) Q: (SAM(H,"PENFUND")) R:HMEMBERS(H,T)

* Employer-based Health Insurance Coverage

E: P_A("HealthCare",T) Q: SAM("EMPHI",H) R: EMPLOYHEALTH(T)

* Medicaid

E: P_A("HealthCare",T) Q: SAM("POHI",H) R:HMEMBERS(H,T)

* Medicare

E: P_A("HealthCare",T) Q: SAM("OLHI",H) R:HMEMBERS(H,T)

* Outflow of savings

E: P_FX(T) Q: (-QSAVING0(H)*QREF(T)) R: SAVING(H,T)

* US income taxes on savings outflows

E: P_FX(T) Q: (-TUSPIT1(H)*QSAVING0(H)*QREF(T)) R: SAVING(H,T)

* CO income taxes on savings outflows

E: P_FX(T) Q: (-TCOPIT1(H)*QSAVING0(H)*QREF(T)) R: SAVING(H,T)

* Social Security Payments

E: P_FX(T) Q: (QSOCSH0(H)) R:HMEMBERS(H,T)

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*  Per Period Capital Endowment

E: P_K(K,T)          Q: QKSH0(k,h)    R: OWN(K,T)

*  Borrowing to finance baseline investment

E: P_FX(T)           Q: (0.355225*SUM(K,QKSH0(K,H))*QREF(T))  R:INVEST("KAP",T)

*  Capital supply shocks for simulations

*E: P_K(K,T)          Q: SHOCK3(K)

*  Construction/Investment Spending

E: P_A(IP,T)         Q: (-KPROP(H)*INVD0(IP))   R: INVEST("KAP",T)

*  Higher Education Spending

E: P_Y("STATEUG",T)      Q: -QADH0("STATEUG",H)        R: EDDEMAND1(H,T)

E: P_Y("STATEG",T)       Q: -QADH0("STATEG",H)         R: EDDEMAND2(H,T)

E: P_Y("PRIVATEUG",T)    Q: -QADH0("PRIVATEUG",H)      R: EDDEMAND3(H,T)

E: P_Y("PRIVATEG",T)     Q: -QADH0("PRIVATEG",H)       R: EDDEMAND4(H,T)

E: P_FOR("STATEUG",T)    Q: -OUTOFSTATE("STATEUG",H)    R: EDDEMAND7(H,T)

E: P_FOR("STATEG",T)     Q: -OUTOFSTATE("STATEG",H)     R: EDDEMAND8(H,T)

E: P_FOR("PRIVATEUG",T)  Q: -OUTOFSTATE("PRIVATEUG",H)  R: EDDEMAND5(H,T)

E: P_FOR("PRIVATEG",T)   Q: -OUTOFSTATE("PRIVATEG",H)   R: EDDEMAND6(H,T)

E: P_FX(T)               Q: QADH0("STATEUG",H)         R: STATEUGSUBS(H,T)

E: P_FX(T)               Q: QADH0("STATEG",H)          R: STATEGSUBS(H,T)

$DEMAND:RAF(T)

*  Demand for "foreign exchange"

D: P_FX(T)            Q: (KLAOUT0*QREF(T))

*  Out-of-state ownership of capital
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E: P_K(K,T)         Q: QKSF0(k)    R: OWN(K,T)

*  Construction/Investment Spending

E: P_A(IP,T)        Q: (-KPROPF*INVD0(IP))   R: INVEST("KAP",T)

$DEMAND:IMPACT_2(T)

D: P_FX(T)          Q: 1

E: P_K(K,T)         Q: SHOCK3(K)

$DEMAND:IMPACT(T)

D: P_Y("Const",T)    Q: 1

E: P_FX(T)          Q: SHOCK(T)

$DEMAND:I_GOVT0(T)

D: P_GC("FED",T)     Q: (FEDPROD0*QREF(T))

E: P_FX(T)           Q: (FEDPROD0*QREF(T))

$DEMAND:I_GOVT1(T)

*COLORADO PERSONAL INCOME TAX

D: P_GC(FSL,T)       Q: (SPEND(FSL)*QREF(T))

E: P_FX(T)          Q: (COINREV)  R: COSAVINGSTAX(T)

$DEMAND:I_GOVT2(T)

*COLORADO GOVERNMENT FEES-FOR-SERVICE

D: P_GC(FSL,T)       Q: (SPEND(FSL)*QREF(T))

$DEMAND:I_GOVT3(T)

*COLORADO CORPORATE INCOME TAX

D: P_GC(FSL,T)       Q: (SPEND(FSL)*QREF(T))

$DEMAND:I_GOVT4(T)
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*COLORADO SALES TAX
D: P_GC(FSL,T)      Q: (SPEND(FSL)*QREF(T))
$DEMAND:I_GOVT5(T)
* TRANSFERS FROM THE FEDERAL GOVERNMENT
D: P_GC(FSL,T)      Q: (SPEND(FSL)*QREF(T))
E: P_FX(T)          Q: (SAM("CYGF","ROW")*QREF(T))
E: P_FX(T)          Q: -537.99516          R: EDSUBBILL(T)
$DEMAND:LOC_GOVT1(T)
*BUSINESS PROPERTY TAX
D: P_GC(FSL,T)      Q: (SPEND(FSL)*QREF(T))
$DEMAND:LOC_GOVT2(T)
*RESIDENTIAL PROPERTY TAX
D: P_GC(FSL,T)      Q: (SPEND(FSL)*QREF(T))
$DEMAND:LOC_GOVT3(T)
*LOCAL SALES TAX
D: P_GC(FSL,T)      Q: (SPEND(FSL)*QREF(T))
$DEMAND:F_GOVT(T)
D: P_FX(T)          Q: (1*QREF(T))
$REPORT:
 V: EMP1(L,IP,T)    I: P_L(L,T)  PROD:A_Y(IP,T)
 V: EMP2(L,FG,T)    I: P_L(L,T)  PROD:A_GOVT(FG,T)
 V: OUTP(IP,T)    O: P_Y(IP,T)  PROD:A_Y(IP,T)
 V: HOUTP(HD,T)   O: P_Y(HD,T)  PROD:A_Y(HD,T)
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  V: GOUTP(FG,T)   O: P_GC(FG,T)  PROD:A_GOVT(FG,T)
  V: YARMIN(IP,T)  I: P_Y(IP,T)   PROD:A_YARM(IP,T)
  V: YARMFORIN(IP,T) I: P_FOR(IP,T) PROD:A_YARM(IP,T)
  V: KINHOME(HD,T)   I: P_K("KAP",T)  PROD: A_H(HD,T)
  V: KINBUS(NED,T)  I: P_K("KAP",T)  PROD: A_Y(NED,T)
  V: KINGOV(FG,T)  I: P_K("KAP",T)  PROD: A_GOVT(FG,T)
$CONSTRAINT:BACHDEGREE(T)
        BACHDEGREE(T)  =E=  (154597.5*A_Y("STATEUG",T)  +
60002.9*A_Y("PRIVATEUG",T))/214600.4;
$CONSTRAINT:GRADDEGREE(T)
        GRADDEGREE(T)  =E=  (17177.5*A_Y("STATEG",T)  +
21082.1*A_Y("PRIVATEG",T))/38259.6;
$CONSTRAINT:NEWBA(PEEPS,T)$UGPROP(PEEPS)
        NEWBA(PEEPS,T)$UGPROP(PEEPS)  =E=
(BACHDEGREE(T)*214600.4*UGPROP(PEEPS))/(214600.4*UGPROP(PEEPS));
$CONSTRAINT:NEWPHD(PEEPS,T)$GPROP(PEEPS)
        NEWPHD(PEEPS,T)$GPROP(PEEPS)  =E=
(GRADDEGREE(T)*38259.6*GPROP(PEEPS))/(38259.6*GPROP(PEEPS));
$CONSTRAINT:BABIES(T)
        BABIES(T) =E= SUM(PEEPS,(FERTILITY(PEEPS)*POP(PEEPS,T)));
$CONSTRAINT:POP(PEEPS,T)
         POP(PEEPS,T)  =E=  POPMIG(PEEPS,T)+TOTPOP0(PEEPS)$TFIRST(T)  +  ((1-
MORTALITY(PEEPS))*POP(PEEPS-1,T-1))
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                    + ((1-MORTALITY("15"))*POP("15",T-1))$ELDERLY(PEEPS)
                    + ((1-MORTALITY("1"))$TNOTFIRST(T)*BABIES(T)$BABY(PEEPS));
$CONSTRAINT:SKILLS(LAB,PEEPS,T)
        SKILLS(LAB,PEEPS,T)                                                  =E=
(WORKMIG(LAB,T))*(TOTALEDAGEWORKING(LAB,PEEPS)$TFIRST(T)
                    +     (214600.4*BALFP(PEEPS)*UGPROP(PEEPS-1))*NEWBA(PEEPS-
1,T-1)$BA(LAB)$UGPROP(PEEPS-1)
                    -     (214600.4*BALFP(PEEPS)*UGPROP(PEEPS-1))*NEWBA(PEEPS-
1,T-1)$GED(LAB)$UGPROP(PEEPS-1)
                    +     (38259.6*PHDLFP(PEEPS)*GPROP(PEEPS-1))*NEWPHD(PEEPS-
1,T-1)$PHD(LAB)$GPROP(PEEPS-1)
                    -     (38259.6*PHDLFP(PEEPS)*GPROP(PEEPS-1))*NEWPHD(PEEPS-
1,T-1)$BA(LAB)$GPROP(PEEPS-1)
                    + NEWB(LAB)*0.66*POP(PEEPS,T-1)$TEEN(PEEPS)
                    +                PARTICIPATION(PEEPS)*SKILLS(LAB,PEEPS-1,T-
1)$TNOTFIRST(T)
                    + PARTICIPATION("15")*SKILLS(LAB,"15",T-1)$ELDERLY(PEEPS));
$CONSTRAINT:KSKILLS(HUMANK,PEEPS,T)
        KSKILLS(HUMANK,PEEPS,T)                                              =E=
(WORKMIG(HUMANK,T))*(TOTALAGEHK(HUMANK,PEEPS)$TFIRST(T)
                    +    KNEWB(HUMANK,PEEPS)*0.389722*0.012*SKILLS("L1",PEEPS-
1,T-1)$ADULT1(PEEPS)
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+ KNEWB(HUMANK,PEEPS)*0.495094*0.027*SKILLS("L2",PEEPS-1,T-1)$ADULT2(PEEPS)

+ KNEWB(HUMANK,PEEPS)*0.417892*0.050*SKILLS("L3",PEEPS-1,T-1)$ADULT3(PEEPS) +
EXPERIENCE(PEEPS,HUMANK)*PARTICIPATION(PEEPS)*KSKILLS(HUMANK,PEEPS-1,T-1)$TNOTFIRST(T)

+
EXPERIENCE("15",HUMANK)*PARTICIPATION("15")*KSKILLS(HUMANK,"15",T-1)$ELDERLY(PEEPS));

$CONSTRAINT:HSKILLS(LAB,PEEPS,H,T)

HSKILLS(LAB,PEEPS,H,T) =E= SKILLS(LAB,PEEPS,T)*LABORAGEHOUSE(LAB,PEEPS,H);

$CONSTRAINT:HKSKILLS(HUMANK,PEEPS,H,T)

* HKSKILLS(HUMANK,PEEPS,H,T) =E= HKPAYRATIO(H,HUMANK)*(KSKILLS(HUMANK,PEEPS,T)*HKAGEHOUSE(HUMANK,PEEPS,H));

HKSKILLS(HUMANK,PEEPS,H,T) =G= (KSKILLS(HUMANK,PEEPS,T)*HKAGEHOUSE(HUMANK,PEEPS,H));

$CONSTRAINT:HPOP(PEEPS,H,T)

HPOP(PEEPS,H,T) =E= POP(PEEPS,T)*POPRATIO(H,PEEPS);

$CONSTRAINT:CCI(T)

CCI(T) =G= sum(NED,P_A(NED,T)*(invd0(NED)/sumispend));

$CONSTRAINT:BASELSUP(LAB,H,T)

```
BASELSUP(LAB,H,T) =G=
(SUM(PEEPS,HSKILLS(LAB,PEEPS,H,T)))/LENDOWMENT(H,LAB);
$CONSTRAINT:BASEHKSUP(HUMANK,H,T)$HKPAYMENTS0(H,HUMANK)
BASEHKSUP(HUMANK,H,T)$HKPAYMENTS0(H,HUMANK) =G=
(SUM(PEEPS,HKSKILLS(HUMANK,PEEPS,H,T)))/HKPAYMENTS0(H,HUMANK);
$CONSTRAINT:HMEMBERS(H,T)
HMEMBERS(H,T) =G= (SUM(PEEPS,HPOP(PEEPS,H,T)))/TOTPOP1(H);
$CONSTRAINT:LSUP(LAB,H,T)
LSUP(LAB,H,T) =G= 0.3*BASELSUP(LAB,H,T)*((P_L(LAB,T)/P_W(H,T))-1) +
BASELSUP(LAB,H,T);
* LSUP(LAB,H,T) =E= BASELSUP(LAB,H,T);
$CONSTRAINT:HKSUP(HUMANK,H,T)$HKPAYMENTS0(H,HUMANK)
* (HKSUP(HUMANK,H,T)-1) =E= (0.3*((P_L(HUMANK,T)/P_W(H,T))-1));
HKSUP(HUMANK,H,T)$HKPAYMENTS0(H,HUMANK) =E=
0.3*BASEHKSUP(HUMANK,H,T)*((P_L(HUMANK,T)/P_W(H,T))-1) +
BASEHKSUP(HUMANK,H,T);
* HKSUP(HUMANK,H,T)$HKPAYMENTS0(H,HUMANK) =E=
BASEHKSUP(HUMANK,H,T);
$CONSTRAINT:MIG(L,H,T)
* MIG(L,H,T) =E= (0.5*(((P_L(L,T-1)+1$TFIRST(T))/(1$TFIRST(T)+P_W(H,T-1)))-
1))+0.030309165$TNOTFIRST(T);
(MIG(L,H,T)-1) =E= MIGPROP(L)*MIGPROP1(H)*((MELAS*(((P_L(L,T-
1)+1$TFIRST(T))/(1$TFIRST(T)+P_W(H,T-1)))-1))+0.030309165$TNOTFIRST(T));
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```
*             MIG(L,H,T) =E= 0;
$CONSTRAINT:WORKMIG(L,T)
          WORKMIG(L,T)    =E=    1    +    (SUM(H,(LABORSHARE(L,H)*(MIG(L,H,T)-
1))))$TNOTFIRST(T);
$CONSTRAINT:POPMIG(PEEPS,T)
*             POPMIG(PEEPS,T) =E= 1;
          POPMIG(PEEPS,T)          =E=          0          +          SUM(H,((HMIG(H,T)-
1)*POPRATIO(H,PEEPS)*TOTPOP0(PEEPS)))$TNOTFIRST(T);
$CONSTRAINT:HMIG(H,T)
          HMIG(H,T)    =E=       1    +       (SUM(L,(SUPPORTSHARE(H,L)*(MIG(L,H,T)-
1))))$TNOTFIRST(T) ;
$CONSTRAINT:OWN(K,T)
*                                        OWN(K,T)    =E=    ((1-DEPRECIATE(K))*(OWN(K,T-
1)+1$TFIRST(T)))+((0.7*(INVEST(K,T)/(1+QREF(T)-QREF(T-1)-
1$TFIRST(T)))+0.3*INVEST(K,T-1))/10);
*             OWN(K,T) =E= QREF(T);
          OWN(K,T)        =E=        ((1-DEPRECIATE(K))*(OWN(K,T-1)+1$TFIRST(T)))+
(DEPRECIATE(K)*INVEST(K,T)) + GRO*INVEST(K,T-1);
$CONSTRAINT:INVEST(K,T)
         INVEST(K,T) =E= QREF(T)*(1+((P_K(K,T)-1)*IELAS(K)));
$CONSTRAINT:EXPDEM(IP,T)
         EXPDEM(IP,T) =E= (1/P_Y(IP,T));
$CONSTRAINT:IMPSUP(IP,T)$QMDA0(IP)
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        IMPSUP(IP,T)$QMDA0(IP)                                             =E=
TFP(T)*PRODSHOCK(IP,T)*(1+(10*((P_FOR(IP,T)$QMDA0(IP)/P_Y(IP,T))-1)));
$CONSTRAINT:SAVING(H,T)
        SAVING(H,T) =E= P_W(H,T)*(A_W(H,T)/qref(t));
$CONSTRAINT:COSAVINGSTAX(T)
        COSAVINGSTAX(T)                                                    =E=
SUM(H,(QSAVING0(H)*SAVING(H,T)))/SUM(H,QSAVING0(H));
$CONSTRAINT:EMPLOYHEALTH(T)
        EMPLOYHEALTH(T) =E= A_INS(T);
$CONSTRAINT:HCOST(T)
        HCOST(T) =E= P_A("HealthCare",T);
$CONSTRAINT:EDDEMAND1(H,T)
        EDDEMAND1(H,T)      =G=        ((EDIELAS*((RA(H,T)/INCOME1(H))-1))+1)
*((EDPELAS*(((1+EDSUB0("STATEUG"))/(P_Y("STATEUG",T)+EDSUB("STATEUG")))-
1))+1)*((EDCELAS*(P_Y("PRIVATEUG",T)-
1))+1)*((EDWELAS*((P_L("L2",T)/P_L("L1",T))-1))+1);
*                    EDDEMAND1(H,T)   =E=     ((EDIELAS*((RA(H,T)/INCOME1(H))-
1))+1)*((EDPELAS*(((1+EDSUB0(HED))/(P_Y("STATEUG",T)+EDSUB(HED)))-1))+1)
*                                            *((EDCELAS*(P_Y("PRIVATEUG",T)-
1))+1)*((EDWELAS*((P_L("L2",T)/P_L("L1",T))-1))+1);
$CONSTRAINT:EDDEMAND2(H,T)
        EDDEMAND2(H,T)      =E=        ((EDIELAS*((RA(H,T)/INCOME1(H))-1))+1)*
((EDPELAS*(((1+EDSUB0("STATEG"))/(P_Y("STATEG",T)+EDSUB("STATEG")))-
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1))+1)*((EDCELAS*(P_Y("PRIVATEG",T)-
1))+1)*((EDWELAS*((P_L("L3",T)/P_L("L2",T))-1))+1);
*                 EDDEMAND2(H,T)  =E=   ((EDIELAS*((RA(H,T)/INCOME1(H))-
1))+1)*((EDPELAS*(((1+EDSUB0(HED))/(P_Y(HED,T)+EDSUB(HED)))-1))+1)
*                                         *((EDCELAS*(P_Y("PRIVATEG",T)-
1))+1)*((EDWELAS*((P_L("L3",T)/P_L("L2",T))-1))+1);
$CONSTRAINT:EDDEMAND3(H,T)
     EDDEMAND3(H,T)      =E=          ((EDIELAS*((RA(H,T)/INCOME1(H))-
1))+1)*((EDPELAS*(((1+EDSUB0("PRIVATEUG"))/(P_Y("PRIVATEUG",T)+EDSUB("PRI
VATEUG")))-
1))+1)*((EDCELAS*(((P_Y("STATEUG",T)+EDSUB("STATEUG"))/(1+EDSUB("STATEUG
")))-1))+1)
                *((EDWELAS*((P_L("L2",T)/P_L("L1",T))-1))+1);
*                 EDDEMAND3(H,T)  =E=   ((EDIELAS*((RA(H,T)/INCOME1(H))-
1))+1)*((EDPELAS*(((1+EDSUB0("PRIVATEUG"))/(P_Y("PRIVATEUG",T)+EDSUB("PRI
VATEUG")))-1))+1)
*((EDCELAS*(((P_Y("STATEUG",T)+EDSUB0("STATEUG"))/(1+EDSUB("STATEUG")))-
1))+1)*((EDWELAS*((P_L("L2",T)/P_L("L1",T))-1))+1);
$CONSTRAINT:EDDEMAND4(H,T)
     EDDEMAND4(H,T)      =E=          ((EDIELAS*((RA(H,T)/INCOME1(H))-
1))+1)*((EDPELAS*(((1+EDSUB0("PRIVATEG"))/(P_Y("PRIVATEG",T)+EDSUB("PRIVA
TEG")))-
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1))+1)*((EDCELAS*(((P_Y("STATEG",T)+EDSUB("STATEG"))/(1+EDSUB("STATEG")))-
1))+1)
                              *((EDWELAS*((P_L("L3",T)/P_L("L2",T))-1))+1);
*                                   EDDEMAND4(H,T)   =E=      ((EDIELAS*((RA(H,T)/INCOME1(H))-
1))+1)*((EDPELAS*(((1+EDSUB0("PRIVATEG"))/(P_Y("PRIVATEG",T)+EDSUB("PRIVA
TEG")))-1))+1)
*
*((EDCELAS*(((P_Y("STATEG",T)+EDSUB0("STATEG"))/(1+EDSUB("STATEG")))-
1))+1)*((EDWELAS*((P_L("L3",T)/P_L("L2",T))-1))+1);
$CONSTRAINT:EDDEMAND5(H,T)
           EDDEMAND5(H,T)           =E=                      ((EDIELAS*((RA(H,T)/INCOME1(H))-
1))+1)*((EDPELAS*(((1)/(P_FOR("PRIVATEUG",T)))-
1))+1)*((EDCELAS*(P_Y("PRIVATEUG",T)-
1))+1)*((EDWELAS*((P_L("L2",T)/P_L("L1",T))-1))+1);
*                                   EDDEMAND1(H,T)   =E=      ((EDIELAS*((RA(H,T)/INCOME1(H))-
1))+1)*((EDPELAS*(((1+EDSUB0(HED))/(P_Y("STATEUG",T)+EDSUB(HED)))-1))+1)
*                                                                *((EDCELAS*(P_Y("PRIVATEUG",T)-
1))+1)*((EDWELAS*((P_L("L2",T)/P_L("L1",T))-1))+1);
$CONSTRAINT:EDDEMAND6(H,T)
           EDDEMAND6(H,T)           =E=                      ((EDIELAS*((RA(H,T)/INCOME1(H))-
1))+1)*((EDPELAS*(((1)/(P_FOR("PRIVATEG",T)))-
1))+1)*((EDCELAS*(P_Y("PRIVATEG",T)-
1))+1)*((EDWELAS*((P_L("L3",T)/P_L("L2",T))-1))+1);
```

*   EDDEMAND2(H,T)   =E=   ((EDIELAS*((RA(H,T)/INCOME1(H))-1))+1)*((EDPELAS*(((1+EDSUB0(HED))/(P_Y(HED,T)+EDSUB(HED)))-1))+1)*

*   *((EDCELAS*(P_Y("PRIVATEG",T)-1))+1)*((EDWELAS*((P_L("L3",T)/P_L("L2",T))-1))+1);

$CONSTRAINT:EDDEMAND7(H,T)

EDDEMAND7(H,T)   =E=   ((EDIELAS*((RA(H,T)/INCOME1(H))-1))+1)*((EDPELAS*(((1)/(P_FOR("STATEUG",T)))-1))+1)*((EDCELAS*(((P_Y("STATEUG",T)+EDSUB("STATEUG"))/(1+EDSUB("STATEUG")))-1))+1)

((EDWELAS((P_L("L2",T)/P_L("L1",T))-1))+1);

*   EDDEMAND3(H,T)   =E=   ((EDIELAS*((RA(H,T)/INCOME1(H))-1))+1)*((EDPELAS*(((1+EDSUB0("PRIVATEUG"))/(P_Y("PRIVATEUG",T)+EDSUB("PRIVATEUG")))-1))+1)

*

((EDCELAS(((P_Y("STATEUG",T)+EDSUB0("STATEUG"))/(1+EDSUB("STATEUG")))-1))+1)*((EDWELAS*((P_L("L2",T)/P_L("L1",T))-1))+1);

$CONSTRAINT:EDDEMAND8(H,T)

EDDEMAND8(H,T)   =E=   ((EDIELAS*((RA(H,T)/INCOME1(H))-1))+1)*((EDPELAS*(((1)/(P_Y("STATEG",T)))-1))+1)*((EDCELAS*(((P_Y("STATEG",T)+EDSUB("STATEG"))/(1+EDSUB("STATEG")))-1))+1)

((EDWELAS((P_L("L3",T)/P_L("L2",T))-1))+1);

```
*                              EDDEMAND4(H,T)   =E=     ((EDIELAS*((RA(H,T)/INCOME1(H))-
1))+1)*((EDPELAS*(((1+EDSUB0("PRIVATEG"))/(P_Y("PRIVATEG",T)+EDSUB("PRIVA
TEG")))-1))+1)
*((EDCELAS*(((P_Y("STATEG",T)+EDSUB0("STATEG"))/(1+EDSUB("STATEG")))-
1))+1)*((EDWELAS*((P_L("L3",T)/P_L("L2",T))-1))+1);
$CONSTRAINT:STATEUGSUBS(H,T)
          STATEUGSUBS(H,T)          =E=          EDDEMAND1(H,T)*P_Y("STATEUG",T)*(-
EDSUB("STATEUG"));
$CONSTRAINT:STATEGSUBS(H,T)
          STATEGSUBS(H,T)           =E=            EDDEMAND2(H,T)*P_Y("STATEG",T)*(-
EDSUB("STATEG"));
$CONSTRAINT:EDSUBBILL(T)
          EDSUBBILL(T)                                                                =E=
(SUM(H,QADH0("STATEUG",H)*STATEUGSUBS(H,T))+SUM(H,QADH0("STATEG",H)*
STATEGSUBS(H,T)))/537.99516;
$OFFTEXT
$SYSINCLUDE mpsgeset COLORADO
A_W.L(H,T) = qref(t);
A_W.LO(H,T) = 0;
A_GOVT.L(FG,T) = qref(t);
A_GOVT.LO(FG,T) = 0;
A_Y.L(IP,T) = qref(t);
A_Y.LO(IP,T) = 0.01;
```

```
A_YARM.L(NED,T) = qref(t);

A_YARM.LO(NED,T) = 0;

A_H.L(HD,T) = qref(t);

A_H.LO(HD,T) = 0;

A_INS.L(T) = QREF(T);

P_L.L(L,T)=1;

P_L.LO(L,T) = 0;

P_W.L(H,T)=1;

P_W.LO(H,T)=0.01;

P_Y.L(IP,T)=1;

P_Y.LO(IP,T)=0.01;

P_A.L(NED,T)=1;

P_A.LO(NED,T)=0.01;

P_GC.L(FG,T) = 1;

P_GC.LO(FG,T)=0;

P_H.L(HD,T) = 1;

P_H.LO(HD,T) = 0;

P_FX.FX(T)=1;

P_K.L(K,T)=newpk0(k);

P_K.LO(K,T)=0.001;

P_FOR.L(IP,T) = 1;

P_FOR.LO(IP,T) = 0.001;

CCI.L(T) = 1;
```

```
CCI.LO(T) = 0.01;

MIG.L(L,H,T)=1+(0.030309165*MIGPROP(L)*MIGPROP1(H))$TNOTFIRST(T);

MIG.LO(L,H,T)=-100;

HMIG.L(H,T) =1+(0.030309165*MIGPROP1(H))$TNOTFIRST(T);

HMIG.LO(H,T)=-100;

POPMIG.L(PEEPS,T)=POPGRO0(PEEPS,T);

POPMIG.LO(PEEPS,T)=-10000;

WORKMIG.L(L,T) = 1+(0.030309165*MIGPROP(L))$TNOTFIRST(T);

WORKMIG.LO(L,T) = -100;

LSUP.L(LAB,H,T)=QREF(T);

LSUP.LO(LAB,H,T) = 0;

HKSUP.L(HUMANK,H,T)$HKPAYMENTS0(H,HUMANK) = 1;

HKSUP.LO(HUMANK,H,T)$HKPAYMENTS0(H,HUMANK) = 0;

BASEHKSUP.L(HUMANK,H,T)$HKPAYMENTS0(H,HUMANK) = QREF(T);

BASEHKSUP.LO(HUMANK,H,T)$HKPAYMENTS0(H,HUMANK) = 0;

I_GOVT0.L(T) = 6548.670*QREF(T);

INVEST.L(K,T)=QREF(T);

OWN.L(K,T)=QREF(T);

HMEMBERS.L(H,T)=QREF(T);

HMEMBERS.LO(H,T)=0.01;

BASELSUP.L(LAB,H,T)=QREF(T);

BASELSUP.LO(LAB,H,T)=0.01;

BACHDEGREE.L(T)=QREF(T);
```

```
BACHDEGREE.LO(T)=0.01;

GRADDEGREE.L(T)=QREF(T);

GRADDEGREE.LO(T)=0.01;

EMPLOYHEALTH.L(T)=QREF(T);

HCOST.L(T) = 1;

POP.L(PEEPS,T) = POP1(PEEPS,T)*QREF(T);

POP.LO(PEEPS,T) = 0;

BABIES.L(T) = SUM(PEEPS,(FERTILITY(PEEPS)*TOTPOP0(PEEPS)));

BABIES.LO(T) = EPS;

HPOP.L(PEEPS,H,T) = TOTPOP0(PEEPS)*POPRATIO(H,PEEPS);

HPOP.LO(PEEPS,H,T) = EPS;

SKILLS.L(LAB,PEEPS,T) = SKILLS0(LAB,PEEPS,T);

SKILLS.LO(LAB,PEEPS,T) = 0;

KSKILLS.L(HUMANK,PEEPS,T) = TOTALAGEHK(HUMANK,PEEPS)*QREF(T);

HSKILLS.L(LAB,PEEPS,H,T) =

TOTALEDAGEWORKING(LAB,PEEPS)*LABORAGEHOUSE(LAB,PEEPS,H)*QREF(T);

HKSKILLS.L(HUMANK,PEEPS,H,T) =

HKPAYRATIO(H,HUMANK)*TOTALAGEHK(HUMANK,PEEPS)*HKAGEHOUSE(HUMA

NK,PEEPS,H)*QREF(T);

NEWBA.L(PEEPS,T) = QREF(T);

NEWBA.LO(PEEPS,T) = 0;

NEWPHD.L(PEEPS,T) = QREF(T);

NEWPHD.LO(PEEPS,T) = 0;
```

```
WORKMIG.L(L,T) = 0;

WORKMIG.LO(L,T) = -100;

EXPDEM.L(IP,T) = 1;

EXPDEM.LO(IP,T) = 0;

IMPSUP.L(IP,T) = 1;

SAVING.L(H,T)=1;

COSAVINGSTAX.L(T)=QREF(T);

COSAVINGSTAX.LO(T)=0;

EDDEMAND1.L(H,T)=QREF(T);

EDDEMAND1.LO(H,T)=EPS;

EDDEMAND2.L(H,T)=QREF(T);

EDDEMAND2.LO(H,T)=EPS;

EDDEMAND3.L(H,T)=QREF(T);

EDDEMAND3.LO(H,T)=EPS;

EDDEMAND4.L(H,T)=QREF(T);

EDDEMAND4.L(H,T)=EPS;

EDDEMAND5.L(H,T)=QREF(T);

EDDEMAND5.LO(H,T)=EPS;

EDDEMAND6.L(H,T)=QREF(T);

EDDEMAND6.LO(H,T)=EPS;

EDDEMAND7.L(H,T)=QREF(T);

EDDEMAND7.LO(H,T)=EPS;

EDDEMAND8.L(H,T)=QREF(T);
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```
EDDEMAND8.LO(H,T)=EPS;

STATEUGSUBS.L(H,T) = EDSUB("STATEUG")*QREF(T);

STATEGSUBS.L(H,T) = EDSUB("STATEG")*QREF(T);

EDSUBBILL.L(T) = QREF(T);

EDSUBBILL.LO(T) = 0;

SET RUN(SM) /BASE,TODAY,SIMM1/;

PARAMETER SUMMARY(*,SM)   SOLUTION SUMMARY;

TABLE TAXCHANGE(SM,*) INDICATORS FOR TAX RATE SIMULATIONS

              S

BASE          0

TODAY         0

SIMM1         1;

IF (RUN("BASE"), COLORADO.ITERLIM=0;);

FILE RESULTS /C:\Users\Chris\Documents\Disser\Disser\cofix.txt/;

LOOP(SM$RUN(SM),

     IF (TAXCHANGE(SM,"S"),

     EDSUB(HED) = 0;

*       TLDI0(IP) = 0.4;

*       TLDG0(FG) = 0.4;

*         DEM("OFFICESF",OFFUSE,T)=DEMCH(T);

      ELSE

     );

$INCLUDE COLORADO.GEN
```

```
COLORADO.OPTFILE = 0;
OPTION SYSOUT=ON;
SOLVE COLORADO USING MCP;
    COLORADO.RESLIM = 30000;
    COLORADO.ITERLIM = 100000;
    COLORADO.WORKFACTOR=100.0;
    SUMMARY("STATUS",SM) = COLORADO.MODELSTAT;
    SUMMARY("ITERS",SM) = COLORADO.ITERUSD;
    SUMMARY("CPU",SM) = COLORADO.RESUSD;
    SUMMARY("CONTROL",SM) = COLORADO.OBJVAL;
   SUMMARY("LAB1_1",SM) = SUM(PEEPS,SKILLS.L("L1",PEEPS,"1"));
    SUMMARY("LAB1_2",SM) = SUM(PEEPS,SKILLS.L("L1",PEEPS,"2"));
    SUMMARY("LAB1_3",SM) = SUM(PEEPS,SKILLS.L("L1",PEEPS,"3"));
    SUMMARY("LAB1_4",SM) = SUM(PEEPS,SKILLS.L("L1",PEEPS,"4"));
    SUMMARY("LAB1_5",SM) = SUM(PEEPS,SKILLS.L("L1",PEEPS,"5"));
    SUMMARY("LAB1_6",SM) = SUM(PEEPS,SKILLS.L("L1",PEEPS,"6"));
    SUMMARY("LAB1_7",SM) = SUM(PEEPS,SKILLS.L("L1",PEEPS,"7"));
    SUMMARY("LAB1_8",SM) = SUM(PEEPS,SKILLS.L("L1",PEEPS,"8"));
    SUMMARY("LAB1_9",SM) = SUM(PEEPS,SKILLS.L("L1",PEEPS,"9"));
    SUMMARY("LAB1_10",SM) = SUM(PEEPS,SKILLS.L("L1",PEEPS,"10"));
    SUMMARY("LAB2_1",SM) = SUM(PEEPS,SKILLS.L("L2",PEEPS,"1"));
    SUMMARY("LAB2_2",SM) = SUM(PEEPS,SKILLS.L("L2",PEEPS,"2"));
    SUMMARY("LAB2_3",SM) = SUM(PEEPS,SKILLS.L("L2",PEEPS,"3"));
```

```
        SUMMARY("LAB2_4",SM) = SUM(PEEPS,SKILLS.L("L2",PEEPS,"4"));
        SUMMARY("LAB2_5",SM) = SUM(PEEPS,SKILLS.L("L2",PEEPS,"5"));
        SUMMARY("LAB2_6",SM) = SUM(PEEPS,SKILLS.L("L2",PEEPS,"6"));
        SUMMARY("LAB2_7",SM) = SUM(PEEPS,SKILLS.L("L2",PEEPS,"7"));
        SUMMARY("LAB2_8",SM) = SUM(PEEPS,SKILLS.L("L2",PEEPS,"8"));
        SUMMARY("LAB2_9",SM) = SUM(PEEPS,SKILLS.L("L2",PEEPS,"9"));
        SUMMARY("LAB2_10",SM) = SUM(PEEPS,SKILLS.L("L2",PEEPS,"10"));
        SUMMARY("LAB3_1",SM) = SUM(PEEPS,SKILLS.L("L3",PEEPS,"1"));
        SUMMARY("LAB3_2",SM) = SUM(PEEPS,SKILLS.L("L3",PEEPS,"2"));
        SUMMARY("LAB3_3",SM) = SUM(PEEPS,SKILLS.L("L3",PEEPS,"3"));
        SUMMARY("LAB3_4",SM) = SUM(PEEPS,SKILLS.L("L3",PEEPS,"4"));
        SUMMARY("LAB3_5",SM) = SUM(PEEPS,SKILLS.L("L3",PEEPS,"5"));
        SUMMARY("LAB3_6",SM) = SUM(PEEPS,SKILLS.L("L3",PEEPS,"6"));
        SUMMARY("LAB3_7",SM) = SUM(PEEPS,SKILLS.L("L3",PEEPS,"7"));
        SUMMARY("LAB3_8",SM) = SUM(PEEPS,SKILLS.L("L3",PEEPS,"8"));
        SUMMARY("LAB3_9",SM) = SUM(PEEPS,SKILLS.L("L3",PEEPS,"9"));
        SUMMARY("LAB3_10",SM) = SUM(PEEPS,SKILLS.L("L3",PEEPS,"10"));
PUT RESULTS;
        );
DISPLAY SUMMARY;
SET SUMMARY1  /STATUS, ITERS, CPU, CONTROL /
PUT 'COLORADO      ';
 LOOP(SM, PUT '     ',SM.TL);
```

```
 PUT /;
LOOP(SUMMARY1, PUT '          ';
      PUT SUMMARY1.TL,
      LOOP(SM, PUT SUMMARY(SUMMARY1,SM) );
      PUT / );
```