The Full Costs of S.139, With and Without its Phase II Requirements

PREPARED FOR

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1. Synopsis

Earlier this year, Senators John McCain and Joseph Lieberman introduced the Climate Stewardship Act of 2003 (S.139) to establish mandatory greenhouse gas (GHG) reductions in the United States. As originally introduced, S.139 would cap GHGs in two phases. Phase I would return aggregate national GHG emissions to their 2000 levels by 2010. Phase II would, starting in 2016, tighten the cap to the emissions levels of 1990. Analyses of the economic impacts of S.139 released by the Massachusetts Institute of Technology (MIT)[1] and by the Energy Information Administration (EIA)[2] estimated per household costs in the range of $100 to $500 per year during the period 2010 through 2020. Partly in response to a perception that these costs would be too high, Senator McCain announced on October 1, 2003 that he would introduce an amendment to S.139 that would eliminate the requirements of Phase II. Only MIT has estimated the cost of S.139 with such an amendment. They find that costs could be as low as $20 per household per year through 2020.

Charles River Associates (CRA) has performed an analysis of the costs of S.139, including a detailed analysis of an amended version that contains only the Phase I restrictions. This analysis uses CRA's MRN and MS-MRT models, which were explicitly designed to explore the impacts of national and international GHG policies. These models capture the full spectrum of economic interactions that can be set in motion by a major policy such as S.139, including several critical interactions that are lacking in other models that have been used to assess the costs of S.139. A range of estimates was prepared with a variety of assumptions for key inputs that were found to affect the size of the cost and impact estimates for both versions of S.139.

- For the original S.139 (i.e., with Phase II), the low-end of CRA's range of estimates indicates marginal control costs of $74 per metric tonne of carbon-equivalent in 2010, rising to $120 per tonne by 2020 (stated in 1999 dollars). These carbon costs imply an 18% to 24% increase in electricity prices and a 32% to 45% increase in refined petroleum product prices such as gasoline. This is very similar to findings of other analysts. Costs per household, which include all the effects of the original S.139 throughout the economy

[1] S. Paltsev, J. M. Reilly, et al. *Emissions Trading to Reduce Greenhouse Gas Emissions in the United States: The McCain-Lieberman Proposal*, Report No. 97, MIT Joint Program on the Science and Policy of Global Change, Cambridge, MA, June 2003.

[2] Energy Information Administration, *Analysis of S.139, the Climate Stewardship Act of 2003*, SR/OIAF/2003-02, Washington, D.C., June 2003.

on economic well-being, are about $760 in 2010, rising to $1,200 by 2020. These cost estimates are substantially higher than other analysts have projected.[3]

- If only Phase I were implemented, CRA's low-end estimates of marginal costs of carbon control are $27 per tonne in 2010, rising to $44 per tonne by 2020. Electricity prices would rise by 7% to 10% and refined petroleum product prices would rise by 12% to 16% as a result. The associated consumer costs are estimated to be $350 per household in 2010, rising to $530 per household by 2020. Again, our control costs on a per-ton basis are similar to other estimates, yet the costs per household are much higher.

How can the overall economic impact on consumers be so much higher than estimated by other models when the underlying technological control costs appear to be so similar? Through extensive sensitivity analyses, we have determined that most of the difference can be attributed to four features of CRA's models that the other models currently lack:

- Current investment decisions are made in light of expectations about all future market conditions and investment opportunities, so that future carbon limits have current costs.
- Individuals adjust their consumption and savings choices over time, taking into account expected changes in future economic conditions attributable to S.139.
- Individuals change their supply of labor and therefore their income, by changing their allocation of time between work and leisure in response to changes in real wages in the present and future.
- Government changes tax rates to balance its budget, taking account of the direct and indirect effect of policies on overall tax revenues, so that the distorting effects of current tax policies are changed by S.139.

The above features are considered advancements in economic modeling methods. Their presence in CRA's model set means that it captures a broader array of the interactions that add up to the full costs and impacts of a policy change.

One implication of these advanced features is that expectations of long-term policy and market directions affect consumer costs in the near-term quite substantially. Since climate change requires policy intervention for the next century and more, it is unrealistic to assume that a policy

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[3] Costs per household are measured in this study as the reduction in household consumption, in order to maintain comparability with the MIT and EIA studies that use loss in consumption and personal disposable income, respectively when they measure costs per household.

adopted in 2003 would terminate in 2020. Therefore the continuation of climate policy beyond 2020 must be addressed and included in the analysis. For this reason, we estimated costs for a wide range of assumptions about the level of the carbon cap after 2020, and the costs of available carbon controls after 2020. The low-end cost estimates cited in this synopsis reflect our most optimistic views on the direction of the carbon cap after 2020, and how control costs may be reduced through technological change. We found that per household costs can only be reduced to the range found by other researchers by imposing unrealistic expectations about the post-2020 policy outcomes, and also removing tax interaction effects that are tied to specific provisions in the Bill.

In summary, a Phase-I only version of S.139 is less costly than the original version of the Bill, but its economic impact on consumers remains substantial even in 2010 through 2020 when one accounts for a more comprehensive set of the interactions in the economy than other models are able to reflect.

2. Overview Of S.139 Provisions

The Climate Stewardship Act of 2003 (S.139) aims to accelerate the reduction of U.S. greenhouse gas emissions. To do this, the Act if implemented would establish a market-based cap and trade system in emission allowances. Because it would regulate GHG emissions at the point where they are released, the Act regulates only entities whose direct emissions are above a minimum threshold and provides for an exclusion of emission sources that are deemed too costly to control. Overall, the Act controls somewhere between 75% and 80% of all U.S. GHG emissions.[4]

Below, we summarize the bill's definition of the gases that are to be controlled, the emitters to be controlled, and the workings of the emission allowance trading system that would be put in place to control emissions.

The Act controls all GHG emissions from "covered entities." The Act includes the same GHGs that are included in the Kyoto Protocol: carbon dioxide (CO_2), methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride. The bill regulates the total carbon equivalent emissions where the carbon equivalent emissions of non-carbon GHGs is based on the IPCC's recommended global warming potential indices (GWPs) to convert emissions of different gases into carbon dioxide equivalents.

The Act defines a covered entity as any entity that:

> (A) owns or controls a source of greenhouse gas emissions in the electric power, industrial, or commercial sectors of the United States economy, refines or imports petroleum products for use in transportation, or produces or imports hydrofluorocarbons, perfluorocarbons, or sulfur hexafluoride; and
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> (B) emits over 10,000 metric tons of greenhouse gas per year, measured in units of carbon dioxide equivalence, or produces or imports--
>
> > (i) petroleum products that, when combusted, will emit,
> >
> > (ii) hydrofluorocarbons, perfluorocarbons, or sulfur hexafluoride that, when used, will emit, or
> >
> > (iii) other greenhouse gases that, when used, will emit,

[4] S. Paltsev, J. M. Reilly, et al. *Emissions Trading to Reduce Greenhouse Gas Emissions in the United States: The McCain-Lieberman Proposal*, Report No. 97, MIT Joint Program on the Science and Policy of Global Change, Cambridge, MA, June 2003. And Energy Information Administration, *Analysis of S.139, the Climate Stewardship Act of 2003*, SR/OIAF/2003-02, Washington, D.C., June 2003.

over 10,000 metric tons of greenhouse gas per year, measured in units of carbon dioxide equivalence.[5]

The Act specifically excludes all direct emissions from the residential and agriculture sectors and entities with annual emissions below the 10,000 metric tons carbon dioxide equivalent (based on GWP) threshold. This exclusion leads to only a small amount of emissions escaping coverage because the bill captures the majority of both direct and indirect emissions from individuals by covering emissions from electric utilities and the indirect emissions from the petroleum refiners' product that they sell specifically gasoline used in the transportation sector.

It is unclear what percentage of the emissions from the commercial sector would be covered, because data do not exist to determine which commercial entities exceed the threshold level. Therefore, we opted to follow the EIA's reference S.139 case and exempt all emissions from the commercial sector.

S.139 controls greenhouse gas emissions by requiring any covered entity to possess emission permits for all of their emissions for which they are responsible under the Act. That is, electricity generators must submit allowances for all their direct emissions from the generation of electricity; whereas petroleum refiners must submit emissions for both their direct emissions from the production of refined petroleum products as well as any emissions associated with the burning of their products in the transportation sector.

As originally introduced, S.139 would cap GHGs in two phases. Phase I commences in 2010 and sets a cap on emissions from covered entities based on their 2000 level emissions. The amount of tradable allowances made available will equal 5896 million metric tons of CO_2 equivalent less year 2000 emissions of greenhouse gases from non-covered entities. This cap stays in place until the end of 2015. Phase II begins in 2016 and the cap is tightened to be a function of 1990 level emissions. The amount of tradable allowances made available will equal 5123 million metric tons of CO_2 equivalent less year 1990 emissions of greenhouse gases from non-covered entities. There are no other provisions in S.139 for altering the targets after 2016. Therefore, in our analysis of the original bill, we assume that the Phase II targets remain in place forever.

The amended bill, however, removes the Phase II cap and instead leaves the Phase I cap in place. Since climate change requires policy intervention for the next century and more, it is unrealistic to assume that a policy adopted in 2003 would terminate in 2020. Therefore the continuation of climate policy beyond Phase I must be addressed and included in the analysis. In our analysis of the amended bill, we assume that the emission cap remains at the Phase I level indefinitely.

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[5] Senate Bill 139 Introduced to the Committee on Environment and Public Works on January 9, 2003.

According to EIA,

> "The EPA is charged with establishing the regulations to create the tradable allowances, and S.139 defines many of the provisions governing the allowances. The bill provides entities with options for banking and borrowing allowances; for limited use of registered reductions from noncovered entities in lieu of allowances; and for obtaining allowance allocation credits to reward past emissions reductions and early action reductions. S.139 establishes a nonprofit Climate Change Credit Corporation (hereafter referred to as the Corporation) to facilitate the market in emission allowances, to buy and sell allowances, and to distribute proceeds from sales in order to reduce the economic impacts of the program. The bill gives responsibility to the Secretary of Commerce for defining the allocation of allowances to the covered sectors and to the Corporation, subject to the final approval of Congress."[6]

There are two important consequences of this method of permit allocation. First, all revenues from auctions are returned to the economy. There are distributional issues among the holders of permits (entities that receive permits for free and those that must purchase permits through an auction) as well as between the recipients of the revenues from the auctioned permits. However, from the standpoint of overall cost, it does not matter how the auction revenues are divided among the recipients, as long as all revenues are distributed. Second, the government has no access to any revenues from permit auctions and therefore cannot use these revenues to reduce pre-existing taxes.

In addition to the permits allocated by the EPA, a covered entity may satisfy a portion of its total allowance submission through credits for "alternative means of compliance" acquired from non-covered sources. These could include permits from another nation's system for trading in greenhouse gas emissions, sequestration activities, and emission reductions from non-covered entities.[7] For Phase I of the original Bill, the portion can be as large as 15%. In Phase II, the portion cannot exceed 10%. In modeling the amended bill, we assume that the maximum amount of permits that can be acquired from non-covered sources is 15% in all years so as to be consistent with the fact that the amended bill only applies Phase I emission caps.

The cost and availability of these permits are highly uncertain. Therefore, in modeling the bill, we consider two cases to bound the range of possibilities regarding these outside permits. In the first case, we assume that the covered entities can acquire the maximum percentage allowed at no cost. In the model, this is simply handled by raising the emissions cap of the covered sectors by this percentage, thus giving them slack equal to the amount of permits they could obtain at no cost. For

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[6] Energy Information Agency, "Analysis of the Climate Stewardship Act," June 2003 (SR/OIAF/2003-02).

[7] Permits could also be obtained through borrowing from the Administrator, but we believe that the rules on borrowing are likely to be too costly and therefore it is unlikely that any entity will take advantage of this provision.

the second case, we assume that these permits would be too costly to acquire and therefore, the covered sectors do not make use of this provision of the Bill.

The bill provides for a great deal of flexibility in the cap and trade program. Entities can freely trade emission allowances among each other. In addition, they can bank allowances for future use. We capture these provisions in our modeling of the bill.

The bill also sets forth other provisions for generating credits. Entities can receive additional credits for taking actions before 2010 to reduce their emissions. Automobile manufacturers can generate credits that they can sell to the greenhouse gas registry if they exceed fleet fuel economy standards by more than 20 percent. Believing that neither provision will be utilized to any significant extent, we did not consider them in our analysis.

3. Description Of MRN Model

For the analysis in this paper, we use our Multi-Region National model.[8] We have employed it in numerous studies to measure the economic costs of the climate change policies. MRN is a computable general equilibrium (CGE) model of region-specific impacts and regional interaction in the U.S. economy. The model solves for income, production levels, relative prices, trade, and consumption by accounting for behavioral as well as technological responses to changes in policy. The equilibrium is fully dynamic, meaning that investment decisions determine the future capital stock, which in turn determines future income and consumption. Furthermore, decisions to consume or invest are taken with correct expectations about future policy and opportunities. Investment today requires foregoing consumption of current output (current GDP). Consumer decisions maximize utility, which implies that an optimal trade-off is made between consumption today and consumption in the future.

Data that characterize the interrelationships of commodities within the economy are of primary importance in quantifying the impacts from alternative carbon abatement implementation. Many of the impacts of reducing carbon emissions indirectly increase the cost of production and consumption. For example, a regulation on the quantity of allowable emissions from electric utilities will result in higher electricity prices. Furthermore, higher electricity prices will raise production costs, especially in sectors that use electricity-intensive processes. As a starting point for characterizing the inputs and outputs in the economy we utilize a Social Accounting Matrix (SAM) developed for each state by the Minnesota IMPLAN Group, Inc. (MIG). The IMPLAN database represents the activities in 530 sectors for all 50 states and the District. Adjustments to the original data were necessary to bring them in line with the EIA's state level energy data, which are more accurate than the corresponding IMPLAN data. The SAM that results from the combination of IMPLAN and EIA data fully tracks the intensities of commodity use for the modeled production and consumption sectors for any regional aggregation of states. In addition, the SAM completes the circular flow with an account of factor incomes, household savings, trade, and institutional transfers.

Conceptually, the SAM is taken to represent a snapshot of the economy along a dynamic growth path. Calibration of the dynamic equilibrium is completed by incorporating growth forecasts for industries, population, and carbon emissions. Currently, the forecasts used in MRN are those made in the Energy Information Administration's 2001 Annual Energy Outlook. For calibration, projections of energy use in industry and transportation are used as constraints on the multi-sector growth model to reveal the factor productivity shifts necessary to meet the projected equilibrium. This new equilibrium, with these productivity shifts, is used as the baseline for policy analysis.

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[8] We use our international CGE model (Multi-Sector Multi-Region Trade model) to provide international prices to MRN, but all reported economic impacts come from MRN.

MRN can be adapted to examine the details of policy impacts on a number of different sectors of the economy. Aggregation of regions and sectors is completely flexible. Since S.139 is a uniform nationwide program, we aggregate all the regions of our modified IMPLAN SAM into one U.S. region for this analysis.

All the important energy sectors in contained in the detailed SAM are represented in MRN since carbon emissions are highly correlated with energy use. We then aggregate the remaining non-energy sectors into five categories to capture the diversity in energy intensity across sectors. We break out motor vehicles separately so that we can correctly account for individuals' responses to higher fuel costs caused by carbon abatement policies. Therefore, the model is run with the following ten sectors:

Table 3.1 MRN model's sectors for analyzing S.139

Energy Sectors	Non-Energy Sectors
Coal extraction	Agriculture
Gas distribution	Energy intensive sectors
Oil and gas extraction	Manufacturing
Oil refining/distribution	Motor vehicles
Electricity generation	Services

MRN explicitly models just the U.S.; therefore, it needs a source for international prices that must be consistent with the chosen MRN scenario. To incorporate external market impacts, we have built a hierarchical structure of models in which relevant international information is passed down from a more complete geographic model to MRN, which is the more detailed regional model. Therefore we decompose the problem into separate models that are consistently linked such that external impacts are incorporated into MRN. This approach avoids the complexity added by modeling the rest of the world.[9]

Our international trade model, Multi-Sector Multi-Region Trade (MS-MRT) model, examines the impacts of international carbon emissions agreements under alternative international abatement policies on world regions and industries. For this analysis, we used a version of MS-MRT that incorporates nine regional trade blocks and nine of the ten commodities in MRN.[10] MS-MRT fully tracks the physical flows of energy and their embodied carbon. Because the United States is one of

[9] For this analysis it is not the regional or sectoral detail that necessitates this decomposition, but rather the special MRN features involved in modeling taxes and personal travel.

[10] For a full description of MS-MRT, see P.M. Bernstein, W.D. Montgomery, T.F. Rutherford (1999) "Effects of Restrictions on International Permit Trading: The MS-MRT Model," *The Energy Journal*, Kyoto Special Issue, pp. 221-256.

the trade blocks, MS-MRT predicts changes in the prices of U.S. imports and exports. Given this information, an open-economy model of the U.S. alone can be run independently of the other regions.

In other words, MRN produces results for the nation as a whole; but because we incorporate the terms of trade impacts from MS-MRT for the same policy, these results are consistent with the international trade implications of international commitments to reduce emissions. MRN takes all international prices for goods and services as exogenous. Utilizing MS-MRT insures that the domestic responses simulated within MRN are consistent with a broader global economic equilibrium.

The user is free to define the model horizon and time steps in the MRN model. To correctly account for the long-term impacts, specifically consumption and investment decisions, of GHG abatement policies, we extend MRN's model horizon out to 2070. With this long horizon, the minimum time steps while maintaining computational feasibility are 5 years. Therefore, in modeling the original Bill, we assume that Phase II commences in 2015 rather than 2016.

Policy Instruments

Currently, MRN only tracks carbon emissions and therefore does not capture the other GHGs. To incorporate carbon emissions in the model, a constructed emissions permit is tracked for each of the three fuel inputs (OIL, GAS, and COL). In the baseline equilibrium these permits are not scarce (their price is zero), and the quantity of permits demanded equals the projected baseline emissions. The carbon permit is required at the fuel's point of purchase according to the carbon content of the purchase. Limiting the number of permits available imposes an emissions constraint, and the permit price reflects the marginal cost of abatement. This method of incorporating emissions, via permits, is convenient in terms of providing a number of policy instruments that involve emissions trading or specific wedges between abatement costs across geographic regions or sectors.

Technical Description of MRN Dynamic General Equilibrium Model

The theoretical concept underlying MRN is that of an Arrow–Debreu equilibrium, in which macro-level outcomes are driven by the self-interested decisions of consumers and producers. Consumers are represented by a single agent (the household sector) that maximizes utility subject to endowments of primary factors and available production technologies that transform factors and intermediates into commodities. All production sectors are assumed to be competitive, exhibiting constant returns to scale. An evolving capital stock is supported by an optimal amount of foregone consumption of current output. The resulting equilibrium is characterized by income and production levels, and a set of relative present-value prices.

Household utility is defined by a Constant Elasticity of Substitution (CES) infinite sum of discounted transitory utility. Utility in a given time period is the CES composite of consumption and leisure. The budget constraint equates the present value of consumption to the present value of income earned in the labor market and the value of the initial capital stock minus the value of post-terminal capital.[11] The representative agent optimally distributes wealth over the horizon by choosing how much output in a given period to consume and how much to forego for investment.

Two primary factors are supplied by the household sector for production: labor, which grows exogenously, and capital. The capital stock depreciates geometrically but can be augmented in each period through an investment activity. We model adjustment costs in the capital stock through a partial putty-clay production structure and equilibrium unemployment. In addition to labor and capital, the model is extended to include primary resource factors specific to the extraction of crude oil and natural gas, and extraction of coal.

Production sectors are assumed to be competitive, exhibiting constant returns to scale (except the natural resource extracting sectors). A nested CES structure is employed for production in the non-resource extraction sectors that utilize new capital. The CES process combines material (intermediate) inputs of non-energy commodities with capital, labor, and energy to produce final goods for consumption and intermediate goods for other sectors. The production nesting is intended to accommodate fuel substitution that might result from carbon abatement.

REPRESENTATION OF INTERNATIONAL TRADE

The model described above was further extended to an open economy with interstate and international trade. We employ an intertemporal balance-of-payments constraint that dictates no change in net indebtedness over the horizon. Capital markets are otherwise unrestricted. Trade is specified such that all goods (except for crude oil) are differentiated by their origin; this is the popular Armington formulation.[12] We assume that crude oil is a homogeneous world good (i.e., the Armington elasticity is infinite). An Armington aggregate good, which is either consumed or used as an intermediate in production, is the CES composite of imports of the good and goods produced within the U.S. Similarly, a constant elasticity of transformation is defined between output destined for home consumption and output for international markets.

[11] Consistent with a formulation of equilibrium unemployment, the wage is net of the premium paid to workers matched to a job. This is the correct rate at which to measure the labor-leisure tradeoff (w_t equals the marginal benefit of leisure). L_t represents the total effective labor units devoted to the labor market – gross of unemployment.

[12] Armington, P.S. (1969) "A Theory of Demand for Products Distinguished by Place of Production," IMF Staff Papers 16, pp. 159-176.

MRN's Personal Automobile Use Component

Analogous to the capital stock that supports production, a motor vehicle earns rents for its owner as it is combined with gasoline and other support commodities to produce vehicle miles travelled. We treat automobile purchases as an investment activity that augments a stock of automobiles. This is a unique view of the social accounting matrix (SAM) and requires a unique set of adjustments, for although the SAM fully tracks the purchases of automobiles and gasoline, it does not capture the joint product that they produce – personal transportation via automobile usage. Similar to the calibration of the social accounts to a dynamic equilibrium, assumptions about rates of return and depreciation, the level of investment, and a given benchmark equilibrium trajectory imply a value of capital stock. This formulation allows us to capture consumers' trade-offs between buying more fuel efficient vehicles and driving fewer miles to reduce emissions.

Tax Instruments

The model takes into account the wedges between prices received by factor owners and marginal products of those factors, and the marginal costs of production and market prices, caused by the inclusion of taxes. The taxes represented in the model include: FICA (or labor taxes), corporate income tax, property taxes, indirect business taxes (or output and sales taxes), and personal income taxes.

Including these taxes and the interaction of these taxes with the government budget and the carbon policy is crucial to correctly estimating the impact of legislation such as the Climate Stewardship Act of 2003. This policy establishes a cap and trade system for controlling GHG emissions. Under this system, regulators have many options for how to allocate permits and their associated revenues, if any. How the permits are allocated affects the government's budget.

From the government's point of view, S.139 essentially calls for the free allocation of all the permits. Because the Act will lead to some reduction in economic activity, government revenues will decline. To maintain the government budget at the same level, regulators must raise taxes. This leads to additional losses in the economy.[13]

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[13] Literally, this Act establishes a non-profit corporation (the Climate Change Credit Corporation) to distribute the permits either through auction or free allocation. The Climate Change Credit Corporation must return all revenues back to the economy. Since the government sees none of these revenues it is simply a redistribution of wealth within the economy.

4. Alternative Cases Analyzed To Reflect S.139

The intertemporal dynamics of MRN imply that its estimates of near-term costs can be sensitive to longer-term expectations associated with a scenario. For this reason, we decided that our analysis of economic impacts of S.139 (original and amended) should be conducted for a variety of cases that reflect different possible sets of expectations about future economic and policy developments after 2020. Initial sensitivity analyses using MRN indicated that the estimated cost of S.139 would depend critically on the following factors:

- The supply curve for the 15% (later 10%) of offsets or credits that could be purchased from outside of the capped system under the provisions of Section 312 of S.139.
- Further changes in emissions caps beyond those explicitly defined by S.139.
- Potential technological innovations that would reduce the costs of achieving large carbon reductions, specifically reflected in the cost of a "backstop technology."

Note that these critical assumptions include uncertainties about the impact of provisions in the Bill itself, as well as uncertainties about issues that the Bill does not directly address. Because of the great uncertainty of all three factors, we decided to consider a range of possible outcomes for each, and to consider all these uncertainties in their various combinations. This generated eight cases that we assessed for the amended S.139. (In our less detailed analysis of the original S.139 provisions, we only assessed four cases, as will be described below.)

Uncertainty about the Supply Curve of Credits for "Alternative Means of Compliance" Under Section 312

S.139 states that a covered entity may satisfy a percentage of its total allowance submission through the use of outside credits for "alternative means of compliance." Some possible sources of these credits are certified international permits, a net increase in sequestration, or submitting a greenhouse gas emissions reduction from a source that is not a covered entity. In the original Bill, the maximum percentage is 15% from 2010 to 2015 and 10% from 2016 onward. Presumably under the amended S.139, the 15% maximum would remain in effect as long as the Phase I cap remains in effect.

The availability of these credits at costs per tonne lower than within-cap emissions reduction options is extremely uncertain. Many believe that offsets from other greenhouse gases will be very cost-effective, but the actual supply curve will not be possible to determine until regulators more precisely define the types of credits that would be acceptable under Section 3.12 for compliance. Additionally, even if the full 15%/10% allotment is used, these credits will not be entirely free.

Rather, they will come at a cost that is less than the cost of the last 15%/10% of within-cap reductions, and this amount is unknown. Further, the economic impact of such credits to the U.S. economy will be quite different if these credits come from uncapped U.S. industry, domestic sequestration activities, or are imported from programs or projects outside of the U.S.

The uncertainties in modeling the impact of this provision are thus very large. Rather than attempt to prepare a set of alternative supply curves, none of which would provide a particularly compelling statement of what is likely to occur, we bound this uncertainty at the widest extremes. At the optimistic end, we simply assume that all of the 15%/10% allotment can be obtained literally for free (at $0/tonne). This is equivalent to simply increasing the S.139 cap by 15% for Phase I, and by 10% for Phase II (in the case of the original Bill). At the pessimistic end, we assume that the supply curve is so steep that the entire cap is more cost-effectively met by within-cap reductions. Neither case can be viewed as a "likely" outcome, but the true outcome will certainly be somewhere inside this range.

UNCERTAINTY ABOUT THE EVOLUTION OF EMISSIONS CAPS BEYOND THOSE EXPLICIT IN S.139

The original and amended Bills are precise about near-term emissions caps, but it is extremely unlikely that these would not be adjusted in future years, should S.139 pass. The pressure to pass such legislation is motivated by a concern that much larger carbon reductions will eventually be needed in order to stabilize global temperatures. S.139 is viewed as no more than a first step toward those reductions. Since expectations about the long-term matter in estimating current costs, we therefore need to make explicit alternative assumptions about what will happen to the cap after the first cap level (which is all that the amended S.139 would define) is implemented in 2010.

The expected amendment to limit S.139 to Phase I may be written so that S.139 would institute a cap that would be in effect only until 2016, as this is how Phase I is specified in the original S.139.[14] Alternatively, the amendment may not simply eliminate the Phase II provisions, but may also rephrase the original Phase I provisions to give the Phase I cap an indeterminate duration, by altering its language to reflect the timing that is assigned to Phase II in the original Bill.[15] However, even if the amended S.139 were to actually assign an end date for the Phase I cap without stating what cap would replace it in 2016, we consider it unrealistic to assess the costs of that Bill as if the carbon cap would disappear only six years after its imposition. Rather, we decided that a realistic low-end assumption for the amended S.139 would leave the cap of Phase I unchanged for the indefinite

[14] S.139, Section 331(a)(1).
[15] S.139, Section 331(a)(2), which states that Phase II will apply "for calendar years beginning after 2015" without mention of any sunset date.

future. This is almost certainly an optimistic assumption, as we believe most people would expect the initial cap to be made more stringent at some point in the future. However, we decided to retain it because other modelers also assume this, making it useful for comparisons.

An alternative expectation for the high-cost end of the spectrum would be that Phase II will ultimately pass as a result of later legislation, and come into effect by 2016, just as originally proposed in S.139. We decided not to use this for the high-end of our range, however. One reason for this decision was that the prices of carbon and associated economic impacts projected even for Phase I "forever" are so large that we doubt a tightened cap would be implemented once those initial impacts are observed in the market place. We therefore decided that a more realistic high-end after enactment of S.139 would be that the experience of the first Phase of implementation would motivate the U.S. to shift from there to a more gradual phase-in of further reductions. We selected a gradual phase-in that is consistent with the "optimal timing" emissions path to stabilize atmospheric CO_2 emissions at 550 ppm.[16] The reductions required of Phase I are not required under the optimal timing scenario until approximately 2030. Our high-end policy path therefore retains the Phase I cap through 2030, and then the cap is further tightened, by about 1% per year.

Table 4.1 presents the different emission caps that we consider.

Table 4.1 Emission caps by model year and scenario

	Model Year		
Scenario	**2010-2014**	**2015-2030**	**2035-End of Model Horizon**
Original Act	Phase I	Phase I	Phase I
Amended Act	Phase I	Phase II	Phase II
Amended Act + Optimal Timing	Phase I	Phase I	1% decline/yr from Phase I

Thus, we do not include anything in our assessed range of impacts that implies a more aggressive future carbon policy than having Phase I ultimately merge into the optimal timing path. However, one can still understand the implications of assuming that Phase II will eventually be enacted by looking at our results for the original S.139. That is, if one truly expects that enactment of the amended S.139 will leave markets expecting that all of the original Phases of S.139 will come to pass on approximately the same schedule, then the near-term impacts of the amended S.139 would be identical to those of the original S.139.

[16] This is often called the "WRE550" path, in reference to its original publication by Wigley, Richels and Edmonds in an article in Nature.

In this paper, we also provide a relatively brief summary of estimated costs of the original S.139. This is intended as a point of reference for understanding our estimated impacts of the amended version of S.139. For the original S.139 analysis, we did not consider a range of possible changes to its caps. We assumed that Phase II would be implemented as prescribed, and would never be adjusted downwards from that level. This was in part because the Phase II cap remains more stringent than the optimal timing path (which we used as our alternative case for amended S.139) until after 2060. Thus attempting a similar gradual merging of Phase II with the optimal timing path would be no different than simply assuming Phase II "forever."

UNCERTAINTY ABOUT BACKSTOP CONTROL TECHNOLOGY COSTS

Assumptions about the cost-effectiveness of carbon abatement technology can have a strong effect on the near-term costs of a policy. This is true for the assumed future costs of such technology as well as the present costs, because expected future prices of carbon affect the incentive to bank emissions early on, and thus motivate more carbon control expenditures than the early phases of the cap directly require. As a result, carbon prices during Phase I rise as future costs of abatement technology increase. A particularly important assumption affecting future carbon price projections is the estimated cost of the "backstop technology" for controlling carbon emissions.

An example of a backstop technology is capturing the CO_2 from coal-based electricity generation, and sequestering it in some way such as underground or on the deep sea bed. This type of sequestration is already possible at costs between $100/tonne and $200/tonne, but only for a small fraction of the current emissions that would otherwise be released. Using this backstop to achieve meaningful reductions of emissions would not be feasible in the near-term except at much higher marginal costs per tonne. On the other hand, with substantial lead time, both for technological advancement and to allow for turnover of the capital stock, very large amounts of sequestration may become viable. The cost of doing so will never become insignificant, however, as the backstop technology will be capital-intensive.

In the MRN model, the existence of a backstop technology is reflected as an exogenously specified price per tonne (denoted in $/tonne of carbon) at which CO_2 can be sequestered. This technology can be deployed in any sector that emits carbon dioxide, and for simplicity, we assume a uniform price across all sectors.[17] Table 4.2 summarizes the two alternative backstop cost trajectories that are used in this analysis. In the optimistic, low-end case, we assume that a backstop cost of about $300/tonne today will start to gradually fall after 2010, eventually becoming an infinite supply of

[17] Realistically, it will be much less costly to develop technology to sequester CO_2 emissions from large point sources and therefore, the cost is likely to vary greatly across sectors. To be conservative, we derive our cost estimates from estimates of carbon capture technologies combined with integrated gasification combined cycle power generation.

carbon reductions at only $100/tonne. The pessimistic, high-end expectation is that the current cost of about $300/tonne for an infinite quantity of carbon sequestration would remain unchanged in real terms.

Table 4.2 Two cases considered for cost of backstop technology ($/tonne carbon-equivalent removed)

Scenario	Model Year				
	2010	2020	2030	2040	2050-2070
Constant	$300	$300	$300	$300	$300
Declining	$300	$275	$200	$125	$100

As mentioned in Section 3, the MRN model receives international prices from the MS-MRT model. To be consistent, these two models were run assuming the same costs for backstop technologies. In addition, technologies would be available globally; thus, the cost of the backstop technology is the same in all Annex B countries.

SUMMARY OF ALL CASES ANALYZED

We considered not just an upper bound and lower bound case, but we also considered all combinations of each of the three uncertainties above for the amended S.139. The resulting eight cases are listed in Table 4.3. The labels shown in the first column are used to identify cases in the tables and figures of the results sections. Table 4.3 also lists the four cases we analyzed for the original S.139.

Table 4.3 Summary of cases considered for original and amended S.139

Case Name	Emission Caps	Backstop Cost	Availability of Outside Credits
For Original S.139:			
Orig-Const Cost-Free	Original Bill	Constant at $300	15,10% at $0 cost
Orig-Const Cost-None			None
Orig-Dec. Cost-Free		Declining	15,10% at $0 cost
Orig-Dec. Cost-None			None
For Amended S.139:			
Phase I-Const Cost-Free	Phase I Only	Constant at $300	15% at $0 cost
Phase I-Const Cost-None			None
Phase I-Dec. Cost-Free		Declining	15% at $0 cost
Phase I-Dec. Cost-None			None
Phase I+Opt.-Const Cost-Free	Phase I + Optimal Timing	Constant at $300	15% at $0 cost
Phase I+Opt.-Const Cost-None			None
Phase I+Opt.-Dec. Cost-Free		Declining	15% at $0 cost
Phase I+Opt.-Dec. Cost-None			None

ASSUMPTIONS TO REFLECT ADDITIONAL PROVISIONS IN THE ACT

Under all scenarios, we attempted to include as many of the other provisions in S.139 as possible. Following is a summary of the remaining scenario specifications and assumption we used in all of the cases analyzed:

- Emission targets and timetables. We applied the emission targets as specified in the Bill, with the exemptions described below. We make only one adjustment that is not exactly consistent with the Bill. In the case of the original Bill, Phase II would start in 2016. However, due to other modeling requirements (particularly the need to run the model through 2070), we run the model in 5-year time steps. Because we need to maintain the fixed time steps, we start Phase II in 2015 rather than 2016 in our analysis of the original Bill.

- Banking of permits. The MRN model is capable of directly optimizing the timing of control choices when banking of permits is allowed. As banking is explicitly allowed in S.139, all model runs included banking.

- Non-covered sectors. S.139 exempts emissions from the agriculture sector, and those from the residential sector that are not associated with transportation. These exemptions are reflected in all the MRN runs.

- Exemptions of small sources. S.139 also allows sources of less than 10,000 tonnes CO_2-equivalent per year to be exempted from the cap-and-trade system. It is less clear on how emissions will be counted for the commercial sector. However, we analyzed the emissions rates of the commercial sector and decided that the majority of sources in this sector would likely receive an exemption under most possible interpretations of the exemption provision. We therefore chose to exempt all commercial entities in all of our cases, and adjusted the caps accordingly. After accounting for non-covered sources and exempted sources, uncapped sectors represent only a bit over 10% of total U.S. carbon emissions.

- Other greenhouse gases. The caps of S. 139 apply to all GHGs, not just CO_2. As noted in Section 3, MRN models only CO_2 explicitly. A substantial share of control options for non-CO_2 gases are likely to be more cost-effective than those on CO_2.[18] On the other hand, non-CO_2 gases are projected to grow at a very rapid rate compared to CO_2 emissions.[19] Thus, the relatively cost-effective controls that may be available from these gases are likely to be quickly used up in simply offsetting their own growth rates. In order to adjust for the lack of non-CO_2 controls in MRN, we assumed that *all* the future growth in the covered non-CO_2 gases would be reduced back to their 1990 levels at zero cost. Since this would more than absorb the estimated reservoir of cheap controls available for these other GHG gases, we believe that this assumption roughly neutralizes any potential for an upward bias in cost estimates from a model that only addresses the CO_2 portion of the cap. Additionally, the provisions to exempt sources with less than 10,000 tonnes per year of CO_2-equivalent emissions, combined with the fact that agriculture is not covered at all by S.139, implies that only a very small fraction of non-CO_2 gases will actually be capped. Rather, these other GHGs are likely to become a cost-reduction option only as part of the 15%/10% "alternative means of compliance" that we have addressed in our ranges of estimates.

- Automobile fuel economy standards. S.139 provides that automobiles must meet the existing corporate average fuel economy standards, but can gain credits if they exceed that standard by 20%. MRN endogenously determines improvements in fuel economy that are a cost-effective policy response. We do not impose any logic that creates a greater incentive at the

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[18] J. M. Reilly, H. D. Jacoby, and R. D. Prinn, *Multi-gas Contributors to Global Climate Change – Climate Impacts and Mitigations Costs of Non-CO_2 Gases*, Pew Center on Global Climate Change, Washington, D.C., February 2003, p.24.

[19] Ibid, Table 3, p. 22 shows that the projected growth through 2020 (based on projections of growth between 2000 and 2010) is 367% for HFCs, 1706% for PFCs and 576% for SF_6, compared to 30% for CO_2.

20% point, but the endogenous changes that we see are not large enough to suggest that this feature would have any effect on our results.

- Tax interaction assumptions. Under S.139, permits are either to be auctioned off by a non-profit corporation or allocated for free. Therefore, the government receives no money from the allocation of permits. This provision means that the government will not be able to use any revenues from auctioning off permits. In order to offset any deficits that result from the economic impacts of the caps, it would have to raise taxes. In all the model runs, the government is assumed to meet changed revenue needs by adjusting the personal income tax rates rather than using allowance auction revenues.

INTERNATIONAL POLICY AND TRADE ASSUMPTIONS

MRN accounts for the interactions of domestic policies with the U.S. trade position. This means that it is important to be explicit about what the rest of the world is assumed to be doing with respect to GHG policy. In all scenarios, we assume that all Annex B countries except the U.S. adopt their Kyoto Protocol limits and that they can freely trade carbon permits with each other. Most importantly, we allow Russia to take credit for and sell all of its permits if it wishes (i.e., we allow "hot air"). This implies (using the MS-MRT model) that the cost of carbon for Annex B countries is $0/tonne in 2010.[20] This is what is assumed in the "business-as-usual" scenario.

In the policy scenarios, we first re-calculate the terms of trade using MS-MRT with the U.S. also having a cap, consistent with the S.139 provisions. We do not, however, have the U.S. purchasing any allowances from the Annex B market in these runs, even for the cases where the U.S. is assumed to be able to obtain 15%/10% of its permits at zero cost.

Many alternative international trade assumptions could have been made. However, we selected this set because they are likely to understate impacts to the U.S. compared to the other realistic alternatives that we could have used. They are also common choices by other modelers, which could ease comparisons of our estimates with other estimates.

[20] However, if the U.S. were to join this market, the price of carbon would be non-zero even with Russian permits being sold.

DISCOUNT RATE

The fact that expectations matter to current decisions implies that the discount rate assumed in the model will also matter. We used a 5% annual discount rate for all runs.

5. Economic Impacts Of The Original Bill (Including Phase II)

In this section we briefly summarize our findings on the economic impacts of S.139 as originally introduced (i.e., including Phase II).[21] This is provided for context and as a point of reference, since there are far more other analysis results available of the impacts of the original Bill. The next section will turn to the economic impacts of an amended version of S.139, which would contain only the provisions of Phase I. Section 6 will provide a more comprehensive set of results and sensitivity analyses than this section, because the amended version of S.139 is the primary focus of this paper.

For any emissions control policy, one of the key drivers to the cost of the program is the cost of abating emissions. Given the market-based mechanism to achieve the cap on emissions under S.139, the price of carbon allowances will increase to the point where a sufficient number of tons are avoided so that the cap is just met. This price will be equal to the cost per tonne of the last tonne removed, or the "marginal control cost". In addition, given the forward-looking behavior, there will be an incentive to bank emissions early on, because carbon prices rise fast enough to make banking profitable in light of the cost of capital. This incentive drives the carbon price upwards in the early years of a cap relative to the exact marginal cost of exactly meeting the cap in those early years. In other words, while there is banking, the price per tonne reflects the marginal cost of the actual reduction in that year, which is greater than the amount required to just meet the cap and not "over control." Although banking causes carbon prices to be higher in the early years, the added supply of banked permits drives carbon prices lower in later years. The net result is to reduce the total cost on a present value basis of meeting the requirements of the Bill. The result when incentives to bank are considered is a price path of carbon that rises at a rate equal to the real interest rate that emitting companies could otherwise earn by investing their money in other ways.

Figure 5.1 reports the marginal cost of abatement or equivalently the carbon permit prices for the four cases that were used to assess the impacts of the original S.139 bill for the full model horizon, through 2070.[22] In all cases, by 2040, the allowance prices reach the assumed backstop price in the given case. However, Figure 5.1 indicates that up through 2020, the stringency of the carbon cap (i.e., whether or not external credits can be purchased at a low price) determines the carbon price or marginal cost of abatement more than the long-term steady-state that prices are headed towards. From 2020 onward, the assumptions about backstop technologies start to have more influence on the trajectory of the carbon price.

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[21] A comprehensive set of results tables for each case presented in this paper is available upon request from the authors at pbernstein@crai.com or asmith@crai.com.

[22] All permit prices are stated in 1999 dollars per tonne of carbon-equivalent.

Figure 5.1 Estimated carbon prices under the original S.139 for four alternative cases

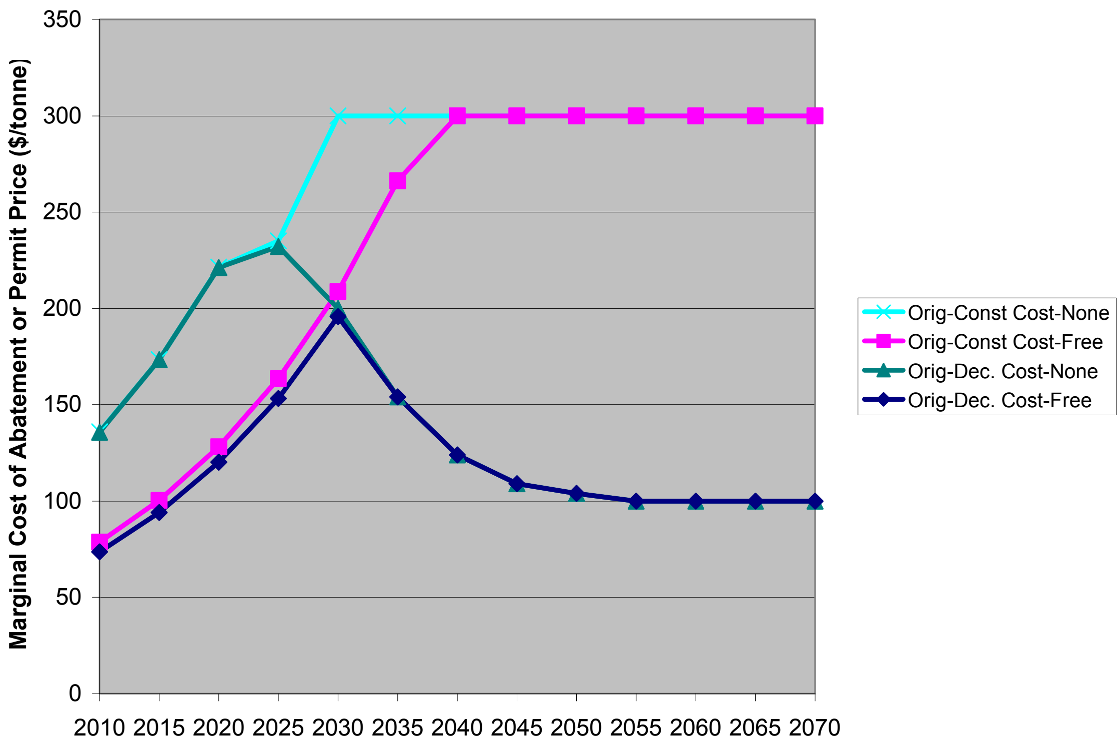


Table 5.1 states the range of the carbon prices specifically during the time frame 2010-2020 and also summarizes several key measures of the economic impact of the original Bill that are consistent with these prices. These include the percent impact to GDP (relative to our no-carbon policy case) and costs to consumers in the form of reduced consumption in each year. The latter metric is stated as a percent loss relative to no carbon policy, and also restated in terms of dollars per year (stated in 1999 dollars). We specifically focus on the impacts to consumption to promote comparability with costs reported by other analysts. There are a number of other impacts that could be used.[23]

In Table 5.1, the low-end carbon tax numbers occur under the case of declining backstop cost and zero cost for outside permits (see Figure 5.1). The high cost estimate occurs under the cases with no outside permits. The choice of the backstop trajectory under the assumption of no outside permits has little effect on the carbon price as illustrated by the fact that the Orig-Const Cost-None line is

[23] Traditionally we have focused our summary of a policy's impact on a measure known to economists as "equivalent variation" (EV). Often colloquially called "welfare", EV is the exact measure that is being maximized in MRN. EV has a close relationship to the loss in consumption value, but it also includes an accounting for how alterations in leisure can enhance consumer welfare. Thus the reduction in EV is usually less than the reduction in consumption alone. We focus on the consumption loss estimates here because that is the estimate that other researchers have been reporting.

nearly identical to that of the Orig-Decl Cost-None line in Figure 5.1. The difference is small because the tightness of the emission caps in this case causes the backstop price to be reached very quickly and hence the constant and declining backstop prices are still quite similar (see Table 4.2).

Table 5.1 Range of cost estimates of the original S.139

Fuel	2010	2015	2020
Carbon Price ($/tonne)	$74 to $136	$94 to $173	$120 to $221
Loss in GDP (%)	0.4% - 0.8%	0.7% - 1.3%	0.9% - 1.6%
Loss in Consumption (%)	1.0% - 1.7%	1.1% - 2.0%	1.3% - 2.2%
Loss in Consumption ($/HH)	$760 - $1,300	$990 - $1,700	$1,200 - $2,100

Under the original Bill, the carbon price could exceed $200/tonne of carbon-equivalent by 2020 if permits from the outside are even more expensive than $200/tonne. On the other hand, if the 15%/10% of credits for "alternative means of compliance" that may be bought outside of the cap could be purchased at a price near $0/tonne, then the carbon price might reach only $120/tonne by 2020.

A carbon price of $200/tonne equates to about a $0.50 rise in the price of gasoline and a 40% increase in the cost of electricity. The access to external credits is critical to lowering the cost, and this assumption is the primary factor underlying the low-end of the range. If external credits can be acquired cheaply, then the price increases would be only half as great. For example, under the low-end assumptions, the price of carbon in 2010 would be around $75/tonne or an increase of about $0.20/gallon of gasoline and a 15% increase in the price of electricity. By 2020, energy cost increases would be about $0.30/gallon of gasoline and about a 24% increase in the price of electricity.

This increase in the cost of energy use has a negative effect on the economy. As the cost for energy rises, industry must alter its methods of producing goods. The most direct reaction of industry will be to reduce use fossil fuels for energy, substituting into more capital-intensive non-fossil sources of energy, and also substituting to less energy-intensive production methods. Both forms of substitution require more capital investment, which will lead to a lower level of consumption in the near-term, and also a reduced rate of return, thereby reducing consumption in the future as well. Because industries are no longer as productive, their revenues fall, which ultimately feeds back to individuals in the form of lower wages. Because of lower wages, labor supply is reduced, further trimming incomes and reducing the productive potential of the economy. In sum, individuals face reduced ability to consume as a result of this type of policy change. The value of the loss in consumption can be quite substantial. On the low end, we find the cost per household to start at

$760 in 2010 rising to $1,200 in 2020. On the high end, the cost per household could exceed $2,000 per year by 2020.

Again, we find that the main determinant of whether the cost is at the high or low end is the assumed cost of credits for "alternative means of compliance." A reduction in the technological costs of control also affects the cost estimates, but not as significantly. For example, the low-end costs shown here assume large reductions in the backstop technology price as well as very cheap outside offsets. However, the low-end cost per household cost estimates would only increase by $100 or $200 if the more pessimistic backstop technology cost assumptions are correct. Similarly, the high-end estimates would only drop by about $100 if the more optimistic assumptions about backstop technology costs are correct.

6. Economic Impacts Of The Amended Bill (Phase I Only)

High cost estimates for the original S.139 prompted Senator McCain to announce that he would amend it to eliminate the second phase of emissions reduction requirements. Although it is unclear whether a Phase II might be passed at a later date, many are interpreting this amended Bill to impose a cap at Phase I levels in the period 2016-2020 as well as from 2010-2015. Nevertheless, the passage of a cap that was always intended as just a first, small step towards much deeper reductions later leaves a large uncertainty about what should be expected "later." As we have noted, current actions to meet the first cap will be affected by actual expectations, and so we need to make some assumptions about what actual expectations may be in order to develop a reasonable set of cost estimates.

For our range of cost estimates associated with the amended S.139, we make two alternative assumptions about future cap levels and timing of their imposition after the Phase I cap level in the amended Bill. In one case we assume that the Phase I cap is never again reduced, even as far in the future as 2070. A second case that we consider when constructing our range of cost estimates is that the Phase I cap is expected to remain in place until after 2030, at which point the U.S. would begin to reduce emissions consistent with an emissions reduction path that economist consider the "optimal timing" for reductions.[24] Note that both of these represent quite optimistic assumptions about future policy expectations. Many people may expect that if an amended S.139 were passed, then a second phase like the original Phase II would be passed later, and become effective sometime between its original date of 2016 and 2030. Obviously, if citizens expect that Phase II would be initiated by 2016 anyway, then the costs of the amended Bill would be no different than the costs of the original Bill. However, for the range that we present, we have used only the two more optimistic assumptions about policy expectations.

In addition to the range that we consider for future policy expectations, our range of impact estimates again reflects the possibility that outside credits for "alternative means of compliance" are (a) available at zero cost and (b) available only at costs comparable to reductions within the capped set of sources. Our range also again reflects the possibility that the cost of the backstop control technology will (a) fall to $100/tonne carbon-equivalent reduced or (b) be at the higher $300/tonne range. Thus, we estimated costs with eight different sets of assumptions about expectations and technology, and the range of costs that we present in this section reflect results from just the low-end and high-end cases. The low-end case is the one that assumes the Phase I cap is unchanged

[24] This is often called the "WRE550" trajectory to achieve atmospheric stabilization of carbon at 550 ppm. WRE stands for Wigley, Richels, and Edmonds, the names of the analysts who first introduced this concept and estimated associated emissions paths for the developed countries.

"forever", zero-cost credits for "alternative means of compliance", and the low cost backstop control technology. The high-end case is the one assuming a slowly tightening cap after 2030, high cost of credits for "alternative means of compliance," and high technology costs.

Figure 6.1 graphs the marginal cost of abatement or equivalently the carbon permit prices for all eight cases that we used to explore the possible economic impact of the amended S.139 bill. As in the case of the original Bill, the inclusion or exclusion of external credits has a large effect on the carbon price. However, in contrast to the cases for the original Bill, the carbon price also is influenced even in the early years by expectations regarding the future cost of the backstop control technology. Interestingly, the long-term evolution of the level of the carbon cap itself has relatively little influence on the near-term carbon prices (at least, for the range of future caps that we used to construct these eight cases.)

Figure 6.1 Estimated carbon prices under the amended S.139 for eight alternative cases

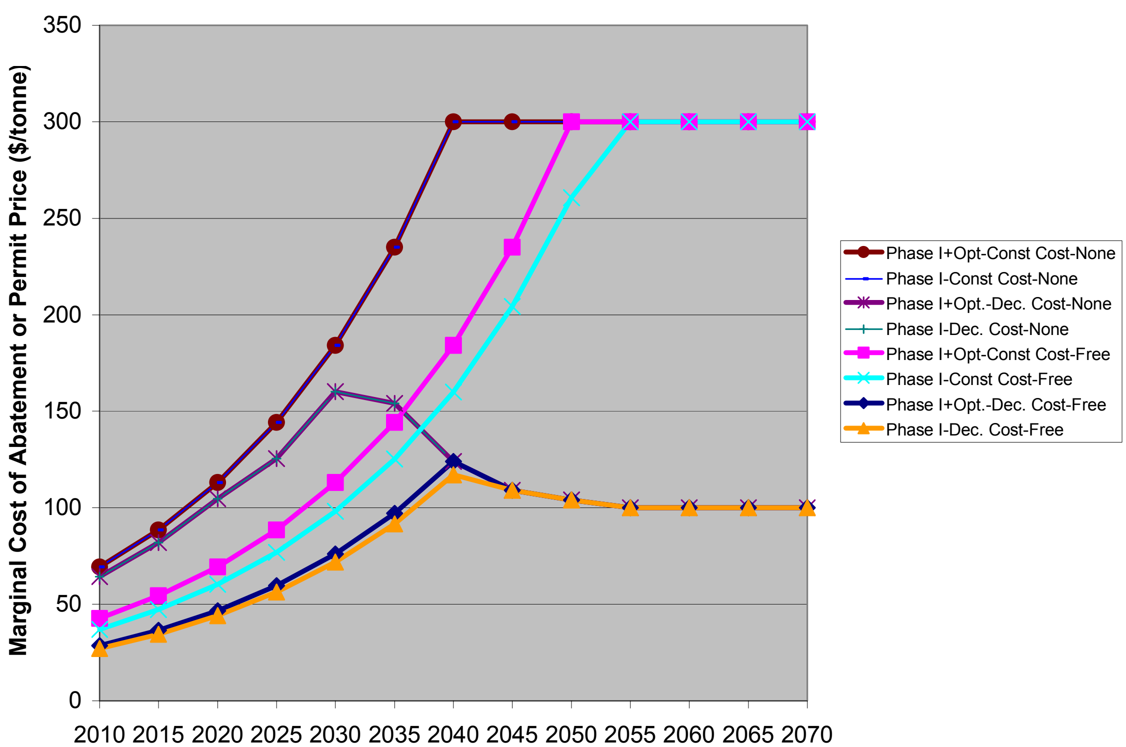


Table 6.1 presents ranges of summary measures of impact over the 2010 to 2020 time frame. In viewing the ranges, it may be useful to know that the primary determinant of estimated costs is the assumption about the cost of obtaining offsets to cover 15% of the capped emissions. Future control technology costs also affect estimated costs, but to a lesser degree. The two sets of future policy expectations that we applied were found to have minimal impact on the ranges reported in Table 6.1, and caused only minor variations in estimated costs of scenarios that lie in the middle of the reported range.

The impact estimates in Table 6.1 indicate that the amendment to remove Phase II could significantly reduce the costs of S.139, *as long as this amendment also implies that Phase II will not be legislated and come into effect at some later date.* The expectation that the carbon cap will remain at Phase I levels at least through 2030 dramatically reduces the incentive to bank emissions, and the estimated carbon prices fall by a factor of two to three compared those estimated for the original Bill.[25] The low-end carbon prices are $27/tonne in 2010 and rise to $44/tonne by 2020. The high-end carbon prices are $69/tonne in 2010 and rise to $110/tonne in 2020. The high-end of the range is nearly at the level of the low-end of the range for the original Bill.

Table 6.1 Range of cost estimates of the amended S.139

	2010	2015	2020
Carbon Price ($/tonne)	$27 to $69	$35 to $88	$44 to $110
Loss in GDP (%)	0.2% to 0.4%	0.3% to 0.7%	0.4% to 0.8%
Loss in Consumption (%)	0.5% to 1.0%	0.5% to 1.2%	0.6% to 1.4%
Loss in Consumption ($/HH)	$350 - $820	$450 - $1,100	$530 - $1,300

The cost to consumers in the form of loss in consumption value also falls, but not as much as the carbon prices. Costs per household in the low-end case are estimated to be $350/year in 2010, rising to $530/year by 2020. On the other hand, the high-end costs have not dropped as much. (That is, our estimated cost range is wider for the amended Bill than it is for the original Bill.) The high-end of our range implies costs per household of $820/year, rising to $1300/year. These costs per

[25] This also means that emissions would be higher in the period 2010-2015 under the amended S.139 than under the original S.139. Our model results indicate that just by eliminating Phase II, emissions in 2010-2015 (the erstwhile Phase I period) would rise by about 100 to 150 million metric tonnes of carbon-equivalent per year compared to emissions projected for the Phase I years of the original Bill. This increase in emissions even in the period 2010-2015 is one of the reasons the amended Bill is less costly.

household are above the low end of the range estimated for the original Bill. They would be even higher if one were to expect a Phase II-like reduction of the cap to occur prior to about 2040.[26]

The carbon price estimates can also be put in context in terms of impact on energy costs. At the high end, the carbon permit price is around $100 by 2020. This equates roughly to an increase in the price of gasoline of about $0.25/gallon and about a 20% increase in the price of electricity. If on the other hand, emitters can purchase very cheap offsets and the cost of sequestering carbon through backstop technologies is expected to drop eventually to the range of $100/tonne, then the carbon price is projected to remain below $50/tonne through 2020, implying price increases of about $0.12/gallon for gasoline and about 10% on electricity bills. Other energy costs, such a natural gas for heating and hot water, would also increase. These imply direct costs to households. Consumer goods and services that require energy as inputs would also increase in cost, adding further to household costs. These indirect costs are one reason why estimates of costs per household are higher than just their increased energy costs.

IMPACT ON ENERGY MARKETS

The primary means for meeting the emission targets laid out in S.139 would be to reduce the burning of fossil fuel. To meet the emission targets, U.S. emissions must be reduced by 4% and 16% in 2010 and 2020, respectively if outside credits are available and by 16% and 27% in 2010 and 2020, respectively if these credits are unavailable. For households and industries to reduce their consumption of fossil energy under a market-based approach such as S.139 would implement, the cost of using these fuels must rise. In large part, the price of carbon imposes this increase, which is passed through to consumers. Table 6.2 reports the changes in the costs of fuels that end-user would bear. These costs include the cost of the carbon allowances that is passed on to consumers from producers of fuels.

[26] In the extreme, if expectations were that the cap of the amended Bill would be reduced to the original Phase II levels by 2016 as a result of future legislation after the amended Bill were to pass, then the estimated costs of the amended Bill would be identical to those of the original Bill.

Table 6.2 Estimated percentage change in total end-user prices for fuels under the amended S.139 (including effect of carbon price)

Fuel	2010	2015	2020
Coal	51% to 140%	68% to 180%	87% to 230%
Gas	12% to 30%	15% to 37%	18% to 44%
Oil	12% to 29%	14% to 35%	16% to 43%
Electricity	7% to 17%	9% to 20%	10% to 23%

Since coal is the most carbon-intensive of the fossil fuels on an energy content basis, and because it has a low base price on an energy content basis, it experiences the largest price increase after accounting for the carbon tax. The price of gas and oil rise too, but not as dramatically. The price of electricity rises because it consumes a large amount of fossil energy per dollar of output. The percent increase in electricity is relatively small, in part because there is a higher base price (as electricity is much more capital-intensive that the primary fossil fuels.) Also, although electricity is a large user of coal at present, under a carbon policy there is much substitution out of coal-fired generation into natural gas-fired or non-fossil based generation. This also dampens the percent impact of the carbon price on electricity.

Producers of fuels do not benefit from these increased prices, however. Rather, they see declining output, as shown in Table 6.3. The disparity in price increases creates a large disparity in the impact on the coal sector relative to the other energy sectors. (As noted above, this is simply the necessary response of the energy system to reduce carbon emissions, after accounting for all available forms of offsets and credits.) The emission caps for the amended Bill are such that gas producers would benefit in the years prior to 2020.[27] Fuel switching to gas thus occurs, but not at a high enough level to offset the overall drop in demand for fossil energy.

Much of the reduction in coal consumption occurs in the electricity sector. Therefore, as coal consumption declines by 24% to 41% in 2010, electricity production drops too. However, electricity production and hence consumption does not decline by the same percentage as coal. A large part of the reason for this is that coal-fired generation makes up less than 60% of electricity generation in 2010; therefore even if no fuel switching occurred in electricity generation, a 10% decline in coal-fired electricity generation would lead to only a 6% reduction in overall electricity generation. The other half of the story is that part of the reduction in coal-fired generation is made up by switching to

[27] However, after 2020, gas production declines under all of our cases for the amended Bill, for after this time, the cap requires a reduction in emissions relative to the baseline that causes it to be too costly for the U.S. reduce its emissions by only reducing its consumption of coal and oil.

gas-fired generation (reflected in the increase in gas consumption). In addition, the electricity sector undertakes some fuel switching to non-carbon fuels.

Table 6.3 Estimated percentage change in energy production under the amended S.139

Fuel	2010	2015	2020
Coal	-42% to -23%	-55% to -35%	-65% to -46%
Gas	0.8% to 1.1%	1% to 1.4%	0.7% to 1.7%
Oil	-6.5% to -2.8%	-8.7% to -3.8%	-11% to -4.8%
Electricity	-8.1% to -3.7%	-10% to -4.8%	-12% to -6.0%

In net, individuals and industry use a mixture of fuel switching, energy efficiency, and reduced economic activity to meet the emissions caps. Stated differently, the economy's carbon intensity drops more than its energy intensity under a GHG abatement policy.

Declining output is not the only way that primary fuel producers will be impacted. The price increases to end-users shown in Table 6.2 primarily reflect increased costs to producers, rather than increases in their profit margins. In fact, prices that fuel producers can charge net of the carbon cost, actually fall for coal and oil, as is shown in Table 6.4. The demand for natural gas rises slightly and hence so does its price net of the carbon cost. The price changes for fossil fuels net of the carbon permit price are much smaller than the price changes after inclusion of the carbon cost, which indicates that energy producers are able to pass along much of the price increase in fuels to consumers.

Table 6.4 Estimated percentage change in fuel prices (net of any carbon costs) under the amended S.139

	2010	2015	2020
Coal	-6.9 to -6.2	-5.5 to -5.1	-4.1
Crude Oil	-2.3 to -0.2	-4.2 to -1.7	-5.9 to -3.1
Gas	0.4	0.2 to 0.5	0.0 to 0.6
Refined Oil	-0.3 to 0.2	-1.0 to -0.4	-1.6 to -0.9

IMPACT ON LABOR-LEISURE TRADE-OFF

Economic output declines under S.139. Therefore, industry needs less labor, which in turn leads to a decline in the real wage rate. The MRN model represents individuals' decisions on how they wish to allocate their time between labor and leisure, and hence can better represent labor market effects than the classical general equilibrium model that does not represent this trade-off. Table 6.5 reports the estimated loss of jobs for the low-end and high-end cases. In 2010, under the amended bill, we estimate between 274,000 and 614,000 fewer jobs.

Table 6.5 Decline in employment under amended S.139 (number of U.S. jobs)

	2010	2015	2020
Upper Estimate	614,000	824,000	963,000
Lower Estimate	274,000	375,000	432,000

Table 6.5 implies that as wage rates fall and many workers may work fewer hours, they can have more leisure time. If someone works less, they will have less income and hence will be able to consume less; however they derive some benefit from having more leisure time. The utility function in MRN captures both of these effects, and the model actually simulates individual choices to maximize utility, rather than maximizing consumption alone.[28]

Using the more comprehensive representation of individual choices and behavior causes MRN to generate larger estimates of losses in consumption than if there were no consideration of the trade-off between labor and leisure and the model maximized only consumption. This is an important difference between MRN and the other models that have been used to study S.139. In most other models, individuals maximize consumption, cannot substitute consumption for leisure, and receive no benefit from this trade-off. These other models will therefore tend to estimate smaller consumption losses. It therefore makes sense to understand the overall welfare loss estimates in MRN in addition to just the consumption losses reported so far. When we consider the benefit of increased leisure with the loss in consumption in evaluating "welfare loss", the welfare loss of the low-end case is $90 and $200 per household in 2010 and 2020, respectively. This contrasts to a loss of $350 to $530 per household when one only accounts for estimated changes in consumption. The difference reflects the estimated gain to consumers because they work less under the policy scenario.

[28] In other words, in the measure of individual utility used in MRN, individuals are estimated to lose out on consumption but benefit from the increased leisure that is the result of the lost jobs, which still results in a loss in welfare.

EFFECT OF ALTERNATIVE EXPECTATIONS ABOUT THE FUTURE

Another reason that consumer costs are increased in the near-term is the effect of the future on current decisions. The MRN model incorporates a full intertemporal optimization, with forward-looking behavior on the part of consumers, who make adjustments to consumption patterns to smooth the impact of future anticipated costs over time, and on the part of businesses, which change investment behavior anticipating future returns on investment.

Table 6.6 is provided to help illustrates this effect. This table compares the percentage change in consumption between the original Bill and the amended Bill under identical assumptions for all inputs other than the level of the cap. Most importantly, these two cases assume the same backstop technology costs and that external credits can be obtained for free. The caps in these two cases are identical in 2010, but tighter under the original Bill in 2015. There is no cap in 2005 for either scenario.

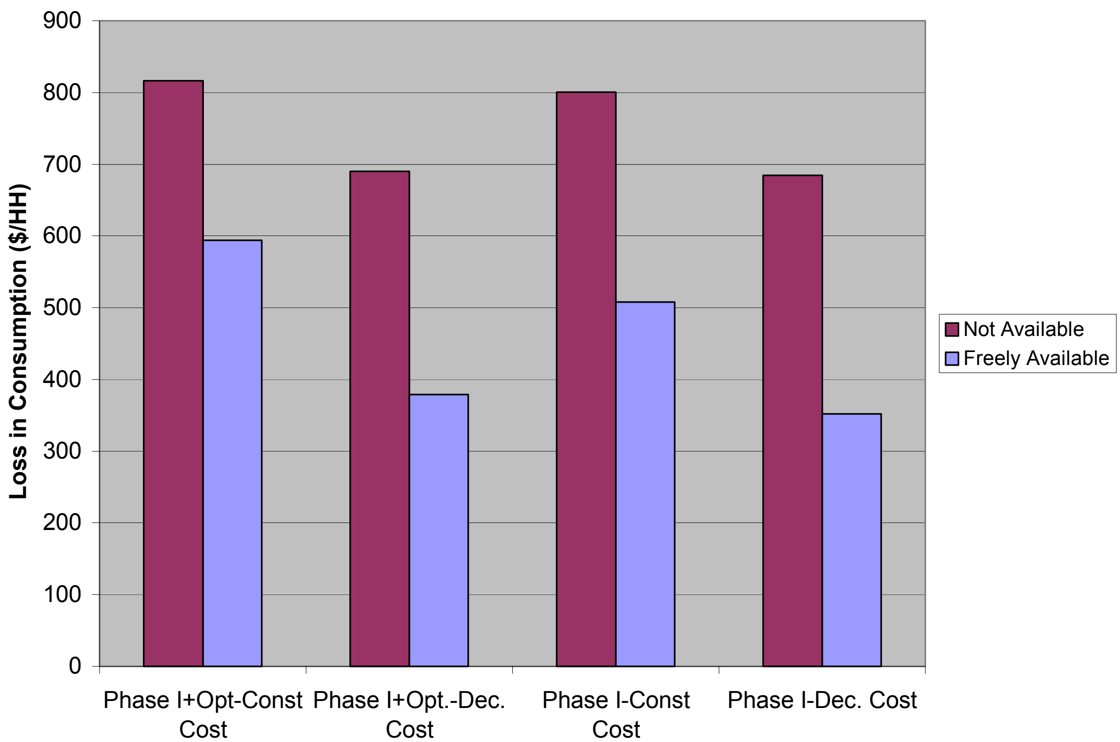
Table 6.6 Comparison of percent change in value of consumption between the original and amended Bills (all other input assumptions identical)

	2005	2010	2015
Amended Bill	-0.26	-0.65	-0.75
Original Bill	-0.43	-1.11	-1.30

Not surprisingly, the costs differ greatly in 2015 since the emission caps under the two bills differ greatly: the targets under the original bill are at 1990 emission levels; whereas the targets for the amended Bill are at 2000 emission levels. However, even though the carbon targets are identical in 2005 and 2010, the costs of the original Bill are about 60 to 70 percent higher. This difference highlights the fact that expectations about the future influence decisions long before the future is realized. In fact, consumption starts to fall in 2005, even though there is no cap in effect in that year. The phenomena apparent in Table 6.6 reflect the fact that industries and households act on their expectations long before the outcome is known.

Figure 6.2 illustrates the importance of future expectations on our results in another way. In all four of these scenarios, the carbon caps imposed in each year *through 2030* are identical. The cost of the backstop technology is also identical in each year through 2030 in each of these cases.[29] This figure shows the estimated loss in household consumption in 2010 for the amended S.139. The costs can be seen to be higher under the assumption that offsets are not available more cheaply than reductions by the capped sources (the red bars on the left) than they are if such offsets are available at $0/tonne (the blue bars on the right). However, for a fixed assumption about the availability of offsets from "alternative means of compliance," estimated consumption losses still vary quite substantially despite identical carbon constraints through 2030, market conditions, and technology costs in that year (and effectively identical costs for 20 more years into the future). These additional variations are almost as large as the change in costs created by the two extreme assumptions about offset prices. Expectations of costs beyond 2030 are the root cause of this remaining variation. After 2030, these scenarios diverge in terms of the cost and use of carbon sequestration and carbon-free technologies and the future level of emission caps.

Figure 6.2 Estimated loss in 2010 household consumption for eight cases reflecting alternative assumptions applied to the amended S.139 caps



[29] Among the scenarios, the cost of the backstop technology is effectively the same through 2030 because the backstop technology goes unused in all 4 cases until after this time.

The paths of projected investment and consumption illustrate how the economy adjusts to different expectations about technology and emission caps. Figures 6.3 and 6.4 show the projected changes in investment and consumption, respectively, relative to the no-policy projection for four of our amended S.139 cases. (These are the four cases which share the assumption that the 15% of the cap that can be met through offsets or international permit purchases are available at zero cost. They are the same cases as those reflected in the blue bars in Figure 6.2).

First, one can see that both investment and consumption are lower relative to their respective no-policy levels. This reflects the fact that economic activity is reduced overall by the necessity of diverting investments to emissions controls, reducing average rates of return on investment, as well as reducing real wage rates. The net effect is that GDP falls, and so net aggregate investment falls at the same time that consumption falls.

The impact of expectations on these paths appears in a couple of ways. As mentioned before, there is some reduction even in 2005, before any cap is actually imposed. Additionally, each of the four cases shown differs in terms of expectations about post-2030 conditions only. Different expectations result in different amounts of reduction in investment and consumption. These figures suggest that the expectations about technology costs that we have tried to capture matter more than the expectations about emission caps that we have applied.[30]

There is also a steep decline in the consumption path even through 2020. This fact tells us that the model is not close to a steady-state solution by 2020, and therefore one should be evaluating the policy for a longer time horizon as we do. Models that do not extend their horizons as far as the steady state will not obtain robust results of impacts through 2020.

[30] However, this finding is more a function of the range of uncertainty that we assumed for the two drivers of expectations than it is about the fundamental role of each type of expectation in determining costs. If we included a case where the expectation was that Phase II would be implemented before 2040, this would have far more impact on the loss in investment and consumption than the technology cost uncertainty. If people facing implementation of cap under amended S.139 believe that in the near future Phase II caps would be voted back in, then the investment and consumption losses in 2010 would double those shown in these figures: about -1.5% to -2% for investment and about -1% to -1.5% for consumption, regardless of the technology cost assumption.

Figure 6.3 Effect of future backstop costs and emission caps on investment (15% free availability of outside credits)

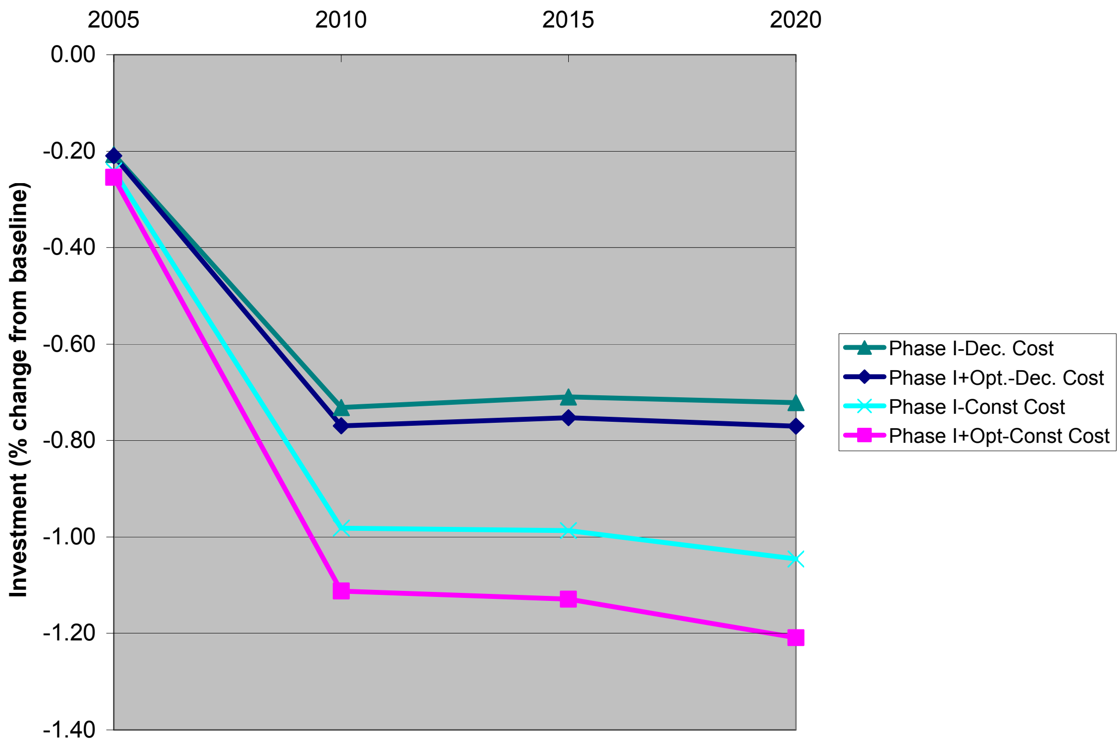
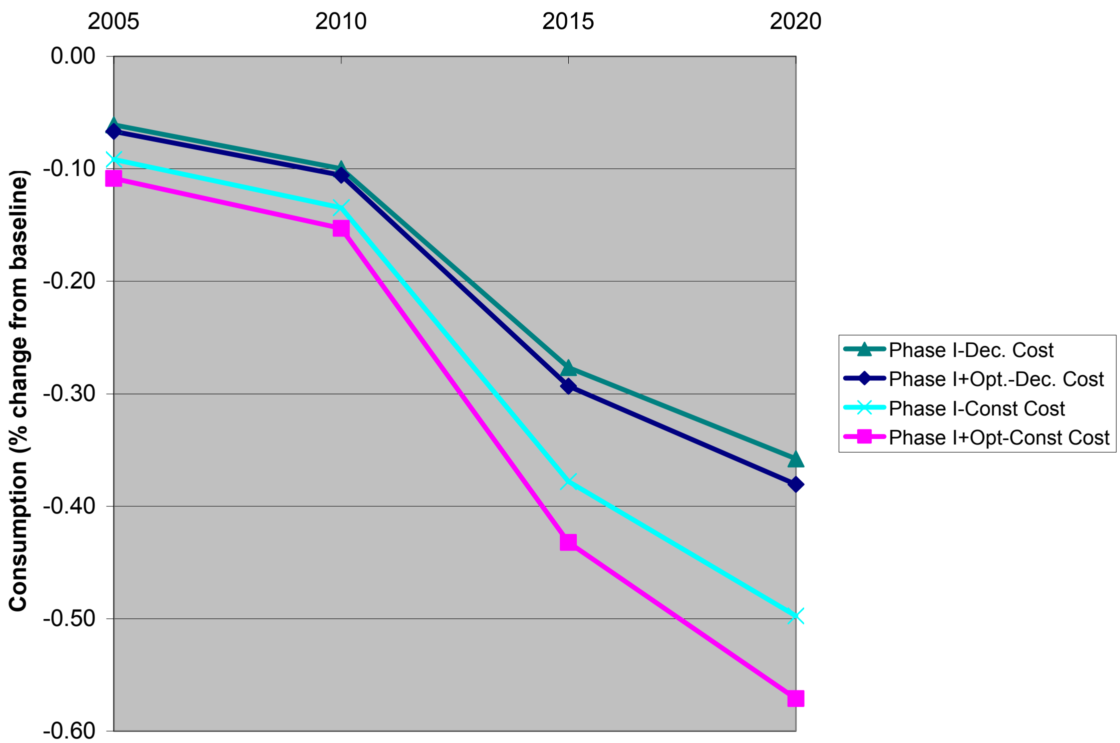


Figure 6.4 Effect of future backstop costs and emission caps on consumption (15% free availability of outside credits)



Role of Automobile Fuel Economy Provisions

The model runs for this analysis do not directly reflect corporate average fuel economy (CAFE) standards, and we have not attempted to simulate the impacts of the provision of S.139 that would reward automobile manufacturers who exceed their CAFE standard by more than 20%. However, MRN will make fuel economy improvements in automobiles if this is a cost-effective action. We have investigated the projected changes in automobile fuel economy as a result of S.139, and they are only about 5% in the near-term, and over the entire model horizon, they never exceed 10% relative to the no-policy case in any of our amended S.139 cases. Thus, although we did not directly model the incentives of S.139 for automobile manufacturers to exceed the existing CAFE standards by more than 20%, existing model results cause us to doubt that manufacturers would take advantage of this opportunity. Therefore we do not feel that incorporation of this feature of the Bill would alter our estimated impacts.

SENSITIVITY ANALYSES

In an effort to understand the differences in cost estimates reported from our model and those of other models, we ran a number of extreme cases to see if we could obtain cost estimates similar to those in other studies. One feature of MRN that is not in many other models is a representation of existing taxes, and how each type of tax affects individual and corporate labor supply, and investment decisions. It is widely known that these taxes can reduce the projected performance of the economy because they reduce incentives to invest or to work. This also creates a phenomenon often called the "tax interaction effect" whereby emissions control policies are projected to reduce consumer consumption by a larger amount than the direct spending on emissions reduction itself. We performed some sensitivity analyses to see how much these effects might be driving up the projected costs relative to the costs that might be expected to result directly from the costs per tonne of carbon reduced.

We found that the effect of taxes on costs is significant. One feature of S.139 that exacerbates tax-related interactions is the provision for a Climate Change Credit Corporation (CCCC) under Subtitle C. This entity would be granted all of the carbon allowances remaining after a certain amount of free allocations to affected businesses. The CCCC would act as a trustee of the people, auction the allowances it is granted, and then disburse the proceeds to many entities. This provision means that the government would have no opportunity to use some portion of auction proceeds to offset declining government revenues due to a reduced GDP. As a result, the government will need to change tax rates in order to keep the debt from growing excessively. In our model runs, we let the personal income tax rate be adjusted to offset the lost tax revenue. The resulting increase in tax rate is fairly small, but it increases estimated consumption losses by about 60%. We determined this by altering our representation of S.139 so that the government would retain a sufficient amount of the allowance revenues from an auction to just offset other tax revenue declines. This eliminates the need for any tax rates to be changed. The remainder of the allowance value was given to the consumers (either via free allocations, direct rebates of auction revenues, or some combination of the two).[31]

This simple but important change could reduce the estimated costs by about 40%. This does not imply that our cost estimates are too high. Rather, it implies that other cost estimates that do not account for tax distortions are too low. For example, MIT's estimated consumer costs might be increased by as much as 60% if tax distortions were to be incorporated into their EPPA model.[32]

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[31] Technically speaking, we applied a lump sum rebate of the allowance values after netting out the requisite share for the government budgetary needs.

[32] Alternatively, S.139 could be amended to remove the provision for the CCCC, and to give the government access to whatever share of the allowance value it would need to offset increasing deficits. Such a provision need not entirely prevent free allocations and rebates to consumers, and it could reduce the costs that we have projected.

Overall, even after accounting for the tax interaction effects, our per household consumption losses for the amended S.139 remain much higher than those of other analysts. This brings us back to our belief that MRN's foresight and intertemporal optimization capabilities are the most fundamental cause of our differences. We have clearly demonstrated that expectations about the future beyond 2020 play a significant role in determining costs even in 2010. However, the question remains whether we might get more similar results if we could somehow "remove" intertemporal dynamics and foresight from the MRN model. We attempted to do this by altering a couple of parameters that drive these phenomena. We removed "foresight" by forcing all carbon prices to remain at their projected 2020 levels.[33] Additionally, we eliminated the ability of consumers to adjust their consumption decisions over time in response to changed costs over time.[34] Finally, we removed the tax rate adjustments. When all three of these changes are combined, we are able to project consumption losses in the range of less than 0.06%, or less than $70 per household per year. This finding supports our belief that the higher costs from our model reflect several advanced features in MRN that are lacking in other models.

[33] This was accomplished in a two-step process. First we ran the model with the more reasonable future expectations. We noted the price it forecasted for 2020. Then we re-ran the same scenario, but locked prices after 2020 to be the 2020 levels of the previous run.

[34] We accomplished this by reducing the model's intertemporal elasticity of substitution in the production of individuals' welfare from 0.5 to .05 (i.e., to nearly zero).

7. Conclusion

In summary, a Phase-I only version of S.139 would be less costly than the original version of the Bill, but its economic impacts would remain substantial, even in the first ten years of the cap (2010 through 2020). We estimate that costs to consumers, in terms of reduced consumption, would likely be above $300 per year per household.

Our estimates of costs are significantly higher than estimates from other models, even though we have used similar baseline, scenario, and control cost assumptions. After exploring model differences and performing sensitivity analyses, we have determined that the higher costs reflect responses of the economy to S.139 that are accounted for in our analysis and not in other studies:

- The MRN model incorporates a full intertemporal optimization, with forward-looking behavior on the part of consumers, who make adjustments to consumption patterns to smooth the impact of future anticipated costs over time, and businesses, which change investment behavior anticipating future returns on investment. There is direct evidence in our daily lives of people making such intertemporal adjustments:

    - The act of building up savings during one's working years in order to maintain a reasonable standard of living after retirement is an example of people attempting to smooth their consumption levels by anticipating future conditions.

    - The act of banking cheap allowances when an emissions cap is in its less stringent phases is an example of how businesses incur current costs to avoid higher future costs, based on expectations about future allowance prices.

  We find that estimated intertemporal adjustment by consumers, combined with reasonable expectations about long-term policy directions, more than doubles the pre-2020 costs of a policy (even though these adjustments reduce the present value of total costs over a 70-year time horizon). These additional pre-2020 costs remain large over the entire range of assumptions about future costs of carbon controls that are realistic to consider.

- The MRN model incorporates existing taxes that allow the government to provide a large suite of services that we need and want. Taxes in some form are necessary, but they do reduce the potential performance of the economy. MRN accounts for tax interactions, and additional pressures to increase tax rates that will result from S.139. We find that the real-world tax considerations in our model cause the full costs of a carbon policy to be about 60% higher than would be projected without accounting for these effects.

Conclusion

The most important implication of our research is that expectations of long-term policy and market directions affect consumer costs in the near-term quite substantially. Since climate change requires policy intervention for the next century and more, it is unrealistic to assume that a policy adopted in 2003 would terminate in 2020. Therefore the continuation of climate policy beyond Phase I must be addressed and included in any analysis of a policy such as the amended S.139 that does not directly set clear goals for the longer-term.

For this reason, we estimated costs for a wide range of assumptions about future costs of technological options to control carbon, and regarding the level of the carbon cap after 2020. The low-end cost estimates cited in this report reflect our most optimistic views on the direction of the carbon cap after 2020, and how control costs may be reduced through technological change. For the baseline projections and economic assumptions that most analysts are using, our per household cost estimates can only be reduced further by imposing unrealistic expectations about post-2020 policies, removing intertemporal adjustments, and also removing tax interaction effects that are tied to specific provisions in the Bill.