MIT Joint Program on the Science and Policy of Global Change

Analysis of U.S. Greenhouse Gas Tax Proposals

Gilbert E. Metcalf, Sergey Paltsev, John M. Reilly, Henry D. Jacoby and Jennifer Holak

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To inform processes of policy development and implementation, climate change research needs to focus on improving the prediction of those variables that are most relevant to economic, social, and environmental effects. In turn, the greenhouse gas and atmospheric aerosol assumptions underlying climate analysis need to be related to the economic, technological, and political forces that drive emissions, and to the results of international agreements and mitigation. Further, assessments of possible societal and ecosystem impacts, and analysis of mitigation strategies, need to be based on realistic evaluation of the uncertainties of climate science.

This report is one of a series intended to communicate research results and improve public understanding of climate issues, thereby contributing to informed debate about the climate issue, the uncertainties, and the economic and social implications of policy alternatives. Titles in the Report Series to date are listed on the inside back cover.

Henry D. Jacoby and Ronald G. Prinn,
Program Co-Directors

For more information, please contact the Joint Program Office

Postal Address: Joint Program on the Science and Policy of Global Change
77 Massachusetts Avenue
MIT E40-428
Cambridge MA 02139-4307 (USA)

Location: One Amherst Street, Cambridge
Building E40, Room 428
Massachusetts Institute of Technology

Access: Phone: (617) 253-7492
Fax: (617) 253-9845
E-mail: globalchange@mit.edu
Web site: http://mit.edu/globalchange/

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Gilbert Metcalf*§, Sergey Paltsev*, John Reilly*†, Henry Jacoby* and Jennifer Holak*

Abstract

The U.S. Congress is considering a set of bills designed to limit the nation's greenhouse gas (GHG) emissions. Several of these proposals call for a cap-and-trade system; others propose an emissions tax. This paper complements the analysis by Paltsev et al. (2007) of cap-and-trade bills and applies the MIT Emissions Prediction and Policy Analysis (EPPA) model to carry out an analysis of the tax proposals. Several lessons emerge from this analysis. First, a low starting tax rate combined with a low rate of growth in the tax rate will not reduce emissions significantly. Second, the costs of GHG reductions are reduced with the inclusion of non-CO_2 gases in the carbon tax scheme. The costs of the Larson plan, for example, fall by 20% with inclusion of the other GHGs. Third, welfare costs of the policies can be affected by the rate of growth of the tax, even after controlling for cumulative emissions. Fourth, a carbon tax – like any form of carbon pricing – is regressive. However, general equilibrium considerations suggest that the short-run measured regressivity may be overstated. A portion of the carbon tax is passed back to workers, owners of equity, and resource owners. To the extent that relatively wealthy resource and equity owners bear some fraction of the tax burden, the regressivity will be reduced. Additionally, the regressivity can be offset with a carefully designed rebate of some or all of the revenue. Finally, the carbon tax bills that have been proposed or submitted are for the most part comparable to many of the carbon cap-and-trade proposals that have been suggested. Thus the choice between a carbon tax and cap-and-trade system can be made on the basis of considerations other than their effectiveness at reducing emissions over some control period. Either approach (or some hybrid of the two approaches) can be equally effective at reducing GHG emissions in the United States.

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* Joint Program on the Science and Policy of Global Change, Massachusetts Institute of Technology
§ Department of Economics, Tufts University and National Bureau of Economic Research
† Corresponding author: John Reilly (Email: jreilly@mit.edu).

1. INTRODUCTION

Legislative proposals to impose price penalties on U.S. greenhouse gas (GHG) emissions fall into two categories: cap-and-trade systems and emissions taxes. Such economic-incentive-based policies can be highly effective in achieving pollution abatement, and they have desirable efficiency characteristics compared to so-called "command-and-control" instruments that mandate investment in particular technologies or specify design standards that apply uniformly across emitters. Ample evidence of the efficacy of price-based approaches is provided by U.S. experience with cap-and-trade programs, especially the SO_2 program, and some measure to impose a price penalty on GHG emissions is likely an essential part of any U.S. effort to reduce emissions.

Either of these approaches – cap-and-trade or tax – could yield a target level of abatement, and in the process they would have similar economic consequences, particularly considering that either can be adjusted over time. There are nonetheless advantages and disadvantages of each approach which are important inputs to discussion of the choice of approach. We review these distinguishing characteristics in Section 2. In Section 3, we discuss issues in the design and implementation of an emissions tax and lay out the features of the three bills under consideration now in the U.S. Congress. These include one submitted by Representative Larson, one by Representatives Stark and McDermott, and a third now in draft form by Representative Dingell. As in the analysis of cap-and-trade proposals by Paltsev, *et al.* (2007), the MIT Emissions Prediction and Policy Analysis (EPPA) model is applied to the analysis, and a brief description is provided in Section 4.

In Section 5 we present model results for the emissions reductions yielded by these proposals along with their economic cost and effects on energy markets. Also illustrated there are the effects of possible modifications of these bills, such as extension from their CO_2 focus to coverage of non-CO_2 GHGs and adjustments in the tax profile over time. Since one concern with such pricing proposals is their distributional consequences, Section 6 explores the impacts of these tax plans by income class. Finally, in Section 7 we provide some conclusions to be drawn from the analysis.

2. PRICE INSTRUMENTS FOR GHG MITIGATION

In a cap-and-trade system a government agency sets the number of emissions allowances, and trading among them determines their price.[1] Firms make abatement decisions based on the relative cost of purchasing (or not selling) allowances compared to the cost of abatement. Even if allowances are given for free, firms face an opportunity cost – the price they could sell them for in the market – if they choose to emit greenhouse gases. Under a tax approach the government sets the emissions price directly, and firms respond through decisions to pay the tax or abate. Under either policy emitters will tend to abate to the point where the marginal cost of emissions reduction is equal to the emissions price.

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[1] For an introduction to U.S. experience with cap-and-trade systems and issues in their application to greenhouse gases see Ellerman, Joskow and Harrison (2003).

Thus far nations have only limited experience with either taxes or cap-and-trade systems for control of greenhouse gases. Finland enacted the first GHG tax in 1990. It was followed by Sweden and Norway in 1991 (Brannlund and Gren, 1999) and Denmark in 1992. Some of these taxes evolved to become combined GHG-energy taxes as is discussed in Anderson and Lohof (1997). Quebec recently passed a GHG tax (Dougherty, 2007) and British Columbia has recently introduced a carbon tax (Fowlie and Anderson, 2008). In addition to these national-level initiatives, the European Union has embraced the cap-and-trade approach through its Emissions Trading Scheme (ETS) to meet its obligations under the Kyoto Protocol[2] and other nations are considering similar systems.

It is important to point out that there is not a stark either-or choice between tradable allowances and taxes. Hybrid instruments can be constructed, for example the addition of a safety valve to a cap-and-trade system where the government stands ready to sell permits at a fixed price thereby preventing permit prices from exceeding this level. With a safety valve, a cap-and-trade system works as a constraint on emissions only so long as the permit price is below the safety valve level; above that level the system works like a tax. Also, to the degree that allocations are auctioned rather than freely distributed, a cap-and-trade system has many characteristics of a tax. Still, even though either instrument, or various hybrids, can be effective at pricing GHGs, the pure versions differ in important respects.

2.1 Efficiency

An emissions tax and a cap-and-trade system can be designed to have equivalent efficiency effects so long as there is no uncertainty in the marginal costs of abatement. In the presence of uncertainty, however, the two systems can differ. Weitzman (1974) explores conditions under which a tax provides higher or lower expected social benefits than a cap-and-trade system in a world with uncertainty.[3] His analysis demonstrates the importance of the relative slopes of marginal damages and abatement costs in choosing the optimal instrument.

Weitzman's analysis needs some modification in the case of GHGs, because marginal abatement costs are a function of the flow of emissions, whereas marginal damages are a function of the stock of gases in the atmosphere. Several economists have modified Weitzman's model to allow for the stock nature of GHGs. While the analysis is more complicated and involves more than simply the relative slopes of marginal abatement and damage curves, the analyses consistently find that taxes dominate cap-and-trade systems for a broad range of parameter values consistent with scientific understanding of the global warming problem.[4] Regardless of these efficiency arguments, some advocates prefer a system with a quantitative cap out of a desire to be sure of some prescribed environmental gain.

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[2] A description and early assessment of the ETS system may be found in Buchner, Carraro and Ellerman (2006).

[3] The relative advantage of price versus quantity instruments depends on uncertainty in the marginal abatement cost curve only. Uncertainty over the marginal damages of emissions affects the net benefits of an emissions control policy but does not affect the relative superiority of one policy instrument over another.

[4] See Hoel and Karp (2002), Newell and Pizer (2003), and Karp and Zhang (2005).

In practice, of course, the efficiency difference among approaches may be smaller than these model estimates because in either case the level of policy stringency can be adjusted as evidence on the cost of abatement is revealed, and to the extent that features such as banking and borrowing allow smoothing of abatement among time periods. By the same token, the difference in certainty of emissions reduction is also easily overstated because a cap may be relaxed if prices rise too high, and tax plans can be tightened in the face of underachievement.

Another potential difference among the systems arises in application to U.S. electric utilities, some of which operate in deregulated markets while others remain subject to state-level rate regulation.[5] In a cap-and-trade system with freely distributed permits it is not clear to what degree regulators will allow utilities to pass the price of emissions allowances (*i.e*., their opportunity cost) through to customers if the permits have been given without charge. If they do not, consumers will face no incentive to reduce electricity consumption, thereby forcing more of the abatement elsewhere at higher cost. In the case of an emissions tax this issue is avoided because the incentive is uniform across utilities under various levels of regulation.[6]

2.2 Political Feasibility

It is argued that a major advantage of cap-and-trade over an emissions tax is its political feasibility. It is noted, for example, that the EU Emissions Trading System (ETS) is a demonstration that a cap-and-trade system can be implemented whereas an effort in the 1990s to implement an EU-wide GHG tax was a failure. A key factor in this EU experience was the fact that a decision to implement a tax required unanimity among EU members whereas the ETS required only majority approval. Political feasibility may thus depend in part on the specific features of different political systems. It is important to keep this factor in mind when considering instrument viability in the United States.

At first glance, U.S. experience also appears to support the argument that a cap-and-trade system is the more likely to be politically feasible. First, the U.S. has successfully implemented several cap-and-trade systems, *e.g*., for NOx emissions in some regions and for sulfur dioxide emissions from electric utilities on a national basis.[7] Second, the most recent effort to employ a tax instrument in this context was the BTU tax proposed by President Clinton in 1994. While the BTU tax passed the House, it failed in the Senate and was ultimately replaced by a 4.3¢ per gallon increase in the federal motor vehicle fuels tax, justified as part of a deficit reduction package.

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[5] Joskow (2006) provides a current overview of the state of competition in electricity markets.

[6] This is only a concern if permits are allocated to electric utilities. If permits are given further upstream (*i.e*. to coal mines or natural gas gathering points), then it is irrelevant whether electric utilities are regulated or not. The cost of permits would be included in the price of fuel purchased by regulated utilities and would presumably be allowed as part of the cost recovery in the rate-making process.

[7] See Ellerman *et al.* (2000) for a description and assessment of the sulfur program, and Ellerman, Joskow and Harrison (2003) for a review of the lessons for greenhouse gas control of previous U.S. experience with these systems.

Analysis of why the Clinton tax proposal failed is beyond the scope of this paper, but one factor is that a BTU tax is not an efficient penalty on CO_2 or GHGs because of the differences in emissions among fuels per heat unit. The tax did not have a sharply articulated focus but rather was a compromise between a carbon tax to address global warming and a broad-based energy tax. A tax based on carbon content would have provided incentives to substitute natural gas for coal, and the tax base was designed to win support from coal state legislators. The lack of a focus and the fundamental compromise embedded in the tax design made it difficult to fend off requests for exemptions and other loopholes. Moreover, the scientific case that climate change is a serious threat has become much more compelling in the past decade. Also, while the Clinton Administration was not successful with the BTU tax, it also made no progress in Congress with the idea of a cap-and-trade system. It may well be that, in a changed political climate motivated by growing concern about climate change the opposition to a tax instrument will be lower.

2.3 Revenue Generation

A GHG tax would raise revenue that could be used to lower other taxes, reduce the federal deficit or finance new government spending. A cap-and-trade system can raise revenue if the government auctions the permits rather than giving them away. While there is precedent in the U.S. for auctioning valuable rights (*e.g.*, broadcast spectrum, offshore oil leases), experience to date with cap-and-trade programs has been that the permits are given to regulated entities for free. However, there appears to be a growing willingness to auction allowances if the trend in proposed cap-and-trade legislation is evidence, but the degree to which such provisions will survive in any final legislation remains to be seen. Similarly, in its 2005-07 trial period the EU ETS allocated all allowances for free, but small percentages of auctioning are planned in some EU parties in the 2008-2012 Kyoto commitment period. Whether a GHG tax or cap-and-trade system with auctioning is chosen, a sizable economic literature demonstrates a "double-dividend" that can be gained from a revenue-raising instrument if the funds collected are used to lower other distorting taxes, such as those on labor and capital.[8]

2.4 Incentives for Rent-Seeking Activity

One reason for the perceived political advantage of cap-and-trade systems is the historic granting of free permits to the regulated entities, usually industrial and commercial firms. Permits are valuable assets and their allocation becomes a tool to help build support for the program. This creates incentives for industries to lobby to receive a large share of these assets. Commonly referred to as *rent seeking*, expenditure of resources to obtain valuable assets from governments is a socially wasteful activity and can lead to particularly inefficient outcomes. In addition, free distribution of allowances to entities that are the point of accounting and regulation can create an inequitable outcome because some firms will receive a valuable asset for free while

[8] See Goulder (1995) for a discussion of double-dividends and Fullerton and Metcalf (1998) for a history of this literature. Gurgel *et al.* (2007) provide an estimate of this effect using a forward-looking version of the MIT EPPA model.

passing most of the cost of abatement on to downstream fuel or electricity users. To the degree the distributional impacts of the policy are a concern, the design of allowance allocation under a cap-and-trade system requires detailed consideration of who actually bears the economic burden of the policy, *not* who happens to be given the task of turning in allowances or even who is directly responsible for abating emissions.

Experience in the EU ETS suggests that rent seeking can lead to restrictions on permits that may undermine some of their efficiency characteristics. For example, the ETS retains some allowances for new entrants, an incentive to create a new entity that would be eligible for some of these assets. It also requires that firms return allowances if an entire facility shuts down. The cheapest abatement option may be to simply shut down some of the highest emitting facilities, but this rule in the ETS creates an incentive to keep them operating at a low level, or to install more expensive abatement technology so that they do not have turn back in valuable allowances. These rules lead firms in these particular situations to equate the marginal cost of abatement to the price of emissions plus the value of the expected additional allocation of allowances or the value of all of the allowances they would have to turn in if they shut down. This result violates the efficiency criteria that all firms face the same marginal cost of abatement.

Another difficult aspect of allocation is what happens over time as adjustments are made to the level of allowances available to entities. The rent-seeking behavior of firms in getting allowances leads them to formulate their case on the basis of "need". There is thus a strong tendency to distribute allowances in some proportion to the level of emissions of firms. If emissions levels continue to be a basis for allocating new allowances in succeeding periods, the incentive to abate emissions is partly undermined because doing so might mean a lower allocation of allowances in the future.

Though competing interests may seek earmarks of expected revenue, a GHG tax does not create the same type of valuable financial asset to be allocated, as does a cap-and-trade system. While this may raise the political barrier to enacting a tax, it also may avoid an industry give-away that is weakly connected to the points where the costs will be felt. A concern with carbon taxes that has been frequently raised is that industry concessions will be required to obtain political support for carbon pricing and that providing free permits is more efficient than excluding industries from a tax. This is unquestionably true, but exclusion is not the only way concessions can be provided to the energy sector through a carbon tax. One alternative approach would be to provide an *emissions floor* similar to the health spending deduction in the personal income tax. An emissions floor would only levy a carbon tax on emissions above a given floor (*e.g.*, 3% of a three year moving average of emissions).

2.5 Administrative Cost

The U.S. already has a well-developed administrative structure to collect taxes. Levying the tax at an upstream level on a relatively small number of firms, all of which already pay taxes, would reduce the administrative and compliance costs of the tax considerably. The farther downstream the implementation, the greater the implementation cost. In contrast, a new structure would be needed if a cap-and-trade system were put in place. Moreover, benchmarking would be required for a cap-and-trade system if permits were allocated on the basis of historic emissions – as was done with the U.S. Acid Rain Program and the EU ETS.

Finally, if the European experience is followed and a downstream cap-and-trade program put in place, administrative complexity would rise considerably. In fact, the ETS exempts emitters of less than 10,000 tons of CO_2 per year and thereby only covers about 50% of the EU's emissions. The administrative costs of the U.S. Acid Rain Program are likely closer to those of an upstream GHG tax than a downstream trading system such as the EU ETS. Some of the cap-and-trade proposals in the U.S. have gone upstream for transportation fuels and so the coverage rises to 85%. Since fuel sales are well recorded and already taxed, there does not appear to be much reason that nearly 100% of emissions of carbon dioxide from fossil fuel combustion could not be covered with little administrative burden. The Acid Rain program, a very successful cap-and-trade system, was limited to a small number of large electric utilities in the United States, and other sources of SO_2, from transportation fuels for example, were regulated through other measures.

3. PROVISIONS OF U.S. TAX PROPOSALS

The economic and environmental effects of an emissions tax depend on its features within a particular country, and also on activities in other countries through the influence of trade in energy, non-energy goods and emissions allowances.

3.1 Proposed Tax System Design

Table 1 summarizes key features of the three tax proposals studied here. The Dingell proposal is still in draft, but Larson's plan has been filed as H.R. 3416 and the one from Stark and McDermott is numbered H.R. 2069. Features of such tax systems that are of importance in determining performance and cost are not fully defined in all cases, requiring additional assumptions on our part. Later we explore some possible extensions of these proposals.

Tax Rates. Emissions tax legislation will set a schedule of tax rates over time. For all three proposals the tax is on CO_2 only. As shown in table, the Larson and Stark-McDermott proposals impose the tax beginning in 2008. This target seems unlikely given the probable time lags in the political process, so we assume all proposals go into effect in 2012, which is the start year in the Dingell draft. Because the EPPA model operates every 5 years, the first period of modeled tax effect is 2015. The proposals involve different initial tax rates, and they also differ in the rules for adjusting that rate over time and for inflation. With the assumption of a 2012 start for all proposals, the resulting time profile of the CO_2 taxes is shown in **Table 2**, with the levels illustrated in **Figure 1**. They range from a constant \$14 per ton CO_2 under the Dingell proposal to a tax rising to \$561 per ton under provisions of the Larson Bill.

Table 1. Congressional Bills.

	Dingell Draft 2007	Larson 2007	Stark-McDermott 2007
Bill Number/ Name		H.R. 3416; America's Energy Security Trust Fund Act of 2007	H.R. 2069; Save Our Climate Act of 2007
Basic Framework	Carbon tax (on just carbon) and gasoline tax	Carbon tax (on just carbon)	Carbon tax (on just carbon)
Tax	\$50/ton C and \$0.50/gallon of gasoline, no increase in tax rates over time	Starting in 2008: \$15/ton CO_2, increase at 10% real annually	Starting in 2008: \$10/ton C, increase by \$10 nominal annually; tax is frozen when CO_2 emissions reach 20% of 1990 levels
Additional Details	• Carbon tax and gasoline tax phased in over 5 years and then adjusted for inflation • Carbon tax covers coal (including lignite and peat), petroleum and any petroleum product, and natural gas • Gasoline tax covers gas, jet fuel, kerosene (petroleum based), *etc.* Exemption for diesel and biofuels that do not contain petroleum	• Carbon tax covers coal (including lignite and peat), petroleum and any petroleum product, and natural gas which is extracted, produced, or manufactured in the U.S. or entered into the U.S. for consumption, use, or warehousing • Tax rate increase includes a cost of living adjustment • No tax on the sale of taxable substances for export •Provisions to ensure a substance is only taxed once, and credits or refunds (without interest) for previously taxed substances used to make another taxable substance	• Carbon tax covers coal (including lignite and peat), petroleum and any petroleum product, and natural gas which is extracted, produced, or manufactured in the U.S. or entered into the U.S. for consumption, use, or warehousing • No tax on the sale or exchange of taxable fuel for export or for deposit in the Strategic Petroleum Reserve •Provisions to ensure a substance is only taxed once, and credits or refunds (without interest) for previously taxed substances used to make another taxable substance
Provisions Related to Foreign Reductions		• It is the sense of Congress that the major GHG emitting countries will join with the U.S. in reducing GHG emissions	
Credit Provisions		• Credit or refund (without interest) for sequestered carbon and qualified offset projects in the U.S.	• Credit or refund (without interest) for embedded or sequestered carbon
Other Features	• Revenue from carbon tax goes to Medicare and Social Security, universal healthcare (upon passage), SCHIP, conservation, renewable energy R&D, and Low Income Home Energy Assistance Program • Revenue from gas tax goes to highway trust fund (40% for mass transit, 60% for roads) • Revenue from tax on jet fuel goes to airport and airway trust fund • Bill includes a phase out of the mortgage interest deduction on large homes. Revenue will be used to expand the Earned Income Tax Credit	• America's Energy Security Trust Fund: revenue from tax goes to: (1) tax credit for R&D and investment in clean energy technology (1/6 of fund or \$10 billion, whichever is less), (2) affected industry transition assistance (portion of funds from 2008, declines annually), (3) payroll tax relief (remaining funds) • Study shall be conducted on the best methods to assess and collect a tax on non-carbon GHGs	• Use of revenue from tax undetermined •A study shall be conducted every 5 years on the environmental, economic, and revenue impacts of the tax

* *Dingell Proposal:* http://www.house.gov/dingell/carbonTaxSummary.shtml; *Larson Proposal:* U.S. House of Representatives, H.R. 3416; *Stark Proposal:* U.S. House of Representatives, H.R. 2069

Note: Larson and Stark proposals start in 2008, but for our runs we started them in 2012.

Table 2. Carbon Tax Rates.

	CO_2-e Price ($/t$CO_2$-e)		
	Dingell	***Stark***	***Larson***
2015	14	10	20
2020	14	23	32
2025	14	34	52
2030	14	43	83
2035	14	51	134
2040	14	58	216
2045	14	64	348
2050	14	69	561

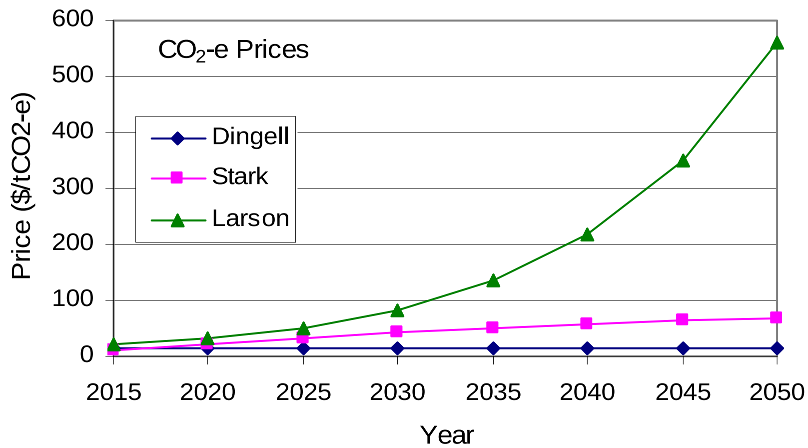

Figure 1. Carbon Tax Rates in the Core Scenarios.

Note also that the Dingell proposal contains a separate $0.50 tax on gasoline, imposed simultaneously with the tax on CO_2 emissions. It is held constant in real terms over time.

In Section 5 we also simulate cases that are modifications of the particular patterns in these bills to explore other regions of the possible space of tax activity and allow a comparison with results from the cap-and-trade analysis by Paltsev, *et al.* (2007). In order to compare the relative stringency of these GHG pricing systems, both among the emissions tax proposals and with the cap-and-trade bills, we estimate the cumulative emissions between 2012, when the tax is assumed to go into effect, and 2050 which is the end of the simulation period.

Point of Taxation. An emissions tax may be imposed either at an upstream level (mines, oil and gas wells), midstream (electric-generating plants and refineries) or downstream (energy using industries). The primary effect of this choice is to determine which entities must comply with the tax by monitoring emissions, maintaining records, and making tax payments. The direct cost of emissions abatement may not be incurred at this stage in the production process, and how much of the direct mitigation cost is passed forward to consumers is not a choice made by firms but rather depends on the underlying elasticities of supply and demand for the goods and services being produced.

For example, if one point of tax collection is at oil refineries, emissions abatement and associated cost would come mainly from reductions in fuel use downstream. The abatement would include additional spending for more efficient vehicles, heating equipment and alternative fuels, or the sacrifice of amenities that increase fuel consumption (*e.g.*, reducing the use of larger, more powerful vehicles). Refiners would bear any cost of abatement at their facilities, but would pass the bulk of the cost on to petroleum product consumers. Similarly, a chemical company will make essentially the same decisions about product line and equipment choices whether it pays a separate natural gas price along with taxes for the emissions released, or simply pays a higher fuel price that includes the tax cost premium.

The fact that cost incidence is determined by market forces then frees-up policy makers to levy the tax at the stage of production where administrative costs are lowest. The current texts of these bills are not specific about points of tax accounting and collection, so in the analysis below we assume that the tax is applied upstream where administrative costs are minimized.

Coverage by Sector and Greenhouse Gas. All three of the current proposals limit the tax to CO_2, omitting the other greenhouse gases (CH_4, N_2O and the industrial gases). In the analysis below we not only explore the CO_2-only cases, but also consider the implications of expanding the tax to cover non-CO_2 greenhouse gases. Specifically, we examine the cost reduction that could be gained by extending the tax to all GHGs while maintaining the same emissions result as under a CO_2-only tax.

A second design issue is the sector coverage. For example, a tax comparable in coverage to the EU ETS would cover electric utilities and heavy industry only. All three of the current proposals apply the tax to U.S. CO_2 from all fossil fuel use. The tax does not apply, however, to non-fossil sources such as processing emissions from the cement industry, and it exempts emissions embodied in fuels that are exported. The proposed tax also does not apply to land-use emissions from agriculture or forestry, which are also generally not included among the capped sources in cap-and-trade proposals. We match this coverage in the simulations, taxing energy use on the basis of carbon content while excluding exported fuels, land use sinks, and processing emissions.

Application of Tax Revenue. Proposals have been made in the past to rebate emissions tax revenues on a per capita basis.[9] Alternatively, the revenue can be used to lower other taxes to achieve distributional and/or efficiency goals.[10] One possible application of these funds is the reduction of taxes either on capital (corporate income, dividends or capital gains) or labor (earned income). Existing taxes distort choices in the economy and reducing them may lower this distorting effect and increase economic activity, an effect termed a “double dividend” because the GHG policy would yield not only an environmental dividend but also an economic one. There is a possibility that the efficiency improvements from tax reduction could completely

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[9] See, for example, the U.S. Sky Trust Proposal at http://www.usskytrust.org.

[10] Metcalf (2007) analyzes an emissions tax with revenue recycling to achieve distributional goals, and Gurgel *et al.* (2007) explore the double-dividend effect of recycling of auctioned permits in a cap-and-trade system to labor and capital taxes.

offset the direct cost of the abatement policy, an outcome called a "strong" double dividend. The case where the emission control cost is reduced but not completely offset by revenue recycling has been referred to as a "weak" double dividend. It is also possible if energy is highly taxed that revenue recycling can actually reduce economic activity (see Metcalf, Babiker and Reilly, 2004), but this outcome is unlikely in the U.S. where energy is only lightly taxed.

As summarized in Table 1, the three current proposals would spread the revenues across a wide variety of applications from lowering Social Security taxes to various forms of fuel assistance and expenditure programs. In the simulations below no attempt is made to model the effect of these specific provisions and the analysis assumes that revenues are redistributed in a lump-sum manner to the modeled consumer in the EPPA representation of the U.S. economy. While the amount of revenue raised through these tax proposals differs from the revenue raised in cap-and-trade proposals, tax revenues raise the same issues as the recycling of allowance auction revenue. For an analysis of this issue see Gurgel *et al.* (2007).

Provision for Tax Credits. However the system is defined in terms of sectors and gases, it may provide for the meeting of the tax obligation with allowances gained from both inside and outside the system. Tax credits are explicitly provided in the Stark and Larson Bills for carbon capture and storage activities. Two of the proposals provide for domestic credits such as those that might be defined for land-use and forestry projects, but they make no mention of crediting of reductions achieved in non-U.S. systems such as the Kyoto-sanctioned Clean Development Mechanism (CDM) or other trading systems such as the EU Emission Trading Scheme. These types of credits are not included in the simulations below.

4. ANALYSIS METHOD

4.1 The Emissions Prediction and Policy Analysis (EPPA) Model

To assess costs and energy system implications of an emissions tax we apply the MIT Emissions Prediction and Policy Analysis (EPPA) model. It is the same version of the model described in Paltsev, *et al.* (2007), so we only briefly describe its main features here. The standard version of the EPPA model is a multi-region, multi-sector recursive-dynamic representation of the global economy (Paltsev *et al.*, 2005). In a recursive-dynamic solution economic actors are modeled as having "myopic" expectations.[11] This assumption means that current period investment, savings, and consumption decisions are made on the basis of current period prices. This version of the model is applied below.

The level of aggregation of the model is presented in **Table 3**. The model includes representation of abatement of non-CO_2 greenhouse gas emissions (CH_4, N_2O, HFCs, PFCs and SF_6) and the calculations consider both the emissions mitigation that occurs as a byproduct of actions directed at CO_2 and reductions resulting from gas-specific control measures. Control can

[11] An alternative, forward-looking version of the EPPA model optimizes choices over time where economic actors are said to have perfect foresight (Gurgel *et al.*, 2007). The behavior of the forward-looking model in terms of abatement and CO_2-e prices is very similar to the recursive model, the main difference being that optimization through time leads to somewhat lower welfare costs as one might expect.

be limited to reductions in the emissions of: CO_2 from the combustion of fossil fuels or extended to include the industrial gases that replace CFCs controlled by the Montreal Protocol and produced at aluminum smelters; CH_4 from a number of sources; and N_2O from chemical production and improved management of inorganic fertilizer applications.

Table 3. EPPA Model Details.

Country or Region†	Sectors	Factors
Developed	***Non-Energy***	Capital
United States (USA)	Agriculture (AGRI)	Labor
Canada (CAN)	Services (SERV)	Crude Oil Resources
Japan (JPN)	Energy-Intensive Products (EINT)	Natural Gas Resources
European Union+ (EUR)	Other Industries Products (OTHR)	Coal Resources
Australia & New Zealand (ANZ)	Transportation (TRAN)	
Former Soviet Union (FSU)	Household Transportation (HTRN)	
Eastern Europe (EET)	***Energy***	Shale Oil Resources
Developing	Coal (COAL)	Nuclear Resources
India (IND)	Crude Oil (OIL)	Hydro Resources
China (CHN)	Refined Oil (ROIL)	Wind/Solar Resources
Indonesia (IDZ)	Natural Gas (GAS)	Land
Higher Income East Asia (ASI)	Electric: Fossil (ELEC)	
Mexico (MEX)	Electric: Hydro (HYDR)	
Central & South America (LAM)	Electric: Nuclear (NUCL)	
Middle East (MES)	Electric: Solar and Wind (SOLW)	
Africa (AFR)	Electric: Biomass (BIOM)	
Rest of World (ROW)	Oil from Shale (SYNO)	
	Synthetic Gas (SYNG)	
	Liquids from Biomass (BI-OIL)	

† Specific detail on regional groupings is provided in Paltsev *et al.* (2005).

Non-energy activities are aggregated to six sectors, as shown in the table. The energy sector, which emits several of the non-CO_2 gases as well as CO_2, is modeled in more detail. The synthetic coal gas industry produces a perfect substitute for natural gas. The oil shale industry produces a perfect substitute for refined oil. All electricity generation technologies produce perfectly substitutable electricity except for Solar and Wind which is modeled as producing an imperfect substitute, reflecting its intermittent output. Biomass use is included both in transport fuel and electric generation although it does not penetrate the electric sector in these simulations. There are 16 geographical regions represented explicitly in the model including major countries (the U.S., Japan, Canada, China, India, and Indonesia) and 10 regions that are aggregations of countries.

When viewing the EPPA model results for emissions prices and welfare costs it is well to remember that in any period the model seeks out the least-cost reductions regardless of what combination of the six categories of gases is controlled or which sector they originate, applying the same marginal emissions penalty across all controlled sources. This set of conditions, often referred to as “what” and “where” flexibility, will tend to lead to least-cost abatement. To the degree that emissions tax legislation departs from these ideal conditions, costs for any level of greenhouse gas reduction will be higher than computed in a model of this type.

The results also depend on a number of aspects of model structure and particular input assumptions that simplify the representation of economic structure and decision-making. For example, the difficulty of achieving any emissions path is influenced by assumptions about population and productivity growth that underlie the no-policy reference case. The simulations also embody a particular representation of the structure of the economy including the relative ease of substitution among the inputs to production and the behavior of consumers in the face of changing prices of fuels, electricity and other goods and services. Further assumptions must be made about the cost and performance of new technologies and what might limit their market penetration. Specifications of alternatives to conventional technologies in the electric sector and in transportation are particularly important. Finally, the EPPA model draws heavily on neoclassical economic theory. While this underpinning is a strength in some regards, the model does not reflect economic rigidities that could lead to unemployment or misallocation of resources, nor does it capture regulatory and policy details that can be important in the utility sector as discussed earlier.

Given the many assumptions that are necessary to model national and global economic systems, the precise numerical results are not as important as the insights to be gained about the general direction of changes in the economy and components of the energy system and about the approximate magnitude of the price and welfare effects to be expected given specific design features of an emissions tax. An uncertainty analysis of these proposals (*e.g.*, Webster *et al.*, 2003), a task beyond the scope of this study, would be required to quantify the range about any particular result, although the relative impacts of caps of different stringency would likely be preserved.

4.2 Assumptions about External Conditions

In addition to the features that may be built into emissions tax legislation, a number of external factors will influence the economic effects of the system. Two are of particular interest.

Non-U.S. mitigation measures. Estimates of the cost of emissions taxes in the U.S. will be influenced by emissions control measures being taken elsewhere. Most important, the level of global control will affect the prices of crude oil and other fossil fuels that the U.S. either imports or exports, and the prices of traded quantities of biofuels. Trade in non-energy goods also will be affected, although the effects on the U.S. are generally small in relation to the influence from trade in energy goods. To facilitate comparison with the analysis of cap-and-trade policies by Paltsev, *et al.* (2007), the same external conditions are assumed here, as follows.

- Europe, Japan, Canada, Australia, and New Zealand follow an allowance path that is falling gradually from the simulated Kyoto emissions levels in 2012 to 50% below 1990 in 2050.
- All other regions adopt a policy beginning in 2025 that returns and holds them at year 2015 emissions levels through 2034, and then returns and maintains them at 2000 emissions levels from 2035 to 2050.

Trade restrictions. Biofuels offer a relatively low-cost alternative for emission mitigation in the transport sector, and if unrestrained (and depending on emissions targets in other countries) the trade in these fuels can have large effects on land use and related issues of environmental degradation and food prices. In the U.S. biofuels are popularly seen as an abundant domestic resource that could reduce dependence on foreign oil, but despite this interest imports of ethanol into the U.S. are currently restricted by tariffs. Paltsev, *et al.* (2007) provide an assessment of the implications of such trade restrictions in a cap-and-trade framework. The insights from that analysis apply equally to an emissions tax, and so no analysis of these effects is supplied here.

5. TAX POLICY COST, EFFECTIVENESS AND ENERGY MARKET EFFECTS

5.1 Emissions Reductions and Welfare Effects

Figure 2 shows the total emissions from non-CO_2 GHGs weighted at their global warming potential value and CO_2 from fossil energy[12] for the U.S. with no mitigation policy and with each of the emissions taxes shown in Table 2 and Figure 1. The Dingell Bill keeps emissions about level for a decade or so, but growth resumes afterward driven by U.S. economic growth. Relative to emissions in the reference scenario (no policy in the U.S. or abroad), U.S. cumulative emissions are 13% lower over the 2012-2050 period. Tax levels under the Stark proposal are sufficient to keep GHG emissions approximately at today's level through mid-century with cumulative emissions 25% lower than in the reference scenario. Tax rates as specified in the Larson Bill would yield substantial reductions relative to the reference scenario with cumulative emissions lower by 46% over the control period.

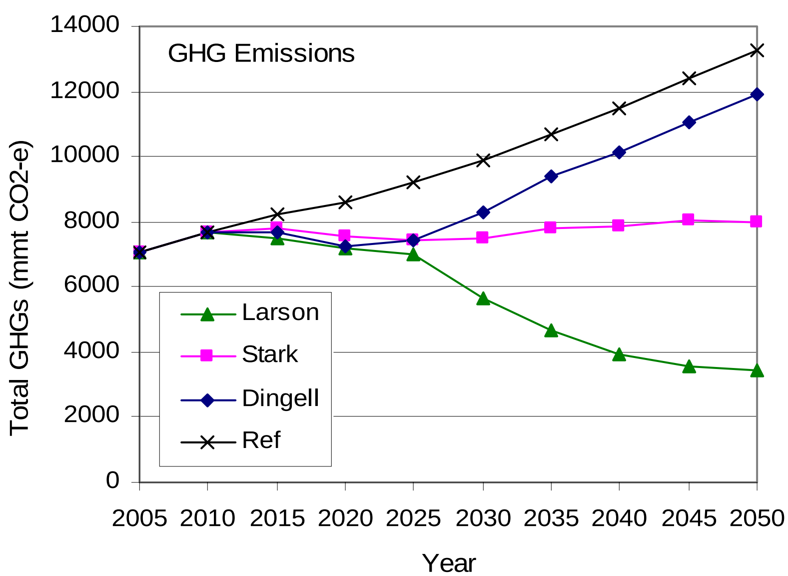

Figure 2. Total GHG emissions for core proposals

[12] We do not include an estimate of the land use sinks or of emissions from cement manufacture.

Welfare effects of these tax provisions are shown in **Table 4** and **Figure 3**. As discussed in Paltsev *et al.* (2007), the version of the EPPA model used here incorporates endogenous labor supply, allowing employment to respond to changes in the market economy. Under this formulation the welfare measure includes not only changes in aggregate market consumption but also effects on leisure time. The measure of overall economic cost we report is the change in welfare measured as equivalent variation.[13]

Table 4. Welfare Changes.

	Welfare Changes (%)		
	Dingell	***Stark***	***Larson***
2015	0.01	0.01	0.01
2020	-0.09	-0.09	-0.16
2025	-0.25	-0.27	-0.24
2030	-0.21	-0.39	-0.74
2035	0.07	-0.32	-1.25
2040	0.21	-0.38	-1.71
2045	0.32	-0.38	-2.08
2050	0.49	-0.33	-2.23
2012-2015	0.10	-0.30	-1.21

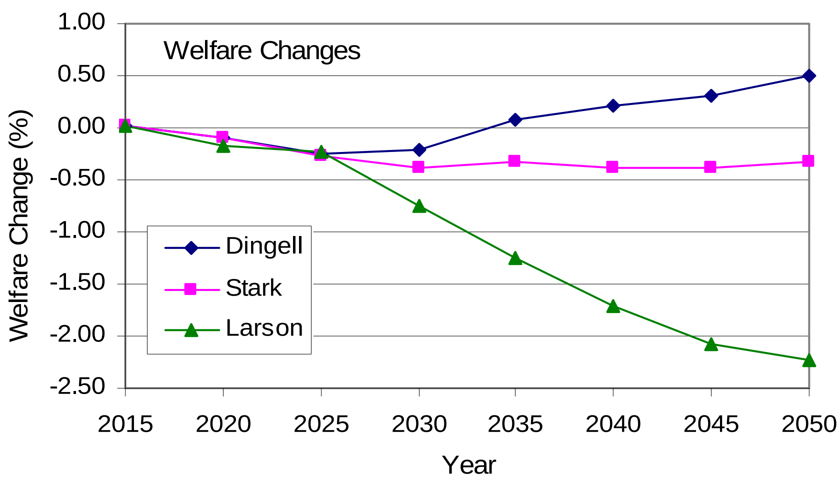

Figure 3. Welfare Impacts of Core Proposals.

[13] The general equilibrium modeling convention is based on economic theory whereby workers willingly choose to work or not, and when they choose not to work they value their non-work time at the marginal wage rate. GHG mitigation tends to increase the cost of consuming market goods and thus workers have a tendency to choose to work less, and thus have more non-work time. As a result, the percentage welfare changes in Figure 3 combine a loss of market consumption that is partly offset by a gain in leisure. Moreover, the denominator is larger by the amount of leisure accounted for in the model. How much non-work time to credit is somewhat arbitrary and so the denominator in this calculation can be made larger or smaller depending on how much time is accounted. For the model used here we assume a reasonable number of potential labor hours rather than accounting all waking hours of people of all ages, and so our measured welfare in the economy is about 18% larger than market consumption as reported in Appendix tables. For a discussion, see Matus *et al.* (in press).

The Dingell proposal has a very small welfare cost until after 2030 when the combination of assumed conditions yields a welfare improvement. The cause of this behavior is the terms-of-trade benefits resulting from emissions mitigation undertaken by other countries which outweigh the effect of the CO_2 tax (mainly through lower oil prices benefiting the fuel-importing U.S.). These terms-of-trade effects also partially counteract the welfare costs attributable to the Stark and Larson proposals. Larson is the most costly, leading to a reduction in welfare of over 2% by 2050. (Note this welfare measure does not include benefits from reduced climate risk or of ancillary benefits as may be gained in reduced air pollution.) Aggregate welfare losses (discounted to 2005 dollars) range from a 0.1% gain under the Dingell plan to a 1.2% loss under Larson.

Because of the importance of terms-of-trade effects it is useful to recall the underlying assumptions about international actions. These cases vary the stringency of the policy in the U.S. but leave unchanged the mitigation efforts of the rest of the world. Under the Larson proposal the U.S. takes on reduction targets similar to other developed countries with the developing countries following later. In the Stark and Dingell cases the U.S. effort eventually falls behind even that of developing countries.

In viewing these results it is well to keep in mind the political realism of the more- and less-stringent cases, where the U.S. makes a stronger or weaker effort in relation to others. For our purpose, a common assumption about external conditions provides a point of departure for comparing different U.S. effort levels. The importance of assumptions about mitigation efforts abroad in assessment of U.S. domestic proposals is further emphasized in Paltsev *et al.* (forthcoming) where we explore alternative scenarios of rest-of-world effort. Together these scenarios highlight the strategic implications of cooperative and non-cooperative mitigation that arise through terms-of-trade effects, further complicating policy coordination among countries with different impressions of climate impacts and with incentives to “free ride” on abatement efforts elsewhere.

5.2 Energy Market Effects

In this section, we consider the impact of the tax on energy markets.

Fuel Price Effects. A carbon tax has substantial effects on fuel and electricity markets, both in terms of prices and quantities consumed. In reviewing these results it is important to distinguish between the producer and consumer prices of fuels where the consumer price equals the fuel price plus a CO2 tax component that depends on the level of the tax and the CO2 content of the fuel. The GHG contents of fuels are relatively stable, so the price inclusive of the GHG tax can be calculated by adding the appropriate CO2 penalty for a gallon, barrel, ton, or tcf of the fuel. Table 5 shows the added cost resulting from a $27 per ton CO2-e tax for a variety of fuels and the percentage increase this implies relative to the average price for these fuels for 2001-2005 (excluding Federal and State excise taxes). (These figures indicate the initial impact assuming prices have not had time to adjust.) The percentage changes in price indicate the increase in the consumer price if the entire tax is passed forward to consumers. In reality (as discussed below), some of the burden of the tax will be shifted back to producers.14

In an upstream system the CO_2 tax will be embedded in the fuel price while in a downstream system consumers will pay separately for the fuel and for the tax. Mixed systems will have the CO_2 tax embedded in some fuel prices and separate from others. We follow the convention of reporting the fuel prices, exclusive of the tax, and electricity prices inclusive of the tax because the effect of CO_2-e prices on the electricity price depends on the mix of fuels, the degree of capture and storage, among other things, that change across scenarios.

Table 5. Relation between a ~$27/ton CO_2 Tax and Fuel Prices.

Fuel	Base Price Ave. 2002-2006 (2005$)	Added Cost ($)	Added Cost (%)
Crude Oil ($/bbl)	$40.00	$12.20	30%
Regular Gasoline ($/gal)	$1.82	$0.26	14%
Heating Oil ($/gal)	$1.35	$0.29	21%
Wellhead Natural Gas ($/tcf)	$5.40	$1.49	28%
Residential Natural Gas ($/tcf)	$11.05	$1.50	14%
Utility Coal ($/short ton)	$26.70	$55.30	207%

Source: U.S. average prices for 2001-2006 computed from DOE EIA price data. Base cost price is the 5-year (2002-2006) average price, except coal (2001-2005). To the gasoline price we have added $0.42 to include the federal and an average of state gasoline excise taxes.

The percentage price increases for fuels will vary from the estimates in Table 5 as the CO_2 tax varies, and also with changes in the fuel price. The EPPA model projects fuel price changes in the reference case, and also estimates how these prices will further change as a result of mitigation policy. In addition, the base price and price projection for any particular year is most appropriately viewed as a five-year average because the model simulates the economy in 5-year time steps. The results for the reference and three tax cases are shown in **Figure 4**. For a sense of the actual fuel prices projected in these scenarios, the index values in the figure can be multiplied by the base prices in Table 5.

The fuel price effects of a CO_2 tax can be summarized as follows: The producer price for petroleum products falls relative to the reference projection due to reductions in the crude oil price. This result reflects the fact that there is significant rent in the crude oil price, and the global policy to restrict GHG emissions reduces oil consumption, acting in effect like a monopsony buyer that extracts some of the producer rent. The reduction in overall world demand for oil has a strong effect, relative to the reference, in all cases. The relatively smaller

[14] More of the tax will be shifted back to producers (and ultimately to owners of fossil fuel resources) if the tax is part of a worldwide GHG pricing system.

difference among the policy cases occurs because only the stringency of the U.S. policy is varying. We also see the effect of strengthening of the policy in developing countries in 2035, which causes oil prices to fall relative to the reference.

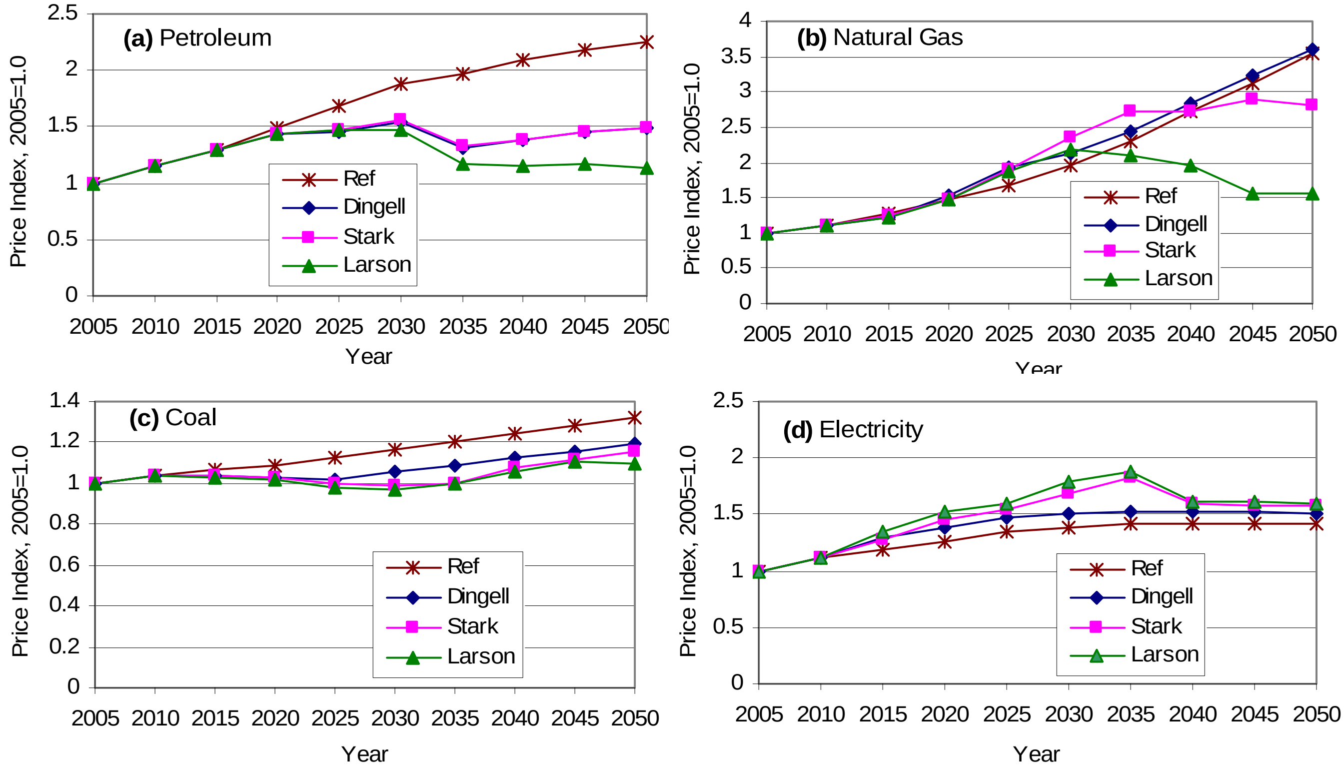

Figure 4. Fuel prices in the reference and core scenarios: **(a)** petroleum product prices, **(b)** natural gas prices, **(c)** coal prices, and **(d)** electricity prices.

Natural gas markets in EPPA are modeled such that international prices do not fully equalize, and so changes in domestic demand can have a larger effect on domestic prices. Whether this result accurately describes emerging global gas markets depends on how fast LNG infrastructure can be developed, especially whether terminals in the U.S. will be built to keep pace with demand, and LNG production facilities abroad can expand. Many analysts see a single world gas market emerging soon, and so the EPPA model structure may underestimate the potential role of natural gas and overestimate the rise in domestic prices. However, with a global policy other regions also change their demand for gas, and exert strong pressure on prices even with a world market.

With the Stark and Larson proposed emissions taxes, U.S. gas prices approximately follow the reference level for the first 10 years, then rise above the reference through 2030 or 2040 depending on the policy case, and then fall below the reference price. This price pattern reflects the changing role of gas under CO_2 policy. Depending on CO_2 and fuel prices, gas can be a relatively low-GHG fuel for electricity generation where it substitutes for coal. However, at higher GHG prices coal generation with CO_2 capture and storage (CCS) is even less CO_2 intensive and more economic. In other end uses for natural gas, such as in space heating, a CO_2

price spurs increased efficiency or a switch to electricity thereby reducing the demand for gas. Thus, the increase in the price of gas in middle years occurs when the increase in demand for gas for electricity generation is strong and offsets decreased demand elsewhere in the economy. As GHG prices rise further, coal with CCS displaces natural gas generation and the demand for gas, and its price, falls relative to the reference. How fast this transition occurs depends on the stringency of the policy. The flat \$50/tC (13.64\$/tCO_2) in the Dingell proposal is insufficient to bring in CCS, and so the main abatement option it spurs is substitution of gas for coal which dominates through 2050. Thus, unlike the other two proposals, we see a somewhat higher gas price through 2050.

There is relatively little rent in coal prices, so the model results show less adjustment in the price (and more in the quantity of coal consumed). Also, once tax rates rise enough to support coal generation with CCS, coal demand and prices recover. The Dingell Bill is, again, different in character because the tax rate is insufficient to spur adoption of CCS. With growth in the economy and rising gas prices, coal generation without CCS begins to grow again. The electricity price is inclusive of the GHG tax and emissions mitigation increases prices relative to the reference. The EPPA model includes increasing adjustment costs when technologies expand rapidly. In the more stringent Stark and Larson cases this feature of the sector results in electricity prices overshooting the long run level and then falling to their more normal long run level by 2040. By that time, the electricity sector is substantially decarbonized. The difference between the electricity price in the policy cases and the reference is the marginal cost of adding capture and sequestration plus any difference in the carbon tax times any remaining emissions. Since we assume a capture efficiency of 90% and upwards, differences in the carbon tax across these two scenarios have a minimal effect on electricity prices. In contrast, in the Dingell Bill CCS is not adopted and so the electricity increase reflects the roll-in of the carbon tax. Note that under the baseline it is assumed that coal generation improves in efficiency, and higher fuel prices (inclusive of the carbon tax) lead to further substitution of labor and capital for fuel implying a further effort to improve efficiency of the coal generation.

Table 6 shows how the carbon tax is distributed between producers and consumers of fossil fuels under the various tax proposals.[15] In addition to the three Congressional proposals, we include a hypothetical carbon tax that allows for 287 billion metric tons of emissions over the 2012-2050 control period. This tax is on all GHGs and starts at \$18 per ton CO_2-e and rises at a 4% rate (real) annually.

The carbon tax on coal products is predominantly shifted forward to consumers in all tax proposals. This reflects the lack of Hotelling rents in coal. The natural gas burden shifting differs significantly between the Dingell proposal and the other proposals. Natural gas prices first rise as demand for gas as a substitute for coal in electricity generation drives its price up. Thus, the incidence on consumers is greater than 100% for some periods because the full tax is

[15] Producer and consumer prices with the emissions tax are compared to a scenario in which the United States is not undertaking a GHG policy but other countries are. The price changes between these scenarios allow us to measure the incidence.

passed forward and the producer price also rises. Carbon capture and storage reverses this substitution into natural gas by 2040 and drives natural gas prices down for all the tax plans except for Dingell's. This illustrates the point that a low carbon pricing policy will simply shift demand from coal to natural gas without providing sufficient incentives to substitute towards non-CO_2 emitting power sources. Between two-thirds and three-quarters of the burden of the carbon tax on crude oil is passed forward to consumers in the form of higher prices. Given the structure of the EPPA model, which includes an efficient global market for crude oil (a Hecksher-Ohlin assumption) but assumes coal and gas are imperfect substitutes among countries (imposing an Armington trade pattern), the oil price incidence is most affected by policies abroad.

Table 6. Consumer Share of Carbon Tax Burden.

	2015	2020	2025	2030	2035	2040	2045	2050
Coal								
Dingell	0.97	0.95	0.91	0.93	0.93	0.93	0.94	0.94
Stark	0.97	0.97	0.95	0.95	0.96	0.97	0.98	0.98
Larson	0.98	0.97	0.97	0.97	0.98	0.99	1.00	1.00
287 bmt	0.98	0.97	0.94	0.94	0.95	0.96	0.97	0.98
Natural Gas								
Dingell	0.78	1.25	2.88	2.23	2.30	2.27	2.19	1.59
Stark	0.79	1.01	1.75	2.03	2.01	1.28	0.86	0.14
Larson	0.78	0.98	1.43	1.33	0.94	0.73	0.60	0.68
287 bmt	0.73	0.98	2.14	2.52	1.85	1.49	0.73	0.14
Crude Oil								
Dingell	0.78	0.67	0.07	0.02	0.55	0.60	0.70	0.71
Stark	0.74	0.76	0.53	0.58	0.74	0.74	0.75	0.71
Larson	0.81	0.81	0.66	0.61	0.72	0.78	0.84	0.88
287 bmt	0.89	0.87	0.85	0.84	0.80	0.78	0.77	0.73

Effects on the Structure of Primary Energy Use. As presented in **Figure 5**, all three CO_2 tax proposals show reductions in primary energy use compared to the reference case, an increase in the use of natural gas through about 2030 that parallels a significant absolute reduction in the use of coal, and growth in the use of coal again after 2030. Shale oil production begins to take market share in 2045 in the reference but it is driven out of the market under all of the tax proposals. The return of coal use in the Stark and Larson scenarios is a result of the economic viability of coal power generation with carbon capture and storage (CCS). Under the Stark Bill most coal use is CCS by 2040 while under the Larson Bill CCS dominates by 2035. As noted previously, in the Dingell scenario coal with CCS is never used. The carbon price is too low to induce the shift to this more expensive technology.

As might be expected from the imposition of a constant tax level, the Dingell Bill has most of its effect in the period to 2025, with some demand reduction and substitution of natural gas for coal. The time of maximum demand reduction is 2025 after which this effect is overwhelmed by economic growth.

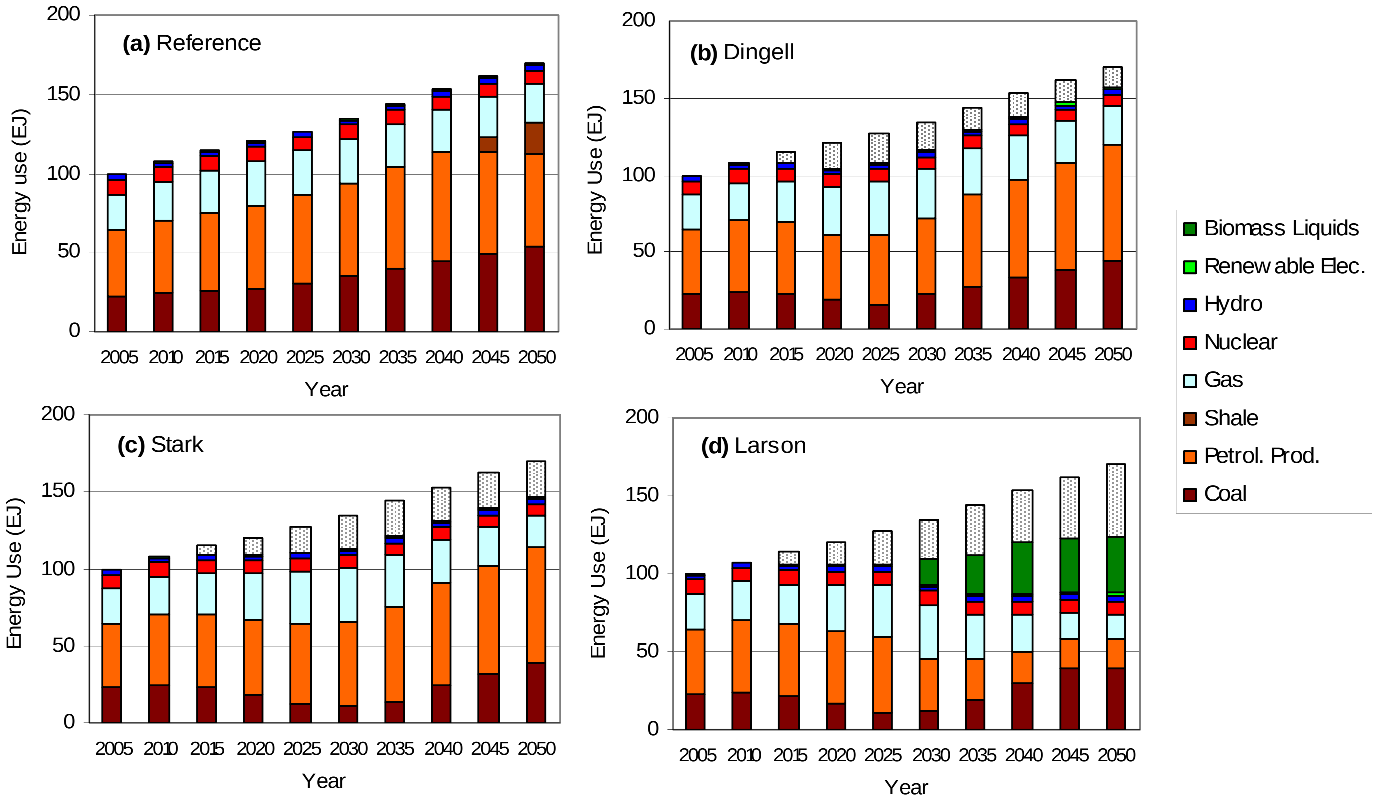

Figure 5. Primary energy use in the reference and core scenarios: **(a)** reference case, **(b)** Dingell, **(c)** Stark, and **(d)** Larson.

The most dramatic change in the structure of energy use would be produced by the Larson proposal. The demand reduction is large and growing with time and the rising tax pressure. Natural gas demand increases above reference levels through about 2030 and then declines as the tax drives even natural gas out of the market. Coal is hit very hard in the period 2020 to 2035, but then recovers as carbon capture and storage (CCS) becomes available as an option at large scale. The other striking feature of the Larson proposal is the very large increase in biofuel liquids to replace petroleum products in the transport sector.[16] In this case petroleum product use falls over 50%, whereas in the reference case petroleum product use rises by about 87%.

[16] At this point it is worth recalling the dependence of results on EPPA model structure and input assumptions. It is assumed that biofuels will be allowed to compete for market share on an economic basis, without constraints because of environmental or other side effects. The same assumption applies to CO_2 capture and storage. Relaxation of these assumptions about competition on an economic basis would raise the estimated emissions price and welfare cost of each of the cap-and-trade cases. On the other hand, the reference scenario does not fully address environmental issues associated with shale oil development and continued expansion of fuel use and

The Stark proposal lies somewhere between the other two systems in terms of effect on energy structure. Coal use is again reduced in the period 2020 to 2035, again to be saved by the large-scale introduction of coal with CCS. Gas use is reduced by mid-century, but not as strongly as under the Larson proposal. Interestingly, at the Stark-proposed tax levels oil stays in the market to 2050, and biofuels do not take market share.

In all these simulations the assumption is made that nuclear power is restrained by public acceptance. If nuclear is allowed to enter on purely economic grounds, given the cost assumptions underlying the analysis, we would see a significant increase in nuclear generation, especially with the tax outlined in the Larson plan. An analysis in Paltsev, *et al.* (2007) of a cap-and-trade system limiting emissions to 203 bmt shows a six-fold increase in nuclear power capacity by 2050 in the absence of political constraints on its use. With projected cumulative emissions of 216 bmt, the Larson proposal should lead to a similar growth in nuclear power. Whether it is realistic to expect a six-fold increase in nuclear capacity in the U.S. over the next forty years remains to be seen. Further, whether nuclear or coal with CCS, or some combination of the two, is used depends critically on their relative cost and the policy environment surrounding them, both of which are highly uncertain.

It is important to note that the large demand for biofuels in the Larson case is a result of it being the main alternative to fossil-based transportation fuel in the EPPA model. If the model included relatively low cost vehicles that could be run in total or in part on electricity—an option requiring improvements in battery technology—then the demand for biofuels could be substantially reduced, to be replaced by demand for electricity. The basic determinant of which technology wins in an economic model, presuming an equal quality of service delivered, is which is less expensive. Where there are close technology competitors, small changes in estimated cost, well within ranges of uncertainty about where breakthroughs may occur, can lead to a different technology choice and mix of energy inputs.

5.3 Alternative Versions of the Tax Proposals

In this section we consider two variants on the tax proposals before Congress. First we consider the impact of including all GHGs in the tax base for the carbon tax. Broadening the base should lower the welfare costs of achieving given reductions. Second, we investigate the impact of altering the rate of adjustment of the carbon tax over time.

Advantages of All-GHG Mitigation Policies. Subjecting non-CO_2 greenhouse gases to the emissions tax can be important in reducing the policy cost. Reilly *et al.* (2006) provide an evaluation of the cost-effectiveness and climate effects of including non-CO_2 GHGs in a control regime. These findings suggest that even though their relative importance falls over time in policies aimed at substantial reductions in greenhouse gases, their overall role in a cost-effective

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associated pollutant emissions. Adding environmental constraints on these could change technological choices in the reference and reduce fossil fuel use from what we project thus leaving less reduction needed to meet a given greenhouse gas target.

strategy should not be overlooked. Initial levels of reduction of several of these gases can be achieved at low cost relative to CO_2, so they are a natural early target for control efforts.

We ran scenarios where the carbon tax is applied to all GHGs and the tax rate is increased at the growth rate specified in the bills, but the initial tax rate is adjusted so that cumulative emissions are unchanged from the tax scenarios analyzed above.[17] For example, the Larson Bill has an initial tax rate in 2015 of $19.96/t$CO_2$-e that grows at 10% real annually and results in 216 bmt of cumulative emissions over the control period. To get the same cumulative emissions while including all GHGs and maintaining the 10% tax rate growth, the initial 2015 tax rate can be lowered to $13.30/t CO_2-e, decreasing the tax rate for all subsequent years as well. By 2050 the tax rate falls sharply relative to the CO_2-only rate: $374 versus $561. Similarly, the tax rates in the Stark plan are reduced by $8.94 per ton in each year. Thus the tax rate in 2015 is $1.50 and rises to $60.05 per ton CO_2-e by 2050. The tax rate under the Dingell plan drops from $13.64 per ton CO_2-e to $12.80. See **Figure 6**.

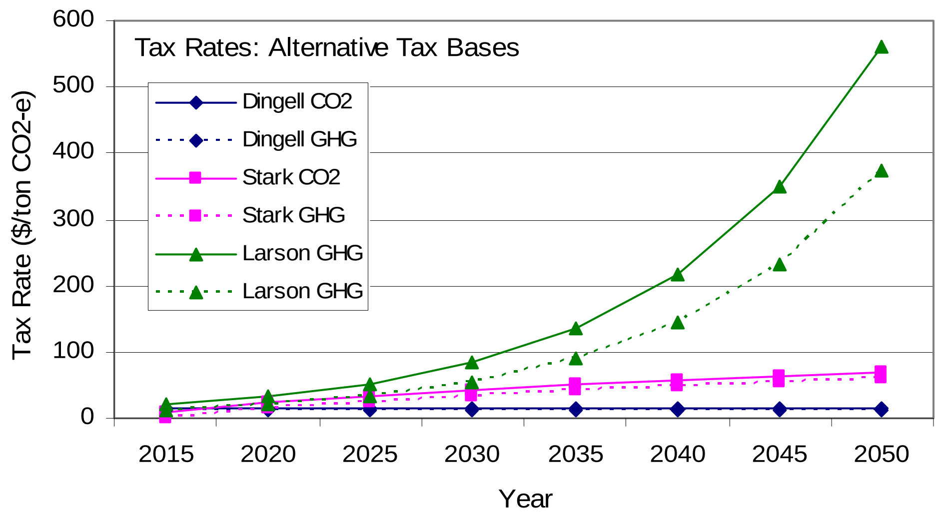

Figure 6. Tax Rates, All-GHG Application and CO_2-Only.

Figure 7 compares the welfare effects of the all-GHG and CO_2-only implementations for the same mitigation in terms of CO_2 equivalent emissions. Including all GHGs in the Dingell tax has little impact on welfare, in large part because the welfare effects are dominated by terms-of-trade effects occurring as a result of the policies undertaken abroad. For the Stark plan, the aggregate NPV welfare costs are reduced from 0.30% to 0.11%, a reduction of nearly two-thirds. Including all GHGs in the Larson plan reduces aggregate NPV welfare costs from 1.21% to 0.96%, a reduction of 20%. The welfare costs under the Larson Bill diverge sharply between 2030 and 2040 due to the differential entry of high-cost liquid biofuels. Biomass liquids enter in a significant way under the CO_2-only scenario in 2030 while they enter a decade later under the all-GHG tax scenario.

[17] For the Dingell tax on all GHGs, we do not include the gasoline tax.

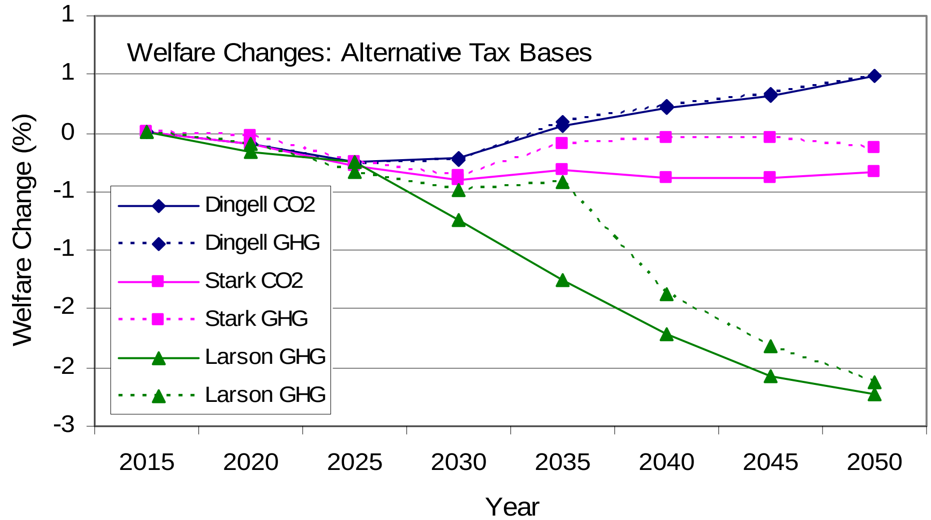

Figure 7. Welfare Costs, All-GHG Application and CO_2-Only.

Adding the other greenhouse gases to the tax base has a substantial impact on GHG mitigation under the various scenarios. **Table 7** shows what share of the reduction in 2015 comes from each gas and how much the gases are reduced under the Larson Bill. The fluorinated gases, for example, are driven nearly to zero and account for one-fifth of the total reduction in that year. **Figure 8** shows the distribution of GHG reductions under the Larson Bill in different years. Half the reductions in 2015 arise from reducing non-CO_2 gases despite their being a small fraction of total GHG emissions in that year. The large jump in CO_2 emission reductions in 2040 reflects the entry of liquid biofuels. Abatement opportunities for the non-CO_2 gases are relatively inexpensive, but are exhausted at relatively low prices. Thus, their share of abatement and their effect on welfare costs is strongest when CO_2-e prices are relatively low (*i.e.* in early years of policies with growing tax rates, such as the Larson Bill, or policies that have relatively lower tax rates overall, such as the Dingell proposal).

Table 7. GHG Reductions in 2015 Under the Larson Bill Applied to all GHGs.

	Reduction (mmt CO_2e)	Share of Total Reduction	Percentage Reduction for Gas
GHG	1093.9	100%	13%
CO_2	533.3	49%	8%
CH_4	229.5	21%	38%
N_2O	125.4	11%	33%
Fluorinated Gases	206.1	19%	96%

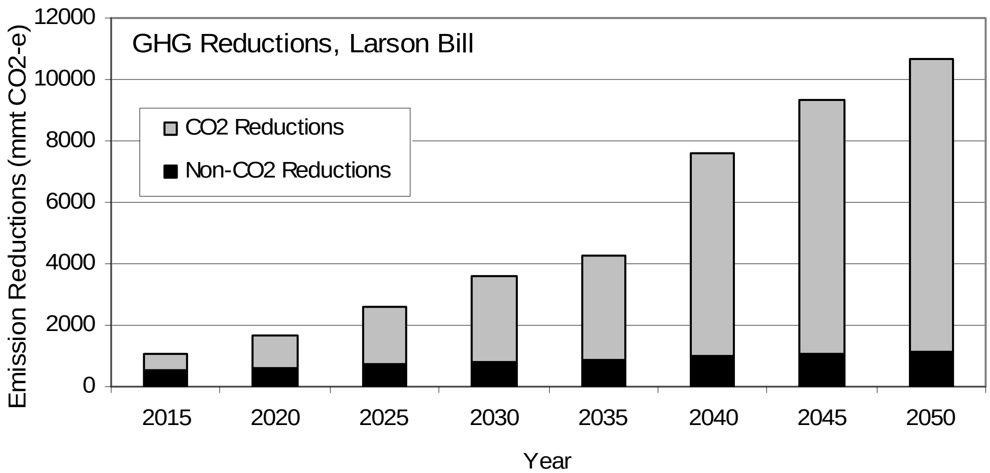

Figure 8. GHG Reductions in the Larson Bill.

Tax Rate Growth. The various tax proposals differ in tax rate adjustment over time. In this section, we analyze how emissions and welfare are affected by changes in the tax rate profile over time. The Dingell proposal fixes the carbon and gasoline tax rates in real terms over the control period. We consider two variants (illustrated in **Figure 9**). First we consider modifying the proposal to allow the carbon tax and tax on gasoline to grow at 4% real over the control period. This reduces aggregate emissions from 350 bmt to 286 bmt, a reduction of 18%. Second, we broaden the tax base in this second variant to cover all greenhouse gases, eliminate the gasoline tax, and set the initial carbon tax to achieve aggregate emissions of 286 bmt as in the first variant. These variants demonstrate that in general an increasing tax rate is needed to keep emissions growth from reoccurring in a growing economy.

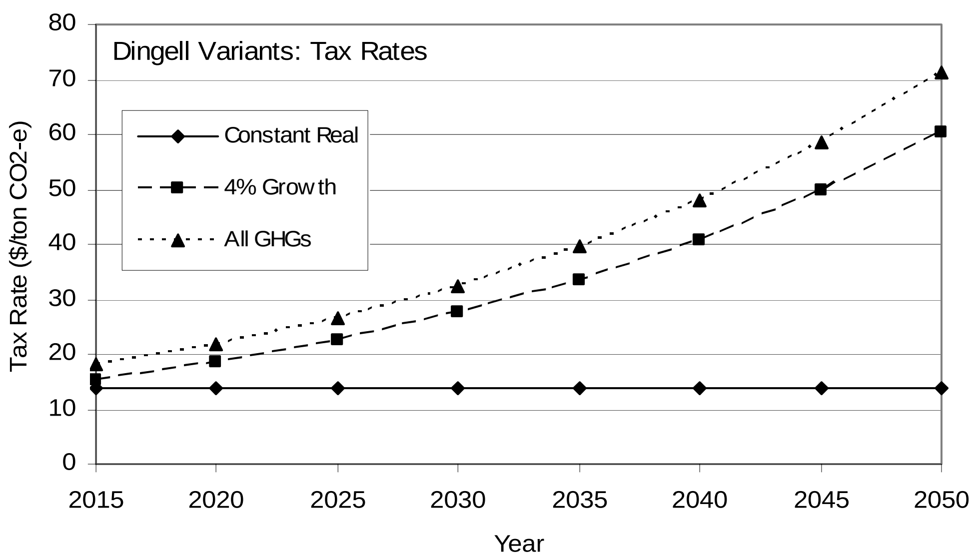

Figure 9. Dingell Tax Rate Variants.

Figure 10 shows the welfare impacts of the original proposal and the two variants. Now there is a modest welfare loss under either variant reflecting the more stringent policy. The figure demonstrates that it is more efficient to broaden the carbon tax to include other GHGs than it is to increase the gasoline tax. Taxing all greenhouse gases instead of carbon along with a higher gasoline tax cuts the aggregate NPV welfare loss nearly in half, from -0.44% to -0.23%. This occurs because of the inexpensive opportunities to reduce other greenhouse gases, many of which have very high global warming potentials. The message from these two scenarios can be extended. In general, it is more efficient to achieve a given GHG reduction through a broad-based carbon tax (or cap-and-trade system) rather than combining a partial carbon pricing scheme with sectoral regulatory schemes.

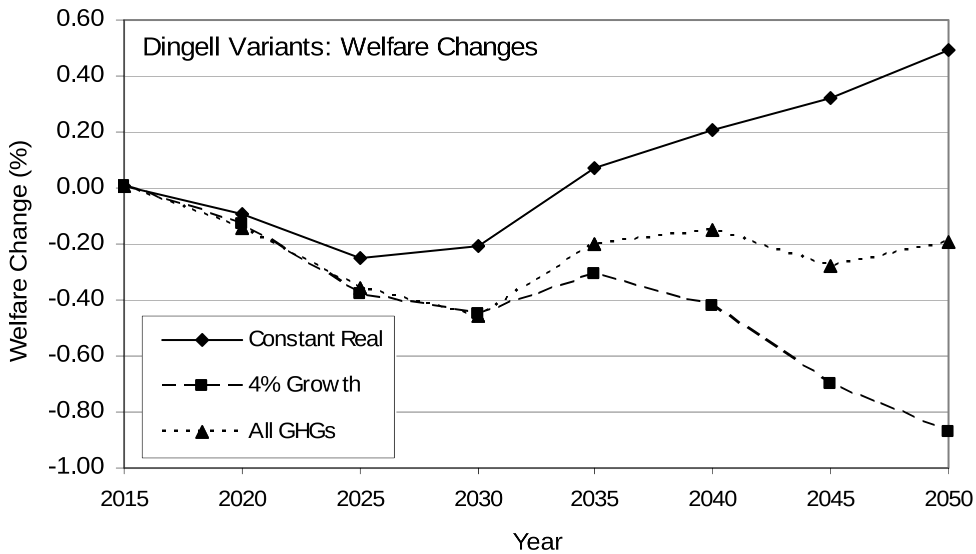

Figure 10. Welfare Changes under the Dingell Variants.

The Stark Bill increases the tax rate by \$10 per ton C (\$2.73 per ton CO_2-e) per year in nominal terms. By the end of the control period, the annual increase in the tax rate is quite small in real terms. Our first variant on this bill is to increase the tax rate by \$10 annually in real terms. This leads to a tax rate of over \$100 per ton CO_2-e (in year 2005 dollars) in 2050 in contrast to the Stark Bill which leads to a rate of just under \$70 per ton CO_2-e by 2050 (in year 2005 dollars). This reduces aggregate emissions modestly from 301 bmt to 289 bmt, a reduction of 4%. The second variant is to broaden the tax base to include all GHGs and increase the tax rate by \$10 real annually. The initial tax rate is set to achieve the same aggregate emissions as in the first variant. To match these aggregate emissions while increasing the tax at the same rate, the tax is imposed beginning in 2016.[18] By 2050 the tax rate rises to roughly \$95 per ton CO_2-e. Tax rates for the original bill plus the two variations are shown in **Figure 11**.

[18] Strictly speaking it begins in 2015 with a tax rate of one-third of a cent per ton CO_2e.

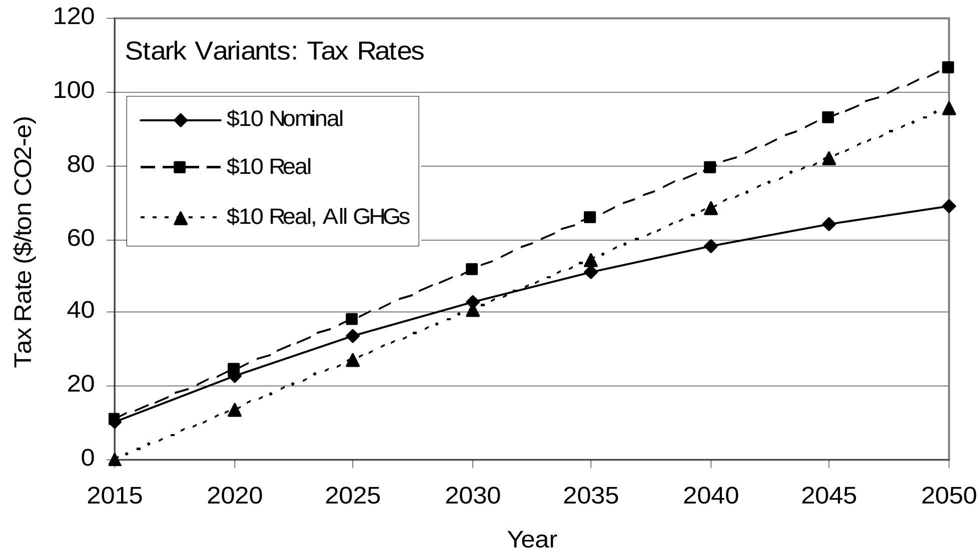

Figure 11. Stark Tax Rate Variants.

Figure 12 shows the welfare impacts of the variations on the Stark Bill. Simply shifting from a nominal to a real increase in the rate raises the welfare cost modestly, especially after 2035 when the tax rates begin to diverge sharply. The aggregate NPV welfare loss rises from 0.30% to 0.35% reflecting the more stringent emission limits in this case. Broadening the tax to include all GHGs allows the tax rate to start at a much lower level. This combined with the greater range of emission reduction options open to firms lowers the welfare cost substantially with the aggregate NPV cost now 0.23%. This scenario provides an opportunity to achieve greater emission reductions at a lower U.S. welfare cost than in the Stark Bill as filed.

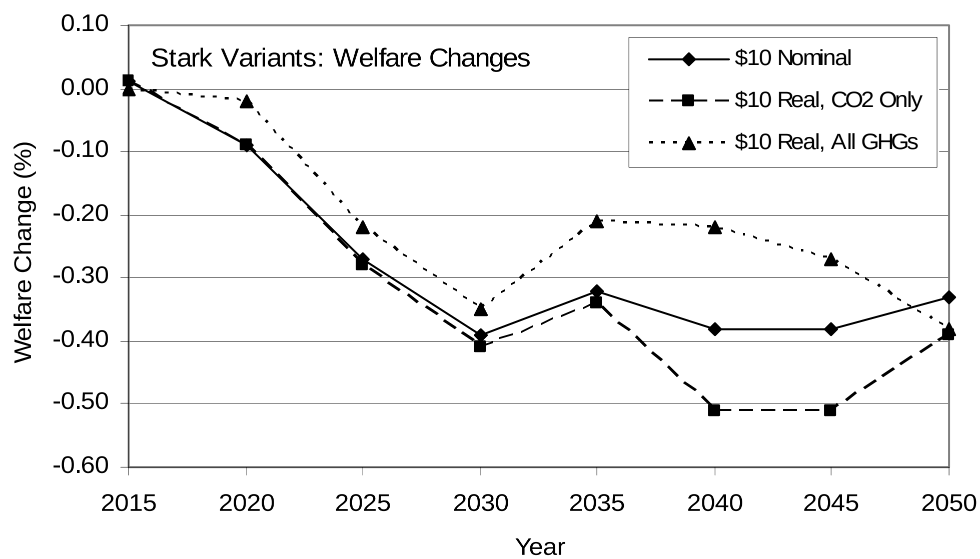

Figure 12. Welfare Changes under the Stark Variants.

Lastly, we look at the Larson Bill to consider how different growth rates for the tax can affect welfare. Recall in the previous sub-section we considered broadening the tax base to cover all GHGs while increasing the rate at a 10% real annual growth rate and lowering the initial tax rate to achieve the same aggregate emissions over the control period (216 bmt). Here we maintain the tax on all GHGs but lower the growth rate for the tax from 10% real to 4% real annually while adjusting the initial tax rate to achieve the same aggregate emissions between 2012 and 2050. The tax rates for the Larson Bill and the two variants are shown in **Figure 13.** The slower growth rate for the tax leads to a rate in 2050 of $150 per ton CO_2-e, a reduction of 60% relative to the 2050 rate for the all-GHG tax rising at 10% annually. As noted above, broadening the tax base to include all GHGs lowers the aggregate NPV welfare cost from 1.21% of welfare to 0.96%. Adjusting the tax schedule to achieve the same emissions while increasing the tax rate at 4% annually lowers the cost further to 0.78% (see **Figure 14** for welfare impacts).

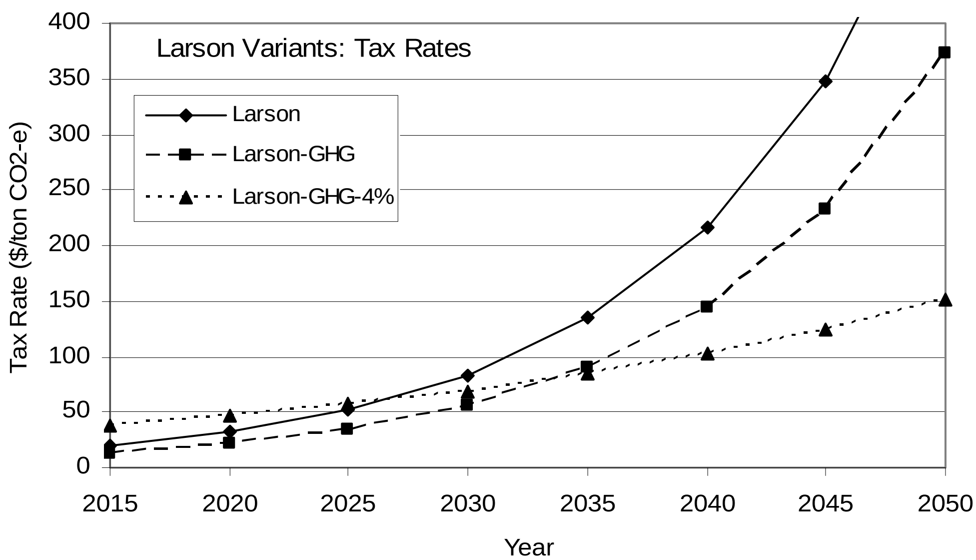

Figure 13. Larson Tax Rate Variants.

This result raises an important policy design point for carbon tax proposals. Optimal tax design would set a schedule of tax rates over the control period. How should we set those rates? Absent uncertainty, the tax rate should grow at an annual rate equal to the rate of return on assets of comparable risk. The argument is straightforward. In the absence of uncertainty, tax and permit systems will operate identically if designed to have the same price profile over time. Consider a permit system in which all the permits are given out at the beginning of the policy. Permits would be an asset that could be used now or saved for future use. Financial arbitrage ensures they earn the same rate of return as other assets. Since permits pay no dividend, their price must increase at this given rate of return. Any other time profile for carbon prices will lead to lower overall welfare. Since a permit system can be replicated with a tax, in the absence of uncertainty the optimal tax system would have tax rates growing at an annual rate equal to the rate of return of otherwise identical assets to permits.[19] That the welfare cost of the Larson Bill decreased with the 4% tax growth rate compared to the 10% tax growth rate reflects this theoretical result.

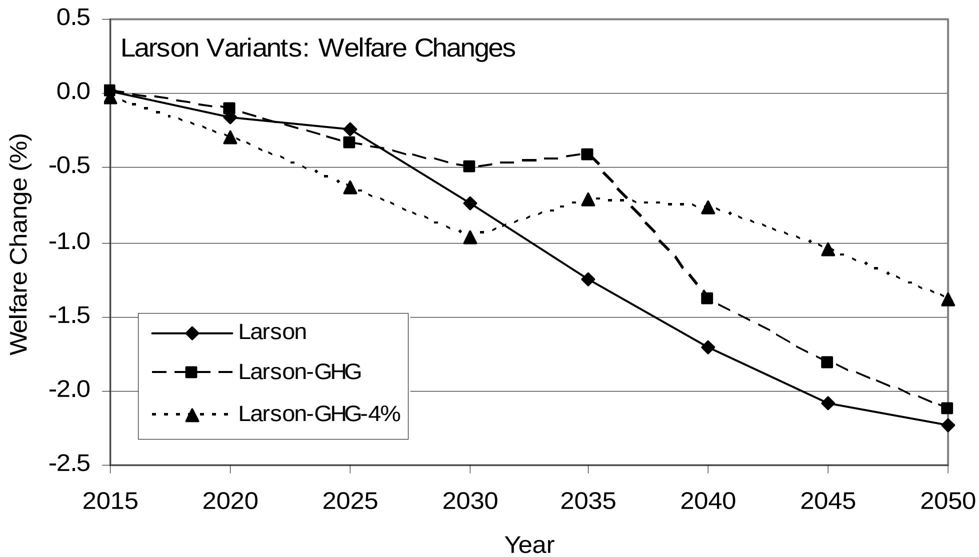

Figure 14. Welfare Changes under the Larson Variants.

5.4 Comparison of the Congressional Tax and Cap-and-Trade Proposals

In Paltsev, *et al.* (2007) we describe and analyze a number of Congressional cap-and-trade proposals. In that analysis, the cap-and-trade bills allow anywhere from 148 to 306 billion metric tons of cumulative emissions between 2012 and 2050. These measures impose reductions in emissions between 24 and 63% from the business as usual scenario. Initial carbon prices range from $7 to $53 per ton CO_2-e in 2015. Prices in 2050 range from $39 to $210 per ton CO_2-e. Welfare losses in most cases are modest, with the largest loss in 2050 equaling less than 2% of welfare.

Since that analysis, attention has focused on revised bills including one by Senators Lieberman and Warner (S.2191) and one by Senators Bingaman and Specter (S.1766). S.2191, depending on the availability of credits, has prices starting around $50 per ton CO_2-e, rising to around $200 in 2050, and limits U.S. cumulative emissions to about 200 bmt.[20] S.1766 creates allowances that limit U.S. cumulative emissions to 250 bmt, but the legislation includes a safety valve feature, the Technology Accelerator Payment (TAP), that may allow emissions to exceed this level of emissions. The TAP price starts at $12/t$CO_2$-e and increases at 5% real per year, reaching nearly $80/t$CO_2$-e by 2050.

[19] The EPPA model is not forward-looking and thus an interest rate is not explicitly identified, but the rate of return on capital is implicit in the base data, and those data are consistent with an overall return on capital in the range of 4 to 5%.

[20] See Appendix D of Paltsev, *et al.* (2008) for a full analysis of the Lieberman-Warner Bill (S.2191).

The Stark tax Bill is closest to the Bingaman-Specter legislation if the TAP price is triggered. In that case, the Bingaman-Specter Bill would likely achieve somewhat higher levels of abatement than Stark because the price is slightly higher and it applies to all GHGs. The Dingell Bill would allow the most emissions between 2012 and 2050 of all the carbon pricing proposals under consideration. Its welfare loss in the long run is, not surprisingly, the lowest of all the proposals, as shown in the summary provided in **Table 8**.

The Larson Bill, with cumulative emissions at 216 bmt, is similar to the Lieberman-Warner Bill, but at higher welfare cost in the long run. This occurs for two reasons. First, Lieberman-Warner includes options for credits that can, if effective, bring uncovered GHGs and sinks under the policy. Second, the Larson Bill starts the tax rate at a lower level but increases it at over twice the growth rate of the cap-and-trade bills with banking.[21] As noted in the last section, the optimal growth rate for a carbon tax in the absence of uncertainty is to grow at the real rate of return.

Table 8. Congressional Tax Proposals Summary.

Proposal	Cumulative Emissions	Price (CO_2-e) 2015	Price (CO_2-e) 2050	Welfare Change (%) 2020	Welfare Change (%) 2050	Welfare Change (%) Total
Carbon Tax Proposals						
Dingell (CO2 only)	349	14	14	-0.09	0.49	0.10
Stark (CO2 only)	301	10	69	-0.09	-0.33	-0.30
Larson (CO2 only)	216	20	561	-0.16	-2.23	-1.21
Dingell (all GHGs)	349	13	13	-0.10	0.49	0.10
Stark (all GHGs)	301	2	60	-0.03	-0.13	-0.11
Larson (all GHGs)	216	13	374	-0.10	-2.13	-0.96
Generic Tax Proposals						
28% Reduction	287	18	70	-0.13	-0.18	-0.21
50% Reduction	203	41	161	-0.32	-1.45	-0.89
58% Reduction	167	53	210	-0.55	-1.79	-1.40

*Cumulative emissions are measured in billions of metric tons of CO_2-e.

The last three rows of Table 8 provide generic carbon tax proposals with tax rates growing optimally in the EPPA model (at 4% real). The tax systems in these proposals differ from the proposed carbon taxes in that they extend to all GHG emissions. They differ from each other in the starting tax rates, which determine the cumulative emissions reductions from the business as usual case. The first proposal reduces cumulative emissions between 2012 and 2050 by a little over one-quarter. With a price of about $20 per ton CO_2-e in 2015 it is similar to the Larson Bill with broader coverage of gases and a lower growth rate in the tax rate. Cumulative emissions are

[21] With banking and borrowing, the price of cap-and-trade permits should grow at the same rate as the expected return on safe assets. Since the allowance distribution in cap-and-trade proposals is such that none of the model runs ever calls for borrowing, a banking option in the cap-and-trade proposals is sufficient for carbon prices to grow at a 4% annual real rate.

one-third higher in this case than that Larson variation, but welfare losses are substantially lower. This scenario can also be contrasted with the Stark proposal which allows just 5% more emissions over the control period than this hypothetical scenario. The tax rate starts out considerably higher, but matches the Stark rate in 2050. Welfare losses are initially slightly higher than under the Stark proposal, but roughly half the loss by 2050. Cumulative welfare losses are about 40% higher in the Stark proposal than under this hypothetical tax proposal.

6. REVENUE AND DISTRIBUTION

Options for use of the revenue from a GHG tax include lump-sum distribution to households, reducing labor or capital taxes, or spending the funds for other purposes (*e.g.*, R&D or low-income fuel assistance). As can be seen from **Table 9** the potential revenue streams are substantial, ranging in just the first period of the policy from $69 billion under the Stark Bill to $126 billion for the Larson Bill.[22] This corresponds to between 4 and 7% of non-carbon tax federal tax revenue. Potential revenue rises most rapidly under the Larson Bill.

Table 9. Carbon Tax Revenue.

	2015	2020	2025	2030	2035	2040	2045	2050
Total Potential Tax Revenue (billions $/yr)								
Dingell	88	82	84	94	109	118	129	141
Stark	69	145	207	263	324	369	415	440
Larson	126	192	296	361	439	536	700	1031
U.S. Pop.	321	334	347	359	369	379	388	397
Potential Tax disbursement/family of 4 ($/yr)								
Dingell	1,102	988	964	1,050	1,181	1,249	1,335	1,420
Stark	857	1,741	2,385	2,930	3,517	3,892	4,280	4,431
Larson	1,567	2,301	3,410	4,020	4,763	5,655	7,218	10,386
CO_2 Revenue as a Percentage of Non-CO2 Federal Tax Revenue (%)								
Dingell	5%	4%	3%	3%	3%	3%	3%	3%
Stark	4%	6%	8%	9%	9%	9%	9%	9%
Larson	7%	9%	11%	12%	13%	14%	16%	21%

Table 9 also shows the potential tax disbursement to a family-of-four household each year. For this purpose we have simply divided the population by 4 as if the population were divided into four-person households and then divided the total revenue by this artificially constructed number of households. The amount ranges from about $857 to $1567 in 2015, and ranges from $1420 to $10,386 in 2050.

[22] We do not include the additional gasoline tax revenue under the Dingell plan since that is earmarked for the Highway and Mass Transit Trust Funds.

To further illustrate the fiscal potential of an emissions tax we also include in Table 9 the carbon tax revenue as a percentage of Federal non-CO_2 tax revenue.[23] The potential tax revenue is substantial, especially under the Larson and Stark proposals. If the revenue were used to cut taxes evenly across different income groups and income sources, this would be approximately the percentage reduction in the Federal tax bill that taxpayers could expect to see. Table 9 illustrates that for the range of tax rates under consideration in these proposals, tax revenues are a constant or growing share of federal tax revenues. This is important if the carbon tax revenue is used to lower other distortionary taxes as policymakers will wish for some assurance that funds will persist to finance the tax reductions elsewhere.

An area of considerable concern is the distributional impact across different income groups of an emissions tax. The EPPA model is not designed to address this issue as it has a representative agent for each country but results from the model can be combined with other data to provide information on this issue. We consider both the incidence of the tax itself as well as the incidence of the rebated funds under an assumption of revenue neutrality.

6.1 Theory of Tax Incidence

We begin with some general comments on incidence analysis. It is important to distinguish between the *statutory* and *economic* incidence of a tax. The statutory incidence refers to who is required to remit the tax to the government. In an upstream tax system as we have conceptualized it, coal producers, natural gas distribution centers, petroleum refineries, and fossil fuel importers would bear the statutory incidence of the tax. The economic incidence refers to which taxpayers suffer a loss in real income following the imposition of the tax. If fuel prices rise in response to the GHG tax by the full amount of the tax then consumers will face higher energy and product prices and will bear the economic burden of the tax. It is important to note that the economic incidence determines the distributional impacts of a tax. Moreover, economic incidence is not a choice made by policy-makers, but is determined by equilibrium price responses following the imposition of a tax.[24]

6.2 A Distributional Analysis

Metcalf (2007) uses data from the National Income and Product Accounts Input-Output Tables along with data from the Consumer Expenditure Survey to measure the burden of carbon taxes and other environmental taxes at the household level in the United States.[25] We use results from the EPPA analysis in two ways to supplement the distributional analysis done in that paper. First, the short-run reductions in carbon emissions from a carbon-only policy are used to predict the revenue that could be raised from the tax in the short-run. This helps determine the average tax rate in the analysis.

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[23] Tax rates in EPPA are based on combined Federal, State and local taxes. For purposes of estimating the Federal share, we have assumed that it grows at the rate of GDP and that remaining tax revenue is State and local taxes.

[24] See Fullerton and Metcalf (2002) for a fuller discussion of tax incidence.

[25] The methodology for this burden analysis is described in Metcalf (1999).

Second, we use output from the EPPA analysis to determine the portion of the tax that is passed forward to consumers in the form of higher prices. Considerable work has been carried out on the incidence of energy taxes in general and – to a limited extent – of carbon taxes in particular.[26] In general it is assumed that these taxes are fully passed forward into higher consumer prices. This follows from the finding from general equilibrium modeling that taxes on consumption are fully passed forward. That result, however, may not extend to energy markets when resource rents may occur. In this case the owner of a scarce and fixed resource asset can bear the burden of an energy tax. This follows from the basic incidence result that the side of the market that is more inelastic bears more of the burden of a tax. Fossil fuel resources in the ground are perfectly inelastic and so would be expected to bear more of the burden of a tax in the long run. Demand becomes more elastic as alternatives to fossil fuels become available. Thus in the short run the tax is passed almost fully to consumers, but in the long run resource owners, who are typically of higher income levels, bear some of the tax burden. The result is that the distribution across households of a carbon tax could look different in the short and long run.

We use data from the 2003 Input-Output Tables and Consumer Expenditure Survey for our analysis. We model a tax of \$15 per ton CO_2 on fossil fuels only in year 2005 dollars. Energy related emissions of CO_2 in 2003 were 5,800 million metric tons. In the absence of behavioral responses, a carbon tax that year would have collected \$87 billion. Based on results from the EPPA analysis of a hypothetical tax that allows for cumulative emissions over the control period of 287 bmt, we assume that the tax would collect \$82 billion in the short run. Before considering short-run forward and backward shifting, we provide results assuming the entire tax is passed forward as has been assumed in previous analyses.

Table 10 shows the price increases for industry commodities in the Input-Output accounts for 2003 that are most impacted by the carbon tax. Not surprisingly the tax disproportionately impacts energy sectors, with coal facing the largest price impact. Note that these price increases are not simply the price of carbon embedded in a unit of fossil fuels as the price of industry commodities depend on a number of inputs in addition to the fuel itself. These are also not the prices faced by consumers. Consumers, for example, purchase almost no coal directly. Instead they purchase electricity produced from coal as well as industrial products where coal is used as an energy source. **Table 11** shows the price increases for commodities arising from the industry price increases in Table 10. Prices for electricity and fuels rise the most with other price increases generally less than 1%.

[26] The distributional impact of energy taxes of one form or another has been considered by Poterba (1989), Bull, Hassett and Metcalf (1994), and others. Recent distributional analyses of carbon taxes have been analyzed by, among others, Hassett, Mathur and Metcalf (2007), and Metcalf (2007). In a related vein, the incidence of cap-and-trade programs with grandfathered permits has been examined by Dinan and Rogers (2002) and Parry (2004). In all cases the authors assume the taxes are fully passed forward to consumers in the form of higher prices.

Table 10. Selected Industry Price Increases Following a $15 per ton CO_2-e Tax.

Industry	Rate
Coal Mining, except oil and gas	19.1%
Petroleum and coal products	16.7%
Electricity	12.6%
Natural Gas	12.3%
Primary metals	3.9%
Other Mining, except oil and gas	2.4%
Pipeline transportation	2.4%
Nonmetallic mineral products	2.1%
Air transportation	1.9%
Paper products	1.7%

Source: Authors' calculations.

Table 11. Selected Commodity Price Increases Following a $15 per ton CO_2-e Tax.

Commodity	Rate
Electricity	12.55%
Natural Gas	12.28%
Home Heating Oil	9.56%
Gasoline	7.73%
Air Transportation	1.86%
Automobile Purchases	0.90%
Mass Transit	0.90%
Food At Work	0.86%
Toiletries	0.72%
Household Supplies	0.71%

Source: Authors' calculations.

These price increases are applied to households in the Consumer Expenditure Survey for 2003. These budget impacts for the carbon tax assume no consumer behavioral response. Consumer substitution away from more carbon-intensive products will contribute to an erosion of the carbon tax base. The burden for consumers, however, will not be reduced as much as tax collections will fall. Firms incur costs to shift away from carbon-intensive inputs, costs that will be passed forward to consumers. Consumers also will engage in welfare-reducing activities as they shift their consumption activities to avoid paying the full carbon tax. Although the burdens reported here do not take account of the range of economic responses to the tax, the impacts provide a reasonable first approximation of the welfare impacts of a carbon tax. Below we discuss whether these behavioral responses affect the distributional analysis.

Table 12 presents distributional impacts assuming full forward shifting. The carbon tax by itself is highly regressive with the lowest income groups facing an average increase in tax related spending equal to 3.7% of their income. This includes both direct spending on fuels as well as the higher cost of commodities resulting from the use of now-more expensive fuels in their production. The percentage of income spent on energy directly and indirectly falls as household income rises, with the top income group facing an increase in spending equal to 0.8% of income. The EPPA analysis assumes a lump sum rebate of the carbon tax revenue. Maintaining that assumption here offsets the regressivity of the tax. Providing a per capita lump sum rebate is highly progressive, with the lowest income groups seeing a benefit equal to 5.6% of income. The benefit as a percentage of income falls so that the top income group receives a rebate equal to 0.6% of income. The net impact is a modestly progressive reform. The lowest income group sees a fall in overall tax burden equal to about 2% of income. Households in the bottom 60% of the income distribution see a decrease in taxes and the top income deciles see increases in taxes of at most 0.2%. Table 12 illustrates the important point that the distributional impact of the tax depends importantly on how the revenue is recycled in the tax system.

Table 12. Distributional Impacts Assuming Full Forward Shifting.

Income Decile	Carbon Tax as Percent of Income (Income Loss)	Lump-Sum Rebate as Percent of Income (Income Gain)	Net Impact
1	-3.7	5.6	1.9
2	-3.0	4.0	1.0
3	-2.3	3.1	0.8
4	-2.0	2.4	0.4
5	-1.7	2.1	0.4
6	-1.5	1.6	0.1
7	-1.3	1.3	0.0
8	-1.2	1.2	0.0
9	-1.0	0.9	-0.1
10	-0.8	0.6	-0.2

Source: Authors' calculations

To consider further the sources of the regressivity of carbon taxes, we measure the distributional impact of a carbon tax applied to coal, natural gas, and petroleum separately in the Consumer Expenditure Survey. Results are shown in **Figure 15**. The distribution of consumer impacts for carbon pricing across the three fuels is remarkably similar. The burden through coal and natural gas appears to be slightly more regressive than the burden through oil, but the differences are quite small. It does not appear that carbon pricing for any of the fuels is especially important for explaining the overall distributional impact of the carbon tax.

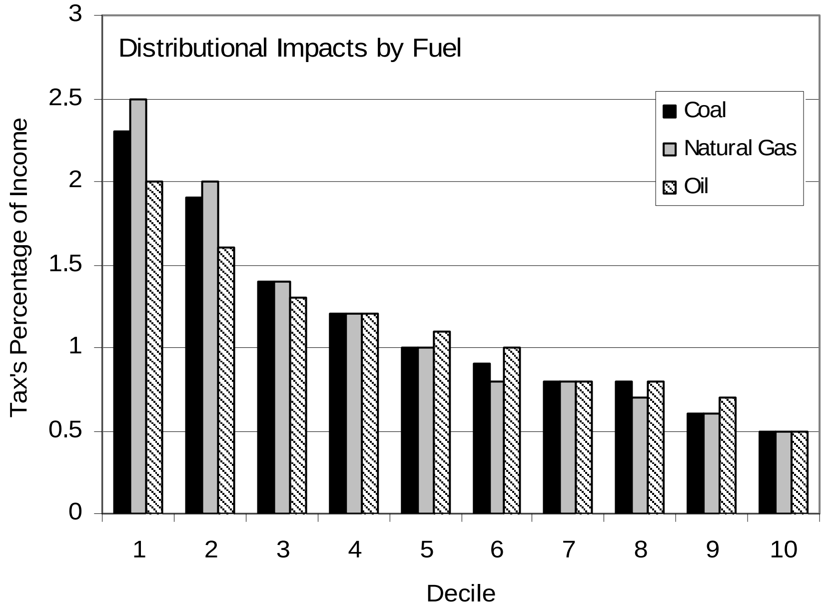

Figure 15. Distributional Impacts by Fuel.

As noted above, behavioral responses by consumers and firms will reduce the burden of the carbon tax to some extent.[27] Behavioral changes raise two issues. The first is the overall revenue burden of the tax following consumer and firm responses to the tax. We have tried to control for this by scaling the amount of tax collected based on results from the EPPA model runs. The second issue is whether these behavioral responses affect the distributional results appreciably. Consider first consumer demand shifts away from more to less carbon intensive consumer goods. The very regressive results we find in Table 12 for the tax (ignoring the rebate) are unlikely to be affected by changes in behavior. For this to occur we would need very different price elasticities for electricity and fuels across the income distribution. While there is some support for differences in income elasticities across income groups, little support exists for very different price elasticities across income groups. Any differences that do exist are likely to exacerbate the regressive results found in Table 12 if low-income households have fewer substitution possibilities than do high-income households.

A second possible area of concern arises from substitution in production. We would expect, for example, a shift in the generation of electricity from coal to natural gas thereby raising the price of natural gas relative to coal. The finding in Figure 15 that the distributional impact of carbon price impacts is similar across fuels suggests that fuel switching should not affect the burden appreciably. These two considerations both maintain the assumption of full forward shifting of the tax. We next consider how relaxing this assumption affects the distributional impact.

The assumption of full forward shifting is at best an approximation for a carbon tax in the short run. We explore the implications of backward shifting by using the results on fuel prices

[27] But note that some of the reduced tax payment is offset by higher deadweight losses arising from the behavioral responses.

from the hypothetical tax that allows 287 bmt emissions over the 2012-2050 control period. For the short-run scenario we use the producer and consumer prices for 2015, the first period for which we have model runs after the tax is imposed. Coal prices are almost entirely shifted forward into higher consumer prices (see Table 6).

Table 13 and **Figure 16** present results for when we allow for different amounts of backward shifting. In the case of the long-run results, we do not claim that these are the actual burdens that would be borne. Rather this is what the distributional burden would be if consumption patterns were the same as in 2003. The point of the exercise is to illustrate the impact that differential shifting has on the distributional burden of the carbon tax. For allocating the burden of the tax shifted backwards, we use the distribution of capital holdings in the Consumer Expenditure Survey (CEX) to distribute the tax. Our operating assumption is that holdings of capital ownership in fossil fuel resource stocks are proportional to capital holdings in the CEX.[28]

Table 13. Impact of Different Shifting Assumptions on Carbon Tax Burden.

Income Decile	Full Forward Shifting (% Change in Income)	Short Run Shifting (% Change in Income)	Long Run Shifting (% Change in Income)
1	-3.7	-3.2	-2.5
2	-3.0	-2.8	-2.2
3	-2.3	-2.4	-2.5
4	-2.0	-1.9	-1.6
5	-1.7	-1.6	-1.4
6	-1.5	-1.4	-1.2
7	-1.3	-1.3	-1.2
8	-1.2	-1.2	-1.1
9	-1.0	-1.1	-1.1
10	-0.8	-0.9	-1.1

Source: Authors' calculations.

The first finding to note in Figure 16 is that even in the short-run backward shifting mitigates the regressivity of the carbon tax.[29] The burden on the lowest decile falls by 11% when some of the tax is shifted backwards. The ratio of the burden in the lowest decile relative to the highest decile falls from 4.5 to 3.5 once one allows for backward shifting in the short run. The change in distributional burden is more striking in the long run. The burden on the lowest two deciles falls by 30% while the burden in the top decile rises by about 35%. Now the ratio in burdens between the top and bottom deciles falls from 4.5 to 2.3.

[28] This overstates the impact on U.S. residents as much of the tax would be shifted to foreign owners of reserves. In fact, one could reasonably argue that nearly *all* of the impact would be foreign owners since the United States accounts for 2.5% of world proved reserves of oil and 3.3% for natural gas BP (2007).

[29] Table 12 only looks at the carbon tax and not the rebate. The rebate is unaffected by the extent of forward shifting.

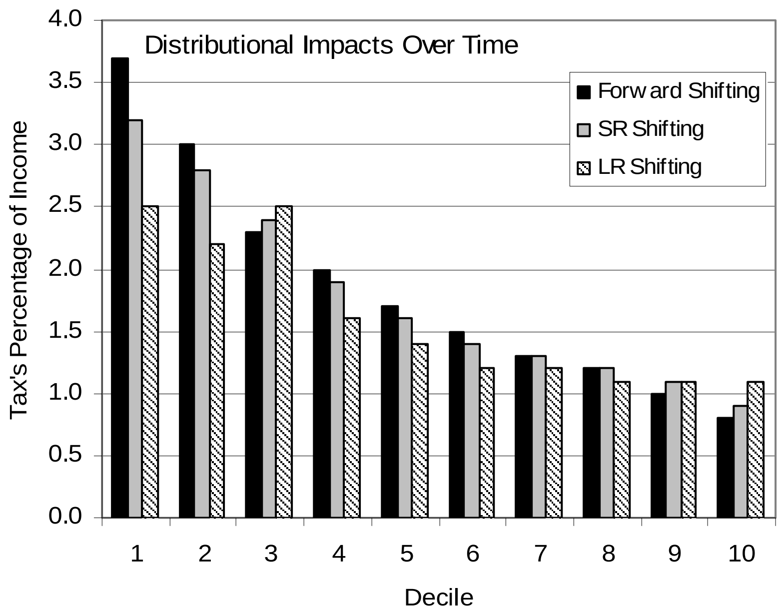

Figure 16. Distributional Impact over Time.

This analysis suggests a number of important points. First, distributional analyses that assume full forward shifting of the tax in the short-run are likely to modestly overstate the regressivity of a carbon tax. Second, the ability to shift the burden of the tax back has larger effects in the longer run and may dampen the regressivity of a carbon tax significantly.[30] In the long-run, it is also likely that some of the tax will be exported to non-U.S. owners of natural gas and oil reserves. Third, how the United States uses the carbon tax revenue affects the overall distribution of the tax significantly. If we ignore the use of proceeds from the carbon tax, it looks distinctly regressive. A lump-sum rebate of the proceeds would be highly progressive and would in fact lead to a modestly progressive carbon tax reform. Such a rebate foregoes the opportunity to use the revenue to make efficiency improvements in the U.S. tax system. Metcalf (2007) analyzes a carbon tax swap where the revenue is used to lower labor income taxes. Green, Hayward and Hassett (2007) emphasize the benefits of using carbon tax revenue to pay for reductions in capital income taxation. Results from Gurgel *et al.* (2007) suggest that the greatest efficiency gains arise from using carbon revenues to lower taxes on capital.

7. CONCLUSION

We have used the MIT EPPA model to evaluate carbon tax proposals as a policy instrument to reduce greenhouse gas emissions. Several lessons emerge from the analysis. First, a low starting tax rate combined with a low rate of growth in the tax rate will not reduce emissions significantly. The Dingell proposal reduces emissions from the reference case by 12% over the

[30] The distributional analysis here uses annual income to rank households. It has long been understood that this biases consumption and energy taxes towards greater regressivity than when a measure of lifetime income is used to rank households. Hassett, Mathur and Metcalf (2007) construct different proxies for lifetime income to address this bias.

2012–2050 control period while the Stark proposal reduces emissions by 25%. The Larson Bill with its more rapid growth rate for the tax rate reduces emissions by nearly 50% over this period. In all cases the welfare impacts are relatively modest ranging from a slightly positive impact for the Dingell plan to a discounted welfare cost of 1.2% for the Larson plan.

Second, the costs of emissions reductions are reduced with the inclusion of non-CO_2 gases in the carbon tax scheme. The costs of the Larson plan, for example, fall by 20% with inclusion of the other GHGs. Third, welfare costs of the policies can be affected by the rate of growth of the tax, even after controlling for cumulative emissions. In our model, that suggests that a tax rising at the rate of interest over the control period will achieve a given cumulative emissions target at minimum cost. Lowering the growth rate for the tax to 4% and including all GHGs lowers the welfare cost of meeting the cumulative emissions reduction in the Larson plan by roughly one-third. For the Stark plan, the welfare cost savings is about one-fourth.

Fourth, a carbon tax – like any form of carbon pricing – is highly regressive. The regressivity can be offset with a carefully designed rebate of some or all of the revenue. Moreover, general equilibrium considerations suggest that the short-run measured regressivity may be overstated. Over time, a portion of the carbon tax is passed back to workers, owners of equity, and resource owners. To the extent that resource and equity owners bear some fraction of the tax burden, the regressivity will be reduced because these assets are disproportionately owned by those with higher incomes.

Finally the carbon tax bills that have been proposed or submitted lead to a range of emissions reductions that are comparable to many of the cap-and-trade proposals that have been suggested. Thus the choice between a carbon tax and cap-and-trade system can be made on the basis of considerations other than their effectiveness at reducing emissions over some control period. Either approach (or some hybrid of the two approaches) can be equally effective at reducing GHG emissions in the United States.

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APPENDIX: Details of Simulation Results*

* ***Only a sample page is attached here***. The full version of Appendix is available as a separate file with this report at http://mit.edu/globalchange/www/MITJPSPGC_Rpt160_Appendix.pdf.

[31] All prices and taxes are in 2005 dollars.

Reference Scenario	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
ECONOMY WIDE INDICATORS										
Population (million)	296	309	321	334	347	359	369	379	388	397
GDP (billion 2005$)	11981	14339	16921	19773	22846	26459	30534	34929	39530	44210
% Change GDP from Reference	--	--	--	--	--	--	--	--	--	--
Market Consumption (billion 2005$)	8217	9858	11533	13384	15364	17761	20467	23392	26456	29567
% Change Consumption from Reference	--	--	--	--	--	--	--	--	--	--
Welfare (billion 2005$)	9656	11773	13933	16342	18948	22016	25414	29032	32780	36553
% Change Welfare from Reference(EV)	--	--	--	--	--	--	--	--	--	--
CO_2-E Price (2005$/t$CO_2$-e)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
***PRICES** (index, 2005=1.00)*										
Petroleum Product	1.00	1.15	1.30	1.48	1.69	1.87	1.97	2.09	2.19	2.25
Natural Gas	1.00	1.11	1.27	1.48	1.66	1.95	2.31	2.73	3.12	3.55
Coal	1.00	1.04	1.07	1.09	1.13	1.16	1.20	1.24	1.28	1.32
Electricity	1.00	1.11	1.19	1.27	1.35	1.38	1.42	1.42	1.42	1.41
***TRADE & PRODUCTION** (selected indicators)*										
Bio Liquids Production in US (EJ)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Net Bio Liquids Imports (EJ)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Net Bio Liquids Imports (billion 2005$)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Net Crude Oil Imports (billion 2005$)	77.40	85.21	93.97	102.60	110.94	126.11	149.39	170.99	159.14	144.83
Net Agriculture Exports (billion 2005$)	25.64	25.53	20.40	19.29	14.24	12.35	11.48	10.92	11.61	14.99
***GHG EMISSIONS** (mmt CO_2-e)*										
GHG Emissions	7091.9	7680.1	8201.5	8595.6	9219.3	9884.8	10711.0	11507.3	12433.3	13283.3
CO_2 Emissions	5984.3	6517.4	6995.2	7357.3	7915.4	8518.8	9283.0	10012.9	10871.0	11655.9
CH_4 Emissions	583.4	602.0	611.6	617.1	630.5	643.1	652.2	663.6	676.5	683.1
N_2O Emissions	385.2	387.9	381.3	372.4	366.5	365.6	372.8	380.8	391.0	407.3
Fluorinated Gases Emissions	140.0	173.8	214.4	250.0	308.1	358.5	404.3	451.3	496.2	538.5
***PRIMARY ENERGY USE** (EJ)*										
Coal	22.6	24.3	25.8	26.6	30.9	35.0	39.9	44.8	49.6	53.3
Total Petroleum Products	42.0	46.0	49.6	52.6	55.2	58.8	63.9	68.8	73.6	78.5
Including Shale Oil	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.7	19.6
Natural Gas	22.5	24.7	26.8	28.9	28.4	28.3	27.7	26.8	25.8	25.1
Nuclear (primary energy eq)	9.3	9.0	8.8	8.7	8.6	8.5	8.4	8.4	8.3	8.3
Hydro (primary energy eq)	2.9	2.8	2.8	2.8	2.8	2.9	2.9	3.0	3.1	3.2
Renewable Elec. (primary energy eq)	0.6	0.7	0.8	1.0	0.9	1.2	1.1	1.4	1.5	1.6
Biomass Liquids	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Primary Energy Use	99.8	107.6	114.6	120.5	126.8	134.6	143.9	153.1	161.9	170.0
Reduced Use from Reference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
***ELECTRICITY PRODUCTION** (EJ)*										
Coal w/o CCS	6.9	7.6	8.3	8.6	10.2	11.7	13.4	15.2	17.0	18.5
Oil w/o CCS	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.5	0.5	0.6
Gas w/o CCS	2.1	2.5	3.1	3.9	3.3	3.1	2.9	2.7	2.4	2.3
Nuclear	3.0	3.0	3.0	3.0	3.0	3.1	3.1	3.1	3.1	3.1
Hydro	0.9	1.0	1.0	1.0	1.0	1.0	1.1	1.1	1.1	1.2
Other Renewables	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.5	0.6	0.6
Gas with CCS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coal with CCS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Electricity Production	13.4	14.6	15.9	17.1	18.2	19.7	21.3	23.1	24.7	26.2

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