MODELING THE ECONOMIC, DEMOGRAPHIC, AND CLIMATE IMPACT OF A CARBON TAX IN MASSACHUSETTS

PREPARED BY

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PREPARED FOR

Committee for a Green Economy (CGE)

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Your grandchildren and ours will thank you for all you have done, Cathy.

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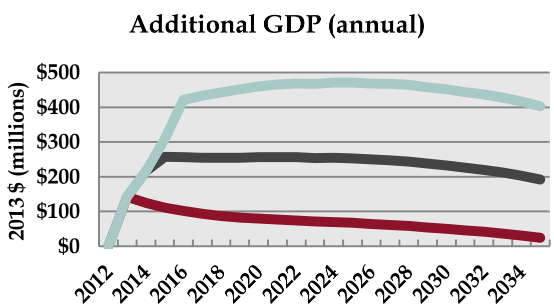
EXECUTIVE SUMMARY

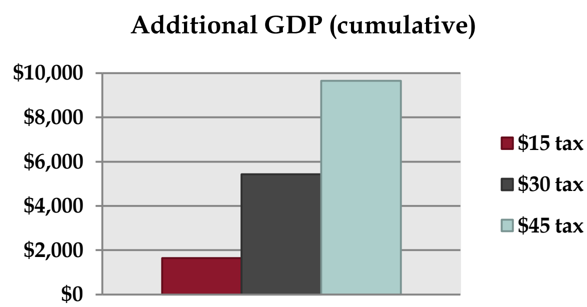
This report explores whether or not a carbon tax in Massachusetts can improve the state economy. A carbon tax levies a fee on carbon dioxide released into the atmosphere from the use of fossil fuels. The state can reinvest this revenue or reduce other taxes. The purpose was to evaluate whether a carbon tax and the recycling of its revenue can create jobs, grow the state's economy, and protect low-income households while also lowering the Massachusetts carbon footprint. This analysis found that it is possible to meet these objectives if the state allocates the carbon tax revenue appropriately. However, not every reinvestment strategy met all objectives. The optimal method of meeting these goals was a 50-50 split in subsequent tax reductions, shared between households and corporations:

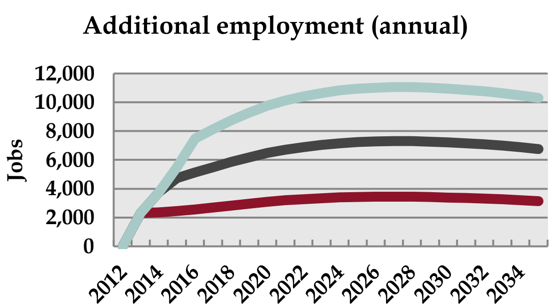
- 50% of the revenue split towards lowering state corporate income taxes
- 50% split to households—25% to lower income taxes and 25% to a lower general sales tax

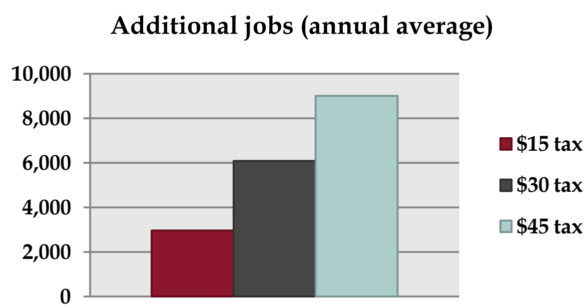
We ran three scenarios: a $15, $30, and $45 tax on each metric ton of carbon emitted by various fuel types, including electricity. In broadest terms with the Conroy-Barrett bill in the Massachusetts State House, we were close to a revenue-neutral analysis, keeping the first $100 million of revenue for an infrastructure and research fund. The remainder of the tax revenue went to general tax cuts throughout the rest of the economy. This included a reduction in corporate income, personal income, and general sales taxes to compensate households (particularly low-income groups) from paying too much after the initial, direct impact of the new carbon tax and ensuing change in prices.

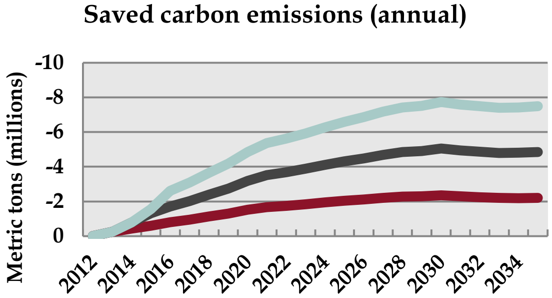
With a 50-50 split between households and firms, the impact on the state was positive, and the level of carbon emissions fell. For the lowest scenario of $15 tax per metric ton, total state gross domestic product (GDP) was nearly $2 billion higher from 2013 to 2035, and was close to $10 billion higher for the case of $45 per metric ton. Depending on the scenario, the economy saw an additional 2,000 to 11,000 jobs over the baseline. The sectors of the economy that benefited the most were those with a high labor-intensity, a strong localization to Massachusetts, and low overall fossil fuel usage.

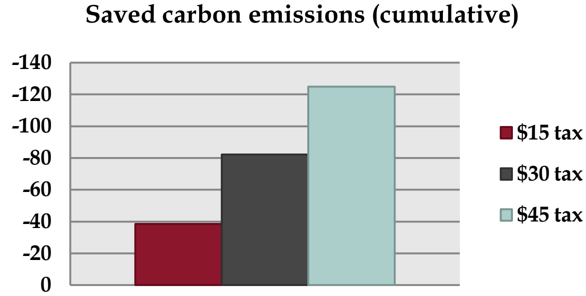


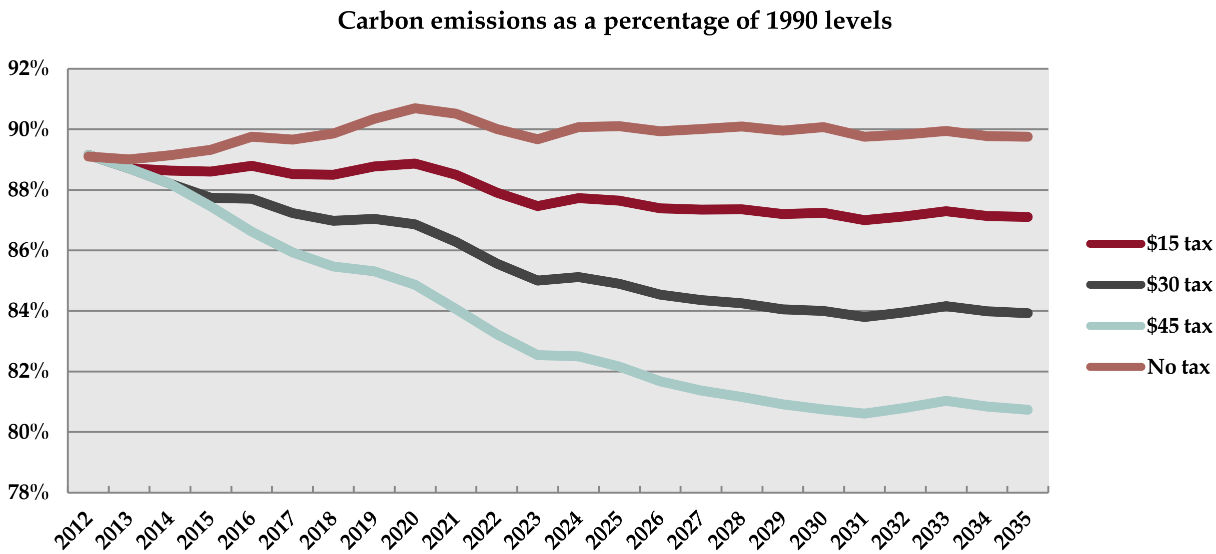












A carbon tax can generate revenue for the state and reduce its emissions below current levels. At $45 per metric ton, tax revenue could total up to $2.5 billion per year. Simultaneously, carbon emissions can fall by 2 million to 8 million metric tons a year. This is enough to reduce carbon emissions in Massachusetts to between 88% and 80% of 1990 emissions levels. Currently, Massachusetts emits approximately 89% of its 1990 emissions levels. These state tax revenues and reductions in emissions increase with a higher tax. Conversely, also, due to diminishing marginal returns, the rates of revenue generation and emissions slow with a higher tax. Ultimately, a carbon tax can be consistent with the stated goals of bettering the state economy, raising new revenues, and reducing emissions.

METHODOLOGY

The analysis evaluated both the economic impact and the effect on carbon dioxide emissions of a hypothetical carbon tax in the state of Massachusetts. We used REMI PI+, a dynamic equilibrium model of the state economy based on public data and peer-reviewed methodology used throughout the United States. We also used the Carbon Tax Analysis Model (CTAM), an open-source model of carbon tax revenues and emissions savings used in other states for similar studies. We employed CTAM for forecast generation of the influence of a tax on consumer behavior and emissions, and subsequently PI+ to observe how these changes would affect the total economy of the state. This included the GDP outlook, job creation, demographic shifts, and cost of living for households.

INTRODUCTION AND BACKGROUND

This study examines the complex interactions between a state's carbon dioxide emissions and its economy, demographics and fiscal policy. Like any state, for Massachusetts the issue lies in finding an optimal means of maximizing the area's economic growth, creating jobs, minimizing living costs and mitigating the cost of doing business, while also reducing greenhouse gas (GHG) emissions as much as possible. These targets do not always have to compete with each other. Stricter emissions standards, for example, can lead to a greater degree of energy efficiency in a state, thus adding to the competitiveness of firms in the area vying for domestic and international market share in key industries. We will use two models, REMI PI$^+$ and the Carbon Tax Analysis Model (CTAM), to examine these factors of economic performance and the emissions of GHG into the Earth's atmosphere in a consistent framework, and report a possible yet positive way for the state to balance these concerns.

The mechanism of interest in this study is a carbon tax. A carbon tax is a Pigovian tax imposed by a government or regulatory body that introduces a fee for releasing carbon dioxide into the atmosphere, typically at the point of combustion of fuels.[1] The idea behind a carbon tax is to discourage the usage of such fuels, which therefore reduces the total carbon emitted into the air. In economic terms, a carbon tax can lead to a reduction in "externalities."[2] Externality is an individual or firm's actions harming the general economy, but that cost does not harm the individual or firm in an acute manner. Carbon dioxide is innocuous to individuals in small quantities; on a global scale, however, more emissions may have serious consequences. Making an argument for or against the danger posed by higher concentrations of carbon in the atmosphere is not the purpose of this paper. The goal is reducing emissions and to evaluate a way to combine it with improvements in the general economy.

A carbon tax is indeed a tax, but it does not solely imply a net increase in taxes levied on households and the business community. Namely, a carbon tax can be "revenue-neutral," where the revenues from the tax go to reducing personal income, sales, or corporate taxes (or any other taxes) in an area. In a situation of revenue-neutrality, a government's share of income out of the total economy does not change, only the allocation of collection. This may also be a more efficient means of collecting taxes. By making the emitter feel some of the pain the cost of emissions, the tax will, in theory, correct for the externality of releasing the GHG. Policymakers can also "recycle" the revenue from a carbon tax by putting it into general tax relief or investment programs including energy efficiency, weatherization, infrastructure, or scientific research that could generate both growth and productivity for the economy in the future. We will use elements of both in our analysis of the economic implications.

The Committee for a Green Economy (CGE) contracted REMI to look into the issue of a carbon tax in the state of Massachusetts. The Bay State, if it were to proceed with such a policy as the carbon tax, would join a number of states and Canadian provinces in introducing and implementing novel carbon emissions legislation.[3] The last major federal legislation to address GHG emissions was the American Clean Energy and Security Act of 2009. This bill usually went by its more common name as the Waxman-Markey bill

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[1] There are many descriptions of carbon taxes in everything from academic papers, to periodical articles, to online sources. For examples of these, please see, <http://www.carbontax.net.au/category/what-is-the-carbon-tax/>, or <http://tinyurl.com/worldbankct>.

[2] See, <http://www.investopedia.com/terms/e/externality.asp>.

[3] For a list as of May 9, 2013, see, <http://www.carbontax.org/progress/states/>.

after its sponsors, Henry Waxman (D-CA) and Ed Markey (D-MA).[4] It designed a federal "cap-and-trade," which works somewhat like a carbon tax in imposing a price on emitting gases. With little action in Washington on this issue, states have begun to take matters into their own hands. California currently has its own cap-and-trade under AB32.[5] British Columbia first enacted a revenue-neutral carbon tax in 2008. Oregon, New York, and Washington have looked into measures in recent history. Massachusetts already participates in the Regional Greenhouse Gas Initiative (RGGI), a cap-and-trade system between states in the Northeast.[6] A carbon tax in Massachusetts would be an enforcement mechanism for RGGI with a price on emissions supplementing an auction price. According to a World Bank report, "domestic emissions trading schemes and economy-wide instruments such as carbon tax or reform of fuel pricing" can support each other as systems to curb emissions.[7]

Much of this study takes inspiration from a similar study for a carbon tax in Oregon, though there are a few major differences. Earlier this year, the Northwest Economic Research Center (NERC) at Portland State University (PSU) released *Carbon Tax Shift: How to Make It Work for Oregon's Economy*.[8] Using CTAM, the researchers there found the amount of tax revenue drawn out of the economy by the tax, and hence the amount of revenue to recycle back into the economy by additional investments and tax cuts. CTAM is an open-source, Excel-based model developed by Keibun Mori for Washington state.[9] NERC replaced the Washington data to make the model reflect Oregon, and we did the same for CTAM to represent the

[4] This bill passed the House before stalling in the Senate. For its text or some of its history, see, <http://www.opencongress.org/bill/111-h2454/show>.
[5] For more information on cap-and-trade in California, see the California Air Resources Board (CARB) page for AB32 here, <http://www.arb.ca.gov/cc/ab32/ab32.htm>.
[6] See a REMI analysis on RGGI and its economic implications for 12-regions in the Northeast, here, <http://www.rggi.org/docs/ProgramReview/November28/12_11_28_REMI_Presentation.pdf>
[7] See p. 31, <http://tinyurl.com/worldbankct>.
[8] See, <http://www.pdx.edu/nerc/sites/www.pdx.edu.nerc/files/carbontax2013.pdf>.
[9] For some discussion of how CTAM works, information on how Mori developed and calibrated it, and the actual Excel document file for download, see, <http://daily.sightline.org/2011/08/10/washington-carbon-tax-new-model-and-analysis/>. Our analysis used this base model with data updates for New England and Massachusetts where appropriate to recalibrate it.

emissions from Massachusetts. *Carbon Tax Shift* found a generally net positive impact on the Oregon economy from the tax when accounting for revenue recycling and neutrality under various levels of taxes and scenarios for the latter. The researchers at NERC, however, used a "static" model of the economy, which did not adjust over time for the incentives and costs created by the tax.

Using REMI's dynamic regional economic model, PI+, and CTAM, we modeled the economic impact of various carbon tax scenarios for Massachusetts under the guidelines given by CGE. The use of a dynamic model—and not a static one—makes this a more robust analysis. A dynamic model will adjust for regional competitiveness for business activity and household locations, which is a vital consideration when introducing new taxes, spending, or any other incentives into the economy. The results of our simulations will look very different in 2025 or 2035 than in 2015 for the same reasons. Our scenarios include a $15, $30, and $45 tax per metric ton of carbon dioxide emissions, with a few options for spreading the revenue back into the economy. This can be through infrastructure spending and cuts to corporate, income, or sales taxes.[10] Economic modeling allows policymakers and citizens to compare alternatives and therefore make an informed decision.

REMI's task and position here is to advise on the economic implications of a carbon tax. We do not seek to advocate any specific policy or action, but rather to provide information and data to aid in the decision-making process with criteria related to macroeconomics. The remainder of this report contains background on REMI and our model, PI+, and information on CTAM. It also has how we integrated CTAM data into our simulations. After that, we describe our scenarios, their results in terms of how the economy does (with indicators like total employment and GDP), and how much the state might emit in carbon dioxide in alternative cases. There will be a wealth of information on the conclusions of the simulations, which will outline a projected difference to the economy from having a carbon tax, or different sorts of carbon taxes, versus doing nothing at all.

[10] While our simulations are not an exact representation of any specific bill, our simulations are in keeping with its structure and principles of having the tax, making some investments, and returning the revenue to the state's taxpayers in an efficient manner while reducing carbon dioxide emissions, <http://lexington.patch.com/blog_posts/support-builds-for-conroy-barrett-anti-climate-change-bill>.

POLICY SCENARIOS

For this study, we have run three overarching scenarios. All scenarios start with a $5 carbon tax on each metric ton of carbon emissions, enforced by fuel type, starting in late 2013. We told CTAM to exempt jet fuel and marine fuel, given those industries' unique nature in trading both inside and outside of the jurisdiction of the state. After that, we have three cases for a peak carbon tax: $15/ton, $30/ton, and $45/ton. Each one of these happens "gently," phased in at the rate of $10/year until the peak rate comes into effect. We follow the same scheme with the revenue in every case. The first $100 million goes towards a state fund for research and infrastructure development. Hence, this study is not quite revenue-neutral, but close to it, given the $100 million is not a significant portion of the anticipated revenue. We return the rest of the money to households and businesses in an even manner.

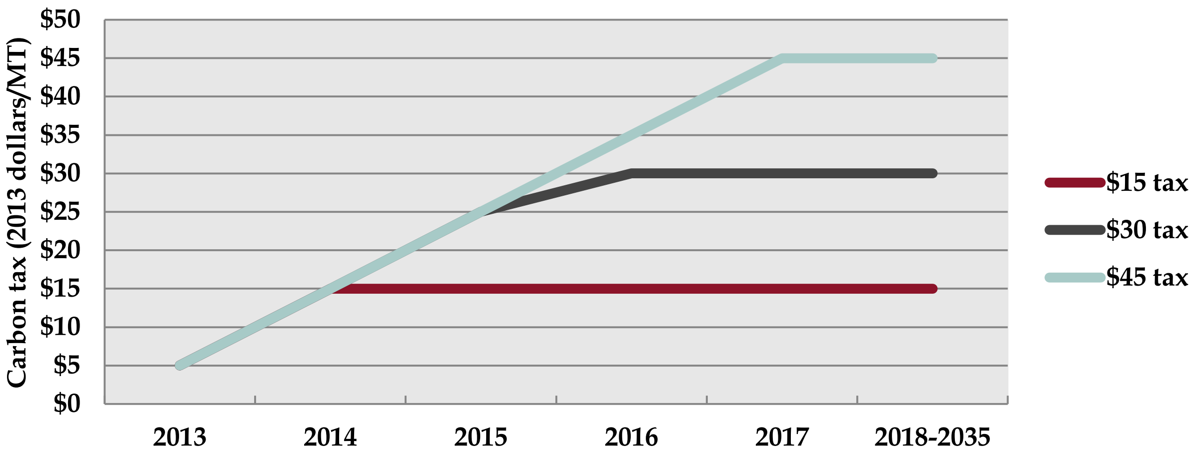

Figure 1.1 – This shows the various levels of carbon tax under the three scenarios. All start at $5/ton, and all use the same phase in rate of $10/year. The eventual result is a low, medium, and high scenario to test the sensitivity of the Massachusetts state economy to the impact of a carbon tax and associated state tax revenues to these degrees.

After the first $100 million, we distributed the remaining revenue back to the economy in a revenue-neutral manner. We split the money between the business sector variables and the household policy variables to give 50% of the revenue to each. An important aspect of a carbon tax is its simplicity and fairness. Everybody pays the tax in proportion to their usage of fuels and therefore their emissions of carbon dioxide into the air, and everybody receives some relief from the state funds available from the carbon tax. It is difficult at this level of modeling to ensure that every household or firm receives the exact money back it pays in the tax. However, broadly, major sectors of the economy see benefits back roughly in kind with their carbon tax payments. At the same time, the tax will introduce incentives to reduce the use of carbon-emitting fuels, which will decrease GHG emissions.

We used these principles to design the tax cuts. The 50% to firms went to reducing state corporate income taxes through the production cost variable in PI$^+$. The half to households went 50% (for a share of the overall of 25%) to lowering the personal income tax. The other 50% of that half went to lowering the state sales tax, which we intend to help reduce some of the "regressive" nature of the carbon tax. A regressive tax is one that falls disproportionally on low-income households or small businesses.[11] A carbon tax will increase the real cost of fuels, gasoline, and electricity more than anything else. A low-income household spends more of its income on these necessities (along with housing, clothing, and food) than a high-income household, which has much more real disposable income. A general sales tax is oftentimes regressive, so reducing the sales tax can correct for some of the regression in the carbon tax. In this way, both sides of labor and capital see relief from taxes, in an even 50-50 manner, and we protected low-income households by giving them a break in their sales tax.

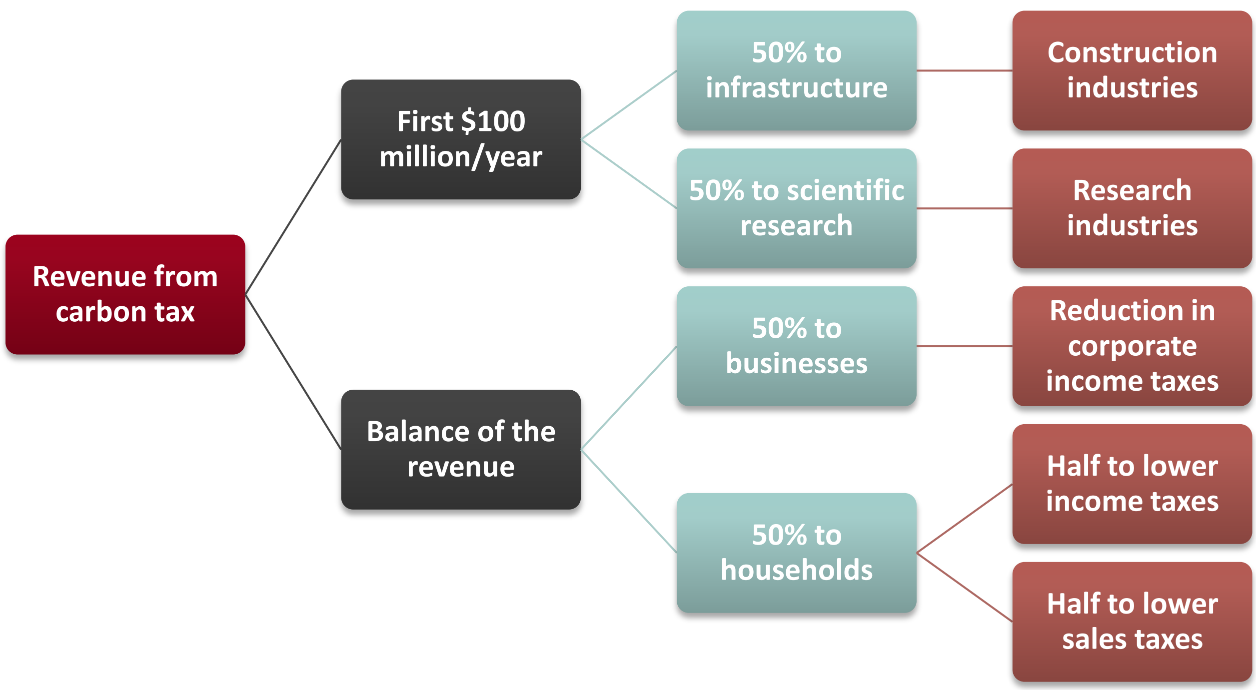

Figure 1.2 – This flow chart shows the path of the state revenue after the collection of the carbon tax. We do not aim for a 100% revenue-neutral situation (which is like Conroy-Barrett); we followed this by sending the first $100 million in annual revenue to the state's investments. The balance goes back to taxpayers in the economy.

[11] See, <http://www.investopedia.com/terms/r/regressivetax.asp>.

SIMULATION RESULTS

The results for the scenarios cover the economic and carbon impacts. On the economic side, this includes the impact to state GDP, total employment across all industries and in the government sector, and granular impacts to industry-level employment, output, and occupation categories. Demographic results include information on how the state's overall population growth changes due to the changes and incentives with a different labor market and costs of living. Results from CTAM on the carbon side will include anticipated impacts to emissions levels because of carbon tax levels, the benchmarked difference from 1990 data in percentage terms, and a detailed table of several factors. Those factors include the level of tax, in $15 increments (starting at $10) to $100, anticipated state revenue from the same, the saved emissions, and the difference from 1990 levels. We do not seek to have absolute answers or any recommendations for Massachusetts as REMI. Instead, we provide information here to isolate causes from effect, and allow policymakers and the public to decide from there.

ADDITIONAL GROSS DOMESTIC PRODUCT (ANNUAL) TO BASELINE

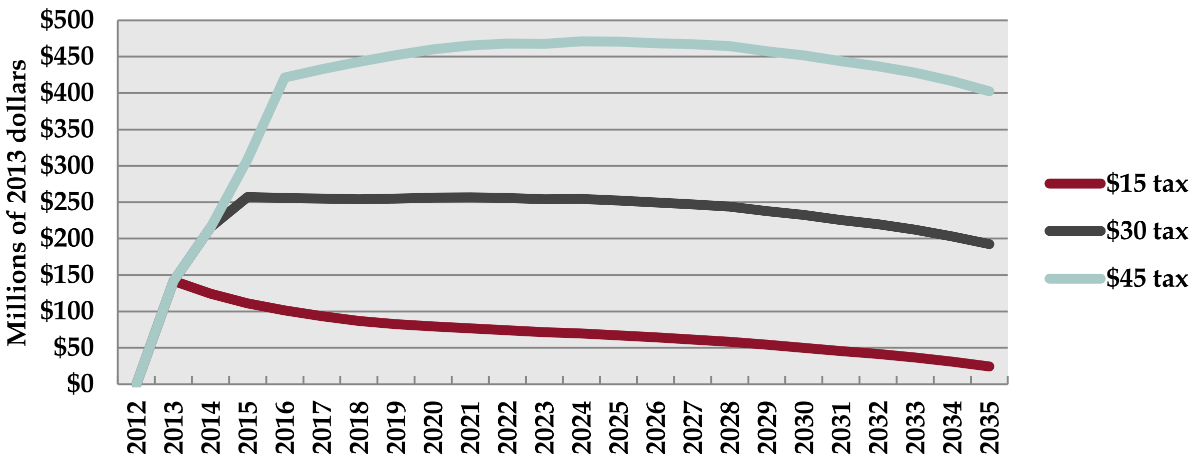

Figure 2.1 – This shows the various levels of carbon tax under the three scenarios. All start at $5/ton, and all use the same phase in rate of $10/year. The eventual result is a low, medium, and high scenario to test the sensitivity of the Massachusetts state economy to the impact of a carbon tax and associated state tax revenues to these degrees.

Additional Gross Domestic Product (Cumulative) to Baseline

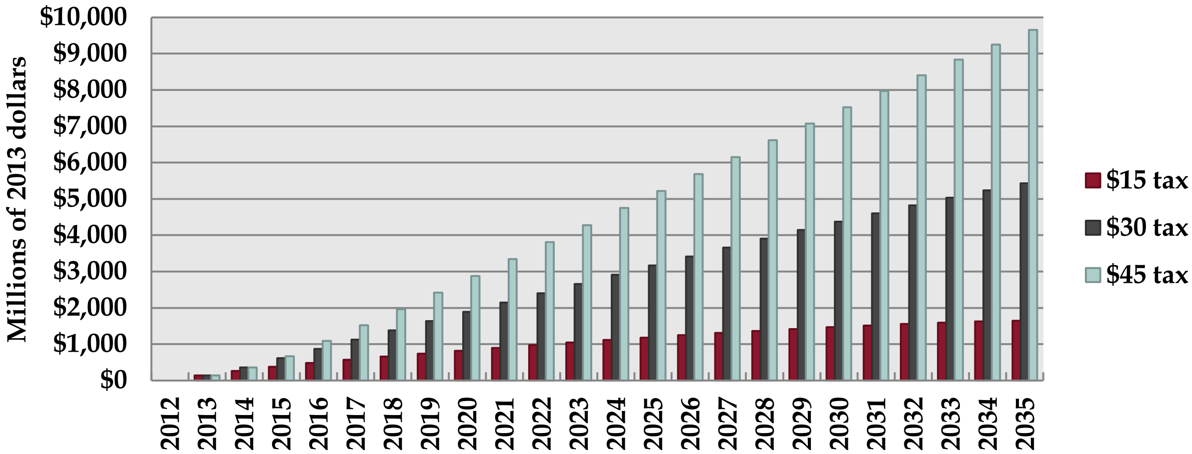

Figure 2.2 – The economy reproduces GDP annually as goods and services go through production, transportation, and consumption. Hence, it is appropriate to sum it over years to give a total GDP impact over a period. For these simulations, the total GDP difference from 2013 to 2035 is between $1 billion to $10 billion in real dollars. For the high case, this is an average of approximately $450 million additional state GDP in any given year.

GDP symbolizes additional economic activity in the state. There are several reasons this rises due to the carbon tax's introduction and ensuing tax relief in other areas. Discouraging fuel consumption in the state of Massachusetts means fewer fuel imports—New England has very little oil or natural gas extraction in its borders and a small amount of the associated supply chain from drilling, transportation, and refining. Reducing fuel imports from the Delaware River refineries or Texas keeps money in the state. Additional consumer spending means more activity in sectors like retail, which are inherently local, which also takes activity away from other states and centralizes them in Massachusetts.

Total Change in Employment from Baseline

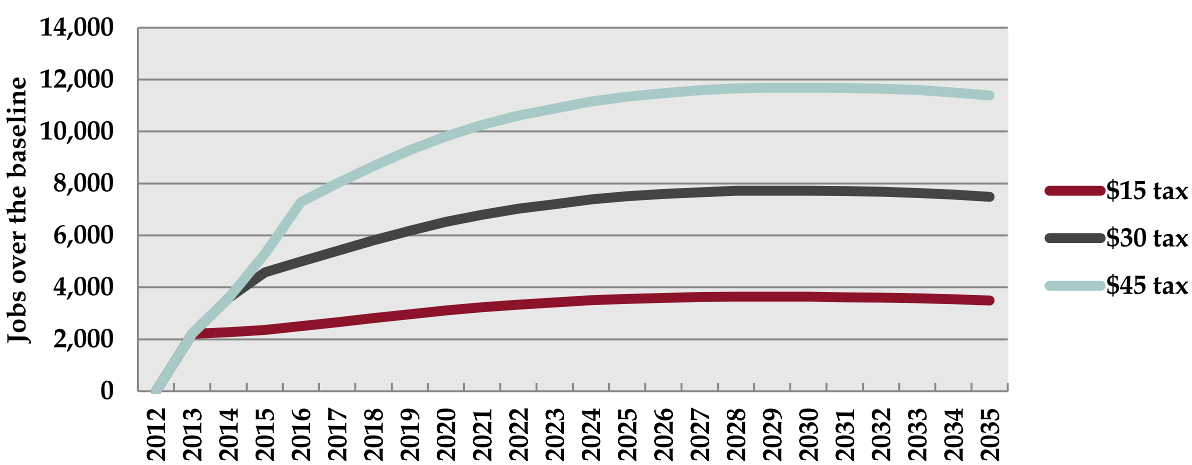

Figure 2.3 – In keeping with a higher GDP, the carbon tax means more jobs in the Massachusetts economy. Do note – these are essentially "job-years," or a unit of labor demand equivalent to a job for twelve months. They are not a measure of additional, new job creation but additionally available jobs over a "no tax" baseline case.

There is a more positive impact to employment than GDP in a proportional sense. There are a couple of changes to economic incentives in the state to make this the case. A carbon tax will discourage the use of emissions-generating fuels in production processes, and this encourages firms to switch towards either machines (capital) or labor inputs. A relatively high cost of fuel also gives an advantage to industries that tend to rely on labor, such as healthcare or business services. Those industries tend to generate a high level of jobs for their output. At the same time, energy-intensive sectors like manufacturers, refineries, or resource extraction—the least likely sorts of business to grow more under a carbon tax—generate a comparatively smaller job count. The balance between GDP and employment would change with any modifications to the 50-50 split between firms and households from the revenue. More of a split towards businesses would increase GDP, but jobs would suffer, and vice versa. This is a rather precarious balance, given that a 60-40 or 40-60 would drive at least one indicator below the baseline.

Population Change from Baseline

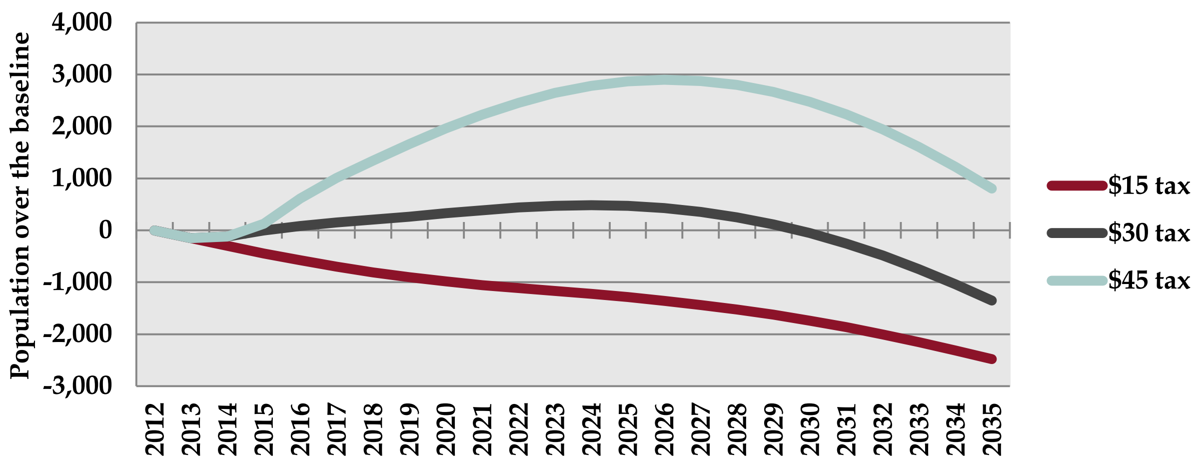

Figure 2.4 – The state's population changes due to the carbon tax. The greater availability of jobs means a stronger pull "in" to the state from the labor market. However, higher energy prices mean a higher cost of living, which encourages households to move elsewhere and additional net commuting from the rest of New England to take work inside Massachusetts. The net is close to zero, depending on scenario, to the tune of a few thousand people.

The next section has data about the projections of the expected carbon tax revenue and changes for emissions. This information comes from CTAM, not REMI, with background data from EIA, some economic/demographic forecast points from PI+, and the original research and methodology inside the carbon model. The calculations are internal, and we will not give it an outstanding endorsement of the capabilities it has because it is not a REMI model. On the other hand, it is very transparent in the way it works, and all of the data used to calibrate it is public and open. Results include the anticipated revenue from the carbon tax under the three scenarios, the level of emissions, how those levels relate to historical data for emissions in 1990, and a "sliding scale" of how the tax level relates to revenue, emissions, and 1990 levels of carbon, and economic performance.

Revenues from Carbon Tax (Annual)

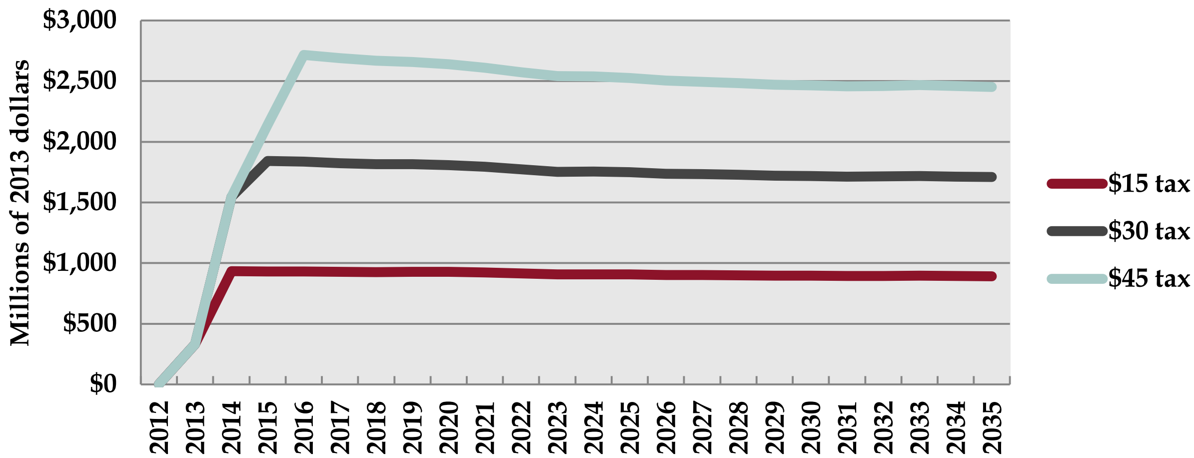

Figure 2.5 – This shows the anticipated carbon tax revenue from CTAM for the three levels. Note these do not scale in a proportional manner, and higher levels of tax rates will eventually lead to a stagnate level of added revenue.

Revenues from Carbon Tax (Cumulative)

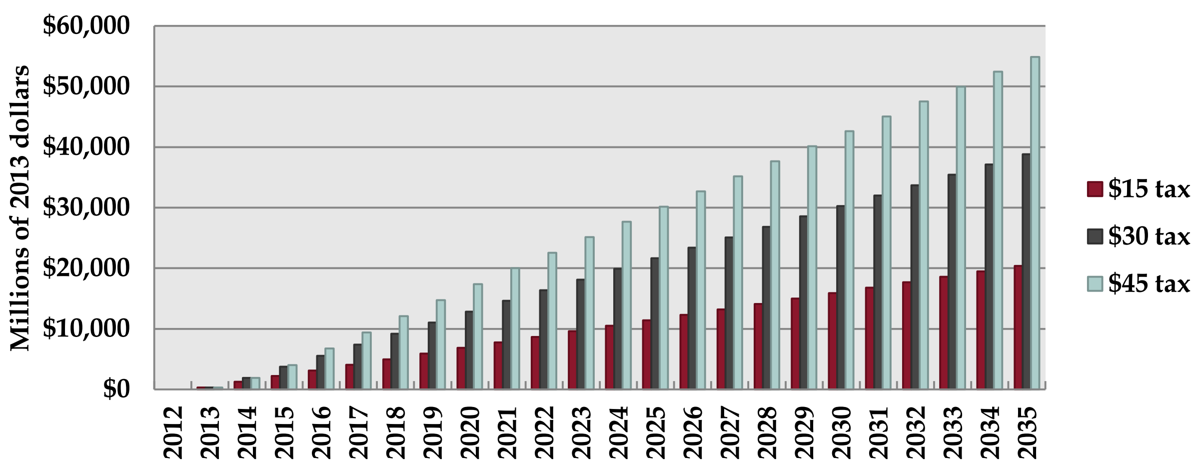

Figure 2.6 – This adds the annual revenues over time. Over the period, from CTAM, Massachusetts could collect between $20 billion and $50 billion in additional tax revenue from taxing carbon. This goes to general tax relief in this simulation, besides the $100 million in each year reserved for a state infrastructure and research fund.

Industry output by the U.S. Census' NAICS definitions, millions of 2013 dollars	2015	2020	2025	2030	2035
Forestry and logging; Fishing, hunting, and trapping	-$1.8	-$3.5	-$3.6	-$3.3	-$2.9
Agriculture and forestry support activities	$0.0	$0.0	$0.0	$0.0	$0.0
Oil and gas extraction	-$0.6	-$0.8	-$0.8	-$0.6	-$0.3
Mining (except oil and gas)	-$0.5	-$1.1	-$1.3	-$1.4	-$1.4
Support activities for mining	$0.0	-$0.1	-$0.1	-$0.1	-$0.1
Utilities	-$112.7	-$127.4	-$133.1	-$137.0	-$142.5
Construction	$29.5	$33.0	$40.8	$36.0	$22.7
Wood product manufacturing	$0.2	$0.2	$0.2	$0.1	$0.0
Nonmetallic mineral product manufacturing	$0.2	-$0.9	-$1.1	-$1.2	-$1.3
Primary metal manufacturing	-$5.0	-$11.1	-$12.4	-$12.6	-$12.2
Fabricated metal product manufacturing	$4.3	$5.1	$5.1	$4.9	$4.4
Machinery manufacturing	$1.0	$1.3	$1.2	$1.2	$1.2
Computer and electronic product manufacturing	$45.3	$102.5	$129.5	$149.6	$163.8
Electrical equipment and appliance manufacturing	$0.9	$0.5	-$0.2	-$0.8	-$1.3
Motor vehicles, bodies and trailers, and parts manufacturing	$1.3	$1.7	$1.8	$1.8	$1.8
Other transportation equipment manufacturing	$2.5	$3.9	$3.9	$3.6	$3.1
Furniture and related product manufacturing	$1.0	$1.3	$1.2	$1.1	$0.9
Miscellaneous manufacturing	$4.1	$4.7	$4.0	$3.4	$3.2
Food manufacturing	$3.9	$4.4	$4.1	$3.6	$3.0
Beverage and tobacco product manufacturing	$2.8	$3.1	$3.0	$2.7	$2.3
Textile mills; Textile product mills	-$0.3	-$0.7	-$0.8	-$0.7	-$0.7
Apparel manufacturing; Leather and allied product manufacturing	$0.7	$0.8	$0.8	$0.7	$0.6
Paper manufacturing	-$0.7	-$2.5	-$2.9	-$3.0	-$3.0
Printing and related support activities	$1.9	$2.3	$2.2	$2.0	$1.7
Petroleum and coal products manufacturing	-$106.8	-$171.4	-$180.5	-$177.6	-$172.7
Chemical manufacturing	-$65.3	-$140.4	-$161.8	-$163.5	-$157.6
Plastics and rubber product manufacturing	-$1.1	-$4.6	-$5.5	-$5.8	-$5.8
Wholesale trade	-$3.6	$8.3	$15.1	$19.4	$22.1
Retail trade	-$31.3	-$14.1	-$3.0	$3.6	$8.0
Air transportation	-$2.3	-$4.8	-$6.0	-$6.5	-$6.7
Rail transportation	-$0.2	-$0.4	-$0.5	-$0.5	-$0.6
Water transportation	-$0.2	-$0.4	-$0.5	-$0.5	-$0.5
Truck transportation	-$0.9	-$1.4	-$1.5	-$1.6	-$1.5
Couriers and messengers	-$0.1	-$0.4	-$0.6	-$0.7	-$0.8
Transit and ground passenger transportation	$0.2	-$0.7	-$1.1	-$1.3	-$1.5
Pipeline transportation	-$0.1	-$0.1	-$0.1	-$0.1	-$0.1
Scenic transportation; Support activities for transportation	-$0.5	-$0.6	-$0.8	-$0.9	-$1.1
Warehousing and storage	$0.3	$0.4	$0.3	$0.2	$0.1
Publishing industries, except Internet	$18.2	$28.6	$31.8	$32.4	$31.7
Motion picture and sound recording industries	$0.7	$0.9	$0.9	$0.9	$0.9
Internet publishing and broadcasting; ISPs, search portals, and data	$7.7	$10.2	$10.2	$9.5	$8.5
Broadcasting, except Internet	$1.6	$2.4	$2.4	$2.1	$1.8
Telecommunications	$15.0	$15.9	$15.1	$13.8	$12.0
Credit intermediation; Funds, trusts, & other financial	$43.7	$44.4	$42.9	$40.2	$37.2
Securities, commodity contracts, investments	$33.3	$47.6	$47.4	$43.3	$38.2
Insurance carriers and related activities	$13.9	$15.6	$14.5	$12.5	$10.5
Real estate	$50.0	$13.6	-$0.5	-$13.0	-$26.6
Rental and leasing services; Leasers of nonfinancial assets	$8.7	$12.0	$13.3	$13.9	$13.7
Professional, scientific, and technical services	$95.9	$108.2	$103.3	$93.8	$82.7
Management of companies and enterprises	$7.0	$10.6	$9.3	$6.8	$3.8
Administrative and support services	$7.6	-$0.8	-$5.2	-$9.4	-$14.4
Waste management and remediation services	$1.0	$0.1	-$0.3	-$0.7	-$1.2
Educational services	$6.9	$2.2	$0.6	-$0.4	-$1.8
Ambulatory health care services	$103.2	$104.4	$105.0	$105.3	$105.5
Hospitals	$30.0	$21.1	$13.5	$8.0	$2.7
Nursing and residential care facilities	$9.4	$8.0	$7.3	$6.5	$5.3
Social assistance	$4.1	$4.1	$3.9	$3.5	$3.0
Performing arts and spectator sports	$4.1	$4.7	$4.7	$4.5	$4.1
Museums, historical sites, zoos, and parks	$0.5	$0.2	$0.0	-$0.1	-$0.3
Amusement, gambling, and recreation	$2.9	$2.1	$1.8	$1.7	$1.5
Accommodation	-$0.5	-$8.8	-$12.2	-$14.5	-$16.8
Food services and drinking places	$22.1	$21.0	$20.0	$17.9	$13.9
Repair and maintenance	$7.3	$6.9	$6.5	$5.9	$5.0
Personal and laundry services	$14.8	$14.6	$14.1	$13.6	$13.2
Membership associations and organizations	$11.2	$12.8	$12.5	$11.5	$9.9
Private household services	$1.2	$1.3	$1.4	$1.4	$1.3

Figure 2.7 – This chart shows the sensitivity and scale of the overall reaction, by NAICS industry, to the carbon tax and revenue recycling. This is for the $30 tax scenario, and the units are in millions of 2013 dollars.

A number of key industries undergo disproportionate relative impact. These include utilities, electronics, petroleum products, chemical manufacturing, retail, professional services, and food services. Such impacts are due to the nature of the sectors' economic inputs and outputs, their dependence on direct consumer spending, and their position in the general economy. One should note, however, that these are small, marginal changes. In percentages, the output of any one of these industries does not change by more than a fraction of a percent in any given year (with the exception of petroleum and coal products, which change by slightly over 2% in the $30 tax run). These industries have their respective reasons for their behavior inside the model based on historical data. The BLS compiles data and tables on these through the North American Industrial Classification System (NAICS), which PI^+ uses.[12]

Utilities include electronic power generation and distribution, water and sewers, and natural gas distribution, and they are a special instance. The Conroy-Barrett legislation exempts power generation and distribution in order to avoid imposing a double hit on a sector already subject to special treatment under the current RGGI framework. Unfortunately, the CTAM model employed in this report cannot reflect these kinds of exemptions. As a result, the data in *Figure 2.7* for utilities attributed to the carbon tax might be due to RGGI. An auction price for carbon in a cap-and-trade market is functionally similar to that of a statutory carbon tax, which means that this carbon tax and RGGI could achieve the same goals of incentivizing efficiency through other means.

Petroleum products and **chemical manufacturing** show the most negative impact, chiefly because of higher fuel costs. Petroleum products involve the refining of crude oil, while chemical manufacturing involves transforming organic or inorganic raw materials into sellable products. This includes basic compounds, resins, rubber, pesticides, fertilizers, pharmaceuticals, photographic and film equipment, paint, soap, and other home and industrial cleaning materials. The tax affects only end-use consumers of carbon-emitting fluids, but nonetheless, these industries are both large and final consumers of liquid fuels and electricity. Higher costs mean a reduction in their market shares (relative to baseline) because of increasing imports and slower rate of investment and growth. These industries are globally very competitive and receive little direct consumption spending, so an increase in consumer demand from lower income and sales taxes would not bring them as much relief.

The majority of economic sectors would see positive effects from the carbon tax. The two sectors showing the biggest gains are the **computers and electronics** and **professional services** sectors. Both are growth sectors for Massachusetts. The electronics sector focuses on hardware for electronics, and professional services includes law, research, accounting, and consulting. Boston is a global leader in many of these. Neither of these industries uses much fuel, relying instead on labor. Lowering corporate taxes in the state offers them an advantage and allows them to grow quicker. On the other hand, **retail** and **food service places** display divergent patterns. Retail involves selling goods without any further transformation while food service requires meal preparation for on- or off-premise consumption. Each sees small changes given their large size, and each suffers initially due to a decline in real incomes from elevated fuel prices. However, food service has the bigger jump from revenue recycling—restaurants are more of a luxury than grocery stores, and general tax reductions lead to slightly more luxury spending from high-income households than spending on bare necessities from low-income households.

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[12] The NAICS is the U.S. Census Bureau's standard accounting for what makes up an industry. The PI^+ model in this case has 70-sectors, which then approximates a 3-digit NAICS configuration. Please see, <http://www.census.gov/eos/www/naics/index.html>.

Industry employment by the U.S. Census' NAICS definitions, number of jobs	2015	2020	2025	2030	2035
Forestry and logging; Fishing, hunting, and trapping	-3	-3	-1	0	0
Agriculture and forestry support activities	0	0	0	0	0
Oil and gas extraction	-10	-10	-8	-5	-3
Mining (except oil and gas)	0	2	5	7	8
Support activities for mining	0	0	0	0	0
Utilities	-120	-112	-101	-91	-84
Construction	469	931	1,244	1,346	1,322
Wood product manufacturing	2	5	7	7	7
Nonmetallic mineral product manufacturing	5	11	15	17	16
Primary metal manufacturing	-3	-1	2	4	5
Fabricated metal product manufacturing	24	43	50	51	49
Machinery manufacturing	7	13	15	14	13
Computer and electronic product manufacturing	98	164	161	145	125
Electrical equipment and appliance manufacturing	5	8	7	6	4
Motor vehicles, bodies and trailers, and parts manufacturing	2	3	3	2	2
Other transportation equipment manufacturing	6	11	11	10	9
Furniture and related product manufacturing	5	8	8	7	6
Miscellaneous manufacturing	15	18	15	12	11
Food manufacturing	14	25	29	29	27
Beverage and tobacco product manufacturing	3	4	4	4	3
Textile mills; Textile product mills	2	5	6	6	6
Apparel manufacturing; Leather and allied product manufacturing	8	11	10	9	7
Paper manufacturing	7	16	20	21	19
Printing and related support activities	13	19	19	17	14
Petroleum and coal products manufacturing	-14	-17	-13	-10	-7
Chemical manufacturing	-34	-44	-29	-14	-4
Plastics and rubber product manufacturing	5	13	19	22	23
Wholesale trade	15	109	152	172	180
Retail trade	-315	66	258	339	368
Air transportation	-3	-4	-3	-1	0
Rail transportation	0	2	2	3	2
Water transportation	1	2	3	4	5
Truck transportation	3	18	28	34	38
Couriers and messengers	7	18	25	30	33
Transit and ground passenger transportation	11	13	17	19	20
Pipeline transportation	0	0	0	0	0
Scenic transportation; Support activities for transportation	-3	-2	-1	-1	-1
Warehousing and storage	4	8	8	7	6
Publishing industries, except Internet	34	47	45	40	33
Motion picture and sound recording industries	5	7	7	6	5
Internet publishing and broadcasting; ISPs, search portals, and data	17	19	16	12	9
Broadcasting, except Internet	6	9	10	9	8
Telecommunications	28	35	35	33	29
Credit intermediation; Funds, trusts, & other financial	105	103	92	77	64
Securities, commodity contracts, investments	158	217	210	185	157
Insurance carriers and related activities	49	57	54	46	37
Real estate	161	167	178	170	149
Rental and leasing services; Leasers of nonfinancial assets	16	21	22	21	19
Professional, scientific, and technical services	548	663	652	597	531
Management of companies and enterprises	35	51	46	38	30
Administrative and support services	231	336	424	479	510
Waste management and remediation services	8	12	16	18	19
Educational services	195	334	440	497	515
Ambulatory health care services	887	928	963	980	992
Hospitals	238	268	281	284	274
Nursing and residential care facilities	156	187	214	229	232
Social assistance	87	119	137	143	141
Performing arts and spectator sports	75	90	91	86	77
Museums, historical sites, zoos, and parks	7	11	14	16	17
Amusement, gambling, and recreation	75	96	114	123	124
Accommodation	14	-5	-3	0	0
Food services and drinking places	447	610	696	714	682
Repair and maintenance	68	77	81	78	71
Personal and laundry services	214	217	209	194	178
Membership associations and organizations	148	184	190	181	163
Private household services	154	148	142	131	119

Figure 2.8 – This is a similar graph to the last one on industry sales, though by employment instead. Employment gains concentrate in the labor-intensive commercial and service industries towards the bottom of the list.

The standard economic concept of labor productivity is essential to understanding the above table. Labor productivity measures how much production a unit of labor can make in a given unit of time. For example, if an artisan can make two chairs a day at a price of $200/chair, then his or her productivity for that day is $400. Taken over the course of a year, that artisan would have an output of $96,000/year for 240 days' worth of work. This applies throughout the general economy, and different industries have varying levels of labor productivity. An engineer or mechanic working for a chemical plant or factory line may have an average labor productivity of over $1,500,000/year, given that industry's milieu as capital-intensive and highly productive. On the other hand, a construction worker might only generate $30,000/year in output given the labor-intensive characteristics of projects. The relationship to equate these concepts together is the following:

Output Units = Labor Units * Labor Productivity

In the scenarios we have constructed, those industries showing the greatest decline in output have high levels of productivity. They do not lose much in employment despite their drop in output. Meanwhile, the industries showing the greatest gains in output, such as professional services or healthcare, are generally in need of much more labor to accomplish their production. A legal partnership needs far more attorneys, clerks, secretaries, and administrators to operate as an enterprise than a woodcutting shop needs operators and maintenance personnel, because of the nature of their technology and production. Thus, while a carbon tax may slightly decrease overall productivity in the state economy, it also directs more of the state's resources into labor-intensive sectors, which yields the additional net employment gains overall shown in the previous tables.

There is a socioeconomic aspect, based on occupations, to these employment numbers, as well. REMI uses the Standard Occupation Classification (SOC) from the BLS and an industry-occupation matrix to bridge between NAICS and SOC.[13] SOC is an equivalent to NAICS for type of work instead of industry—what does the employee actually do by profession instead of where they work by industrial category. Certain types of firms hire certain patterns of workers, which leads to the data on impacts below. Occupations are generally a better measure of wages and skills sets than the industries alone. Analysis of occupations allows for a better understanding of how a given policy could influence the labor market from the household perspective. This should give a good idea of some of the distributional aspects of this policy. This is not an absolute measure or a forward projection of how these occupations will see changes, but it does supply some numbers for comparison.

There are two lessons to learn from a carbon tax impact on occupations. One, the tax increases demand for nearly all occupations. Two, there is a broad, positive net impact across all levels of education and professional standing in the state economy. This means that workers will be able to use their skills sets and training to shift from waning to waxing industries. A graduate from a state school with an engineering degree might now be more likely to work for an architectural design firm instead of a chemical plant, but they will still be able to find a fit with their occupation between some industries. The same could happen with a high school graduate moving from truck transportation into grounds and maintenance. The broad impact across all occupations, from top executives to the construction trades, means that no socioeconomic class absorbs a disproportionate impact of the carbon tax. All levels of education and all lifestyles see some impacts and nearly all of them are positive.

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[13] See, <http://www.bls.gov/SOC/>.

Occupational employment by the BLS' SOC definitions, number of jobs	2015	2020	2025	2030	2035
Top executives	71	102	114	113	105
Advertising, marketing, promotions, public relations, and sales managers	19	29	32	31	29
Operations specialties managers	53	73	77	75	69
Other management occupations	91	123	141	144	138
Business operations specialists	134	194	215	215	204
Financial specialists	128	167	169	157	140
Computer occupations	157	213	220	208	191
Mathematical science occupations	4	5	5	5	4
Architects, surveyors, and cartographers	10	13	13	12	11
Engineers	49	75	79	76	70
Drafters, engineering technicians, and mapping technicians	25	36	37	35	31
Life scientists	7	9	10	10	9
Physical scientists	6	8	9	9	8
Social scientists and related workers	9	10	11	10	10
Life, physical, and social science technicians	6	8	9	9	8
Counselors and Social workers	51	59	65	66	65
Miscellaneous community and social service specialists	26	31	34	34	33
Religious workers	2	2	3	3	3
Lawyers, judges, and related workers	31	34	32	28	24
Legal support workers	18	21	20	19	16
Postsecondary teachers	61	97	124	138	141
Preschool, primary, secondary, and special education school teachers	64	77	85	85	77
Other teachers and instructors	26	38	46	50	50
Librarians, curators, and archivists	7	9	10	10	10
Other education, training, and library occupations	30	40	47	48	47
Art and design workers	17	25	26	25	23
Entertainers and performers, sports and related workers	31	42	48	49	48
Media and communication workers	31	41	43	41	38
Media and communication equipment workers	8	10	10	9	9
Health diagnosing and treating practitioners	313	346	366	373	371
Health technologists and technicians	184	206	219	224	222
Other healthcare practitioners and technical occupations	6	7	8	8	8
Nursing, psychiatric, and home health aides	170	204	228	243	251
Occupational therapy and physical therapist assistants and aides	16	18	19	20	21
Other healthcare support occupations	141	145	148	147	144
Supervisors of protective service workers	4	4	4	4	4
Fire fighting and prevention workers	3	3	3	3	2
Law enforcement workers	12	11	10	9	7
Other protective service workers	49	67	80	86	88
Supervisors of food preparation and serving workers	35	48	55	57	55
Cooks and food preparation workers	110	151	173	179	171
Food and beverage serving workers	267	368	424	438	422
Other food preparation and serving related workers	55	71	81	82	78
Supervisors of building and grounds cleaning and maintenance workers	8	10	12	12	12
Building cleaning and pest control workers	145	152	160	157	147
Grounds maintenance workers	42	57	69	75	78
Supervisors of personal care and service workers	9	10	11	11	10
Animal care and service workers	16	19	20	20	19
Entertainment attendants and related workers	27	32	36	36	35
Funeral service workers	11	11	11	10	10
Personal appearance workers	76	82	82	79	75
Baggage porters, bellhops, and concierges; Tour and travel guides	3	4	4	5	5
Other personal care and service workers	182	213	231	237	235
Supervisors of sales workers	-12	21	37	43	44
Retail sales workers	-82	112	210	248	257
Sales representatives, services	78	103	105	98	88
Sales representatives, wholesale and manufacturing	21	54	69	74	75
Other sales and related workers	43	56	63	64	60
Supervisors of office and administrative support workers	55	72	79	79	76
Communications equipment operators	5	5	5	5	4
Financial clerks	149	189	205	203	193

Information and record clerks	213	265	286	284	273
Material recording, scheduling, dispatching, and distributing workers	0	56	82	91	91
Secretaries and administrative assistants	214	261	281	278	264
Other office and administrative support workers	157	206	227	226	215
Supervisors of farming, fishing, and forestry workers	0	0	0	0	0
Agricultural workers	1	3	3	4	4
Fishing and hunting workers	0	0	0	0	0
Forest, conservation, and logging workers	-1	-1	0	0	0
Supervisors of construction and extraction workers	30	60	80	86	85
Construction trades workers	252	498	665	719	706
Helpers, construction trades	20	42	57	62	62
Other construction and related workers	11	17	21	22	21
Extraction workers	0	2	4	5	5
Supervisors of installation, maintenance, and repair workers	7	14	19	20	20
Electrical and electronic equipment mechanics, installers, and repairers	11	21	27	28	28
Vehicle and mobile equipment mechanics, installers, and repairers	20	43	55	59	58
Other installation, maintenance, and repair occupations	72	123	158	170	166
Supervisors of production workers	6	12	15	16	15
Assemblers and fabricators	38	65	72	71	68
Food processing workers	1	11	15	17	16
Metal workers and plastic workers	27	50	61	64	62
Printing workers	8	12	12	11	9
Textile, apparel, and furnishings workers	35	37	36	33	29
Woodworkers	3	5	6	6	6
Plant and system operators	-18	-19	-16	-13	-12
Other production occupations	34	60	76	82	82
Supervisors of transportation and material moving workers	5	10	13	14	15
Air transportation workers	0	0	0	1	1
Motor vehicle operators	50	97	127	140	143
Rail transportation workers	0	1	1	1	1
Water transportation workers	1	2	3	3	4
Other transportation workers	16	18	18	18	16
Material moving workers	48	109	144	158	160
Military personnel	0	0	0	0	0

Figure 2.9 – This shows the employment impact by occupation instead of by industry. Any given industry employs a wide variety of skill sets and educational backgrounds. For instance, a large bank will have executives, analysts, administration professionals, accountants, sales representatives, customer service agents, all the way down to maintenance crews for buildings. The categories above are from the SOC from the BLS; it is the standard, federal data way of classifying types of jobs across different industries.

CHANGE IN CONSUMER PRICES FROM BASELINE

Introducing the carbon tax would ordinarily affect the price for consumers' goods in four categories: fuel oil and other fuels, motor vehicle fuels, natural gas, and electricity. The higher the tax, the greater the impact will be on these price indices. On the other hand, these higher costs will see some offset because carbon tax revenue will return to the state's households in the form of lower sales taxes and lower personal income taxes. One should also note that market price changes shown might very well trend lower overall—even after the carbon tax. The energy industry has undergone tremendous changes in the past five years, including the natural gas hydraulic fracturing revolution, switching of electrical power generation towards natural gas, and a drop in demand due to a weak economy. Prices are constantly fluctuating, and these changes are against a wavering baseline.

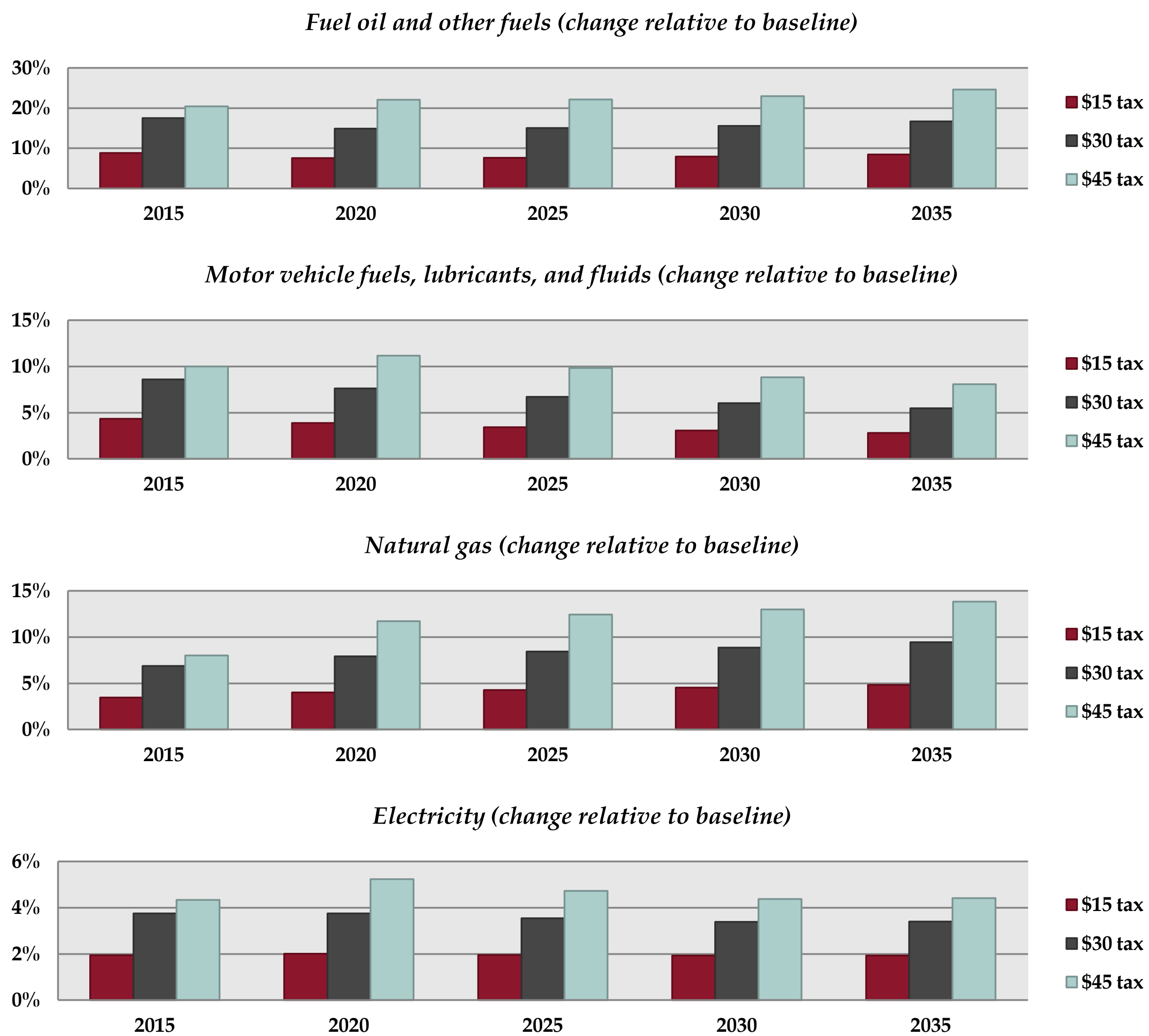

Figure 2.10 – Emissions from this fuel usage means their prices must go somewhat upwards. However, these prices are against a baseline of falling fuel prices since 2007 due to reduced demand, the shale gas revolution, and additional crude oil drilling throughout North America. Prices might be higher relative to baseline, but the realized, sticker consumer prices might still be lower than the high prices experienced in the 2000s decade.

CHANGE IN CONSUMER PRICES FROM BASELINE

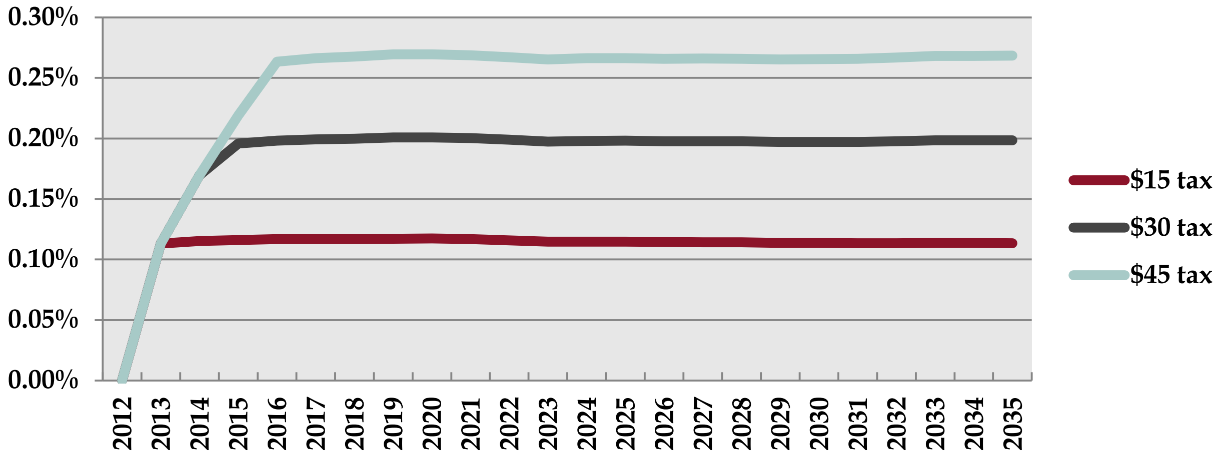

Figure 2.11 – REMI does not have a 1:1 version of the consumer price index (CPI) inside of it, though we do estimate it with something called the PCE-Index (Personal Consumption Expenditure Index), which produces similar results. This shows the average change in the total cost of living for a household in Massachusetts. Note this is essentially a "one-time" adjustment upwards over a baseline and not a change in the long-term growth rate.

CHANGES IN CONSUMER PRICES FOR INCOME GROUPS

Year	PCE - 2013$ (<$5,900)	PCE - 2013$ ($5,900-$11,700)	PCE - 2013$ ($11,700-$17,600)	PCE - 2013$ ($17,600-$23,400)	PCE - 2013$ ($23,400-$35,100)	PCE - 2013$ ($35,100-$46,800)	PCE - 2013$ ($46,800-$58,500)	PCE - 2013$ ($58,500+)
2012	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2013	0.11%	0.11%	0.12%	0.12%	0.12%	0.12%	0.12%	0.11%
2014	0.16%	0.17%	0.19%	0.18%	0.18%	0.18%	0.18%	0.17%
2015	0.19%	0.20%	0.22%	0.21%	0.21%	0.21%	0.21%	0.19%
2016	0.19%	0.20%	0.22%	0.21%	0.21%	0.21%	0.21%	0.20%
2017	0.19%	0.20%	0.22%	0.21%	0.21%	0.21%	0.21%	0.20%
2018	0.19%	0.20%	0.22%	0.21%	0.21%	0.21%	0.21%	0.20%
2019	0.19%	0.20%	0.22%	0.21%	0.21%	0.21%	0.21%	0.20%
2020	0.19%	0.20%	0.22%	0.21%	0.21%	0.21%	0.21%	0.20%
2021	0.19%	0.20%	0.22%	0.21%	0.21%	0.21%	0.21%	0.20%
2022	0.19%	0.20%	0.21%	0.21%	0.21%	0.21%	0.21%	0.20%
2023	0.19%	0.20%	0.21%	0.21%	0.21%	0.20%	0.21%	0.20%
2024	0.19%	0.20%	0.21%	0.21%	0.21%	0.20%	0.21%	0.20%
2025	0.19%	0.20%	0.21%	0.21%	0.21%	0.21%	0.21%	0.20%
2026	0.19%	0.20%	0.21%	0.21%	0.21%	0.20%	0.21%	0.20%
2027	0.19%	0.20%	0.21%	0.21%	0.21%	0.20%	0.21%	0.20%
2028	0.19%	0.20%	0.21%	0.21%	0.21%	0.20%	0.21%	0.20%
2029	0.19%	0.20%	0.21%	0.21%	0.21%	0.20%	0.21%	0.20%
2030	0.19%	0.20%	0.21%	0.21%	0.21%	0.20%	0.21%	0.20%
2031	0.19%	0.20%	0.21%	0.21%	0.21%	0.20%	0.21%	0.20%

2032	0.19%	0.20%	0.21%	0.21%	0.21%	0.20%	0.21%	0.20%
2033	0.19%	0.20%	0.21%	0.21%	0.21%	0.20%	0.21%	0.20%
2034	0.19%	0.20%	0.21%	0.21%	0.21%	0.20%	0.21%	0.20%
2035	0.19%	0.20%	0.21%	0.21%	0.21%	0.20%	0.21%	0.20%

Figure 2.12 – This shows the change in CPI for income groups with the $30 tax (the middle "red" scenario). The REMI model includes, as an econometric estimation, different price indices for different sizes of household income. The methodology for the above calculations is online.[14] The theory is different homes spend differently based on their income. For example, a low-income home will spend a larger proportion of total income on food, fuel, and rent (all necessities) compared to an upper-income family, which will have more disposable income for luxury goods such as electronics, travel, and entertainment. The above calculations project a somewhat larger impact from a carbon tax on working homes with incomes from $20,000/year to $40,000/year. However, this is not a large differentiation amid the groups. Judging from above, the carbon tax will not impose much of a disproportionate effect on the working poor or other low-income people, especially given the sales and income tax offsets included in Conroy-Barrett.

[14] See our document with the methodology for decomposing the impact by different income groups, <http://www.remi.com/download/documentation/pi+/pi+_version_1.3/Income_Distribution.pdf>

This section shows changes to carbon emissions from CTAM. We found data from the Environmental Protection Service (EPA) on emissions in 1990, and the rest of the results come from CTAM and its research on calculating emissions and the price elasticities to various fuel times. Like REMI, CTAM works best as a difference engine for finding the hypothetical impact between different scenarios than finding the absolute level of forecasted emissions in any given year.

Forecasted Carbon Dioxide Emissions

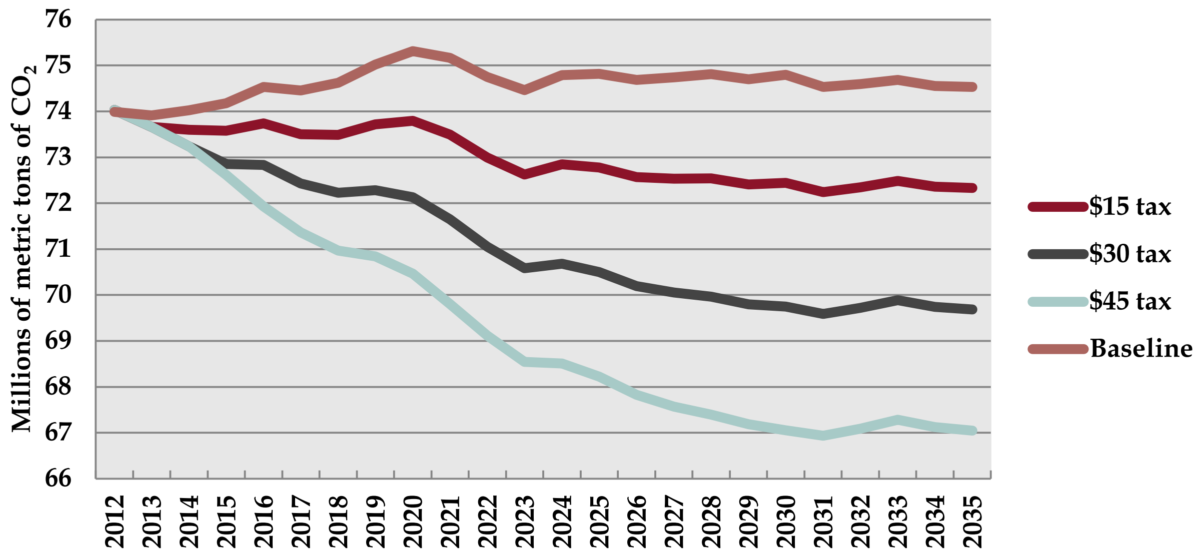

Figure 2.13 – According to CTAM and sans the tax, emissions of carbon dioxide from Massachusetts are stable around 64 million MT per annum. Increasing the carbon tax reduces this by as much as 7 million MT per year.

Differences in Carbon Emissions from Baseline

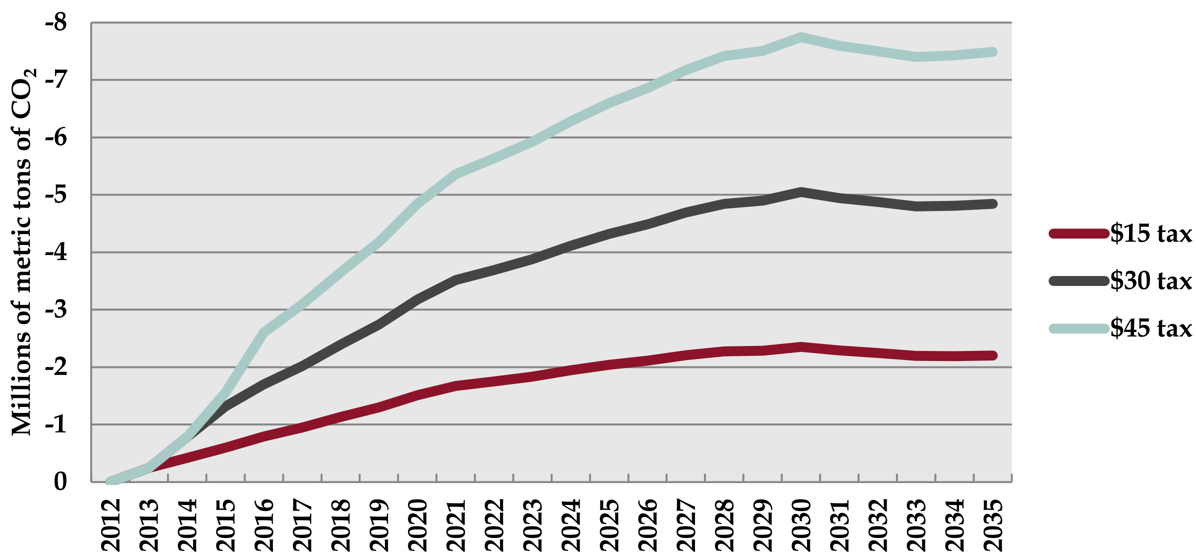

Figure 2.14 – This is the same data as Figure 2.13, only transformed to make the cardinal "Baseline" into the zero line on this chart. The difference from zero is the anticipated emissions reduction, per year, in CTAM under the price conditions of the three levels. This modeling suggests significant reductions in carbon emissions.

The next part looks at these levels of emissions compared to 1990. For several reasons—the important one being the Kyoto Protocol—1990 is a goal year of levels for limiting carbon emissions.[15] Massachusetts is already below this level for a few reasons. These include the slow rate of population growth in New England compared to the rest of the United States, low macroeconomic growth, the recession of a few years' past, and historically low natural gas prices. Natural gas is, relatively, less carbon-intensive than other sorts of fossil fuels, and the switching from households, firms, and power companies away from petroleum and coal and towards gas does save emission. Massachusetts is already below 1990 levels,[16] and a carbon tax would allow it to go beyond Kyoto or other requirements.

THE 1990 BENCHMARK

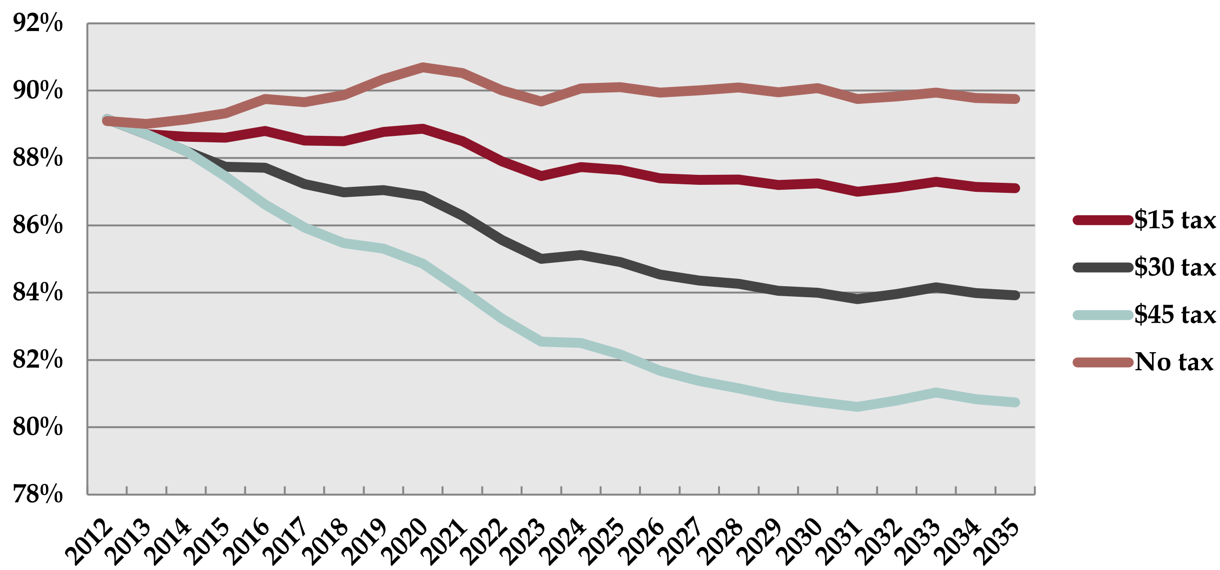

Figure 2.15 – This gives the range the state might achieve with these levels of carbon taxes in relationship to emissions in 1990. The baseline always stays below 92% in CTAM, but the $45 tax could bring the state below 85% of 1990 levels and downwards. This should give some idea of the range of the possible for these carbon taxes.

The next table looks at a number of similar scenarios to those above, and it gives a "menu" of possible options for the state in increasing the carbon tax beyond the three in blue, red, and green. We did not complete an economic impact study, including revenue-neutrality and state investment, for each of these. That would have required a geometric increase in the number of simulations in PI+. This is not an onerous task, but it would have quickly created more data to consider and many more lines in the above figures without complicating the general story of the carbon tax in the Massachusetts economy. For the sake of simplicity, we left it to three and reported the results as you saw them in the earlier section. The "XYZ" consideration below has the level of carbon tax, associated revenue estimations from CTAM, the amount of emissions in millions of metric tons (both the sum from 2013 to 2035), and the difference from 1990 levels in 2035 in a final column. Higher taxes could lead to more state revenues, but also a somewhat higher cost of living for households in Massachusetts.

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[15] See the United Nations page on it, here, at <http://unfccc.int/kyoto_protocol/items/2830.php>.
[16] The 1990 levels were 83.04 million MT of carbon in the state of Massachusetts according to the data, <http://www.epa.gov/statelocalclimate/documents/pdf/CO2FFC_2010.pdf>.

Carbon tax rate	Carbon tax revenue (annual average)	Total emissions, 2013-2035	Total emissions savings, 2013-2035	Rate of 1990 emissions in 2035
No tax	$0	1790.714	0.00%	89.75%
$10 tax	$596	1766.845	-1.33%	88.17%
$25 tax	$1,426	1722.974	-3.78%	84.98%
$40 tax	$2,150	1680.003	-6.18%	81.80%
$55 tax	$2,771	1638.116	-8.52%	78.62%
$70 tax	$3,282	1598.022	-10.76%	75.43%
$85 tax	$3,701	1559.728	-12.90%	72.25%
$100 tax	$4,023	1524.193	-14.88%	69.06%

Figure 2.16 – Reading from left to right, the units are millions of 2013 dollars, millions of metric tons of carbon dioxide, percentage change, and percentage change. Specifically, the fourth column shows the saved emissions (in percentage terms) from the baseline, and the fifth column is the 2035 quantity of emissions in comparison to the 1990 benchmark from the Kyoto protocol requirements. A higher tax intuitively means more revenue and a greater reduction in emissions. On the other hand, there is a diminishing of returns with higher taxes. The higher the tax, the slower the growth rate to revenue coming into the state and emission saved. The figure below shows this trend and finds a hypothetical limit of revenue and emissions savings for the state at some high tax level.

AVERAGE ANNUAL CARBON TAX REVENUE

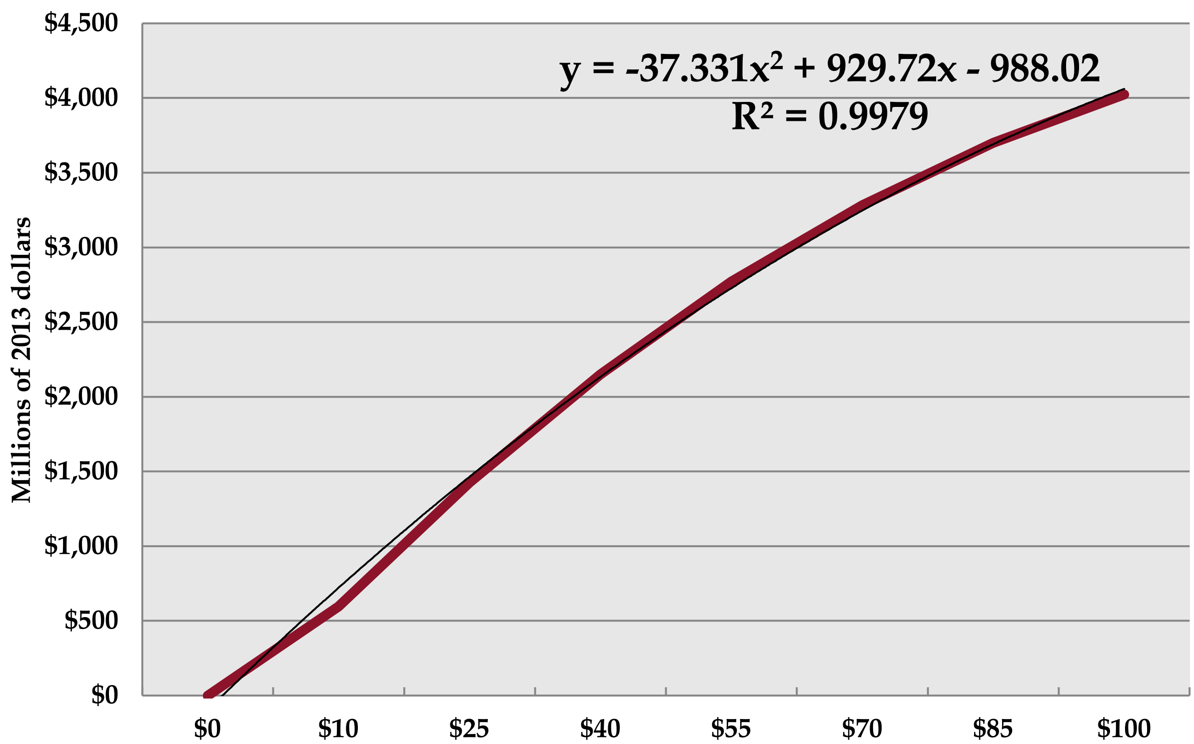

Figure 2.17 – This is the second column from the left in graphical form. A higher tax meant more revenue, but at a decreasing rate because the "easiest" savings in CTAM already happened. This suggests a "tipping point" of around a $120 tax after which you would not see any marginal gain to additional revenue for the state or any reductions in total emissions. This suggests a "range of the possible" for a carbon tax in the state.

REGIONAL ECONOMIC MODELS, INC. (REMI)

REMI is from Amherst, Massachusetts, though this paper and its content originate in our office in Washington, DC. REMI is an economic services firm, specializing in issues related to regional modeling, policy analysis, and forecasting. REMI began as a research project by a professor at UMass-Amherst, Dr. George Treyz, in the 1970s when assessing the construction of the Mass Pike. Eventually, in 1980, Dr. Treyz founded a business around his research, which has grown to the present firm. REMI provides software, support services, as well as issue expertise in nearly every state, the District of Columbia, and in several foreign nations around the globe. Model users are primarily in state governments, but also include federal agencies, planning organizations, consulting firms, universities, and private industry involved in policy and infrastructure development.

REMI is a Massachusetts firm, and we have an institutional presence in the state's modeling and policymaking processes. Currently, REMI works with such organizations as the Boston Redevelopment Authority (BRA), the Massachusetts Department of Revenue, and the Massachusetts Institute of Technology (MIT).[17] Our relationship with these groups includes providing a software package with a model customized to the state, helping with the interface, vetting data, and interpreting results. In some cases, REMI runs simulations and reports results, such as here.

[17] For a full list, see, <http://www.remi.com/clients>. Other clients in Massachusetts include NERA Economic Consulting, ICF International, the Economic Development Research Group (EDRG), UMass-Amherst, and the Northeast States for Coordinated Air Use Management (NESCAUM).

THE PI+ MODEL

REMI used a 1-region, 70-sector version of the PI+ model configured to the state of Massachusetts for this study. PI+ is a fully dynamic, multiregional, computerized model of the state economy. The REMI model relies on four different quantitative methodologies in its framework, which allows them to highlight each other's strengths while compensating weaknesses. These methodologies include:

1. **Input/output tabulation (IO)** – IO modeling is sometimes called "social accounting" because it shows the interrelationships between different industries and households in the economy. This includes the flow of goods and services between firms in supply chains, final sales to households, and wages paid to and spent by individuals. These interconnections create multipliers. The data for the table comes from the Bureau of Labor Statistics (BLS)[18] and the theoretical underpinnings for IO modeling comes from the Nobel laureate Wassily Leontief.
2. **Econometrics** – The REMI model includes statistical parameters for behavior of firms and households based on historical data. In modeling terms, this is the source of our elasticities and parameters. This includes how actors respond to changes in prices or wages and the "rate of adjustment" from a shock until the economy returns to a new balance.
3. **Computable General Equilibrium** – This is a broad class of models. Computable general equilibrium modeling adds market concepts and the principles of equilibrium economics to the REMI algorithm. This includes markets for housing, labor, consumer goods, and importantly, a concept of market shares and competitiveness for businesses. For example, consumers in the state of Massachusetts may demand automobiles, but in all likelihood those cars come from plants in Michigan or the Southeast, or even overseas. This flow of goods and services can change over time, and with it the attractiveness of the state for labor and capital, given changes in economic conditions. With a carbon tax, this is very crucial, given that changes in fuel and energy prices may greatly influence a new general equilibrium for Massachusetts.
4. **Economic Geography** – Geography gives the REMI model a sense of agglomeration, labor pooling, and economies of scale. Labor-intensive industries, such as healthcare or professional services in Boston and Cambridge, tend to cluster in urban centers where specialized pools of educated workers are easy to obtain. Manufacturers tend to do the same thing given their tendency to locate near their input suppliers, customers, and transportation hubs. This allows them to lower their costs and increase their productivity.

REMI began as a research inquiry, and the literature behind PI+ is public and oftentimes appears in peer-reviewed journals. These include the *Journal of Regional Science*, *American Economic Review*, and the *Review of Economics and Statistics*.[19] REMI only uses data from public sources. References include the Bureau of Economic Analysis (BEA), BLS, the U.S. Census Bureau, and the Energy Information Administration (EIA) at the Departments of Commerce and Energy.[20] The forecast for future economic conditions comes from macroeconomic and industry trends identified by the Research Seminar in Quantitative Economics

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[18] For the most recent BLS make and use table, which we then transform into an IO table from there, see, <http://www.bls.gov/emp/ep_data_input_output_matrix.htm>.
[19] For journal citations from the above publications, see p. 46 of our equations document online, <www.remi.com/download/documentation/pi+/pi+_version_1.4/PI+_v1.4_Model_Equations(2).pdf>.
[20]For a full listing of data sources and types, see our document online of data sources and procedures, <www.remi.com/download/documentation/pi+/pi+_version_1.4/Data_Sources_and_Estimation_Procedures.pdf>.

(RSQE) at the University of Michigan in Ann Arbor, MI and the BLS.[21] The REMI model exists in a block structure of simultaneous equations:

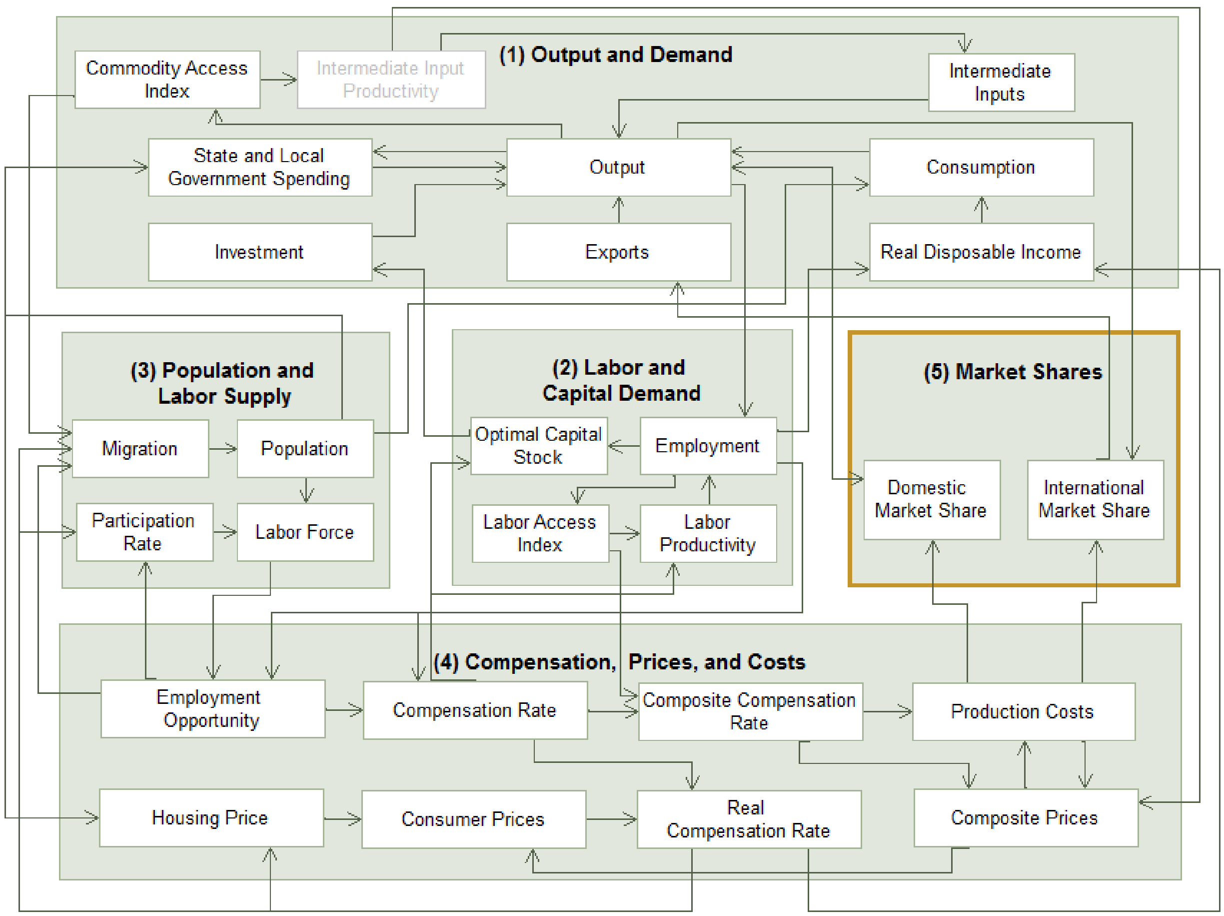

Figure 3.1 – This is the overall structure of REMI's representation of the state economy. Each rectangle is a "stock," a finite concept such as population or the number of jobs. Each arrow shows an equation that links them together. For example, the population times the participation rate equals the labor force; government spending, plus capital investment, plus net exports, plus consumption, and minus intermediates, then equals GDP.

Each of the five blocks above adds its own perspective on the economy. Block 1 is the macroeconomy, given the GDP components outlined in the text for *Figure 1* above. Block 2 is the business perspective on the economy; sales orders come in from Block 1, and industries have to make production decisions (in terms of hiring workers and investing in capital) to eventually generate their needed output. Block 3 is the demographic portion of the model, which includes natural births and deaths, migration within the United States and from the rest of the world, and participation in the labor market. Block 4 introduces equilibrium concepts to the REMI model: households appraise the labor market, housing, and the cost of living when making location decisions. For businesses, they make an analogous consideration about their costs for labor, capital, intermediates, and fuel. Block 5 quantifies regional competitiveness, which means how much an area will export and displace imports when competing on a domestic and international

[21] See, <http://rsqe.econ.lsa.umich.edu/>.

marketplace against other states and nations. For these simulations, we changed these variables to illustrate the direct effects of a carbon tax in Massachusetts:

- **Consumer prices** – For higher fuel oil, electricity, natural gas, gasoline, and motor oil prices due to the carbon tax, but also a lower general sales tax in the case of revenue recycling
- **Production costs** – To illustrate the higher cost of input fuels to industries, but to also show the positive shock of lower business and corporate income taxes in the state
- **Real disposable income** – This concept is the amount of money left over to households to spend after taxes, which goes up if the state lowers income tax rates

PI+ has two purposes: forecasting and policy analysis by the examination of alternative worlds. The model has an underlying forecast based on the government data, by county, and the macroeconomic trends described on p. 8 near the top. To use the model, we introduced "exogenous" changes to the variables in the structure in *Figure 1*. We call these "policy variables," and they represent the direct effect of a carbon tax on the Massachusetts economy. From there, the model automatically passes the changes through the rest of the structure until the model reaches a new equilibrium at some point in the future after adjusting over time. We used CTAM to develop the differences in emissions from the carbon tax and the amount of carbon tax revenue and recycling to introduce into PI+.

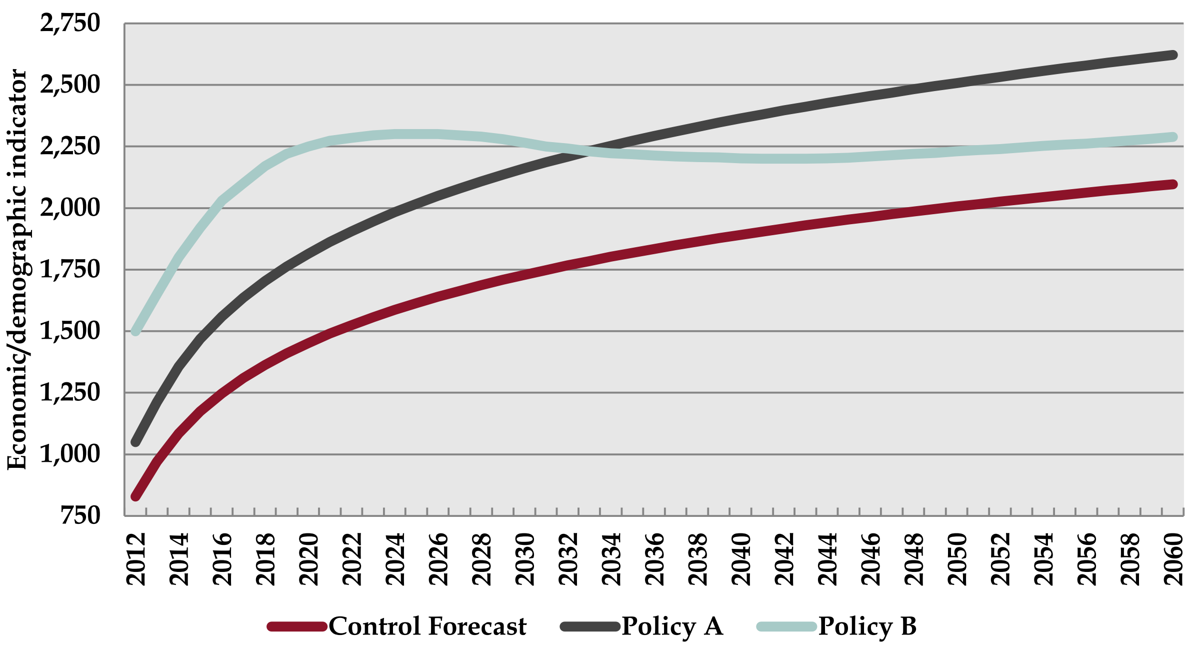

Figure 3.2 - This shows the basic methodology and comparisons inside of the REMI model. The blue line is the control, the "do-nothing" null hypothesis. From there, we looked at alternative policies, here represented by the generic Policy A and Policy B. Both A and B are better than the control, and B generates short-term gains while A is the better idea in the long run. CTAM works in terms of tax revenue and carbon emissions, while the REMI equilibrium model concentrates on economic and demographic outputs like GDP or population.

CARBON TAX ANALYSIS MODEL (CTAM)

We updated CTAM for Massachusetts data, which we describe here. Longer, fuller descriptions of this model are available in other places. A concise explanation is on pp. 22-23 of the aforementioned NERC study. In broad terms, CTAM uses projections from EIA about the anticipated consumption of different fuel types (such as gasoline, kerosene, coal, natural gas, or petroleum distillates) by Census regions. EIA generates these forecasts using the National Energy Modeling System (NEMS), their internal government model used to generate energy forecasts into the future.[22] CTAM then shares these fuel consumption quantities into the states underlying the Census regions. For Washington and Oregon, this was out of the Pacific region; for Massachusetts, this was out of New England. The fuel quantities become emissions by multiplying with the rates of emissions. For instance, one gallon of gasoline everywhere will generate approximately the same amount of carbon dioxide upon its combustion, which CTAM assumes. This exercise, taken together, gives CTAM's user the ability to see a base forecast of emissions in a state or region, where one can then begin to ask it scenarios of carbon taxes.

CTAM relies on a meta-analysis of price elasticities by fuel type to determine how sensitive the users of various fuels are to changes in their prices. By extension, these elasticities determine how effective a carbon tax is at discouraging economic actors from burning fossil fuels, and therefore reducing carbon emissions. NERC did not update the elasticities for the Oregon study—explicitly, per agreement with CGE, REMI did not update these numbers either. These default elasticities represent a "most likely" scenario of price and emissions sensitivities to a carbon tax. Alternative elasticities would generate a different result, though not one substantially different from the information presented in this study's results. CTAM allows its user to pick an initial rate of carbon tax for 2014, a maximum rate at some point in the future (such as $40 per carbon ton), and a rate of phasing. We adjusted these numbers to generate the high-level inputs destined for the macroeconomic simulations in PI+.

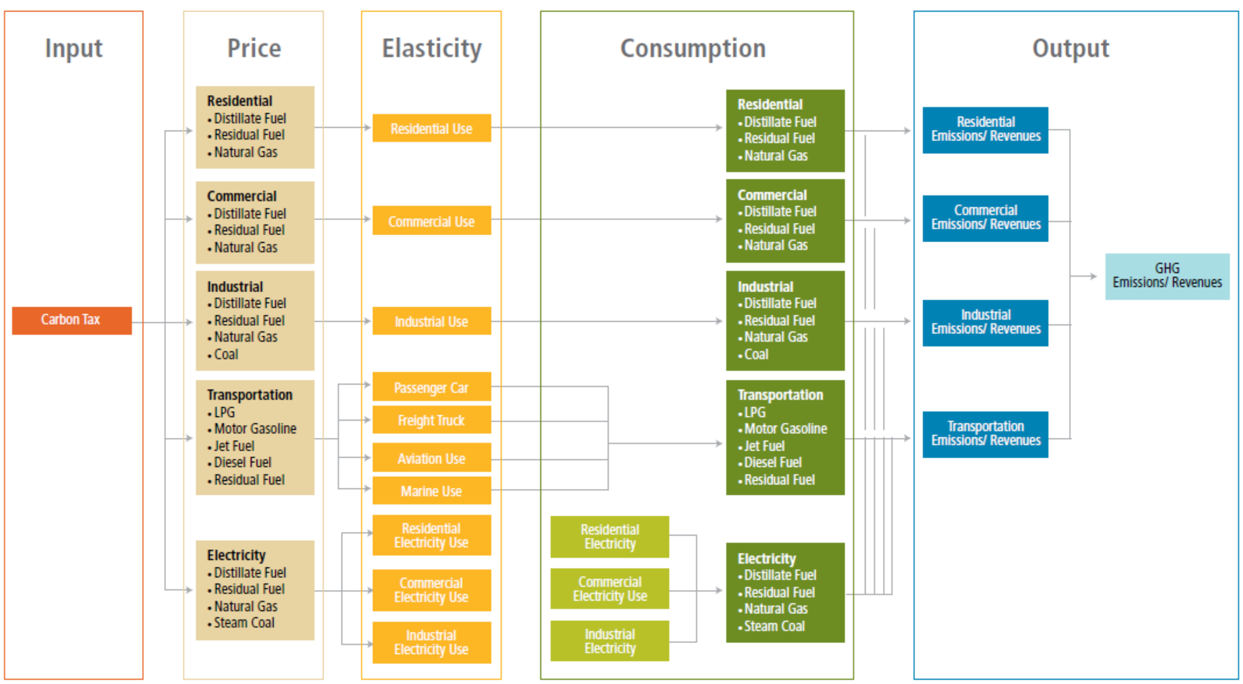

Figure 4.1 – This shows the main processes inside of CTAM, taken from p. 26 of the NERC study. A new tax changes the price of fuels, which therefore leads to a difference in consumption after a response described in the

[22] See the EIA page on NEMS, <http://www.eia.gov/oiaf/aeo/overview/>.

elasticities. From there, the model multiplies the emissions by fuel type, and generates an output of how much the economy emits (or saves in emissions) and generates in total revenue by area due to the new carbon tax.

We updated CTAM to be specific to Massachusetts for our runs. Where applicable, we substituted the Pacific region (Alaska, Hawaii, Washington, Oregon, and California) data with equivalent data for New England (from the most recent *Annual Energy Outlook* from the EIA for 2013).[23] Where necessary, we shared this down to Massachusetts-level out of the other states in New England. We updated the macroeconomic parameters in CTAM for consistency with PI+, which were specifically growths in the state's total number of households (0.9%) and GDP (3.0%). Climate policies often set the achievement of some level of emissions watermarked to 1990 as a key goal. This can include matching 1990 levels, trying to go below 85% of the same, or some other proportion. We updated the historical emissions in CTAM for Massachusetts from data out of the Environmental Protection Agency (EPA).[24]

[23] See, <http://www.eia.gov/forecasts/aeo/>.

[24] Go here, <http://www.epa.gov/statelocalclimate/documents/pdf/CO2FFC_2010.pdf>. Interestingly, Massachusetts is already well below 1990 levels of emissions owing to its small population growth, low growth in GDP (relative to the nation), the weak national economy from 2008 to present, and the switch from coal to natural gas as a fuel source for electrical power generation. The state has already achieved this important benchmark, but it could continue to improve from there. CTAM does not cover every type of emission in the EPA document. Consequently, we made an adjustment upwards at a level consistent with the difference between CTAM and EPA in 2010 emissions for every subsequent year. This means the level of emissions start at the same level, which dictates where the state is relative to 1990, and we can concentrate on the change in emissions in the actual analysis.

INTEGRATING PI+ AND CTAM

Next, we completed a bridge to bring the emissions and taxation simulations in CTAM into the economic simulations of the regional economic model. CTAM has four major sectors of the state economy—residential, commercial, industrial, and transportation. The majority of transportation GHG emissions comes from motor gasoline, which is a consumption item for households, given the model reported separate categories for motor gasoline purchased by commercial or industrial enterprises. CTAM has more data than REMI in terms of fuel types. REMI only has three available energy types, which are natural gas, electricity, and petroleum. CTAM breaks petroleum into further categories, including gasoline, diesel, distillates, lubricants, and a few others. We had to agglomerate this detail from CTAM up to general petroleum layer to make these categories consistent with each other. The following table shows the exact results in CTAM and the way we bridged them into PI+:

	CTAM	PI+
Residential	Kerosene, Distillate Fuel Oil	Consumer Price (Fuel oil and other fuels)
	Natural Gas	Consumer Price (Natural gas)
	Electricity	Consumer Price (Electricity)
Commercial	Liquefied Petroleum Gases, Motor Gasoline, Kerosene, Distillate Fuel Oil	Residual (Commercial Sectors) Fuel Costs
	Natural Gas	Natural Gas (Commercial Sectors) Fuel Costs
	Electricity	Electricity (Commercial Sectors) Fuel Costs
Industrial	Motor Gasoline, Distillate Fuel Oil	Residual (Industrial Sectors) Fuel Costs
	Natural Gas	Natural Gas (Industrial Sectors) Fuel Costs
	Electricity	Electricity (Industrial Sectors) Fuel Costs
Transport	Motor Gasoline	Consumer Price (Motor vehicle fuels, lubricants, and fluids)
	Distillate Fuel Oil	Consumer Price (Fuel oil and other fuels)

Figure 5.1 – This shows the revenue category in CTAM mapped into a price variable in PI+. We only included those of a degree to influence the economy. These changes in prices will generate the dynamic adjustments to the overall regional competitiveness for Massachusetts' industries, commercial operations, industries, and households.

With the revenue raised, we faced finding some way of allocating the surplus to keep the state constraint of a balanced budget. We sent the money to the NAICS industries that best proxy those for scientific research and development and infrastructure development, which involve a good deal of professional services and construction, when the first $100 million of carbon tax revenue went specifically to these sorts of programs.[25] We reduced production costs to show the impact of a reduction in corporate taxes, spread by the amount each industry pays, which we spread based on output. Lower sales taxes meant a general reduction in the prices for consumer categories eligible for the sales tax. Lower income taxes meant more disposable income for households to spend.

[25] The model for this simulation contained 70-sectors, which appropriates 3-digit NAICS. REMI only goes so deep in the NAICS to ensure the quality of the data in the model. The U.S. Census withholds the deepest industry detail for reasons of individual and business privacy. For a listing of our sectors, see, <http://www.remi.com/download/documentation/pi+/pi+_version_1.4/NAICS_Industries_for_PI+-Hierarchical_v1.4.pdf>

HYPOTHETICAL TAX CASES

After implementing the carbon tax to reduce state emissions, the choice about how to return the revenue to the state economy is an important one. It is a complex balance between maintaining competitiveness by lowering costs for business, maintaining high returns to work and investment by lowering income taxes, and protecting low-income households with a reduced amount of regressive taxes, such as the sales tax. This section provides a description of the relative advantages of the three versus each other in terms of GDP, total employment, and real income as well as the reasons for their patterns as they echo in the economy. We ran hypothetical tax cuts of $100 million in the three categories. We then made comparisons between them about their performance in the tables below. One should note these are not a general lesson about the efficiency of certain taxes against each other—far from it. These are small changes, on the margin, and not typical or universal cases of designing a tax code for a state economy. The results would look very different with a different sense of scale or emphasis.

GROSS DOMESTIC PRODUCT IMPACT

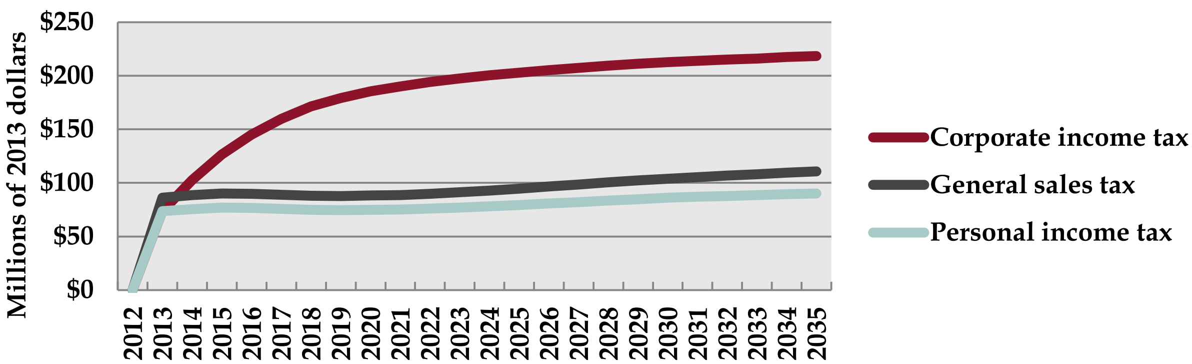

Figure 6.1 – GDP growth comes from competitiveness in the REMI model as a representation of the way a real economy works. Lower costs and higher productivity drive market shares; this expands business activity and economic growth. Here, lower corporate income taxes enable firms in Massachusetts to export more and displace imports, which means more GDP in the state. The sales and income tax generate more demand and consumer spending, but not a change to long-run competitiveness, which means they do not drive GDP quite as much.

TOTAL EMPLOYMENT IMPACT

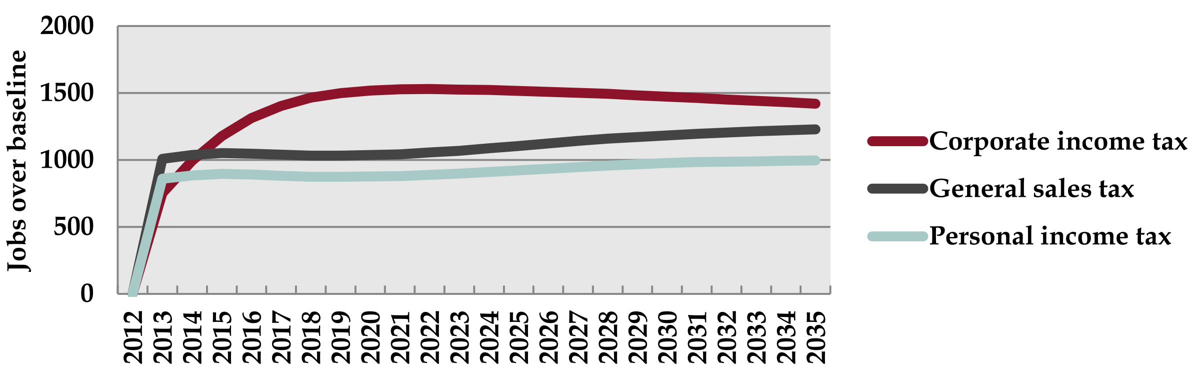

Figure 6.2 – There is a similar pattern to the GDP one, but with less of a deviation than the corporate income tax. Consumer spending goes towards labor-intensive industries, which can mean more jobs in the short-term than other initiatives that might increase the state's long-term competitiveness through lowering costs and more productivity.

HOUSEHOLD INCOME IMPACT

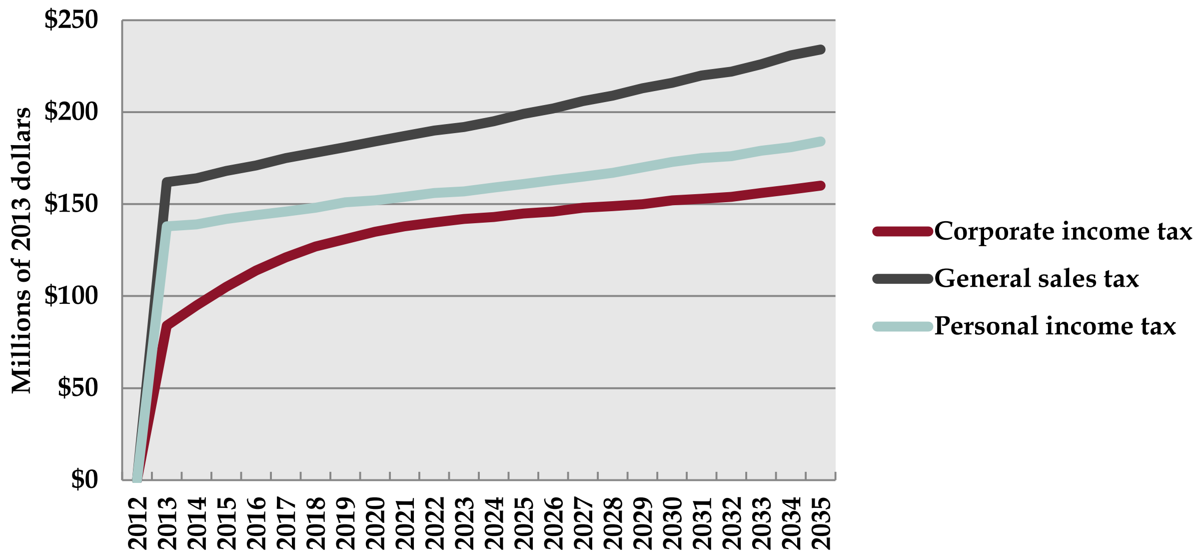

Figure 6.3 – Lowering sales or income taxes, however, gives the biggest boost to household incomes. Intuitively, this should make sense – this means more money left in paychecks and lower prices at retail. Some of the money might leave the state, given most states' need to import many consumer staples, but this still increases the disposable income of households to a greater degree than waiting for competitiveness to stoke the labor market.

When using small examples on the margin, lower business costs do the most to further the state's health in terms of its GDP. However, lower personal taxes do somewhat more in terms of increasing the real incomes of households. Both approaches have their strengths and weaknesses:

Category	*Strengths*	*Weaknesses*
Corporate income tax	Improves state competitiveness, grows the economy, generates more tax revenue for the statehouse in Boston to work with	Does not necessarily pass all of this benefit along to households to the same degree as the other tax categories
General sales tax	Reduces the cost of living for households, which makes them richer in real terms and helps low-income families the most	Additional consumer spending means more net imports to the state and does not improve competitiveness
Personal income tax	Attracts economic migrants looking for a high return to work in terms of wages, can increase the state's overall level of productivity	"Between" the other two in strengths, and it does not help low-income households as much as sales taxes

Figure 6.4 – This chart shows the relative strengths and weaknesses of these three approaches. No one answer is right – it is a matter of the state's priorities and balancing the costs of the carbon tax with the benefits here of reducing other major sorts of taxes. There is not necessarily one answer between the three for the state.

There are good things and bad things about each way. The choice for Massachusetts is balancing the multifaceted priorities of growing the state economy, keeping the returns to work high, and protecting low-income households from potential downsides or regressive taxes. The 50-50 revenue recycling option in this report manages to maintain a positive impact to GDP, employment, and a minimal impact on the cost of living. Alternative approaches might create different results, but this gives some guidelines for the ups and the downs of making these small changes on the margin in the state.


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Scott Nystrom is a Senior Economic Associate in REMI's DC office. He holds a B.A. in history, B.S. in economics, and M.A. in economic history, all *summa cum laude*, from Iowa State University in Ames, IA. He heads REMI's software training and technical consulting services for the District of Columbia and the surrounding area. Some of Mr. Nystrom's previous analyses include the economic impact of federal fiscal policies, such as the "fiscal cliff" or federal sequestration, energy projects like the Keystone XL pipeline and LNG exports, tax incentives in Arkansas and Missouri, and the $500 billion regional transportation plan for the Southern California Association of Governments (SCAG). Other projects include analyzing state renewable portfolios and Medicaid expansion in North Carolina.

Ali Zaidi is an Assistant Economist and the research associate in REMI's DC office. He holds a B.A. in economics from the University of Massachusetts-Amherst, and he is currently finishing his B.S. in computer science from the same institution. He worked on calibrating the CTAM model used here for the state of Massachusetts and assisting Mr. Nystrom in running and validating its results, the simulations in PI^{+}, and assuring the quality of this report and its results.

WORD CLOUD

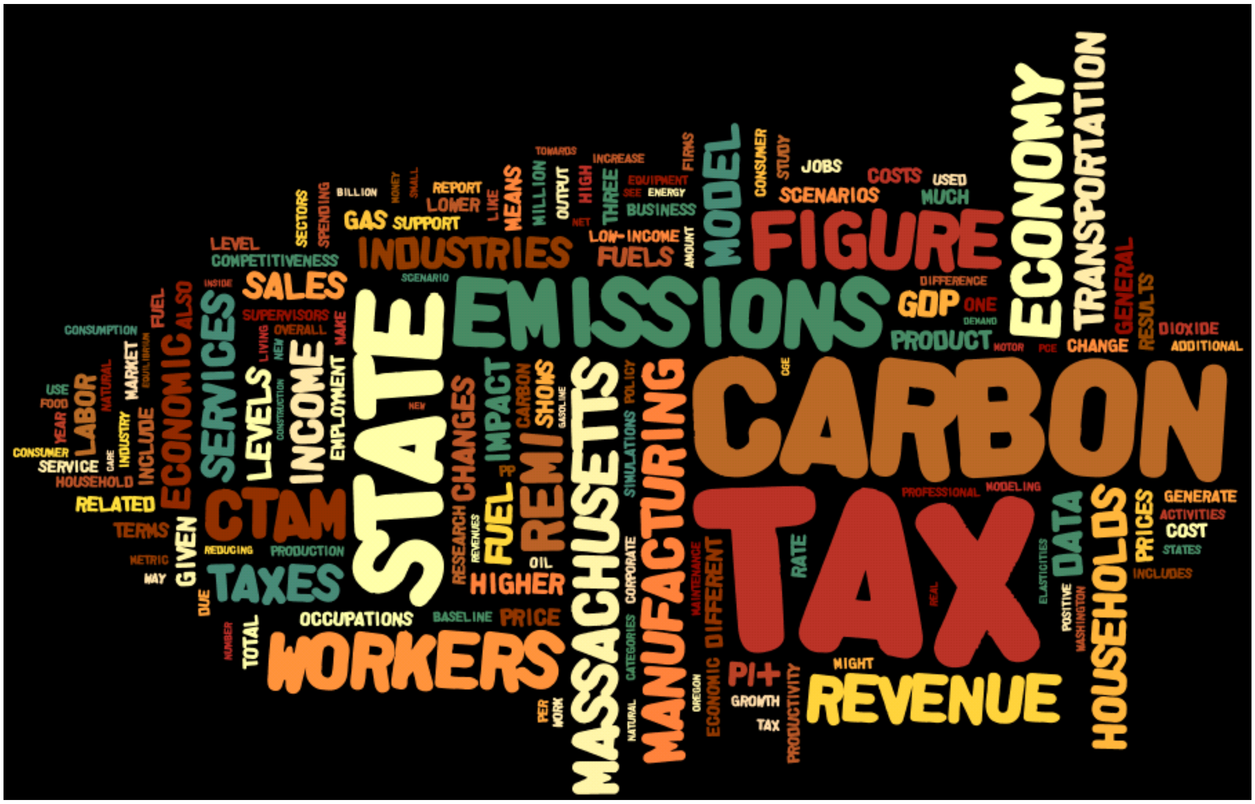
CARBON
TAX
STATE
EMISSIONS
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FIGURE
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TRANSPORTATION
REVENUE
WORKERS
MANUFACTURING
HOUSEHOLDS
CTAM
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