The Economics of Climate Change Legislation in North Carolina

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Executive Summary

In 2005, the North Carolina Legislature approved Session Law 2005-442, which established the Legislative Commission on Global Climate Change (LCGCC). The Commission's mandate was to "study issues related to global warming, the emerging carbon economy, and whether it is appropriate and desirable for the state to establish a global warming pollutant reduction goal."[1]

A separate but overlapping organization is the North Carolina Climate Action Plan Advisory Group (CAPAG), which describes itself as "a voluntary advisory group to the NC Department of Environment and Natural Resources (DENR) … administered by its Division of Air Quality (DAQ) with assistance and facilitation from the Center for Climate Strategies (CCS)."[2] CAPAG charged itself with developing an action plan with recommendations to reduce the state's greenhouse gas emissions, coordinating with the LCGCC in the process.

In October 2007, CAPAG released a draft final report that offers 56 recommendations for reducing GHG emissions covering four sectors of the state economy. The report provides estimates of the amount of the GHG reduction and estimates of the net present value (NPV) of the costs, or cost savings, of implementation. According to the report, the implementation of all 56 proposals would reduce GHG emissions in North Carolina by 827.7 million metric tons of carbon dioxide equivalent (MMtCO_2e) between 2007 and 2020.[3]

Table 1 summarizes the estimated reduction in total emissions and the professed cost savings for eight of CAPAG's 56 recommendations. The recommendations fall into three categories – Energy Demand and Supply, Transportation and Cap and Trade. We choose the recommendations falling into these categories because they are responsible for more than half the promised GHG emission reductions and most of the cost savings claimed by CAPAG. According

[1] General Assembly of North Carolina, *An Act to Establish the Legislative Commission on Global Warming*, S 1134, Session Law 2005-442 (September 27, 2005). http://www.ncleg.net/gascripts/DocumentSites/browseDocSite.asp?nID=14&sFolderName=\Authorizing%20Legislation. See also *An Act to Extend the Legislative Commission on Global Warming*, S 1591 S.L. 2006-73 (July 10, 2006), http://www.ncleg.net/documentsites/committees/LCGCC/Authorizing%20Legislation/SL%202006-73%20LCGCC%20ext%20auth.pdf.

[2] Memo from The Center for Climate Strategies to North Carolina Climate Action Plan Advisory Group, February 16, 2006, http://www.ncclimatechange.us/capag.cfm.

[3] North Carolina Climate Action Plan Advisory Group, "Recommended Mitigation Options for Controlling Greenhouse Gas Emissions: Draft Final Report" (October 2007), http://www.ncclimatechange.us/capag.cfm; 1-11.

to CAPAG, all eight recommendations would reduce GHG emissions by 465.5 $MMtCO_2e$ between 2007 and 2020. Moreover, the reduction in GHG would be accompanied by net savings of $5,708.2 million, in present value terms, to North Carolina citizens.

The energy demand and supply proposals include an “Environmental Portfolio Standard” that would mandate a specified percentage of renewable energy production in the electricity sector; create new Public Benefit Charges on electricity use; and dedicate a portion of private utility revenues to energy efficiency programs to reduce demand. CAPAG estimates that these proposals would reduce GHG emissions by 322.5 $MMtCO_2e$ and confer net cost savings of about $2.5 billion between 2007 and 2020.

Table 1: CAPAG Estimates 2007-2020

Recommendation	Reduction ($MMtCO_2e$)	NPV of Cost Change ($, million)
Energy Demand and Supply	322.5	- 2,502.2
Transportation	95.6	- 3,490.0
Cap and Trade	47.4	284.0
Total	**465.5**	**- 5,708.2**

The CAPAG recommendations for the transportation sector include a “Biofuels Bundle” that would mandate targets to increase ethanol use in gasoline and diesel fuel, implement a proposal to adopt California Emission Standards on light duty vehicles and set new registration fees for vehicles based on emissions output. These proposals would reduce emissions by 95.6 $MMtCO_2e$ and save North Carolinians $3.5 billion.

CAPAG also proposes to include North Carolina in a regional or national system to cap GHG emissions and issue tradable permits that allow businesses in specified industries to emit greenhouse gases. According to CAPAG, the system would reduce emissions by 47.4 $MMtCO_2e$ and cost $284 million.

While CAPAG was doing its work, researches at Appalachian State University Energy Center (ASU) produced their own estimates of the economic effects of 31 CAPAG recommendations. The ASU researchers utilized the North Carolina Energy Scenario Economic Impact Model (NC-ESEIM), which was developed to quantify the potential impacts on the state economy of major energy policy initiatives designed to reduce greenhouse gas emissions. They reported that, over the period 2007 to 2020, the CAPAG policy measures would increase employment in the state by 328,738 jobs, boost income by just over $14.2 billion, and raise value added by over $20.5 billion.[4]

Table 2 provides details of the ASU results broken out by category. Seven proposals that target energy supply would, according to ASU, create 46,000 jobs and increase incomes in North Carolina by over $3.1 billion. Fourteen proposals attempt to reduce emissions by reducing energy demand and would add 133,000 jobs and boost incomes by $4.6 billion. Ten proposals would reduce GHG emissions by altering the state's agriculture, forestry policies and waste disposal policies, which are expected to create almost 150,000 jobs and add $6.5 billion to income.

Table 2: ASU Cumulative Estimates to 2020

Recommendation	Employment (Jobs)	Income ($ millions)	Value Added ($ millions)
Energy Demand Proposals	132,985	4,632	4,449
Energy Supply Proposals	45,996	3,122	5,887
Agriculture &Forestry and Waste Proposals	149,757	6,455	10,225
Total	**328,738**	**14,209**	**20,561**

The CAPAG and ASU scenarios do not stand up to scrutiny. The cost-benefit methodology employed by CAPAG suffers from three serious problems: CAPAG (1) failed to quantify benefits in a way (dollar terms) that can be meaningfully compared to costs, (2) misinterpreted costs to be benefits and (3) understated the true costs of its recommendations.

The ASU report also contains serious methodological flaws. The use of a multiplier analysis is not appropriate. The model does not allow the changing price of electricity to affect production or determine the price deflator (inflation) component of state Gross Domestic Product (GDP), with the result that GDP is projected to vary directly with electricity costs. The assumptions about what determines investment – the key driver of this input-output model – are too optimistic. Finally, the assumptions about the evolution of energy costs (particularly the sharp drop in the cost of renewable energy) over time are implausible.

[4]David Ponder and Jeffry Tiller, "Preliminary Draft Results, Economic Impact Analysis of Bundled Climate Mitigation Options: Prepared for the North Carolina Climate Action Advisory Group," October 27, 2007, PowerPoint Presentation.

The John Locke Foundation contracted with the Beacon Hill Institute (BHI) to provide independent estimates of the economic and fiscal impact of selected CAPAG proposals. To that end, BHI constructed a STAMP® (State Tax Analysis Modeling Program) for North Carolina (NC-STAMP), with which we estimated the economic effects of the eight CAPAG recommendations.[5] We assume that the proposals become effective in 2008, and we report results through 2011. Table 3 summarizes the results for 2011, again with the eight recommendations combined into three categories.

Table 3: Summary of BHI Estimates for 2011

Recommendation	Net Employment (Jobs)	Investment ($millions)	Real Disposable Income ($ millions)	Real State GDP ($ millions)	State and Local Revenue ($ millions)
Energy Demand & Supply	(2,473)	(76.7)	(242.5)	(360.3)	170.3
Transportation	(1,202)	(27.7)	(46.5)	(168.0)	(17.5)
Cap and Trade	(29,808)	(397.9)	(1,976.5)	(4,002.6)	(337.3)
Total*	**(33,483)**	**(502.4)**	**(2,265.5)**	**(4,530.9)**	**(184.6)**

*Minor differences are due to rounding.

We find that the proposals would exert significant negative effects on the state economy. By 2011, the state would shed more than 33,000 jobs. Annual investment would drop by about $502.4 million, real disposable income by more than $2.2 billion and real state Gross Domestic Product (GDP) by about $4.5 billion. The energy Cap and Trade system causes most of the harm. The negative economic effects would spill over into state and local tax collections. We estimate a loss of $184.6 million in revenues in 2011.

The proposals' negative economic and fiscal effects stem from the price and tax increases they would impose on the energy and transportation sectors. Our results contrast with the positive results produced by CAPAG and ASU, which suffer from the previously-described deficiencies.

[5] Detailed information about the North Carolina -STAMP® model can be found in Appendix B

Introduction

The debate concerning the environmental and economic impacts of global climate change has intensified in recent years. This development has encouraged many state governments to consider public policy initiatives designed to address climate-related issues. The initiatives focus particularly on the mitigation and reduction of Greenhouse Gasses (GHG) through the development and implementation of state-level climate action plans.

Prior to the authorization and establishment of climate action plans, state legislatures usually establish preliminary fact-finding commissions to determine the most beneficial strategies for mitigating GHG emissions. In North Carolina, the Clean Smokestacks Act of 2002 (CSA) required the Department of Environment and Natural Resources and the Division of Air Quality (DAQ) to submit a report to the Environmental Management Commission (EMC) and the Environmental Review Committee (ERC) of the General Assembly.

In 2005, the Department of Environment and Natural Resources and the Division of Air Quality submitted a report to the General Assembly in which they attempted to identify and evaluate strategies for the reduction of GHG emissions. In addition to the recommendations for potential state actions, the Division of Air Quality provided an inventory and forecast of GHG emissions from 1990-2020 for the state of North Carolina.

More importantly, the report advocated the formation of a DAQ stakeholder process that would work further to develop specific policy actions for the reduction of GHG emissions. Furthermore, the report recommended that the stakeholders compile the findings of this process in a climate action plan that would guide the GHG mitigation planning of North Carolina policymakers.

Subsequent to the 2005 release of the DAQ report, the General Assembly created the North Carolina Legislative Commission on Global Climate Change (LCGCC). The questions of whether a reduction in GHG emissions constitutes a sensible policy goal and, if so, what comprises the optimal level of GHG reductions were among the fact-finding mandates imposed by the General Assembly on the LCGCC.

The proceedings of the LCGCC have transpired concurrently and often in cooperation with other facets of the GHG planning process, including other state agencies such as the DENR and DAQ. A voluntarily formed stakeholder group known as the North Carolina Climate Action Plan Advisory Group (CAPAG) has been particularly influential in the process; it shares participants with the LCGCC and submits its findings for consideration to the Commission. CAPAG describes itself as "a voluntary advisory group to the NC Department of Environment and Natural Resources (DENR) … administered by its Division of Air Quality (DAQ) with assistance and facilitation from the Center for Climate Strategies (CCS)."[6] While the LCGCC and CAPAG comprise formally independent and separate entities, both groups have exhibited a substantial willingness to cooperate in the GHG planning process.

In October 2007, CAPAG released a draft final report that offers 56 recommendations for reducing GHG emissions that cover four sectors of the state economy. For each proposal, the report provides estimates of the amount of the GHG reduction and the cost of implementing the proposal in terms of its net present value (NPV). CAPAG estimates that, between 2010 and 2020, all 56 proposals would reduce GHG emissions in North Carolina by 827.7 million metric tons of carbon dioxide equivalent ($MMtCO_2e$).[7] The CAPAG report also claims that these measures would bring "significant cost savings for the State's economy" and that the state would save $5.7 billion in present value terms.[8]

While CAPAG was doing its work, the Appalachian State University (ASU) Energy Center was producing its own estimates. In producing the estimates, the ASU researchers utilized the North Carolina Energy Scenario Economic Impact Model (NC-ESEIM), which was developed to quantify the potential impacts on the state economy of major energy policy initiatives. ASU reported that 31 CAPAG policy measures would increase employment in the state by 328,738 jobs, boost income by just over $14 billion, and raise value added by over $20 billion over the period 2007 to 2020.[9]

The promising scenarios offered by CAPAG and ASU do not stand up to scrutiny. For reasons we detail below, and in previous comments prepared for the John Locke Foundation, we do not

[6] CAPAG, "Memo," February 16, 2006.
[7] CAPAG, *Draft Final Report,* 1-11.
[8] Ibid, ES-2.
[9] Ponder and Tiller, "Preliminary Draft Results."

believe that the promised benefits cant be expected to materialize.[10] We reviewed the cost-benefit methodology employed in the CAPAG and ASU reports and found serious flaws in both.

In this report we review the previously released BHI critiques of the CAPAG and ASU methodologies. We then describe eight recommendations that are responsible for more than half of the GHG reductions and most of the claimed cost savings. Finally, we present the results from the BHI simulations of the eight CAPAG proposals using our NC-STAMP model. Appendices A and B provide explanations of our methodology.

The CAPAG Report

In October 2007, CAPAG released a draft report containing the advisory group's recommendations for legislative, administrative and regulatory measures that would reduce green house gas emissions in North Carolina. Representatives from environmental groups, academia, industry, government, the general public and Center for Climate Strategies assisted CAPAG in formulating its recommendations.[11]

As a consultant to CAPAG, CCS directed "technical working groups" that provided analyses of the 56 recommended policy options designed to mitigate greenhouse gas emissions.[12] The analyses addressed the likely reduction in GHG emissions as well as the costs and benefits of each policy option.

The CAPAG report provides an assessment of the likely impact of adopting its policy recommendations. The report estimates that, if all 56 policy options were fully implemented, North Carolina's greenhouse gas emissions would be reduced 47% by 2020, resulting in emission levels that are within 1% of 1990 levels.[13]

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[10] See Benjamin Powell, *Peer Review: North Carolina Climate Action Plan Advisory Group Recommended Mitigation Options for Controlling Greenhouse Gas Emissions* (The Beacon Hill Institute at Suffolk University, Boston: December 2007) and Jonathan Haughton, *Peer Review: North Carolina Energy Scenario Economic Impact Model* (The Beacon Hill Institute at Suffolk University, Boston: December 2007).
[11] CAPAG, "Memo," February 16, 2006.
[12] Full report and appendices can be downloaded at: www.ncclimatechange.us.
[13] CAPAG, *Draft Final Report*, ES-2.

The CAPAG report claims that the implementation of these measures would bring "significant cost savings for the State's economy."[14] Advisory groups that developed climate action plans with the assistance of CCS in other states reached similar conclusions with regard to the economic impact of the recommended policy actions. The CAPAG report quantifies costs for 37 of the 56 recommended options, claiming that 16 would generate net cost savings. CAPAG estimates that the state would save almost $6 billion in present value terms if all 56 options were adopted.

The Beacon Hill Institute at Suffolk University (BHI) reviewed the cost-benefit methodology employed in the CAPAG report. BHI identified three serious problems with the methodology used by CAPAG:

1. CAPAG failed to quantify benefits in a way that they can be meaningfully compared to costs;
2. When estimating economic impacts, CAPAG often misinterpreted costs to be benefits; and
3. CAPAG's estimates of the costs left out important factors, causing it to understate the true costs of its recommendations.[15]

The CAPAG findings do not hold up under scrutiny and are an artifact of CAPAG's unrealistic assumptions and incomplete listing of costs. The report gives the impression that state policy makers can have a free lunch – that North Carolina can both reduce greenhouse gas emissions *and* at the same time provide cost savings to business and consumers.

The ASU Report

Researchers at Appalachian State University used the North Carolina Energy Scenario Economic Impact Model (NC-ESEIM) to quantify the potential impacts on the state economy of major energy policy initiatives designed to reduce greenhouse gas emissions. The primary economic impacts simulated by the model are wages, state Gross Domestic Product and jobs. The model also calculates energy cost savings and energy price changes.

[14] Ibid, ES-2.
[15] The peer review can be downloaded at http://www.johnlocke.org/site-docs/CCSPeerReview.pdf.

The model is based on a significant extension of an Input-Output (I-O) analysis. The I-O approach is defined as a static linear model of all purchases and sales between sectors of an economy, based on the technological relationships of production.

The model has serious flaws.[16] The ASU analysis uses the classical "multiplier" treatment of an investment. It assumes that private investments lead to savings in the quantity of energy used (and imported) thus leaving residents with more money to spend on other items, which in turn boosts state Gross Domestic Product. Second, power generating costs change over time (at fixed annual rates, depending on the fuel). The analysis assumes that the cost of producing electricity from renewable sources (e.g. wind, biomass or hydropower), which starts high, falls below the cost of generating electricity from conventional fuels by 2016.

Among the flaws are the following:

1. The use of a multiplier analysis is not appropriate in a full-employment context.
2. The model does not allow the changing price of electricity to affect production or the price deflator (inflation) component of state Gross Domestic Product (GDP), with the ultimately nonsensical result that GDP is projected to rise when electricity is produced inefficiently (more expensively), and to fall when electricity is produced with higher efficiency (less expensively). If this were true, we should welcome higher energy prices and high inflation because they increase nominal GDP.
3. The assertions about what determines investment – the key driver of the input-output model – are too optimistic.
4. The assumptions about the evolution of energy costs over time are implausible.

Problems (1) and (2) could be remedied with the use of a Computable General Equilibrium model (as noted by Rose and Wei), while the issues raised in (3) and (4) could be addressed on the basis of a wider review of the available literature.[17]

The results of the ASU analysis are not compelling. By using a demand-driven input-output analysis at its core, the model assumes that the state economy has slack capacity; and it lacks an

[16] Ponder and Tiller, "Preliminary Draft Results."
[17] Adam Rose and Dan Wei, "Review of North Carolina Energy Scenario Economic Impact Model," Pennsylvania State University (November 29, 2005):5.

adequate mechanism for energy prices to feed back into measures of real incomes or investment decisions. The analysis also makes unduly optimistic assumptions about the future course of cost reductions in the production of energy from renewable sources. Finally, it is too sanguine about the potential for state spending to trigger private investment and influence individual behavior in energy conservation.

North Carolina-STAMP

BHI has constructed a Computable General Equilibrium (CGE) model for North Carolina in order to produce more accurate estimates of the economic impact of several CAPAG recommendations, including the proposal for a Cap and Trade system for North Carolina. The purpose of the model, called NC-STAMP (North Carolina State Tax Analysis Modeling Program) is to identify the economic effects of a variety of state policy changes. [18]

NC-STAMP is a five-year dynamic CGE model that has been programmed to simulate changes in taxes, prices (general and sector specific) and other economic inputs. As such, it provides a mathematical description of the economic relationships among producers, households, government and the rest of the world. It is general in the sense that it takes all the important markets and flows into account. It is an equilibrium model because it assumes that demand equals supply in every market (goods and services, labor and capital). This is achieved by allowing prices to adjust within the model. It is computable because it can be used to generate numeric solutions to concrete policy and tax changes, with the help of a computer.[19]

[18] Detailed information about North Carolina-STAMP can be found in Appendix B.
[19] For a clear introduction to CGE tax models, see John B. Shoven and John Whalley, "Applied General-Equilibrium Models of Taxation and International Trade: An Introduction and Survey," *Journal of Economic Literature* 22 (September, 1984), 1008. Shoven and Whalley have also written a useful book on the practice of CGE modeling entitled *Applying General Equilibrium* (Cambridge: Cambridge University Press, 1992).

Eight CAPAG Recommendations

Here we provide an analysis of the eight most important policies recommended by CAPAG. Table 4 contains the recommendations and the expected reduction in total emissions and in total costs, in net present value terms, for 2007 to 2020, as calculated by CAPAG.

Table 4: CAPAG Policy Recommendations for BHI Simulations

Recommendation	GHG Reduction 2007-2020 ($MMtCO_2e$)	Net Present Value of Costs ($ million)
Energy Demand		
RCI-1: Demand Side Management	77.1	(1,895.0)
RCI-2: Expand Energy Efficiency Funds	54.8	(1,346.0)
ES-7: Public Benefits Charge	24.4	329.0
Energy Supply		
ES-2b: Environmental Portfolio Standard	166.2	409.8
Transportation		
TLU-3a: Surcharges to Raise Revenue	15.7	(1,800.0)
TLU-5: California Emission Standard	44.5	(1,690.0)
TLU-6: Biofuels Bundle	35.4	Not Quantified
ES-4: Cap and Trade	47.4	284.0
Total	**465.5**	**(5,708.2)**

The eight CAPAG recommendations listed in Table 4 would reduce GHG emissions by 465.5 $MMtCO_2e$ between 2007 and 2020. Moreover, the reduction in GHG would be accompanied by net savings of $5,708.2 million to North Carolina citizens, if we are to believe the CAPAG analysis. We divide the recommendations under the categories Energy Demand and Supply, Transportation and Cap and Trade.

Energy Demand and Supply

We have selected four proposals affecting energy supply and demand, three from the demand side and one from the supply side.

Energy Demand

CAPAG estimates that its recommendations for reducing energy demand in the Residential, Commercial and Industrial sectors would reduce GHG emissions by 218.7 $MMtCO_2e$ between 2007 and 2020, for a savings of $4 billion in NPV. BHI simulated three CAPAG proposals estimated to reduce GHG emissions by 156.3 $MMtCO_2e$ and to save $2.9 billion in NPV.

RCI-1: Demand Side Management Programs

CAPAG recommends Demand Side Management (DSM) programs aimed at reducing consumption of conventional electricity and fossil fuel sources. The programs would support residential building programs by providing energy efficiency and renewable energy programs to new and existing residents primarily in rental properties. The commercial and industrial building programs would promote energy efficiency for new and existing commercial and industrial buildings and promote renewable energy efforts as well.[20]

Utilities would develop and manage their own DSM programs, with supervision and input from the North Carolina Utilities Commission. CAPAG calls for the utility industry to invest a percentage of total revenues, beginning in 2008 and reaching 1.5% of industry revenues by 2012.[21]

RCI-2: Expand Energy Efficiency Funds

In the proposal labeled RCI-2, CAPAG calls for a Systems Benefit Charge (SBC) that is virtually identical to the one proposed by ES-7 in the energy sector. Neither proposal makes any reference to the other and they offer different levels of funding for the SBC: ES-7 proposes a SBC that reaches $72 million in 2012 and RCI-2 proposes charges equal to 1% of electricity and gas revenues.[22] CAPAG estimates that the expansion of energy efficiency funds would provide North Carolinians with $1.346 billion in savings for 2008-2020 in NPV terms.

[20] CAPAG, *Draft Final Report,* E-4.
[21] Ibid, E-5.
[22] Ibid, E-11, F-34.

ES-7: Public Benefits Charge

A Public Benefits Charge (PBC) is a mechanism to help fund statewide energy programs such as efficiency, renewable energy, low-income assistance, research and development and others. Twenty-two states and the District of Columbia have enacted PBCs over the past 6 years; North Carolina has not.

Typically, public benefit programs are funded from a fee paid by utility ratepayers in the form of a System Benefits Charge or wire charge. The wire charges are measured in millage rates (mills) – similar to local property taxes. PBC charges in other states range from less than 0.5 mills/kWh to 4.0 mills per kWh; with an average, weighted by total applicable kilowatt-hours in each state, of 0.93 mills per kWh.[23]

CAPAG claims that North Carolina currently has a PBC that generates $3.5 million in revenue. However, the charge is not a PBC per se, but rather a fee used to help fund the nonprofit Advanced Energy Group, which was established in 1980 by the state Utilities Commission to research and "implement new technologies for distributed generation, load management, conservation and energy efficiency."[24]

CAPAG proposes to implement a PBC in North Carolina that would raise enough revenue to equal the average raised by the states that currently assess a PBC, which they estimate to be $72 million per year. CAPAG assumes an average rate of $8.44 per customer, though PBCs are generally charged on a kWh basis.[25]

Energy Supply

CAPAG estimates that its energy sector recommendations would reduce GHG emissions by 375 MMtCO_2e between 2007 and 2020 for a savings of $5.9 million in NPV. BHI considered one CAPAG proposal under this heading – the Environmental Portfolio Standard – estimated by CAPAG to reduce GHG emissions by 166.2 MMtCO_2e and to cost $409.8 million in 2005 NPV dollars between 2007 and 2020.

[23] North Carolina State Energy Office, *North Carolina State Energy Plan*, (June 2003, Revised Edition, January 2005), 74.
[24] For more about Advanced Energy see http://www.advancedenergy.org/corporate/index.html.
[25] CAPAG, *Draft Final Report*, F-34.

An Environmental Portfolio Standard (also known as a Renewable Portfolio Standard) requires electric utilities to produce a certain percentage of retail electricity from renewable sources. A portion of the standard can be satisfied through implementing energy efficiency measures or through the purchase of a renewable energy credit (REC) from a renewable energy producer. Renewable energy sources include solar, ocean current, tidal and wave energy, micro-hydropower and biomass.

CAPAG proposes EPS goals of 10% by 2017 and 20% by 2020, with increases of 1% per year from 2008 through 2017.[26] The program would be implemented in conjunction with a subsidy of $0.005 per kilowatt hour of renewable energy generation outlined in the ES-1 proposal.[27]

Transportation

CAPAG estimates that the transportation sector is directly responsible for 29% of GHG emissions. Its recommendations for the transportation sector are predicted to reduce emissions by 232.3 $MMtCO_2e$ by 2020. BHI simulated three CAPAG transportation proposals that are estimated to reduce GHG emissions by 95.6 $MMtCO_2e$ and two proposals that are projected to save North Carolinians $3.5 billion in 2005 NPV dollars.

TLU-3a: Surcharges to Raise Revenue

CAPAG recommends imposing motor vehicle registration fees based on vehicle emissions to penalize vehicles with higher GHG emissions. The proposal would not be revenue neutral and CAPAG estimates that the extra revenue would be used to support transportation related projects. CAPAG estimates that the vehicle surcharge would average $7.25 registered vehicle and would raise $37 million in new revenue.[28]

TLU-5: Tailpipe GHG standards

CAPAG recommends that North Carolina adopt California Clean Car standards. The standards would require that all new cars sold in North Carolina reduce GHG emissions by 30%, to be phased in between 2009 and 2016. CAPAG calculates that the savings from reduced fuel consumption, net of increased vehicle costs, would be approximately $60 per year per resident.

[26] Ibid, F-2.
[27] Ibid.
[28] Ibid, G-17.

CAPAG translates this into a savings of $38 per ton of CO_2e, for a net savings of $1.7 billion, in net present value terms, for the period to year 2020.

TLU-6: Biofuels Bundle

CAPAG proposal TLU-6 would increase the percentage of biofuel sales in the state's gasoline and diesel markets. Biofuels are produced from either a starch or cellulosic ethanol base, procured from plants. CAPAG proposes several incentives, combined with a state government mandate, to achieve its goals. CAPAG also proposes to eliminate the motor fuels tax on the biofuel portion of gasoline and diesel and provide a $0.25 per gallon tax credit.[29]

CAPAG sets out a timeframe for replacing gasoline and diesel with biofuels. The first target is to replace 10% of gasoline sales and 5% of diesel sales by 2010. CAPAG calls for the penetration rate to rise 5% every five years until reaching 25% of gasoline sales and 20% of diesel sales by 2025.[30] There would also be a cost trigger built into the system, where if the cost of alternative fuel exceeds conventional fuel by more than a specified amount, the renewable fuel standard would be suspended until the cost is back in the "acceptable" range.

ES-4: Cap and Trade

A Cap and Trade system is a pseudo-market mechanism in which CO_2 and other GHG emissions are limited or capped at a specified level, and where those participating in the system can trade permits (a permit is an allowance to emit one ton of CO_2 or GHG). The permit allows emitters either to reduce their emissions or to buy a permit to release GHG, whichever is less expensive. The market for permits is created by government fiat and the value of the permits depends on the number issued. Therefore, the number of permits issued or allocated is, in effect, the cap. The cap can apply to single industrial sectors, such as manufacturing or electric utilities, a combination of sectors or all sectors in the economy.

CAPAG recommends a Cap and Trade program applicable to North Carolina within the framework of a national or regional plan. Although CAPAG provides estimates of the costs and GHG reductions of such a program, it does not provide the details of a prospective regulatory program.[31]

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[29] Ibid, G-30.
[30] Ibid, G-29.
[31] Ibid, F-22.

BHI based its analysis of a Cap and Trade program for North Carolina on the national proposal contained in America's Climate Security Act of 2007 (S. 2191).[32] The Act includes the following provisions:

- An emissions cap of 5,775 $MMTCO_2e$ by 2012, declining to 1,732 $MMTCO_2e$ by 2050;
- Permission to participate in allowance trading, borrowing and banking;
- A domestic offset program to sequester GHGs in agriculture and forests;
- A Carbon Market Efficiency Board to observe and report on the national GHG emission market and provide cost relief measures if it determines that the market poses significant harm to the U.S. economy;
- The distribution of emission allowances, including initially giving allowances to specified owners and operators of covered facilities, states and load-serving entities;
- The establishment of a Climate Change Credit Corporation to auction emission allowances; and
- The use of auction proceeds for zero- or low-carbon energy technologies programs.

The Act aims to reduce total U.S. greenhouse gas emissions to 70 percent below their 2005 levels by the year 2050, utilizing a Cap and Trade system. The system would cover the electric power, industrial petroleum based fuels and chemical sectors.

[32] *America's Climate Security Act of 2007*, S 2191 110th Cong. 1st sess. http://www.govtrack.us/congress/bill.xpd?bill=s110-2191 (accessed April 17, 2008).

BHI Estimates and Results

Each of these proposals consists of either a tax or a fee added to the purchase of a product, such as a vehicle surcharge, or seeks to increase the purchase and use of products such as biofuels that emit fewer greenhouse gases. BHI used the NC-STAMP model to measure the changes to the North Carolina economy that would take place as a result of the CAPAG recommendations. Each estimate represents the change that would take place in the indicated variable against a "baseline" assumption about the value that variable would take in the indicated year.

Energy Demand and Supply

Table 5 presents the effects on selected economic indicators and on state and local government funds attributable to the following policy changes:

- Demand Side Management Programs – RCI-1;
- Expanded Energy Efficiency Funds – RCI-2;
- Public Benefits Charge – ES-7; and
- Environmental Portfolio Standard – ES-2b.

The CAPAG recommendations for the energy sector would harm the North Carolina economy. The private sector would shed 2,267 jobs in 2008, with losses increasing to 3,824 jobs by 2011. The revenue raised from the public benefits charge would allow the public sector to add 936 jobs in 2008, increasing to 1,351 by 2011. In total, the measures would extinguish an estimated 1,331 jobs in 2008 and 2,473 jobs by 2011, almost double the job losses under the policies proposed for the transportation sector.

Although North Carolina would lose jobs, the wage rate would remain steady. North Carolinians would face higher utility prices, which in turn would increase their cost of living. The cost of living increase would, in turn, put upward pressure on households' wage demands, since people would need more money to cover their basic needs. The higher wage demands would add to the already higher energy costs, leading producers to reduce their demand for labor, which would act to temper the original increase in wage demands. These opposing forces balance out, with wages remaining unchanged compared to the counterfactual.

Table 5: Economic and Fiscal Impact of Energy Sector Recommendations

	2008	2009	2010	2011
Total Employment (Jobs)	(1,331)	(1,628)	(1,996)	(2,473)
Private (Jobs)	(2,267)	(2,695)	(3,202)	(3,824)
Government (Jobs)	936	1,067	1,206	1,351
Gross Wage Rate ($)	-	-	-	0.23
Investment ($ millions)	(44.50)	(53.38)	(63.95)	(76.72)
Nominal Personal Income ($ millions)	(107.00)	(131.50)	(161.50)	(199.50)
Real Disposable Income ($millions)	(146.50)	(173.50)	(205.00)	(242.50)
Real DI per Capita ($)	(12.11)	(13.96)	(15.92)	(17.99)
Real Gross Domestic Product ($millions)	(205.44)	(248.17)	(298.71)	(360.27)
State Funds ($ millions)	**127.55**	**152.82**	**180.85**	**214.44**
Sales and Use Tax	143.13	171.40	203.05	241.37
Corporate Income Tax	(1.85)	(2.14)	(2.39)	(2.71)
Franchise Tax	(2.25)	(2.62)	(3.03)	(3.52)
Motor fuel taxes	(0.67)	(0.80)	(0.96)	(1.18)
Highway use tax	(0.33)	(0.40)	(0.47)	(0.55)
Insurance taxes	(0.21)	(0.25)	(0.30)	(0.36)
Motor vehicle fees	(0.15)	(0.18)	(0.22)	(0.27)
Personal income tax	(5.60)	(6.90)	(8.60)	(11.02)
Cigarette and tobacco taxes	(0.12)	(0.14)	(0.16)	(0.18)
Alcohol taxes	(0.12)	(0.14)	(0.17)	(0.20)
Inheritance tax	(0.04)	(0.05)	(0.07)	(0.10)
Unemployment insurance tax	(0.71)	(0.83)	(0.96)	(1.11)
Natural gas tax	(1.28)	(1.46)	(1.68)	(1.92)
Other taxes	(0.20)	(0.23)	(0.28)	(0.33)
Fees	(2.09)	(2.48)	(2.94)	(3.52)
Local Funds ($ millions)	**(25.89)**	**(30.87)**	**(36.79)**	**(44.16)**
Local tax on residential property	(1.19)	(1.58)	(2.14)	(2.98)
Local tax on business property	(7.05)	(8.43)	(10.07)	(12.04)
Local sales and use taxes	(8.90)	(10.65)	(12.62)	(15.02)
Local other taxes and fees	(8.75)	(10.22)	(11.96)	(14.12)
Total Funds ($ millions)	**101.66**	**121.95**	**144.06**	**170.29**

Figures are on Calendar Year Basis

The combination of higher energy prices and lower employment under the CAPAG proposals would reduce incomes in North Carolina. Real disposable income would fall by $146.5 million in 2008, sliding another $100 million, to reach a loss of $242.5 million in 2011.

The higher cost of energy would hurt firms' profit margins, causing them to reduce investment in North Carolina. We estimate that investment in North Carolina would drop by $44.5 million in 2008 and $76.7 million in 2011, with the utility sector accounting for three-quarters of the decrease by 2011.

The combination of lower investment, employment and incomes would shave $205.4 million off of real GDP in North Carolina for 2008 and $360.3 million by 2011.

State government revenues increase due to the new public benefits charge and expanded energy efficiency funds, which we treat as taxes on the utility sector. As a result, tax revenue would increase by $143.1 million in 2008 and $241.4 million in 2011. The drop in employment and real incomes would reduce other state tax revenues resulting in net state tax revenue gains of $127.6 million in 2008 and $214.4 million in 2011. The negative economic effects of the proposals also reduce local tax revenues by $25.9 million in 2008 and by $44.2 million by 2011.

Transportation

Table 6 presents the changes in different economic indicators and in state and local government funds, due to the following policy changes that affect the Transportation industry:

- Vehicle Surcharge – TLU-3a
- California Emissions Standard – TLU-5
- Biofuels Bundle – TLU-6

The first economic indicator we consider is employment. The public sector would be able to expand employment slightly due to the increase in the revenue from the higher vehicle fees, while the number of jobs in the private sector would fall compared to baseline employment levels. This would be caused by the increase in vehicle fees and the higher fuel and vehicle prices associated with the adoption of the Biofuels Bundle program and the California Emissions Standards. We estimate that North Carolina would employ 1,003 fewer people in 2008 and 1,202 in 2011 under the plan.

Employment losses lead to a slight drop in annual wages – by $46 in 2008 and by $55 in 2011. These decreases in wages and employment cause total personal income in the state to fall by $365 million in 2009 and by $469.5 million in 2011. The increase in vehicle surcharges, the decrease in total personal income and a rise in fuel and vehicle prices combine to reduce real disposable income by $45 million in 2008 and by $46.5 million in 2011.

Table 6: Economic and Fiscal Impact of CAPAG Transportation Sector Proposals

	2008	2009	2010	2011
Total Employment (Jobs)	(1,003)	(1,042)	(1,104)	(1,202)
Private (Jobs)	(1,164)	(1,204)	(1,263)	(1,351)
Government (Jobs)	161	162	159	150
Gross Wage Rate ($)	(45.50)	(48.50)	(51.50)	(54.80)
Investment ($ millions)	(24.16)	(25.31)	(26.48)	(27.74)
Nominal Personal Income ($ millions)	(365.00)	(398.00)	(432.50)	(469.50)
Real Disposable Income ($millions)	(45.00)	(44.00)	(44.50)	(46.50)
Real DI per Capita ($)	(3.07)	(2.80)	(2.62)	(2.49)
Real state Gross Domestic Product ($millions)	(122.74)	(133.11)	(147.92)	(167.99)
State Funds ($ millions)	**(0.02)**	**(1.70)**	**(3.27)**	**(5.09)**
Sales and Use Tax	(5.86)	(6.16)	(6.39)	(6.68)
Corporate Income Tax	(0.93)	(0.97)	(0.98)	(1.01)
Franchise Tax	(0.92)	(0.97)	(1.01)	(1.06)
Motor fuel taxes	(2.77)	(2.81)	(2.86)	(2.92)
Highway use tax	(0.09)	(0.08)	(0.08)	(0.08)
Insurance taxes	(0.03)	(0.01)	0.01	0.03
Motor vehicle fees	36.81	37.18	37.60	38.09
Personal income tax	(20.26)	(21.83)	(23.43)	(25.22)
Cigarette and tobacco taxes	(0.14)	(0.13)	(0.13)	(0.13)
Alcohol taxes	(0.21)	(0.21)	(0.22)	(0.22)
Inheritance tax	(0.03)	(0.03)	(0.04)	(0.04)
Unemployment insurance tax	(1.91)	(1.98)	(2.04)	(2.10)
Natural gas tax	(0.03)	(0.03)	(0.03)	(0.03)
Other taxes	(0.53)	(0.53)	(0.53)	(0.52)
Fees	(3.16)	(3.16)	(3.17)	(3.20)
Local Funds ($ millions)	**(10.45)**	**(11.00)**	**(11.62)**	**(12.45)**
Local tax on residential property	(0.79)	(0.90)	(1.06)	(1.30)
Local tax on business property	(2.88)	(3.11)	(3.36)	(3.63)
Local sales and use taxes	(2.98)	(3.13)	(3.25)	(3.40)
Local other taxes and fees	(3.81)	(3.86)	(3.96)	(4.13)
Total Funds ($ millions)	**(10.47)**	**(12.69)**	**(14.89)**	**(17.54)**

Figures are on Calendar Year Basis

Investment in North Carolina would also suffer under the transportation proposals; it would fall below the baseline level by $24.2 million in 2008 and $27.7 million in 2011. The combined negative economic effects on investment, employment and incomes would shave $122.7 million off real GDP in North Carolina in 2008 and $167.9 million in 2011.

The proposed transportation policies would hurt the North Carolina economy, but they also encroach on the ability of state and local governments to provide goods and services. The negative effect on income and employment shrink the state's personal income tax collections by $20.3 million in 2008 and $25.2 million in 2011 and the state's sales tax revenue by $5.9 million in 2008 and $6.7 million in 2011. These losses alone nearly cancel out the extra revenue generated from the increase in the state's motor vehicle fees. Local governments also would suffer revenue losses under the proposals – $10.5 million in 2008, increasing to nearly $12.5 million in 2011.

Note that this loss in government revenue, at both the state and local levels, would not result from a drop in the taxes paid by the individuals or businesses in North Carolina. After all, the vehicle surcharge is really a fee increase. The damage to the economy brought about by the forced use of more costly production methods, as well as the increase in the fees would translate into lower revenues for other taxes, while also causing North Carolina residents to lose jobs and purchasing power.

Cap and Trade

Table 7 presents the changes to the different economic indicators and to the state and local governments' funds caused by implementing a Cap and Trade system based on the Climate Security Act of 2007.

The Cap and Trade system would produce the most damage to the North Carolina economy. The economy would shed 24,640 jobs in 2008, with losses increasing to 29,808 jobs in 2011. The private sector would absorb the brunt of the job loses, as energy and transportation price increases push up the cost of doing business in the state. Some firms would react by cutting back on production and subsequently payrolls; others would relocate to a lower cost (foreign) production site; and yet others, no longer able to compete, would simply shut their doors. State and local governments would not be immune to the price increases and, unless measures were made to boost revenues, which would likely damage the North Carolina economy even further, they would not be able to provide the same level of services as before, leading to job losses. State and local government in North Carolina would need to reduce their payrolls by 2,185 in 2008 and 3,095 in 2011.

Table 7: Economic and Fiscal Impact of Cap and Trade

	2008	2009	2010	2011
Total Employment (Jobs)	(24,640)	(25,904)	(27,552)	(29,808)
Private (Jobs)	(22,455)	(23,514)	(24,876)	(26,713)
Government (Jobs)	(2,185)	(2,390)	(2,676)	(3,095)
Gross Wage Rate ($)	(215.50)	(222.00)	(227.00)	(229.91)
Investment ($ millions)	(330.49)	(351.10)	(373.44)	(397.93)
Nominal Personal Income ($ millions)	(2,259.50)	(2,418.00)	(2,598.50)	(2,808.50)
Real Disposable Income ($millions)	(1,766.50)	(1,826.50)	(1,895.00)	(1,976.50)
Real Disposable Income per Capita ($)	(131.82)	(131.53)	(130.47)	(128.32)
Real Gross Domestic Product ($ millions)	(3,601.41)	(3,711.59)	(3,841.71)	(4,002.64)
State Funds ($ millions)	**(164.01)**	**(175.93)**	**(190.59)**	**(211.47)**
Sales and Use Tax	0.25	(0.33)	(1.07)	(2.05)
Corporate Income Tax	(13.89)	(14.27)	(14.12)	(14.28)
Franchise Tax	(15.10)	(15.60)	(16.12)	(16.68)
Motor fuel taxes	9.63	9.27	8.72	7.80
Highway use tax	(3.93)	(4.05)	(4.19)	(4.35)
Insurance taxes	(2.56)	(2.68)	(2.82)	(2.99)
Motor vehicle fees	2.20	2.15	2.05	1.88
Personal income tax	(113.74)	(122.34)	(133.39)	(149.07)
Cigarette and tobacco taxes	(1.43)	(1.44)	(1.45)	(1.46)
Alcohol taxes	(1.45)	(1.50)	(1.55)	(1.62)
Inheritance tax	(0.72)	(0.81)	(0.94)	(1.12)
Unemployment insurance tax	(10.25)	(10.41)	(10.60)	(10.81)
Natural gas tax	1.85	1.87	1.89	1.91
Other taxes	(1.03)	(1.09)	(1.16)	(1.25)
Fees	(13.85)	(14.73)	(15.86)	(17.39)
Local Funds ($ millions)	**(90.67)**	**(99.39)**	**(110.72)**	**(125.83)**
Local tax on residential property	(21.60)	(24.85)	(29.38)	(35.86)
Local tax on business property	(47.35)	(50.28)	(53.53)	(57.02)
Local sales and use taxes	0.13	(0.17)	(0.55)	(1.05)
Local other taxes and fees	(21.86)	(24.10)	(27.27)	(31.91)
Total Funds ($ millions)	**(254.68)**	**(275.32)**	**(301.31)**	**(337.30)**

Figures are on Calendar Year Basis

The higher cost of energy would hurt profit margins, causing firms to reduce investment in North Carolina. We estimate that investment in North Carolina would drop by $330.5 million in 2008 and $397.9 million in 2011.

The job losses would result in sharply lower incomes for North Carolina residents. Annual gross wages would drop by over $215.5 in 2008 and $229.9 by 2011, and real (price-adjusted) disposable income would slump by $1.7 billion or $131.8 dollars per person in 2008 and $1.9

billion, or $128.2 per person in 2011. The combined negative economic effects on investment, employment and incomes would shave $3.6 billion off real GDP in North Carolina in 2008 and $4 billion in 2011.

Conclusion

In its draft final report, CAPAG offered 56 recommendations for reducing GHG emissions covering four sectors of the state economy. CAPAG mandates the use of less efficient and more expensive renewable energy sources, public funding for untested programs to promote energy efficiency and participation in a national or regional Cap and Trade program to limit GHG emissions.

Contrary to CAPAG's assertions, the implementation of these measures would not bring "significant cost savings for the State's economy" but would rather increase costs in the energy, transportation and building sectors.[33] The programs would raise the prices consumers and businesses in North Carolina pay for energy, transportation and construction. It is, at the same time, unlikely that these new programs would lead to improvements in efficiency that would offset the increased prices at some undetermined date in the future. Meanwhile, the North Carolina business community would see a reduction in its competitive advantage over other states that resisted the pressure to adopt similar legislation. State GDP would be one percentage point below baseline by 2011.

The North Carolina legislature should consider the CAPAG proposals in light of their likely economic consequences. It should understand that, whatever the benefits of those proposals, they will exert measurable, negative effects on the state economy. To assert that it is possible to adopt sweeping greenhouse gas legislation without exerting such effects is to throw economic analysis, as well as common sense, to the wind.

[33] CAPAG, *Draft Final Report*, ES-2.

Appendix A: Simulation Methodology

BHI simulated the implementation of eight CAPAG recommendations using NC-STAMP. Each proposal was entered into the model as a change in the price of energy, or the introduction of a tax, for an industrial sector, specifically, the utility or transportation sector. This appendix contains a description of the methodology BHI used to estimate the price change or tax.

Energy Demand

RCI-1: Demand Side Management Programs

BHI assumed the program would begin by allocating 0.5% of utility revenues in 2008, increasing by 0.25% per year until reaching a maximum of 1.5% of revenues in 2011. BHI treats the revenues as an excise tax levied on the utility sector. The revenues raised by this excise tax would flow through a "Special Other" state government fund. From this fund, 25% of the revenue is allocated to the general fund and distributed to all sectors in proportion to all other general fund revenue. We assumed that this 25% would support staffing and other needs to implement the program. The remaining 75% of the funds are allocated to the construction, real estate, electrical equipment and professional, technical and scientific services sectors with equal weighting.

RCI-2: Expand Energy Efficiency Funds

In proposal RCI-2, CAPAG calls for a Public Benefit Charge (PBC) that is virtually identical to the one proposed by ES-7 in the energy sector.

For modeling purposes, BHI assumes that these recommendations are separate and additive in terms of their impact on utility prices. BHI increased the implicit excise tax on the utility sector – also used to model ES-7 – by an additional 1% of industry revenues. The revenue was allocated to the "Special Other" state fund and allocated to the construction, real estate, electrical equipment and professional, technical and scientific services sectors using the same method as in our treatment of RCI-1.

ES-7 Public Benefits Charge

Since electricity usage in North Carolina is projected to continue to rise over the next few years, the revenue from the PBC would also rise in line with electricity usage. BHI estimates that an average PBC would raise $120 million in revenue by 2011. We treat the PBC as a new excise tax on the utility sector and allocate the revenue to the Special Other fund in the North Carolina-STAMP model simulations

Energy Supply

ES-2b: Environmental Portfolio Standard

BHI utilized data from the Energy Information Administration of the U.S. Department of Energy and results from a report by LaCapra Associates prepared for the North Carolina Utilities Commission to estimate the effect the EPS would have on electricity prices.[34] Using this information, we estimate that prices for the North Carolina utility sector would increase by 0.44% in 2008 and by 1.61% in 2011. We increased the price index for the utility sector in NC-STAMP by these amounts against the counterfactual of no change in policy.

Transportation

TLU-5: Tailpipe GHG standards

The CAPAG report cites three studies of the effects of tighter emission standards for new cars: one shows huge cost savings; the second assumes that it would cost $1,000 to upgrade each vehicle, but there would be net savings; and the third estimates that the upgrade would cost $3,000 per vehicle, resulting in a situation where "savings on fuel would offset less than half of that cost for consumers."[35] Following these estimates, "in an effort to be conservative," CAPAG opts for the results of the second study, and thus finds nearly $1.69 billion in net savings.[36]

BHI uses the mean of the cost estimates cited by CAPAG ($1,000 to $3,000) for the stricter emissions standards, or $2,000 per new car. CAPAG cites a California Air Resources Board estimate that fuel savings offset over 100% of their estimate of $1,000 in manufacturing cost

[34] LaCarpa Associates, *Analysis of a Renewable Portfolio Standard for the State of North Carolina* (December, 2006): 61, http://www.ncuc.net/rps/rps.htm (accessed April 17, 2008).
[35] CAPAG, *Draft Final Report*, G-27.
[36] Ibid, G-28.

estimates, and a national automobile manufacturer's estimate that the fuel savings would offset less than half of the increased manufacturing costs. We assume that the fuel savings would amount to half the manufacturing costs, or $1,000, resulting in net cost of $1,000 per new vehicle sold in North Carolina.

Using U.S. Bureau of Transportation Statistics data for national new car sales and car registration data for North Carolina, we calculate the ratio of vehicle registrations in North Carolina to total registrations in the United States as 2.5%.[37] We apply this ratio to total new car sales in the United States, as reported by the U.S. Department of Commerce, to estimate the number of new cars sold in North Carolina in 2005.[38] We grow this figure by the average growth rate for new cars in the U.S. from 1990 to 2004, or 1.3%, to estimate new car sales in North Carolina for 2008-2011. We multiply the estimated increase in new car cost, $1,000 per car, by the new car sales to estimate the total increase in new car costs at $449 million in 2008. This figure represents 3.04% of the total transportation equipment manufacturing sector in the NC-STAMP model.

We increase the price index for the transportation equipment manufacturing sector by 3.04% in the transportation simulation, against the counterfactual of no change, to estimate the impact of TLU-5 on the North Carolina economy.

TLU-3a: Surcharges to Raise Revenue

BHI uses the CAPAG estimates of increases in motor vehicle fees of $37 million in the NC-STAMP model against the counterfactual of no increase. Since it is not clear from the CAPAG report exactly how these funds are to be used, other than to support a reduction in vehicle miles traveled, or the true effectiveness of the programs, we allocate the funds to the state highway and highway trust funds.

TLU-6: Biofuels Bundle

CAPAG provides no estimate of the costs or savings from the biofuels bundle recommendations. BHI, however, has provided estimates through 2011. Ethanol is less expensive than gasoline or diesel fuel on a per gallon basis, but ethanol produces less energy than gasoline and diesel. This

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[37] U.S. Department of Transportation, Bureau of Transportation Statistics, "State Transportation Statistics 2005," in "Table 5-1: Motor-Vehicle Registrations," http://www.bts.gov/publications/state_transportation_statistics/state_transportation_statistics_2005/index.html, (accessed April 17, 2008).
[38] U.S. Department of Commerce, Bureau of Economic Analysis, "Underlying Detail for the National Income and Product Account Tables," http://www.bea.doc.gov/, table 7.2.5S. (accessed April 17, 2008).

lower energy concentration translates into a lower driving mileage per gallon for ethanol relative to gasoline and diesel. As a result ethanol becomes more expensive to use than gasoline or diesel. Since CAPAG does not specify the cost differential for the proposed "cost trigger" we assume no cost trigger in our analysis.

Using data from the U.S. Bureau of Transportation Statistics (BTS) and the U.S. Energy Information Agency (EIA), BHI estimates that reaching the percentages mandated in TLU-6 would add 1.16% to transportation costs over the period of 2008 to 2011.

We begin with the BTS estimate of motor fuel use for each state for 2005.[39] We inflate this figure through 2011 using the annual percentage change in the EIA estimate for U.S. energy consumption for motor fuels.[40] We then estimate the amount of ethanol consumption in North Carolina for 2008-2011 by inflating the EIA estimate for 2005 by the estimated increase in U.S. ethanol consumption for 2006 to 2011.[41] The ethanol projection is subtracted from the gasoline projection for each year, since the gasoline figure includes ethanol, according to a note in the EIA table. We next calculated the total British Thermal Units (BTUs) that our predicted consumption of gasoline and ethanol combined would produce for each year, using the BTU per gallon figures from the EIA.[42]

We calculated the number of gallons of ethanol that would be consumed in North Carolina to reach the percentage mandated by CAPAG. This is not straightforward, since every new gallon of ethanol produces fewer BTUs than the gallon of gasoline it replaces. Thus, if we were simply to replace gasoline, gallon for gallon, with ethanol, drivers would not be able to travel the same distance as before. To complete the calculation we utilize the Microsoft EXCEL "solver" utility. Solver allows us to compute the number of gallons of ethanol and gasoline that would satisfy the

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[39] U.S. Department of Transportation, Bureau of Transportation Statistics, "State Transportation Statistics 2006, in "Table 7-4: Motor Fuel Use: 2005," http://www.bts.gov/publications/state_transportation_statistics/state_transportation_statistics_2006/html/table_07_04.html (accessed April 17, 2008).

[40] U.S. Department of Energy; Energy Information Administration, "Energy Consumption by Sector and Source," in "Table 2: Energy Price and Expenditure Estimates by Source, 1970-2005, North Carolina," http://www.eia.doe.gov/oiaf/aeo/excel/aeotab_2.xls (accessed April 17, 2008).

[41] U.S. Department of Energy; Energy Information Administration in "Table C4: Estimated Consumption of Alternative Fuels by State and Fuel Type, 2005," http://www.eia.doe.gov/cneaf/alternate/page/atftables/afvtransfuel_II.html (accessed April 17, 2008).

[42] U.S. Department of Energy; Energy Information Administration, "Forecasts and Analysis, Alternative Fuels: Ethanol," http://www.eia.doe.gov/oiaf/ethanol3.html. See also the calculator at "Energy Kids Page," http://www.eia.doe.gov/kids/energyfacts/science/energy_calculator.html#mogascalc. (accessed April 17, 2008).

CAPAG goal, while keeping the total number of BTUs generated from both unchanged from the initial calculation. This calculation is performed for each year.

Finally, we calculated the dollar cost of the new mix of gasoline and ethanol consumption in North Carolina. We used EIA projections for gasoline and ethanol prices to calculate the difference between the cost of the original mix of gasoline and ethanol and the new mix, or $179 million.[43] This represents 0.83% of the transportation sector spending in the NC-STAMP model.

The process was repeated to estimate the increase in costs under the diesel portion of the CAPAG Biofuels Bundle proposal. We estimated that diesel fuel would increase costs by $5.6 million, which represents 0.33% of the revenues of the transportation sector in the NC-STAMP model. We increased the price index for the transportation sector in NC-STAMP by 1.16% (0.83 + 0.33) against the counterfactual of no change in policy.

ES-4 Cap and Trade

BHI modeled a Cap and Trade program for North Carolina based on the national proposal contained in America's Climate Security Act of 2007 (S. 2191).[44] The National Association of Manufacturers (NAM) and the American Council for Capital Formation analyzed the Climate Security Act using the National Energy Modeling System (NEMS). The NEMS model is used by the U.S. Energy Information Administration (EIA) to respond to requests by Congress and federal agencies for analyses of energy and environmental proposals. The NAM study reports national and state specific results based on high and low cost assumptions, including changes in energy and transportation fuel prices.[45]

BHI utilized the NEMS price change results for the U.S. and North Carolina to provide the basis for the price change inputs to NC-STAMP. The NAM study assumes the Cap and Trade system would become effective in 2011 and predicts U.S. price changes for the years 2014, 2020 and 2030.[46] The study also reports estimates for North Carolina in 2020.[47] The study presents the

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[43] U.S. Department of Energy; Energy Information Administration, *Annual Energy Outlook: 2008 (Early Release)* in “Table 3. Energy Prices by Sector and Source,” http://www.eia.doe.gov/oiaf/aeo/excel/aeotab_3.xls (accessed April 17, 2008).
[44] *America's Climate Security Act of 2007*, S 2191, 110th Cong. 1st sess., GovTrack.us, http://www.govtrack.us/congress/bill.xpd?bill=s110-2191 (accessed April 17, 2008).
[45] American Council for Capital Formation and National Association of Manufacturers, *Analysis of Lieberman-Warner Climate Security Act (S. 2191) Using the National Energy Modeling System* (March 13, 2008) Internet; http://www.accf.org/pdf/NAM/fullstudy031208.pdf (accessed April 17, 2008).
[46] Ibid, 8.

price changes for gasoline, residential and industrial electricity, natural gas and coal fired electricity under the low and high cost scenarios against the baseline. They also report changes in overall energy expenditures for 2012 and 2014.

BHI calculated the ratio of the 2020 prices changes in North Carolina to the prices changes in the United States for each category of energy listed above. This ratio was used to adjust the 2014 prices reported for the United States to approximate North Carolina price changes in 2014.

BHI used 2005 North Carolina energy expenditures by their commodity source (coal, natural gas, gasoline, retail electricity), as reported by the Energy Information Agency of the U.S. Department of Energy, to determine the percentage of energy expenditures by source to the total energy expenditures for the four categories.[48] The percentages were used to allocate the price changes for each source of energy, as reported by NAM, to the total change for the North Carolina energy sector. The result for each category was summed to arrive at an adjusted 2014 price change for the energy sector.

We obtained the estimated price change for 2012 by using the ratio of 2012 to 2014 national prices, as reported by NAM. Using this methodology, we estimated that the energy price would increase by 11.4% in the first year of Cap and Trade. On the basis of this calculation, we increased the price index for the utility sector by 11.4% in NC-STAMP and ran the simulation against the counterfactual of no change.

We estimated the transportation sector price increase resulting from the implementation of a Cap and Trade system using a similar method as above. We first calculated the average U.S. gasoline price increase reported by NAM. The U.S. price increase for gasoline in 2014 was adjusted to North Carolina using the difference between the North Carolina and U.S. prices increase reported for the year 2020.

We calculated the ratio of gasoline expenditures to total transportation expenditures for North Carolina. This percentage was multiplied by the percentage increase in North Carolina gasoline price to obtain the total estimated increase in transportation prices under Cap and Trade, or 7.8%,

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[47] See ACCF and NAM, "North Carolina: Economic Impact on the State from the Lieberman-Warner Proposed Legislation to Reduce Greenhouse Gas Emissions," from *Analysis* http://www.accf.org/pdf/NAM/NorthCarolina.pdf (accessed April 17, 2008).
[48] U.S. Department of Energy; Energy Information Administration, in "Table 1: Energy Price and Expenditure Estimates by Source, 1970-2005, North Carolina," http://www.eia.doe.gov/states/sep_prices/total/pr_tot_nc.html (accessed April 17, 2008).

for the first year. We increased the price index for the transportation sector by 7.8% in the NC-STAMP model and ran the simulation against the counterfactual of no change.

Appendix B: NC-STAMP

NC-STAMP is a comprehensive model of the North Carolina economy, designed to capture the principal effects of city and state tax changes on that economy. NC-STAMP is a five-year dynamic Computable General Equilibrium (CGE) tax model. As such, it provides a mathematical description of the economic relationships among producers, households, government and the rest of the world. It is general in the sense that it takes all the important markets and flows into account. Because it assumes that demand equals supply in every market (goods, services, labor and capital), STAMP is an equilibrium model. It reaches equilibrium by allowing prices to adjust within the model. With the help of a computer, the model is able to generate numeric solutions to concrete policy and tax changes. It is, in particular, a tax model because it pays detailed attention to identifying the role played by different taxes or equivalent price changes.[49]

We begin by distinguishing between producers and consumers. Consumers/households earn income by supplying labor (wages and salaries) and capital (dividends and interest). Some of these consumers also receive transfer payments such as pensions from the government. Consumers maximize their discounted utility, which they get from consumption and leisure. Their spending decisions are strongly influenced by the structure of prices they face; and the amount of labor that they are willing to provide depends to a substantial degree on the wage rates before them, as well as the taxes they have to pay.

Producers/firms buy inputs (labor, capital and intermediate goods that are produced by other firms) and transform them into outputs. Producers maximize profits and are likely to change their decisions about how much to buy or produce depending on the prices they face for inputs and outputs.

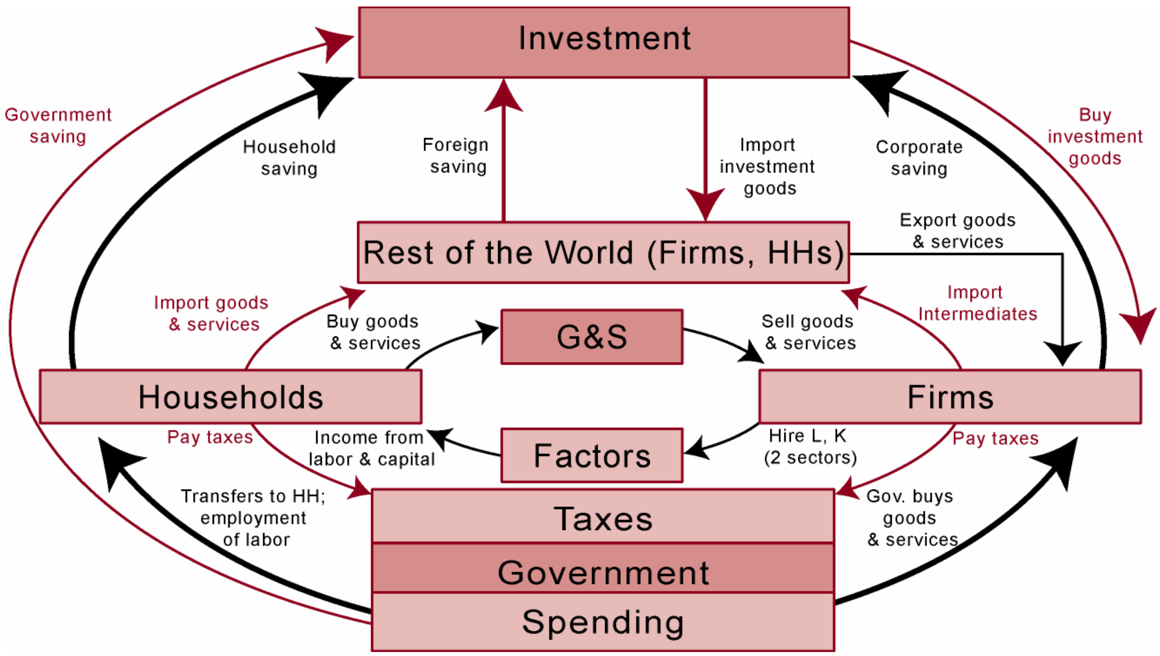
In addition, there is a government sector that collects taxes and fees and provides services and transfers. The rest-of-the world sector consists of the entire world outside of North Carolina. The relationships between these components are set out in the circular flow diagram shown in Figure 1.[50] The arrows in the diagram represent flows of money (for instance, households purchase

[49] Shoven and Whalley, "Applied General-Equilibrium Models."

[50] Based on a similar diagram in Peter Berck, Elise Golan, and B. Smith with John Barnhart and Andrew Dabalen. "Dynamic Revenue Analysis for California." University of California at Berkeley and California Department of Finance (1996): 117, http://www.dof.ca.gov.

goods and services), and flows of goods and services (for instance, households supply their labor to firms). The separate box for government shows the flows of funds to government in the form of taxes, as well as government purchases of goods and services and government hiring of labor and capital.

Figure 1. Circular Flow Diagram



Complex as it may seem, the diagram in Figure 1 is still too simple, because it lumps all households into one group, and all firms into another. To provide further detail it is necessary to create *sectors*; NC-STAMP has 81 economic sectors. Each sector is an aggregate that pulls together segments of the economy. We separate households into seven income classes and firms into 27 industrial sectors. In addition, we distinguish between 30 types of taxes and funds (four at the federal level, 13 at the state level, and 12 at the city level) and 13 categories of government spending (two at the federal level, six at the state level, and five at the city level). To complete the model, there are two factor sectors (labor, capital), an investment sector and a sector that represents the rest of the world. The availability of suitably disaggregated data (for households and firms) as well as the particular state and city taxes and funds, dictate the choice of sectors.

Sub-national models, such as NC-STAMP, are similar in many ways to national and international CGE models. However, they differ in a number of important respects. Specifically:

a. In a national model, most saving goes toward domestic investment; however, this need not be true at the regional level. If citizens of North Carolina save more than they spend, then the excess saving will leak out of the state.
b. The smaller the unit under consideration, the greater the importance of trade with the rest of the world. This is an important consideration for state models.
c. Migration is likely to be larger – and more responsive – across cities and states than across nations.
d. In sub-national models, taxes are interdependent. So, for instance, the amount of revenue collected by the Federal personal income tax depends significantly on whether there is a state or local income tax (which may be deducted from income before computing the Federal tax).
e. Data are less available at the sub-national than national level. This explains why scores of national CGE models have been built, but relatively few sub-national models.

Constructing a CGE model

The construction of a CGE model involves several steps. First, one needs to organize the data needed by the model. NC-STAMP starts with data for a single fiscal year, 2006, which we use as a basis to develop a steady state path in the model through fiscal year 2011. This steady state path is attained by applying growth rates for investment, population, employment and inflation throughout the time frame of the model. In NC-STAMP, the investment growth rate is assumed to be 1.31%.[51] The growth rate for population is assumed to be 1.7%.[52] The inflation growth rate is assumed to be 3.00%[53]. To attain a reasonable steady state path, the data for the base year, fiscal year 2006, must be very detailed. Most of the data are organized into a *Social Accounting Matrix (SAM)*, which in this case consists of an 81 by 81 matrix that accounts for the main economic and fiscal flows in the state.

[51] This figure is derived from taking the average nominal US gross domestic investment for the period 1929-2004 as published by the Bureau of Economic Analysis.
[52] This figure is the Census projection for North Carolina for the period 2005-2010.
[53] This figure is based on data obtained from the U.S. Bureau of Labor Statistics.

The model also requires some additional information – for instance, data on employment and on the structure of the Federal income tax – which are put in separate files. And the model requires information on "elasticities;" these are the parameters, taken from the academic literature, that measure the responsiveness of the different agents in the economy to changes in prices and costs. These are set out in detail in Section 4 of this appendix. The economy is assumed to be competitive, and to run at full employment (by which we mean that there is no involuntary unemployment).

Second, the model needs to be specified in detail; the next section of this appendix sets out details of the model that we constructed for North Carolina, along with some comments explaining the choices made at each step.

The third step is to program the model. For this we used the specialized GAMS (General Algebraic Modeling System) software. Before use, the model must be calibrated. We calibrate the model under the assumption that the data gathered for the first year, 2006, represents the optimal levels of the different variables for that year and, as mentioned earlier, using elasticities from the literature. We know the model is correctly calibrated if, and only if, when it is run for the first year, it replicates the values for all the variables that we had in our data. Calibration is a crucial step in modeling the economy under consideration for obvious reasons.

The fourth step is to then open the model for growth into future years and solve the model. Although this step may seem trivial, it is one of the most time consuming ones, since we check for both consistency of publicly available data and the results the model returns. Once the model solves for the five year period it considers, we run some counterfactuals to check on how well it captures the changes in the variables that are considered in the model.

After making sure that the model solves for all its years, and that it returns consistent results, it is ready for policy analysis. To allow for an easier use of the model, we develop a client interface in Excel, where any user can change a tax rate or a level of revenue to be collected from particular taxes, and can then use the internet to get the changes that those policy changes would make in the economy. For the analysis in this report, however, specific programming was needed to simulate the different changes mentioned. *It is very important to note that NC - STAMP is a policy model and not a forecasting model; in other words it is designed to answer "what if?" questions, not to provide economic forecasts.*

Organizing the Data

The starting point in building a CGE model is to determine the degree of detail that is desired and to organize the collected data into the useful format of a Social Accounting Matrix (SAM) for the base year. The SAM that we developed for North Carolina is an 81 by 81 matrix. Each of the 5,929 cells in the matrix represents the dollar value of a flow from one sector of the economy to another – for instance, purchases of business services by the utilities sector, or labor earnings flowing to middle-income households. Reading along a row, one finds the payments received by that sector; reading down a column, one sees the payments made by that sector. The SAM is balanced, which means that the sum of the entries in any given row equals the sum of the entries in the corresponding column. Thus, for instance, the revenue received by utilities must equal spending by that sector, so that all incoming and outgoing funds are completely accounted for.

For NC-STAMP, we distinguish 27 industrial sectors, two factors (labor and capital), seven household categories, an investment sector, 41 government sectors (23 for taxes, 13 for spending, five government funds) and a sector for the rest of the world. In sectoring the economy we sought to strike a balance between providing a high level of detail (especially on the tax side) and keeping the model to a manageable size. An additional limitation is that the lack of finely disaggregated data limits the degree of detail that is possible. Data availability also determined some of the choices we made; for instance, it is possible to get a breakdown of households into seven income categories (see below for further details), and while we might have preferred a different set of categories, we were constrained by the nature of the data available.

Industrial sectors

Although data for 49 sectors were actually available from the Bureau of Economic Analysis, NC-STAMP contains only 27 industrial sectors since some sectors were too small to merit separate attention. In these cases, we combined some industries, such as textiles and apparel. In other cases, there were no matching employment figures, and so it was easier to work with aggregates.

Factor Sectors

We distinguish between two factors, labor and capital (the latter which includes land). Businesses pay wages and salaries to labor, and rent on the capital they use to the capital owners.

Since the model does not allow firms to have profits, as it assumes perfect competition general equilibrium, the payments to capital include the redistribution of any earnings that companies have.

Household Sectors

In NC-STAMP, households receive wages, capital income and transfers and they use this income to buy goods and services, to pay taxes and fees and to save. We distinguish seven household sectors, which group households by their levels of income. Expenditure data are available for households in each of these categories, which make it relatively straightforward to work with this structure. One purpose of this disaggregation of households is to allow one to trace the distributive effect of tax changes and another one is to allow different groups to have different levels of sensitivity to labor market conditions.

Investment Sector

There is one investment/savings sector. Both households and the government save and invest. Information is available from the Bureau of Economic Analysis (BEA) on the pattern of gross investment by destination (i.e., how much gross investment went into adding to the stock of capital in utilities, in industry, and so on). We have constructed measures of the capital stock in each sector, and by applying published depreciation rates and adding gross investment, arrived at the capital stock in the subsequent period. This permits the model to track the expansion of the economy over time. The BEA also produces a matrix, built for the U.S. for 1997, which maps investment by destination with investment by source. This mapping allows one to determine, for example, how much of the investment destined for utilities is spent on purchasing goods and services from the construction sector and the transport sector. Thus if investment rises, it is possible to identify which sectors would face an expansion in the demand for their output.

Government Sectors

NC-STAMP was designed primarily to analyze the effects of major changes in the structure of state taxes, so we have paid particular attention to providing sufficient detail for government transactions. The sectoring is summarized below in Table 8.

The North Carolina government collects revenue from taxes and fees. Specific tax categories at the state level included in the model are: sales and use, cigarettes and tobacco, motor fuels, alcohol, inheritance, insurance, corporate and personal incomes. The rest of the state taxes are grouped into a residual category (other local taxes).

The revenues from the taxes go to either the NC general fund, the NC capital projects fund or to other funds, or a combination of them. Funds then allocate the money into the five spending categories: education, health and welfare, transportation, public safety or others.

Table 8: Government Sectors

Federal Government Receipts		
USSSTX	Social Security (OASDI and MEDICARE)	Receives payments from employers and households; pays out transfers to households.
USPITX	Federal Personal Income Tax	Receives payments from households, which are put into the Federal normal spending account.
USCITX	Federal Corporation Income Tax	Receives payments from corporations and channels them into the Federal normal spending account.
USOTTX	Other Federal Taxes	Includes excises on motor fuel, alcohol, and tobacco; estate and gift taxes. Also funneled into the Federal normal spending account.
Federal Government Expenditure		
USNOND	Federal Normal Spending	Federal government purchases goods and services, hires labor, and transfers money to NC and to Federal defense fund.
USDEFF	Federal Defense Spending	Purchases goods and services, and pays labor for military purposes.
NC State Government Receipts		
STPITX	State Personal Income Tax	Revenues go into NC State general fund and other fund.
STSATX	State Sales and Use Tax	Revenues go into NC State general fund and other fund.
STCITX	State Corporate Income Tax	Revenues go into NC State general fund and other fund.
STIHTX	North Carolina State Inheritance Tax	Revenues go into NC State general fund.
STINTX	North Carolina State Insurance Tax	Revenues go into NC State general fund and other fund.
STFUTX	State Taxes on Motor Fuels	Revenues go into NC State Highway trust fund and highway fund.
STFRTX	State Franchise Tax	Revenues go into NC State general fund.
STHUTX	State Highway Use Tax	Revenues go into NC State highway trust fund.
STNGTX	State Natural Gas Tax	Revenues go into NC State general fund.
STALTX	State Alcohol Beverage Taxes	Revenues go into NC State general fund and other fund.

Table 8: Government Sectors (Cont.)

STTCTX	State Tax on Cigarettes and Tobacco	Revenues go into NC State general fund.
STOTTX	State Other Taxes	Revenues go into NC State general fund and Other funds.
STMOTX	State Motor Vehicle Fee	Revenues go into NC State general fund.
STWKTX	State Unemployment Insurance Tax	Sector combines workers unemployment funds. Receipts go into other funds.
STFEES	State Fees, License Permits and Other Revenue	Revenues go into all funds.
STGENF	State General Fund	An accounting device. Tax revenue is channeled into this fund before being distributed to other uses.
STHITF	State Highway Trust Fund	Revenues go into NC State general fund and State highway fund.
STHWF	State Highway Fund	Revenues go into NC State general fund and Other fund.
STPROF	State Proprietary Funds	Tax revenue is channeled into this fund from state fees and the general fund before being distributed to state general, health other spending.
STOTHF	State Other Funds	Collects revenue from several taxes and distributes to several types of state government expenditures
STOTHSF	State Special Other Fund	Collects Revenues from new taxes introduced for the simulations. It is used to distribute the revenue to the appropriate sector or state government expenditures.
NC State Government Expenditure		
STGGSP	State General Spending	General government spending.
STEDUC	State Spending on Education	Mainly purchases of goods and services and labor in the higher education sector.
STHELT	State Spending on Health & Welfare	Buys some services; mainly transfers funds to local health spending fund.
STPBSF	Public Safety	Public safety and fire departments spending.
STTRAN	State Spending on Transport	Mainly buys engineering services and construction.
STOTHS	State Other Spending	Miscellaneous other spending by the state on labor, goods and services.
Local Government Receipts		
LOPRTX	Local Tax on Residential Property	Revenues go into the local general fund.
LOPBTX	Local Tax on Business Property	Revenues go into the local general fund.
LOOTTX	Local Taxes Other	Revenues go to the local general fund.
LOSATX	Local Sales and Use Tax	Revenues go to all three funds (general, capital projects and other).

Table 8: Government Sectors (Cont.)		
Local Government Expenditure		
LOEDUC	Local Spending on Education	Purchases goods and services and (mainly) pays teacher salaries.
LOHELT	Local Spending on Health & Welfare	Purchases goods and services and pays labor; large transfers to the poorest category of households.
LOPBSF	Local Public Safety	Public safety and fire departments local spending.
LOTRAN	Local Spending on Local Transportation	Mainly buys engineering services and construction.
LOOTHS	Local Other Spending	Includes spending on police and firefighters, road repair, and miscellaneous local government services.

Rest of the World

To complete the model, we have included a sector for the rest of the world (ROWSCT). This refers to the world outside of North Carolina, i.e., the rest of the United States and other countries. Information on flows between North Carolina and the rest of the world is difficult to piece together, and is an area where considerable professional judgment was required.

NC-STAMP Equations

NC-STAMP is a dynamic CGE model which assumes a steady state growth path. Absent from any "shocks", the economy is assumed to remain on this path. If the economy experiences a shock, such as a tax change, the economy will diverge from this steady state path and eventually turn onto a new path. The size and length of the divergence will depend on the size of the shock to the economy. Below we set out the equations used in NC-STAMP and the assumptions inherent in them.

Household Demand

Households are assumed to maximize their well being ("utility") by picking baskets of goods and services, subject to their budget constraints. The key set of equations in this section is labeled *Private Consumption*, and consists of a set of demand functions. These demand functions, based on a Cobb-Douglas utility function, take on the simple form,

$$X_{t,i} = \lambda_i * \frac{I_t}{P_{t,i}}, \quad i = 1,...,n; t = 1,...n,$$

where $X_{t,i}$ is the quantity demanded of good i at time t, $P_{t,i}$ is the price of good i at time t, I_t is income at time t, and λ_i are parameters that measure the share of income that is devoted to good i. This is the simplest specification that is theoretically satisfactory: it is additive (so spending equals income less taxes less saving), has downward-sloping demand (ensuring that when the price of a good rises, the quantity demanded falls), is zero degree homogeneous in prices and income (so that if prices and incomes were to double, the quantity demanded would not change), and meets the technical requirement of symmetry of the Slutsky matrix. More complex formulations are possible, but there is a lack of reliable data on the elasticity parameters that would be needed in such cases.

Household Gross Factor Income

Comments: The gross income of households in each of the seven groups (indexed by h in the set H) is found by first summing factor income (y_f) from labor and capital, subtracting the social security contributions paid by employees, and then allocating the total to each group on the basis of fixed shares. Factor payments are allocated to each household group using the same fixed shares as were found in the base year.

Eq. 1.

$$y_{t,h} = \sum_{f \in F} \frac{\alpha_{h,f} a^{w}_{t,h}}{\sum_{h \in H} \alpha_{h,f} a^{w}_{t,h}} y_{t,f} \left(1 - FFP_f\right)\left(1 - \sum_{g \in GF} \tau^{fh}_{t,g,f}\right) \qquad \forall t \in T, h \in H, f \in F$$

Description: Household income is the sum of income from each factor (labor and capital) less factor taxes, distributed by household groups according to their share of total.

Data: The information on earnings for each household group comes from NC (North Carolina) IMPLAN (an economic impact modeling system which allows users to perform in-depth regional analysis. See http://www.implan.com for more details).

Household Disposable Income

Comments: Disposable household income is gross income, less taxes on household income and property (mainly personal income tax (USPITX, STPITX) and residential property tax (LOPRTX)), plus transfer payments (such as social security and unemployment benefits).

Eq. 2.

$$y_{t,h}^{d} = y_{t,h} - \sum_{g \in GI} t_{t,g,h} a_{t,h}^{hh} - \sum_{g \in GH} \tau_{t,g,h}^{h} a_{t,h}^{hh} + \sum_{g \in G} w_{hg} a_{t,h}^{n} \tau_{t,h,g}^{pc} \quad \forall\, h \in H, t \in T$$

Description: Disposable household income is the household income less income taxes and other household taxes (property taxes etc), plus the government transfer payments.

Private Consumption Expenditure

Comments: This is the simplest demand system that is consistent with theoretical first principles, and it requires only a limited number of parameters.

Eq. 3.

$$c_{t,i,h} = \overline{c}_{t,i,h} \left(\frac{y_{t,h}^{d}}{\overline{y}_{t,h}^{d}} \div \frac{p_{t,h}}{\overline{p}_{t,h}} \right)^{\beta_{ih}} \prod_{i' \in I} \left[\frac{p_{t,i'}}{p_{t,i'}} \frac{\left(1 + \sum_{g \in GS} \tau_{t,g,i'}^{c} \right)}{\left(1 + \sum_{g \in GS} \tau_{t,g,i'}^{q} \right)} \right]^{\lambda_{i'i}} \quad \forall i \in I, h \in H, t \in T$$

Description: Consumption is a function of baseline consumption, adjusted to reflect the change in household disposable income (in constant prices), and the change in after-tax prices.

Data: By construction, this equation has zero cross price elasticities. In the absence of adequate estimates of demand elasticities we follow the approach taken by Berck et al., setting all income and own-price elasticities equal to unity.

Direct Household Purchases of Imports

Comments: Some household spending goes directly to buy goods and services outside North Carolina.

Eq. 4. $$m_{t,h} = \overline{m_{t,h}} \left(\frac{y^d_{t,h}}{\overline{\overline{y^d_{t,h}}}} \div \frac{p_{t,h}}{\overline{\overline{p_{t,h}}}} \right)^{\eta^m_h} \quad \forall h \in H, t \in T$$

Description: Household imports will increase with the increase in disposable income, in constant prices.

Household Savings

Comments: In NC-STAMP, household savings is the residual after spending and taxes have been subtracted from income. Thus savings are seen as occurring passively.

Eq. 5. $$s_{t,h} = y^d_{t,h} - \sum_{i \in I} c_{t,i,h} p_{t,i} \left(1 + \sum_{g \in GS} \tau^c_{t,g,i} \right) \text{-} m_{t,h} \quad \forall h \in H, t \in T$$

Description: See comments above.

Data: The savings rates for households at each income level were adjusted based on professional judgement, to account for the imputed savings by corporations (which indirectly represents savings by the owners of the corporations).

Consumer Price Index

Comments: The price index in the reference period is set equal to 1. There is a separate price index for each household group. This allows one to compute the real (rather than nominal) income for each household group. For instance, a tax on foodstuffs would tend to hit poor households relatively hard, and the CPI for poor households would pick up this effect.

Eq. 6. $$p_{t,h} = \frac{\sum_{i \in I} p_{t,i} \left(1 + \sum_{g \in GS} \tau^{c}_{t,g,i}\right) c_{t,i,h}}{\sum_{i \in I} \overline{p}_{t,i} \left(1 + \sum_{g \in GS} \tau^{q}_{t,g,i}\right) c_{t,i,h}} \quad \forall\, h \in H, t \in T$$

Description: Price index by household group is a function of the baseline price index, adjusted by the change in after-tax prices by industry, according to their corresponding share of consumption.

Data: The consumption of each good by each household group (c_{ih}) is derived from reports published by State and Federal agencies. The model also generates some of its own values.

Labor Supply

Comments: In NC-STAMP we model the labor participation rate, defined as the proportion of households in any given income category that work. The participation rate is assumed to rise if wage rates rise, if the taxes levied on earnings fall, or if the transfer payments paid out per non-working household fall. The participation rate for low-income households is assumed to be highly sensitive to the level of transfer payments, but relatively insensitive to changes in taxes or the wage rate. On the other hand, high-income households are assumed to respond substantially to changes in the taxes and wage rates they face.

Eq. 7. $$a^{w}_{t,h} = \overline{a}^{w}_{t,h} \frac{a^{hh}_{t,h}}{\overline{a}^{hh}_{t,h}} \left(\frac{r^{a}_{t,L}}{\overline{r}^{a}_{t,L}} \div \frac{p_{t,h}}{\overline{p}_{t,h}} \right)^{\eta^{ls}_{h}} \left[\prod_{g \in GI} \left(\frac{t^{pi}_{t,g,h}}{\overline{t}^{pi}_{t,g,h}} \div \frac{p_{t,h}}{\overline{p}_{t,h}} \right)^{\eta^{PIT}_{h,g}} \right]^{1/GINUM} \left(\frac{\sum_{g \in G} \frac{w_{t,h,g}}{p_{t,h}}}{\sum_{g \in G} \frac{\overline{w}_{t,h,g}}{\overline{p}_{t,h}}} \right)^{\eta^{tp}_{h}}$$

$$\forall t \in T, h \in H$$

Description: The supply of labor is a function of the baseline supply of labor adjusted by population growth, the net change in wages, income taxes, and government transfer payments. We used professional judgment in determining the proper elasticities for each household group.

Data: The data on working households by income class came from IMPLAN.

Population

Comments: The number of households in each income group depends first and foremost on the initial number of households. To this we add the natural growth of the population and net in-migration. Migration in turn depends on the level of after-tax income, and the proportion of households that are not working (which reflects the employment prospects facing new migrants). This formulation is in the spirit of the migration model popularized by Harris and Todaro.[54]

Eq. 8.

$$a_{t,h}^{hh} = \bar{a}_{t,h}^{hh} + \bar{a}_{t,h}^{i}\left(\frac{y_{t,h}^{d}}{a_{t,h}^{hh}} \div \frac{\bar{y}_{t,h}^{d}}{\bar{a}_{t,h}^{hh}} \div \frac{p_{t,h}}{\bar{p}_{t,h}}\right)^{\eta_h^{yd}} \left(\frac{a_{t,h}^{n}}{a_{t,h}^{hh}} \div \frac{\bar{a}_{t,h}^{n}}{\bar{a}_{t,h}^{hh}}\right)^{\eta_h^{u}}$$
$$- \bar{a}_{h}^{o}\left(\frac{\bar{y}_{t,h}^{d}}{\bar{a}_{t,h}^{hh}} \div \frac{y_{t,h}^{d}}{a_{t,h}^{hh}} \div \frac{\bar{p}_{t,h}}{p_{t,h}}\right)^{\eta_h^{yd}} \left(\frac{\bar{a}_{t,h}^{n}}{\bar{a}_{t,h}^{hh}} \div \frac{a_{t,h}^{n}}{a_{t,h}^{hh}}\right)^{\eta_h^{u}}, \ \forall h \in H, t \in T$$

Description: See comments above.

Data: The elasticities used in this equation are the same as those used for California by Berck et al. and "reflect the middle ground found in the literature about migration."[55]

Number of Non-Working Households

Comments: This is a simple accounting equation; the number of non-working households is the total number of households, less the number that are working.

Eq. 9. $a_{t,h}^{n} = a_{t,h}^{hh} - a_{t,h}^{w} \quad \forall h \in H, t \in T$

Description: See comments above.

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[54] John R. Harris and Michael P. Todaro, "Migration, Unemployment and Development: A Two Sector Analysis," *American Economic Review* 40 (1970): 126-42.
[55] Berck, et. al. "Dynamic Revenue Analysis." See footnote 50.

The Behavior of Producers/Firms

Producers are assumed to maximize profit. Combining intermediate inputs with labor and capital produces output. The amount of intermediate inputs required per unit of output is fixed, but firms have considerable leeway to vary the amounts of capital and labor that they use in production. The value of output less intermediate inputs is value added, and it is useful to compute a price for this value added; it is this price that determines factor demand – i.e. drives firms to hire more or less labor and capital. The amounts of labor and capital inputs, in turn, drive the total value of output via the production function.

Intermediate Demand

Comments: Intermediate goods constitute a fixed share of the value of production.

Eq. 10. $$v_{t,i} = \sum_{i' \in I} \alpha_{t,i,i'} q_{t,i'} \qquad \forall\, i \in I, t \in T$$

Description: See comments above.

Data: From the NC input-output table, derived from data from IMPLAN, which in turn are based on data from by the Bureau of Economic Analysis.

Production Function

Comments: Output is determined by the quantities of labor and capital used in production; it is assumed that enough intermediate goods will be available. We use a Constant Elasticity of Substitution (CES) production function, which allows a degree of substitution between labor and capital; in other words, if the price of labor rises, firms will cut back on the number of workers they hire, and use more capital instead.

Eq. 11. $$q_{t,i} = \gamma_{t,i} \left[\sum_{f \in F} \alpha_{t,f,i} \left(u^{d}_{t,f,i} \right)^{-\rho_i} + g\alpha_{t,i} \left(gk_t \right)^{-\rho_i} \right]^{-1/\rho_i} \qquad \forall\, i \in I, t \in T$$

Description: In addition to labor and capital used in production, we account for infrastructure.

Data: We use values for the elasticity of substitution that are close to, but slightly lower than, one. This is relatively standard in CGE models. The Bureau of Economic Analysis is the source of information on the shares of labor and capital in production.

Price of Value Added

Comments: Define value-added as the value of output less the cost of intermediate inputs. One may then define a "price" of value added, which we then use below in the factor demand (i.e. labor demand, capital demand) equations.

Eq. 12.
$$p_{t,i}^{va} = p_{t,i}^{d} - \sum_{i' \in I} \alpha_{t,i',i} \, p_{t,i'} \left(1 + \sum_{g \in GS} \tau_{t,g,i'}^{v} \right) \qquad \forall \, i \in I, t \in T$$

Description: Price of value-added by industry is the domestic price by industry minus the production prices by industry according to their share in domestic supply, including taxes on intermediates, if any.

Data: Prices are set equal to unit in the baseline case.

Factor Demand

Comments: It is possible to construct a profit function that expresses profits as a function of factor inputs. Microeconomic theory shows that the partial first derivative of the profit function, with respect to a given factor demand variable, gives the demand equation for that factor. The left hand side of the equation shows payments to labor (including the cost of factor taxes such as the employer share of social security contributions). The right hand side gives the amount of value added attributable to the factor. There are separate equations for labor and for capital, for each of the 27 industrial sectors.

Eq. 13.
$$r_{t,f,i} r_{t,f}^{a} \left(1 + \sum_{g \in GF} \tau_{t,f,g,i}^{x} \right) u_{t,f,i}^{d} = p_{t,i}^{va} q_{t,i} \alpha_{t,f,i} \qquad \forall \, i \in I, f \in F, t \in T$$

Description: The factor demand at the current intra-industry rental rate (for labor and capital) times the overall rental rate, including factor taxes is a function of the price of value-added times the industry domestic supply.

Data: Information on the wage bills comes from the Bureau of Economic Analysis. The total wage bill is divided by the number of workers (from the Bureau of Labor Statistics) to get measures of wage rates by industry. The intersectoral wage differentials are not allowed to vary within the model. The cost of capital was derived as property-type income divided by the capital stock. The capital stock was constructed by disaggregating the national aggregate level of capital using a series of proxy measures; further details of the methodology are provided in Appendix 2 of the *Texas State Tax Analysis Modeling Program: Texas-STAMP* (1999) and although this refers to Texas, the same approach was taken in computing the capital stock for North Carolina.[56]

Factor Income

Comments: The total income accruing to factors – i.e. to labor and capital – is computed here.

Eq. 14. $$y_{t,f} = \sum_{i \in I} r_{t,f,i} r^{a}_{t,f} u^{d}_{t,f,i} + \sum_{g \in G} r_{t,f,g} r^{a}_{t,f} u^{d}_{t,f,g} \qquad \forall f \in F, t \in T$$

Description: The factor income is the sum of factor demand times rental rates, for all industries and government sectors.

Trade with other States and Countries

From a North Carolina perspective, the "rest of the world" consists of the remainder of the United States as well as the world outside the U.S. Goods produced in North Carolina are assumed to be approximate, but not perfect, substitutes for goods produced elsewhere. Thus, if prices rise in North Carolina, the state's exports will fall and its imports will rise, but the adjustment need not be very large. There is no need for trade to be balanced; capital flows simply adjust to cover the gap between exports and imports. In this section we also develop a measure of the average price

[56] David G. Tuerck, Jonathan Haughton, In-Mee Baek, James Connolly and Scott Fontaine, *The Texas State Tax Analysis Modeling Program: Methodology and Applications. The Beacon Hill Institute at Suffolk University* (February 1999) http://www.beaconhill.org/BHIStudies/TexasSTAMP299/TexasSTAMPFinal19Feb99.pdf.

faced by domestic households and firms for goods and services produced by each industry, the price is a weighted average of the price of locally produced and imported goods.

Demand for Exports

Comments: Exports depend on the price of goods within North Carolina relative to the price outside the state. If the domestic price rises relative to the foreign price, exports will fall. Note that the elasticity here is negative.

Eq. 15.
$$e_{t,i} = \overline{e}_{t,i} \left[\frac{p_{t,i}^{d} \div \overline{p}_{t,i}^{w}}{1 + \sum_{g \in G} \tau_{t,g,i}^{m}} \right]^{\eta_i^e} \qquad \forall i \in I, t \in T$$

Description: Current exports are a function of baseline exports adjusted by the change in domestic prices versus fixed world prices.

Data: The trade data for North Carolina are not particularly reliable; we have used our judgement, combined with BEA data, to arrive at sensible estimates. The elasticities we use are similar to those employed by Berck et al.[57]

Domestic Share of Domestic Consumption

Comments: The demand for imports is handled indirectly, by modeling the share of domestic consumption that is supplied by domestic firms (*d*), following the approach pioneered by Armington.[58] This share depends on the domestic price relative to the price of the same goods in the rest of the world. We ignore import tariffs on the grounds that they are a tiny fraction (less than 1%) of the value of goods imported into North Carolina.

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[57] Berck, et al. "Dynamic Revenue Analysis."
[58] Paul Armington, "A Theory of Demand for Products Distinguished by Place of Production," *International Monetary Fund Staff Papers* 16 (1969): 159-78.

Eq. 16. $$d_{t,i} = \bar{d}_{t,i} \left[\frac{p^d_{t,i} \div \bar{p}^w_{t,i}}{1+\sum_{g\in G} \tau^m_{t,g,i}} \right]^{\eta^d_i} \quad \forall i \in I, t \in T$$

Description: See comments above.

Data: As with export demand we have used our judgement, combined with BEA data, to arrive at sensible estimates.

Intermediate Demand for Imports

Comments: Imports consist of the share of domestic consumption that is not supplied by domestic production.

Eq. 17. $$m_{t,i} = \left(1 - d_{t,i}\right) x_{t,i} \quad \forall i \in I, t \in T$$

Description: See comments above.

Average Prices by Industry

Comments: These aggregated prices are computed for each industry, and are weighted averages of the domestic price and the import price, with the weights consisting of the respective shares in consumption. The price is set to unity in the baseline situation.

Eq. 18. $$p_{t,i} = d_{t,i} p^d_{t,i} + \left(1 - d_{t,i}\right) \bar{p}^w_{t,i} \quad \forall i \in I, t \in T$$

Investment

We first constructed a measure of the capital stock for each industrial sector for 2003. This stock, less depreciation and plus gross investment gives the capital stock for 2004. Gross investment is determined, sector-by-sector, based on the net of tax rate of return (relative to the return in the base period). For instance, once investment by the agricultural sector has been determined, it is transformed with the help of the capital coefficient matrix into the demand for goods and services for each sector in the economy.[59]

Capital Stock

Comments: The capital stock in time *t* is the capital stock from the previous period adjusted for depreciation, and augmented by gross investment.

Eq. 19. $$u_{t,K,i} = u_{t-1,K,i}\left(1-\delta_i\right)+n_{t,i} \quad \forall i \in I, t \in T$$

Description: See comments above.

Data: A complete discussion of the construction of capital stock figures is given in Texas *State Tax Modeling Program: Texas-STAMP* (1999); the same approach and the same data sources are used for North Carolina.[60]

Gross Investment by Sector of Destination

Comments: The amount of gross investment in any given sector depends on the after-tax rate of return in that sector relative to the return in the base period. The terminology here can be confusing; investment destined for agriculture, for instance, consists of the purchases of goods that will add to the capital stock in the agricultural sector; the goods themselves will mainly come from other sectors (the sectors of source).

Eq. 20. $$n_{t,i} = \overline{n}_{t,i}\left[\frac{r_{t,K,i}\left(1-\sum_{g\in GK}\tau^{x}_{t,g,K,i}\right)u_{t,K,i}}{\overline{r}_{t,K,i}\left(1-\sum_{g\in GK}\tau_{t,g,K,i}\right)\overline{u}_{t,K,i}}\right]^{\eta^{i}} \quad \forall i \in I, t \in T$$

[59] The Capital Coefficient Matrix is a matrix of investments by using industries. It contains distribution ratios of new structures and equipment to using industries from the 1992 BEA capital flow tables.
[60] Tuerck, et al, *Texas STAMP*.

Description: Gross investment is the baseline gross investment by industry adjusted to the change in after-tax capital rental rates.

Data: The rate of return is computed as the property-type income for each sector (from BEA) divided by the capital stock (authors' computations). Based on the econometric results from STAMP models estimated for North Carolina and elsewhere, we estimated the investment demand elasticity to be about 0.3.

Gross Investment by Sector of Source

Comments: Given that investment has been determined for each sector of destination, this equation allows one to determine who will actually produce the investment goods. This is done with the help of a capital coefficient matrix.

Eq. 21. $$p_{t,i}\left(1+\sum_{g\in GS}\tau^{n}_{t,g,i}\right)cn_{t,i}=\sum_{i'\in I}\beta_{i,i'}n_{t,i'} \qquad \forall i\in I, t\in T$$

Description: The gross investment by source in after-tax prices is a function of investment by destination according to the capital coefficient matrix.

Data: Based on the 1992 capital coefficient matrix for the United States from the BEA/Department of Commerce.[61]

Government

Government derives income from a wide range of taxes. It purchases goods and services and makes transfers (such as pensions) to individuals. Some government spending is assumed to remain unchanged even if tax revenues vary; the rest of spending is endogenous, in that it responds to the availability of funds. Notionally, most revenues flow into the North Carolina General Fund; they are then used in part to buy goods and services, but some are also transferred to local government units.

[61] BEA, See footnote 59.

Government Income

Comments: This equation adds up government income from multiple sources, including indirect taxes (sales, motor fuels) and direct taxes (income, franchise tax).

Eq. 22.

$$y_{t,g} = \sum_{i \in I} \tau^{v}_{t,g,i} v_{t,i} p_{t,i} + \sum_{i \in I} \tau^{m}_{t,g,i} m_{t,i} pw^{0}_{t,i} + \sum_{h \in H} \sum_{i \in I} \tau^{c}_{t,g,i} c_{t,i,h} p_{t,i}$$
$$+ \sum_{i \in I} \tau^{n}_{t,g,i} cn_{t,i,n} p_{t,i} + \sum_{i \in I} \sum_{g' \in G} \tau^{g}_{t,g,i} c_{t,i,g'} p_{t,i} + \sum_{i \in I} \sum_{f \in F} \tau^{x}_{t,g,f,i} r_{t,f,i} r^{a}_{t,f} u^{d}_{t,f,i}$$
$$+ \sum_{g' \in G} \sum_{f \in F} \tau^{x}_{t,g,f,g'} r_{t,f,g'} r^{a}_{t,f} u^{d}_{t,f,g'} + \sum_{f \in F} \tau^{fh}_{t,g,f} y_{t,f} + \sum_{h \in H} \tau^{pi}_{t,h,g} a^{hh}_{t,h}$$
$$+ \sum_{h \in H} \tau^{h}_{t,h,g} a^{hh}_{h} \qquad \forall g \in G, t \in T$$

Description: Income by government sector is the sum of taxes on intermediates, imports, consumption, investment, government consumption, factors, income taxes and other household taxes.

Government Endogenous Purchases of Goods and Services

Comments: Spending on these items is assumed to take a fixed fraction of total government receipts (from taxes and net intergovernmental transfers, less government savings). The endogenous sectors are state spending on education, health, safety, transport and "other," and local spending on education and health.

Eq. 23.

$$p_{t,i}\left(1 + \sum_{g \in GS} \tau^{g}_{t,g,i}\right) cg_{t,i,g} = \alpha_{i,g}\left(y_{t,g} + \sum_{g' \in G} b_{t,g,g'} - \sum_{g' \in G} b_{t,g',g} + b_{t,ussstx,g} - \sum_{h \in H} w_{t,h,g} a^{n}_{t,h} \tau^{pc}_{t,h,g} - \overline{s}_{t,g}\right)$$
$$\forall i \in I, g \in GN, t \in T$$

Description: The government spending in after-tax prices computed according to their share of government income plus net inter-government transfers less government savings and transfer payments. Note that only state and local governments are endogenous in the model.

Data: The shares of spending going to these sectors are based on a careful analysis of North Carolina government budget and financial reports.

Government Endogenous Rental of Factors

Comments: As in the case of goods and services, government is also assumed to devote a fixed share of its total spending to the purchase of labor and capital services for those sectors considered to be endogenous.

Eq. 24.

$$u^{d}_{t,f,g} r^{a}_{t,f} r_{t,f,g} = \alpha_{f,g} \left(y_{t,g} + \sum_{g' \in G} b_{t,g,g'} - \sum_{g' \in G} b_{t,g',g} + b_{t,ussstx,g} - \sum_{h \in H} w_{t,h,g} a^{n}_{t,h} \tau^{pc}_{t,h,g} - \overline{s}_{t,g} \right)$$
$$\forall f \in F, g \in GN, t \in T$$

Description: The government factor demand is computed according to the share of each government in total government spending, including net inter-government transfers, less savings and transfer payments.

Government Infrastructure Capital Stock

Comments: The government adds to its infrastructure capital stock through its spending on the government transportation sector, STTRAN.

Eq. 25.

$$gk_{t+1} = gk_{t}(1-\delta) + \sum_{g \in G} b_{t+1,STTRAN,g} - \sum_{g \in G} b_{t+1,g,STTRAN} + \sum_{g \in G} b_{t+1,LOTRAN,g}$$
$$\forall t \in T$$

Description: The infrastructure capital stock for the current year is the infrastructure for the previous year, less depreciation plus the net spending on transportation by state and local governments.

Data: The data for government infrastructure capital stock is based on national data from the BEA.

Government Savings

Comments: Government saving is a residual, consisting of revenue less spending.

Eq. 26.

$$s_{t,g} = y_{t,g} - \sum_{i \in I} cg_{t,i,g}\, p_{t,i} \left(1 + \sum_{g \in GS} \tau^{g}_{t,g,i}\right) - \sum_{f \in F} u^{d}_{t,f,g} r_{t,f,g} r^{a}_{t,f} \left(1 + \sum_{g' \in GF} \tau^{x}_{t,f,g',g}\right) - \left(\sum_{h \in H} w_{t,h,g} a^{n}_{t,h} \tau^{pc}_{hg}\right) - \sum_{g' \in G} b_{t,g',g} + b_{t,ussstx,g} + \sum_{g' \in G} b_{t,g,g'} \quad \forall g \in G, t \in T$$

Description: Government savings is the residual from government income, after spending and factor rental, transfer payments, plus net inter-governmental transfers.

Distribution of Taxes to Spending and Transfers

Comments: Tax units, in this case those sectors collecting revenue, distribute some of their receipts to spending units, and others directly in the form of transfers to households. The matrix IGTD (in the miscellaneous input file) identifies which units pass on their revenues to other spending units, and the flows are recorded in this equation.

Eq. 27.

$$b_{t,g',g} = \mu_{t,g',g} \left(y_{t,g} - \left(\sum_{h \in H} w_{t,h,g} a^{n}_{t,h} \tau^{pc}_{t,h,g} - \overline{s}_{t,g} \right) \right) \quad \forall g, g' \in G$$

Description: The intra-fund accounting to distribute the government income, less transfer payments and savings.

Data: This equation is based on institutional arrangements in place in NC.

Endogenous Distribution of NC Funds

Comments: This equation details the flows from state funds to state spending sectors and from state spending sectors to local spending sectors.

Eq. 28. $$b_{t,g,g'} = \mu_{t,g,g'}\left(\sum_{g''} b_{t,g',g''} + w_{g',INVEST} + w_{g',ROWSCT}\right) \quad \forall g, g' \in G$$

Description: Some funds are fixed to the original share.

Data: Based on an analysis of the current pattern of spending in NC.

State Personal Income

Comments: This equation defines state personal income as earnings (from labor and capital) plus transfer payments.

Eq.29. $$y_t^s = \sum_{h \in H} y_{t,h} + \sum_{h \in H}\sum_{g \in G} w_{t,h,g}\, a_{t,h}^n \tau_{h,g}^{pc} \qquad \forall t \in T$$

Description: State personal income is the sum of household income and government transfer payments.

Model Closure

Labor Market Clearing

Comments: Labor supply equals labor demand. For this to occur, the wage rate must adjust to bring about this market clearing.

Eq. 30. $$\sum_{h \in H} a_{t,h}^w = \left(\sum_{z \in Z} u_{t,L,z}^d\right)\varepsilon_t \quad \forall t \in T$$

Description: Total working households equals the sum of private employment and government employment.

Capital Market Clearing

Comments: Capital markets also clear for each sector. In other words, demand for capital by industries equals supply of capital.

Eq. 31. $u^{s}_{t,K,i} = u^{d}_{t,K,i} \quad \forall i \in I, t \in T$

Description: See comments above.

Goods Market Clearing

Comments: Domestic demand (intermediate, consumer, government and investment demand) plus exports less imports must equal domestic supply.

Eq. 32. $q_{t,i} = x_{t,i} + e_{t,i} - m_{t,i} \quad \forall i \in I, t \in T$

Description: See comments above.

Domestic Demand Defined

Comments: These equations define domestic demand for each sector.

Eq.33. $x_{t,i} = v_{t,i} + \sum_{h \in H} c_{t,i,h} + \sum_{g \in G} cg_{t,i,g} + cn_{t,i} \quad \forall i \in I, t \in T$

Description: Domestic demand is the sum of intermediate demand, household consumption, government consumption and investments.

PIT for Non Income Tax Units

Comments: This equation sets the personal income tax for non-income tax units to zero; this is a technicality that ensures the solution to the model does not create income tax revenue in an inappropriate place.

Eq.34. $t_{t,g,h} = 0 \quad \forall h \in H, g \notin GI, t \in T$

Setting Intergovernmental Transfers to Zero if Not in Original SAM

Comments: This is another housekeeping equation that ensures the solution to the model does not create inter-governmental transfers where they should not occur.

Eq.35. $b_{t,g,g'} = 0 \quad \forall g, g' \in G, t \in T \quad \text{where } \bar{b}_{gg'} = 0$

Federal Social Security Transfers to NC

Comments: Transfers paid to NC households from the Federal social security system are assumed to be mainly determined by the number of households in the state.

Eq.36. $$b_{\text{t,h,USSSTX}} = \bar{b}_{\text{t,h,USSSTX}} \times \left(\frac{\overline{a^n_{t,h}}}{a_{t,h}} \right)$$

Description: Transfer payments are adjusted by the change in nonworking households.

Exogenous Federal Transfers to Households

Comments: Federal transfers to households are assumed to vary with the number of households in the state.

Eq.37. $$b_{\text{t,h,USNOND}} = \bar{b}_{\text{t,h,USNOND}} \times \left(\frac{a^n_{t,h}}{\overline{a^n_{t,h}}} \right)$$

Description: Transfer payments are adjusted by the change in nonworking households.

Goods and Services Demand by Exogenous Government Units

Comments: The purchases of goods and services by some government sectors are considered to be exogenous to the model. This equation fixes these values.

Eq. 38. $cg_{t,i,g} = \overline{cg}_{t,i,g} \quad \forall i \in I, g \in GX, t \in T$

Factor Rentals Paid by Exogenous Government Units

Comments: The purchases of the services of labor and capital are considered to be exogenous to the model. This equation fixes these values.

Eq. 39. $u^{d}_{t,f,g} = \overline{u}^{d}_{t,f,g} \quad \forall f \in F, g \in GX, t \in T$

Intersectoral Wage Differentials

Comments: Although wage rates differ from sector to sector, these differentials are assumed to remain fixed, as set by this equation. Household labor supply responds to overall wage rates, and not to the wage rates in any particular sector.

Eq. 40. $r_{t,L,i} = \overline{r}_{t,L,i} \quad \forall i \in I, t \in T$

Government Rental Rate for Capital to Initial Level

Comments: For NC-STAMP, we have set these rental rates to zero, in the absence of viable information about the rental rates paid by government on the capital that it uses. However, the relevant equations are included, and so government rental rates could be incorporated in a future version of the model.

Eq. 41. $r_{t,K,g} = \overline{r}_{t,K,g} \quad \forall g \in G, t \in T$

Economy Wide Scalar for Capital

Comments: The model allows both for an overall cost of capital, and sector-specific returns. This equation sets the overall scalar to its original level, so that only the sector-specific returns vary endogenously.

Eq. 42. $r^{a}_{t,K} = \overline{r}^{a}_{t,K} \quad \forall f \in F, t \in T$

Setting Transfer Payments to Zero

Comments: This equation ensures that if transfer payments to households were zero in the original social accounting matrix, they remain at zero.

Eq. 43. $w_{t,h,g} = 0 \quad \forall\ h \in H, g \in GWX, t \in T$ where $\bar{w}_{t,h,g} = 0$

Objective Function

Comments: This equation measures utility over the entire period of the dynamic model as measured by the sum of state personal income discounted. The variable is of interest in its own right. However, it is a convenient variable for GAMS to maximize (or minimize), because it is an unrestricted variable without a subscript.

Eq. 44. $U = \sum_{t \in T} \beta_t statey_t \qquad t \in T$

Description: Utility is defined as the net present value of future state personal income levels.

Elasticity Assumptions for NC-STAMP

For the model to work, one has to introduce values for the relevant elasticities. These are drawn from the existing literature, as follows:

ETAM: Import elasticity with respect to domestic price for producers' purchase of intermediates. Most of the data on elasticities are taken from Reinert, Roland-Holst, and Shiells. The two most recent are Reinert and Roland-Holst[62] and Roland-Holst, Reinert and Shiells[63].

In the first study, the authors estimate an Armington model for 163 mining and manufacturing sectors. Two-thirds of the elasticities were positive and statistically significant, ranging from a low of 0.13 for chocolate to 3.49 for wine, brandy and brandy spirits. The second study looked at the impact of NAFTA. In this study many of the aggregate industries had an elasticity of 1.50. Since import data for goods between states is almost impossible to obtain, we made some

[62]Kenneth.A. Reinert and David .W. Roland-Holst, "Armington Elasticities for United States Manufacturing Sectors," *Journal of Policy Modeling* 14, no.5 (1992): 631-639.
[63] David W. Roland-Holst, Kenneth.A. Reinert and Clinton.R. Shiells, "A General Equilibrium Analysis of North American Economic Integration," in *Modeling Trade Policy: Applied General Equilibrium Assessments of North American Free Trade* ed. Clinton .R. Shiells and Joseph F. Francois (New York: Cambridge Univ. Press, 1994), 47-82.

assumptions and used 1.50 for most industries and a slightly lower elasticity of 0.50 for a handful of less traded industries such as service industries.

While these elasticities are slightly higher than the literature on national trade, we believe that goods in a state are more price-sensitive to goods in the Rest of the World (including other states) than national goods. Therefore, we converted the elasticities to a domestic share elasticity for each industry using the following equation. ETAD = ETAM * IMPORT / (DOM. DEMAND * DOM. SUPPLY SHARE OF DOM. DEMAND). The estimates for this elasticity were taken from the literature.

ETAE: Export elasticity with respect to domestic price for the sale producers' goods. Used in the export demand equation. The NAFTA study was also helpful with exports. We used an elasticity of 1.65 for industries which had an import elasticity of 1.50 and an export elasticity of 0.65 for those which had an import elasticity of 0.50.

SIGMA: Elasticity of substitution between capital and labor. Values in the literature range between 0.15 and 1.809 for industries with the majority close to 1, and we have used values of 0.90 for industries with substantial substitution and 0.8 in other cases (as shown in Table 2). This measurement is used to calculate RHO, which is the exponent in the production function. The equation is: RHO = (1- SIGMA)/SIGMA.

The following elasticities are used in household-specific equations:

ETAPIT: Labor supply elasticity with respect to income taxes. This elasticity appears as an exponent in the labor supply equation. Measurements were based on estimates taken from the literature. The labor supply elasticities (ETARA) are widely divergent in the literature and suffer from a lack of disaggregation. They range from close to zero to 2.3 for net wages, with rather high positive values for women, particularly married woman. This means that the *tax* elasticities are negative. There is some evidence of greater (absolute) tax elasticities at higher income levels, which is why we assume a graduated scale from -0.15 for the lowest income category to -0.35 in the top category (see Table 10).[64]

[64] Note that ETAPIT = -ETARA (t/(1-t)), where t is the income tax rate.

Table 9: Industry Elasticities

	ETAM	ETAE	ETAY	ETAOP	SIGMA
AGRICF	1.500000	-1.650000	1.000000	-1.000000	0.900000
MINING	1.500000	-1.650000	1.000000	-1.000000	0.800000
CONSTR	1.500000	-1.650000	1.000000	-1.000000	0.900000
FOODPR	1.500000	-1.650000	1.000000	-1.000000	0.900000
APPARL	1.500000	-1.650000	1.000000	-1.000000	0.900000
MFRCON	1.500000	-1.650000	1.000000	-1.000000	0.800000
PPAPER	1.500000	-1.650000	1.000000	-1.000000	0.800000
CHEMIC	1.500000	-1.650000	1.000000	-1.000000	0.800000
ELECTR	1.500000	-1.650000	1.000000	-1.000000	0.900000
COMPUT	1.500000	-1.650000	1.000000	-1.000000	0.900000
MVOTRA	1.500000	-1.650000	1.000000	-1.000000	0.800000
METALS	1.500000	-1.650000	1.000000	-1.000000	0.800000
MACHIN	1.500000	-1.650000	1.000000	-1.000000	0.900000
MFROTH	1.500000	-1.650000	1.000000	-1.000000	0.900000
TRANSP	1.500000	-1.650000	1.000000	-1.000000	0.900000
INFORM	1.500000	-1.650000	1.000000	-1.000000	0.900000
UTILIT	1.500000	-1.650000	1.000000	-1.000000	0.800000
WHOLSA	0.500000	-0.650000	1.000000	-1.000000	0.900000
RETAIL	0.500000	-0.650000	1.000000	-1.000000	0.900000
BANKNG	1.500000	-1.650000	1.000000	-1.000000	0.900000
INSURS	1.500000	-1.650000	1.000000	-1.000000	0.900000
REALST	1.500000	-1.650000	1.000000	-1.000000	0.900000
PROTEC	1.500000	-1.650000	1.000000	-1.000000	0.800000
MANGAD	1.500000	-1.650000	1.000000	-1.000000	0.800000
HEALTH	0.500000	-0.650000	1.000000	-1.000000	0.800000
ENTRHO	0.500000	-0.650000	1.000000	-1.000000	0.800000
OTHSVC	0.500000	-0.650000	1.000000	-1.000000	0.800000
USNOND	0	0	0	0	0
USDEFF	0	0	0	0	0
STGGSP	0	0	0	0	0
STEDUC	0	0	0	0	0
STHELT	0	0	0	0	0
STPBSF	0	0	0	0	0
STTRAN	0	0	0	0	0
STOTHS	0	0	0	0	0
LOEDUC	0	0	0	0	0
LOHELT	0	0	0	0	0
LOPBSF	0	0	0	0	0
LOTRAN	0	0	0	0	0
LOOTHS	0	0	0	0	0

ETATP: Household response to transfer payments. The transfer payment elasticities reflect a study by Robins on the effects of a negative income tax (NIT).[65] It is also a reflection of the observation that income received by upper income groups is on average largely unaffected by transfer payments.

ETAYD: Responsiveness of immigration to after tax income. The tying of migration to disposable income or unemployment finds little support in the economic literature. Studies by Bartik and others put the range of responses to a change in wage rates at between 0.835 and 2.39.[66] We used these as a basis for our after tax earnings elasticities. This elasticity appears in the population equation.

ETAU: Responsiveness of immigration to unemployment. We made some assumptions based on the responsiveness to employment elasticities in the literature.

ETAMH: Income elasticity of demand for imports by household. This elasticity appears in the household import equation.

Table 10 provides elasticities, a summary of set names and a summary of parameter names.

Table 10: Household Related Elasticities

	ETAPIT	ETATP	ETARA	ETAYD	ETAU	ETAMH
LESS10	-0.15	-0.05	0.17	1.30	-0.80	0.70
LESS25	-0.18	-0.05	0.17	1.50	-0.80	0.70
LESS50	-0.20	-0.04	0.20	1.60	-0.80	0.70
LESS75	-0.25	-0.04	0.30	1.80	-0.80	0.70
LES100	-0.25	-0.03	0.40	2.00	-0.80	0.70
LES150	-0.30	-0.03	0.50	2.10	-0.80	0.70
MOR150	-0.35	-0.02	0.50	2.30	-0.80	0.70

[65] Phillip K. Robins, "A Comparison of the Labor Supply Findings from the Four Negative Income Tax Experiments." *Journal of Human Resources* 20 (1985): 567-82.

[66] For one response see Timothy Bartik, *Who Benefits from State and Local Economic Development Policy?* (Kalamazoo: W.E. Upjohn Institute for Employment Research, 1991).

Table 11: Summary of Set Names

Sets	Dimension	Math	GAMS
Factors	2	$f \in F$	F
Governments – All	39	$g \in G$	G
Governments - Factor Taxes	6	$g \in GF$	GF
Governments - Per Household Taxes	8	$g \in GH$	GH
Governments - Income Taxes	2	$g \in GI$	GI
Governments - Capital Income Taxes	6	$g \in GK$	GK
Governments - Endogenous Spending	16	$g \in GN$	GN
Governments - Sales or Excise Taxes	11	$g \in GS$	GS
Governments - Endogenous Transfer Payments	1	$g \in GWN$	GWN
Governments - Exogenous Transfer Payments	4	$g \in GWX$	GWX
Governments - Exogenous Spending	6	$g \in GX$	GX
Households	7	$h \in H$	H
Industries	27	$i \in I$ or $j \in I$	I
All Social Accounting Matrix Accounts	77	$z \in Z$	Z

Table 12: Summary of Parameter Names

Parameters	Dimension	Math	GAMS
Input Output Coefficients	77 x 77	-	A(Z,Z1)
Domestic Input Output Coefficients	27 x 27	α_{ii}	AD(Z,Z1)
Government Spending Shares of Net Income	39 x 39	α_{ig} ,α_{fg}	AG(Z,G)
Factor Share Exponents in Production Function	2 x 27	α_{fi}	ALPHA(F,I)
Initial Shares of Consumption	27 x 7	α_{ih}	ALPHA(I,H)
Deductibility of Taxes	3 x 3	$\alpha_{gg}{}^{t}$	ATAX(G,G1)
Income Elasticities of Demand	27 x 7	β_{ih}	BETA(I,H)
Capital Coefficient Matrix	27 x 27	β_{ii}	CCM(I,J)
Depreciation Rate	27	δ_{i}	DEPR(I)
Export Price Elasticities	27	$\eta_{i}{}^{e}$	ETAE(I)
Domestic Demand Elasticity	27	$\eta_{i}{}^{d}$	ETAD(I)
Investment Supply Elasticity	1	η_{i}	ETAI
L Supply Elasticity with respect to Average Wage	7	$\eta_{h}{}^{ls}$	ETARA(H)
Labor Supply Elasticity with respect to TP's[67]	7	$\eta_{h}{}^{tp}$	ETATP(H)
Labor Supply Elasticity with respect to Taxes	7	$\eta_{h}{}^{PIT}$	ETAPIT(H)
Responsiveness of In-Migration to Unemployment	7	$\eta_{h}{}^{u}$	ETAU(H)
Responsiveness of In-Migration to Disp. Income	7	$\eta_{h}{}^{yd}$	ETAYD(H)
Production Function Scale	27	γ_{i}	GAMMA(I)
Types of Inter-Government Transfers	39 x 39	-	IGTD(G,G1)
Correction Factor between Households and Jobs	1	ε	JOBCOR
Price Elasticities of Demand	27 x 27	$\lambda_{ii'}$	LAMBDA(I,J)
Miscellaneous Industry Parameters	27 x 10	-	MISC(Z,*)
Income Tax Table Data in Input File	7 x 8	-	MISCG(G,H,*)
Miscellaneous Household Parameters	7 x 8	-	MISCH(H,*)
Natural Rate of Population Growth	7	π_{h}	NRPG(H)
Substitution Exponent in Production Function	27	ρ_{i}	RHO(I)
Social Accounting Matrix	77 x 77	$\sigma_{zz'}$	SAM(Z,Z1)
Consumption Sales and Excise Tax Rates	9 x 27	$\tau_{gi}{}^{c}$	TAUC(G,I)
Factor Tax Rates	5 x 2 x 77	τ_{gfz}	TAUF(G,F,Z)
Factor Taxes applied to Factors	5 x 2	-	TAUFF(GF,G)
Employee Portion of Factor Taxes	5 x 2	τ_{gf}	TAUFH(G,F)
Experimental Factor Tax Rates	5 x 2 x 77	$\tau_{gfz}{}^{x}$	TAUFX(G,F,Z)
Government Sales and Excise Tax Rates	9 x 27	$\tau_{gi}{}^{g}$	TAUG(G,I)
Household Taxes other than PIT	1 x 7	τ_{gh}	TAUH(G,H)
Investment Sales and Excise Tax Rates	9 x 27	$\tau_{gi}{}^{n}$	TAUN(G,I)
Sales and Excise Tax Rates	9 x 27	$\tau_{qi}{}^{q}$	TAUQ(G,I)
Intermediate Good Sales and Excise Tax Rates	9 x 27	$\tau_{gi}{}^{v}$	TAUV(G,I)
Tax Bracket Base Amount	2 x 7	$\tau_{gh}{}^{b}$	TAXBASE(G,H)
Tax Bracket Minimum Taxable Earnings	2 x 7	$\tau_{gh}{}^{d}$	TAXBM(G,H)
Tax Constant to Correct Calculated to Observed	2 x 7	$\tau_{gh}{}^{c}$	TAXCVC(G,H)
Tax Deduction other than Standard and other PIT	2 x 7	$\tau_{gh}{}^{o}$	TAXOD(G,H)
Percentage Itemizing	2 x 7	$\tau_{gh}{}^{i}$	TAXPI(G,H)
Tax Destination Shares	39 x 39	$\mu_{gg'}$	TAXS(G,G1)
Tax Deduction for Standard Deductions	2 x 7	$\tau_{gh}{}^{s}$	TAXSD(G,H)
Percent of Households Receiving TP's	7 x 6	$\tau_{hg}{}^{pc}$	TPC(H,G)

[67] TP is abbreviation for transfer payments.

Table 12 (Continued)			
Variables	**Dimension**	**Math**	**GAMS**
Public Consumption	27 x 39	c_{ig}	CG(I,G)
Private Consumption	27 x 7	c_{ih}	CH(I,H)
Gross Investment by Sector of Source	27	c_{in}	CN(I)
Consumer Price Index	7	p_h	CPI(H)
Exports	27	e_i	CX(I)
Domestic Share of Domestic Consumption	27	d_i	D(I)
Domestic Demand	27	x_i	DD(I)
Domestic Supply	27	q_i	DS(I)
Sectoral Factor Demand	2 x 77	u_{fi}^d, u_{fg}^d	FD(F,Z)
Number of Households	7	a_h	HH(H)
Number of Non-Working Households	7	a_h^n	HN(H)
Number of Working Households	7	a_h^w	HW(H)
Household Out-Migration	7	a_h^o	MO(H)
Household In-Migration	7	a_h^i	MI(H)
Inter-Governmental Transfers	37 x 37	$B_{gg'}$	IGT(G,G1)
Capital Stock	27	u_{Ki}^s	KS(I)
Imports	27	m_i	M(I)
Gross Investment by Sector of Destination	27	n_i	N(I)
Net Capital Inflow	1	z	NKI
Aggregate Price	27	p_i	P(I)
Aggregate Price including Sales/Excise Taxes	27	p_i^c	PC(I)
Domestic Producer Price	27	p_i^d	PD(I)
Per Household Personal Income Taxes	2 x 7	t_{gh}	PIT(G,H)
Producer Price Index	1	p	PPI
Value Added Price	27	p_i^{va}	PVA(I)
World Price (Rest of US and Rest of World)	27	p_i^w	PW(I)
Sectoral Factor Rental Rates	2 x 27	r_{fi}, r_{fg}	R(F,I)
Economy Wide Scalar for Factor Rental Rates	2	r_f^a	RA(F)
Government Savings	39	s_g	S(G)
Private Savings	7	s_h	S(H)
State Personal Income	1	q	SPI
Transfer Payments	7 x 39	w_{hg}	TP(H,G)
Intermediate Goods	27	v_i	V(I)
Factor Income	2	y_f	Y(F)
Government Income	39	y_g	Y(G)
Household Income	7	y_h	Y(H)
Household after Tax Income including TP's	7	Y_h^d	YD(H)

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The Beacon Hill Institute at Suffolk University in Boston focuses on federal, state and local economic policies as they affect citizens and businesses. The institute conducts research and educational programs to provide timely, concise and readable analyses that help voters, policymakers and opinion leaders understand today's leading public policy issues.

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