

**THE ECONOMIC RENT POTENTIAL FROM
CO₂ ABATEMENT POLICIES
IN THE UNITED STATES**

John M. Polimeni
Associate Professor of Economics
Albany College of Pharmacy and Health Sciences
106 New Scotland Avenue
Albany, NY 12208
John.polimeni@acphs.edu

1. INTRODUCTION

Increasingly, climate change has come to the fore as an environmental issue with nearly universal agreement that the current trend is unsustainable and must be addressed. Of particular concern is the amount of carbon dioxide (CO₂) emitted into the atmosphere, the primary contributor to climate change through the combustion of fossil fuels. In the United States alone, CO₂ emissions account for approximately 85% of all U.S. greenhouse gas emissions, most of which come from fossil fuels (EPA, 2008). Reducing the risk of the damage caused by climate change requires the world to substantially reduce CO₂ production. In the past five to ten years several proposals to address climate change have been suggested; most prominently cap-and-trade and carbon taxes. These market-based approaches differ from the traditional command-and-control policies, such as Corporate Average Fuel Efficiency (CAFÉ) standards which mandate minimum fleet mileage standards for vehicles sold in the United States, by providing firms a cost-effective and flexible form of environmental regulation. Other benefits also exist, such as technological innovation to reduce greenhouse gas emissions and potential revenue sources for governments; the more a firm emits CO₂, the more they pay, either in taxes or through purchased emission permits.

Not surprisingly, revenue generation from these fiscal regulatory policies is controversial as they contribute to the overall costs of the firm and there is concern over the distribution and equity of these costs that will be passed on to the consumer. Market-based approaches, such as carbon taxation and cap-and-trade, are preferred by economists to the command-and-control policies generally used by environmental protection agencies. However, from an economic efficiency point-of-view, a carbon tax is less costly because the tax is more broadly focused and better addresses the negative externality of carbon emissions than a tax on specific forms of fossil fuels (Metcalf, 2009).

For practical policy purposes, however, the immediate issue is how to develop a climate policy regime with a robust emissions mitigation effort as its centerpiece, one that

can progressively incorporate rapidly industrializing nations, and that can adjust over time as more is learned about the science, economics, and technological change that characterizes the climate change problem (Aldy and Stavins, 2008). There is much debate throughout the world today as to what is the best policy mechanism to curb CO₂ emissions. In the United States several different versions of CO₂ abatement policies have been proposed and debated. However, the two most often mentioned are versions of carbon taxes and cap-and-trade, which are described in the following paragraphs.

2. AN OVERVIEW OF CARBON TAXES

2.1 Carbon Taxes

Simply put, a carbon tax is a tariff on the CO₂ emissions. Carbon is present in all forms of fossil fuels and converted to CO₂ when the fuel is burned. A carbon tax is easily administered if paid for upstream, the point where the fuels are extracted or imported, because the carbon content of all forms of fossil fuels are well-known. Of the three most popular fossil fuels used, coal, natural gas, and petroleum, coal produces the most CO₂ while natural gas emits the least. Thus, under a carbon tax coal would be taxed the highest, followed by petroleum, then natural gas.

The use of taxes as a method to reduce environmental degradation has a long history. Pigou (1920) argued that taxes can be used to mitigate the effects of a negative externality such as CO₂ emissions. William Baumol (1972) further developed these ideas by illustrating how taxes could be used to obtain environmental standards in a cost effective way. The key to implementing this policy is that the carbon tax must be set at a level that will counterbalance the negative externality; in other words, at any given emissions level, the tax rate should equal the social marginal damages (Figure 1) from producing an additional unit of emissions or, more or less equivalently, the social marginal benefit from abating a unit of emissions. If the marginal abatement costs are lower than the carbon tax, then firms will reduce their emissions. Figure 1 illustrates that

the low marginal abatement cost (MAC) firm will pay abatement costs of area C and pays a tax to the government equal to area D+E. On the other hand the high marginal abatement cost firm will pay abatement costs of area D and pay a tax to the government equal to area B+C+D.

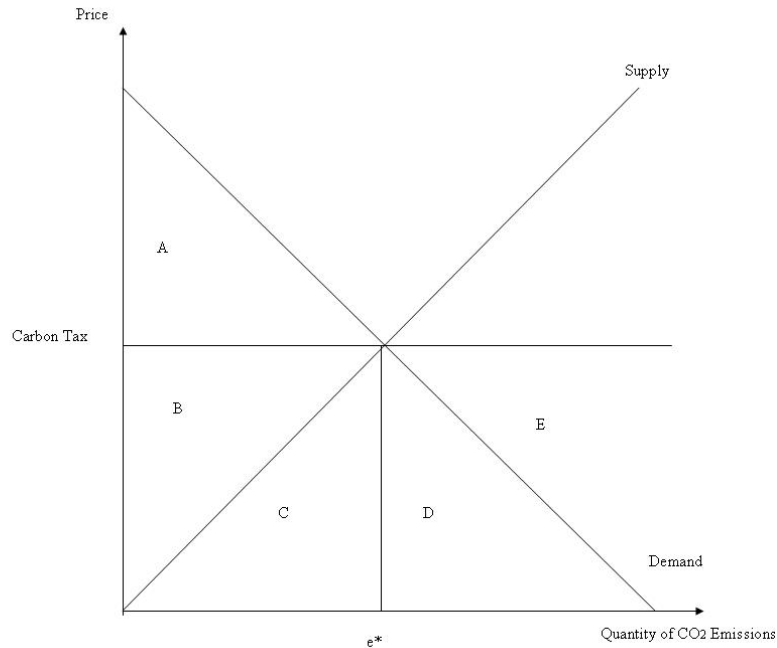


Figure 1. The Effects of a Carbon Tax on Individual Firms

The tax will increase production costs which will cause firms to reduce their supply. Thus, emissions levels are reduced, but at the same time part of the tax is shifted onto consumers. The amount of the price increase for consumers will depend upon the elasticity of demand for the product. However, at least part of the tax will be passed on to consumers to bear which is why detractors claim this option to be regressive in nature (see Figure 2).

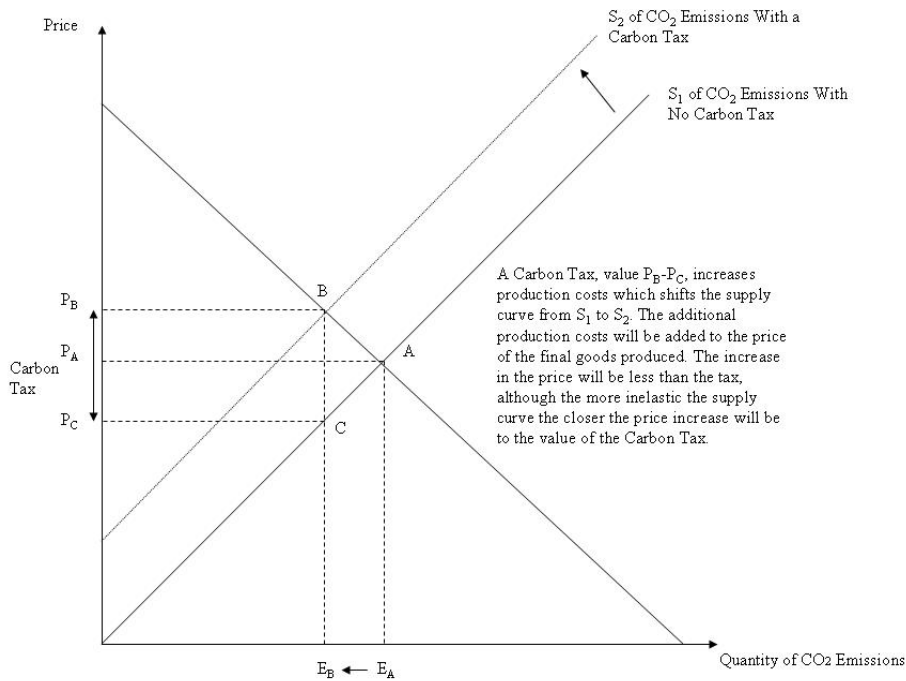


Figure 2. The Effects of a Carbon Tax on the Market

The central premise of a carbon tax therefore is to obtain large reductions in CO₂ emissions rapidly by creating an incentive to do so. The prices of carbon emitting fuels and energy do not include any of the costs of carbon emissions. Furthermore, as will be shown through examples from several European countries that tax carbon content, not using carbon taxes removes any incentive for individuals and corporations to take measures to reduce carbon emissions and alter their consumption behavior and choices. No one will argue that carbon taxes will completely eliminate climate change problems; however the taxes can be used in a positive manner.

Proponents argue that the carbon tax will send price signals throughout the market leading to new technologies and renewable energy sources. They claim that the price signals will provide economic incentives to reduce or eliminate emissions at the source, which will reduce clean-up costs from released emissions and substitute fossil fuels with renewable energy sources such as wind energy. Furthermore, advocates claim that the end result will be more energy-efficient technologies adapted (Andersen, 1999). In

economics terms there would be a demand effect, a reduction in the demand for carbon producing energy sources as a result of the price increase, and a substitution effect, a substitution of fossil fuels for lower carbon based fuels.

On the other hand, opponents will argue that carbon taxation will have a negative impact on economic growth. They claim that an increase in taxes will depress real disposable incomes which will reduce overall demand leading to lower economic gross domestic product levels. In addition, adversaries argue that carbon taxation will lead to inflation because the taxes are levied on households and the whole tax will be reflected in the consumer price index if cheaper alternatives to fossil fuels are not readily available for industry and consumers. This is in contrast to a carbon tax that would be levied on producers which would pass some fraction of the tax onto consumers.

2.2 Carbon Taxes in Europe

While many economists find carbon taxes the preferable method for abating CO₂ emissions very few countries actually implement this policy. European environmental policies, based on the precautionary principle and the polluter pays principle, could be more easily implemented using carbon taxes. While not developed for the purpose of reducing greenhouse gas emissions, European Union member states have long used energy taxes. However, the implementation of these tax schemes has been very diverse, often differentiating among users, types of energy, and industry. Moreover, these energy taxes were not initiated with the intent of reducing CO₂ emissions but with the purpose of generating revenue to reduce taxes in other areas of the economy.

A few European countries have developed taxes with the purpose of reducing CO₂ emissions. In 1990 Finland initiated their version of the carbon tax, widely regarded to be the first country to use such a tax. The first adaptation of the tax was strictly on carbon content. However, the second derivation of the tax included energy. Sweden followed with their own version of a carbon tax soon after in 1991. The tax has been set to \$150 per ton of carbon with the exception of fuels used for electricity generation and industries

only have to pay one-half of the tax (Johansson, 2000). Swedish energy policy requires that non-industrial consumers pay a tax on electricity but exempts fuels from renewable sources such as biofuels and biomass (Johansson, 2000). Due to this tax policy the use of renewable fuels for heating and industry has vastly expanded in Sweden. The next European country to use a carbon tax was Great Britain in 2001 which instituted the tax for the industrial, commercial, and public sectors. Tax revenues are partially used to provide subsidies for energy efficiency and renewable energy initiatives. Since 2003 with the development of the Energy Taxation Directive, Europe has had an European Union level carbon tax policy. However, that is not to say that individual member states do not have their own policies aimed at carbon emissions. The policies of several such countries (Denmark, Sweden, and the United Kingdom) will be briefly examined below. Abatement policies differ greatly between the countries so providing a complete and detailed account of the various policies is difficult. Therefore, specifics, such as the amount of taxation, will not be discussed as these details change often and will provide little information as for the purposes of the discussion in this paper. Since there are many derivations to the carbon and CO₂ tax policies of every country, particularly those examined below, the reader is encouraged to go to the European Union's internet sites related to energy and the environment, as well as each country's energy and environment web sites for complete information.

Denmark has a three-pronged tax system aimed at energy, CO₂, and sulfur. The energy tax is imposed on the carbon content of fossil fuels with the exception of natural gas (Speck, 2008). The CO₂ tax is self explanatory. The sulfur tax is levied on all fossil fuels with a 0.05% or higher sulfur content (Speck, 2008). The purpose of this tax scheme is to reduce the amount of emissions into the atmosphere by encouraging reduced consumption of energy products with carbon or sulfur content or by promoting technology that prevents CO₂ or sulfur emissions. However, Denmark has a complex tax differentiation program established for industries. Industries can receive a complete energy tax refund for energy used for purposes other than space heating in which case industries must pay the full tax. The CO₂ tax scheme is even more complex as industries

pay according to type of usage. However, industries can reduce their level of taxation through a variety of agreements available with the government.

Sweden uses four types of taxes on energy and carbon indexed to their Consumer Price Index to ensure that the real value of the taxes remain constant over time. Energy taxes were first used on gasoline in 1924 and then extended to include oils and coal in 1957, liquefied petroleum gas in 1964, and natural gas in 1985 (Speck, 2008). The country developed both a CO₂ tax and a sulfur tax in 1991. The CO₂ tax rates are based upon the carbon content of the fossil fuel being used. The sulfur tax is only implemented on heavy fuel oil, peat fuel, and coal. Any fuel with a sulfur content less than 0.05% in weight is exempt from the tax. The last type of tax to abate greenhouse gas emissions that Sweden uses is a nitrogen oxide (NO_x) charge which was first initiated in 1992. Originally, the NO_x tax was imposed on emissions from energy plants fifty gigawatt hours or larger, but later decreased to twenty-five gigawatt hours (Speck, 2008).

In contrast to the above, the tax scheme that the United Kingdom has developed to reduce CO₂ emissions is relatively simple. In 1990 the United Kingdom introduced the Fossil Fuel Levy for all consumers of electricity. The revenues generated from this tax were used to subsidize renewable energy projects, especially nuclear power. In 2001 the Climate Change Levy was introduced. This tax was on non-domestic energy use and did not include household use. The revenues from this tax have been used as a tax shifting program (Speck, 2008).

The main components of the CO₂ abatement programs of three European countries have been briefly examined due to their complexity and often-changing nature. However, the CO₂ abatement policies that exist in individual countries must be just the beginning as the European Union has created a European-wide policy aimed at reducing CO₂ emissions. The first such effort was the Energy Taxation Directive (ETD) created in 2003 and implemented January 1, 2004. The ETD created minimum taxation levels for all forms of energy products aimed at the consumer level (Hasselknippe and Christiansen, 2003). The second effort, the European Union Emissions Trading Scheme (ETS) targets

the energy sector and energy-intensive sectors at the producer level but are different from energy and carbon taxation. Double taxation of emissions is not supposed to occur between these two schemes, so countries are restricted from additional emissions taxes on installations already covered by the ETD (Hasselknippe and Christiansen, 2003). Therefore, the two abatement programs have been developed to work in conjunction with each other rather than in competition. The next section will explain how cap-and-trade schemes work and then show the European Union uses cap-and-trade for abatement. Furthermore, the cap-and-trade proposals currently under discussion in the United States will be explained.

3. AN OVERVIEW OF CAP-AND-TRADE

3.1 Cap-and-Trade

Cap-and-trade programs are based on the economic theories developed by Ronald Coase (1960) who argued that property rights can improve environmental conditions, which he found to be more effective than taxes (Raymond and Shively, 2008). A cap-and-trade program sets a ceiling on the total greenhouse gas emissions, where each firm is issued a permit to emit one unit of pollution during a given time period. For CO₂ for example, a firm must have one permit to emit one ton of CO₂ emissions. Over time, the ceiling for allowable emissions is lowered until the target level is reached. Such a method is what was used to reduce sulfur emissions in the United States; a major factor in reducing acid rain (Benkovic and Kruger, 2001).

The idea behind this concept is that some firms will be able to reduce their emissions below the required levels much easier than other firms. As shown in Figure 3, low polluting firms have smaller abatement costs and can then sell their allocated pollution permits to high polluting firms with greater abatement costs because these firms have more difficulty lowering their emissions levels. Thus, the preset level of pollution is reached while at the same time minimizing the marginal abatement costs by rewarding

firms that are able to reduce their emissions efficiently. The firms with high marginal abatement costs will either purchase permits from low marginal abatement cost firms or invest in new infrastructure or technology to reduce their pollution levels. In either case, the total amount of emissions will be reduced to the amount specified by the regulatory body. Proponents of cap-and-trade claim that a cap-and-trade system allows for more efficiency and information sharing in the market which will enable firms to lose less profits. Advocates also argue that permits are a more flexible regulatory option because prices can be adjusted depending upon economic conditions. They will also point out that under cap-and-trade regulation all firms have the same marginal cost of abatement. Opponents on the other hand, argue that cap-and-trade is regressive; most negatively affecting poorer households (Galbraith, 2009). Furthermore, challengers claim that the cap-and-trade system does not provide firms any incentive to reduce pollution levels beyond what is allowable.

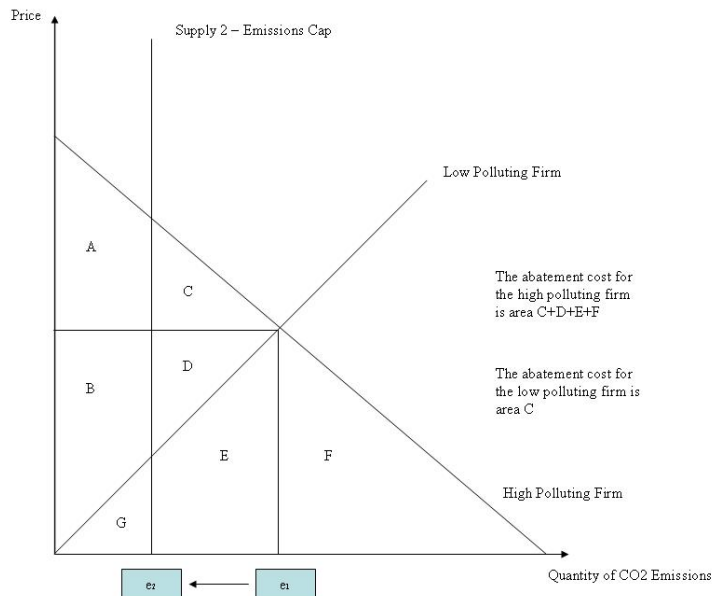


Figure 3. The Effects of Cap-and-Trade on the Market

3.2 European Union Emissions Trading Scheme

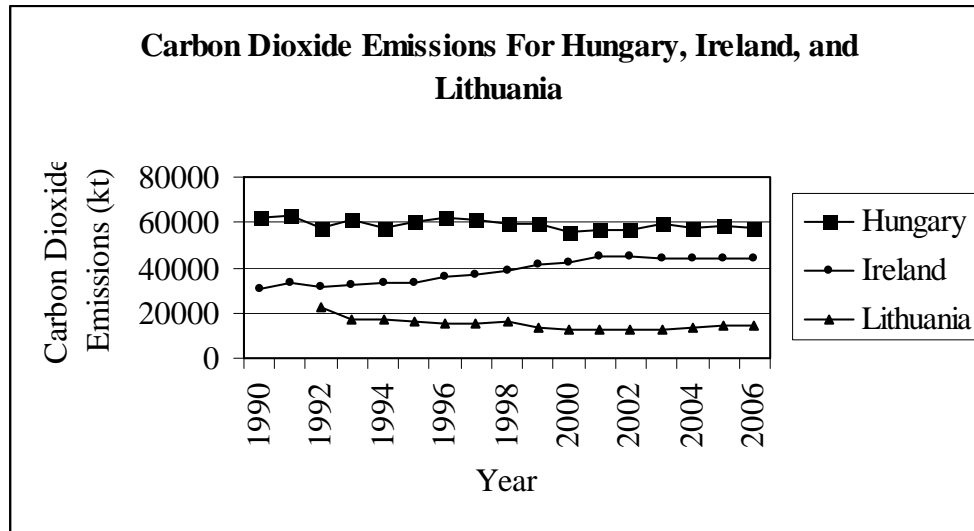
The European Union instituted the Emissions Trading Scheme (ETS) in efforts to comply with the Kyoto Protocol. The ETS program works in conjunction with individual member

states carbon and energy tax programs, as well as the European Union ETD scheme which sets minimum energy tax rates, creating an incredibly complex CO₂ regulatory agenda. Under the European Union ETS agreement each member state is allowed a certain number of allowances based on their national allocation plan (Convery and Redmond, 2007). The objective of the European Union ETS is to reduce CO₂ emissions by 2020 by at least twenty percent of 1990 emissions levels. Each European Union allowance enables a firm to emit one ton of CO₂. Those firms that emit less than their allowances can sell any excess permits to firms that have difficulty keeping their emission levels low. These high-polluting firms either have to continue purchasing allowances from low-polluting firms or invest in CO₂ reducing technology. The ETS program is aimed towards large firms; for example, power plants that are larger than twenty megawatts (Andersen, 1999). The ETS program also covers the most energy intensive industries (ferrous metal plants, cement factories, glass factories, ceramic products, as well as pulp and paper factories) and refineries (Andersen, 1999).

Similar to the carbon tax programs that have been developed, one of the premises behind cap-and-trade programs such as the European Union ETS is to send a price signal or price signals throughout the market. In the case of the European Union ETS there are two types of costs that are imposed on industries. First, there are the direct costs that firms must incur when they purchase allowance permits. The level of these costs will be dependent upon the amount of CO₂ emissions the industry produces and whether or not the company must purchase additional permits from less polluting companies. Additionally, there is an indirect cost to households as carbon producing firms factor the costs of emissions certificates into consumer prices. Therefore, the implementation of the European Union ETS program is of prime importance.

Phase I of the European Union ETS was launched in 2005. For this first phase the European Union gave nearly all of the total allowances, valued at €65 to €130 billion, to firms for free (Convery and Redmond, 2007). Only three European Union members, Ireland, Hungary, and Lithuania, chose to auction some of their allowances which accounted for 0.12 percent of the total permits (Hahn, 2009). All three of these countries

used the revenues generated from the auctions to offset some of the administrative costs of conducting the auctions. As shown in Figure 4, the auctioning of allowances in these three countries has had little effect, albeit in a small sample of three years. During that time period the CO₂ emissions for these three countries remained relatively constant.

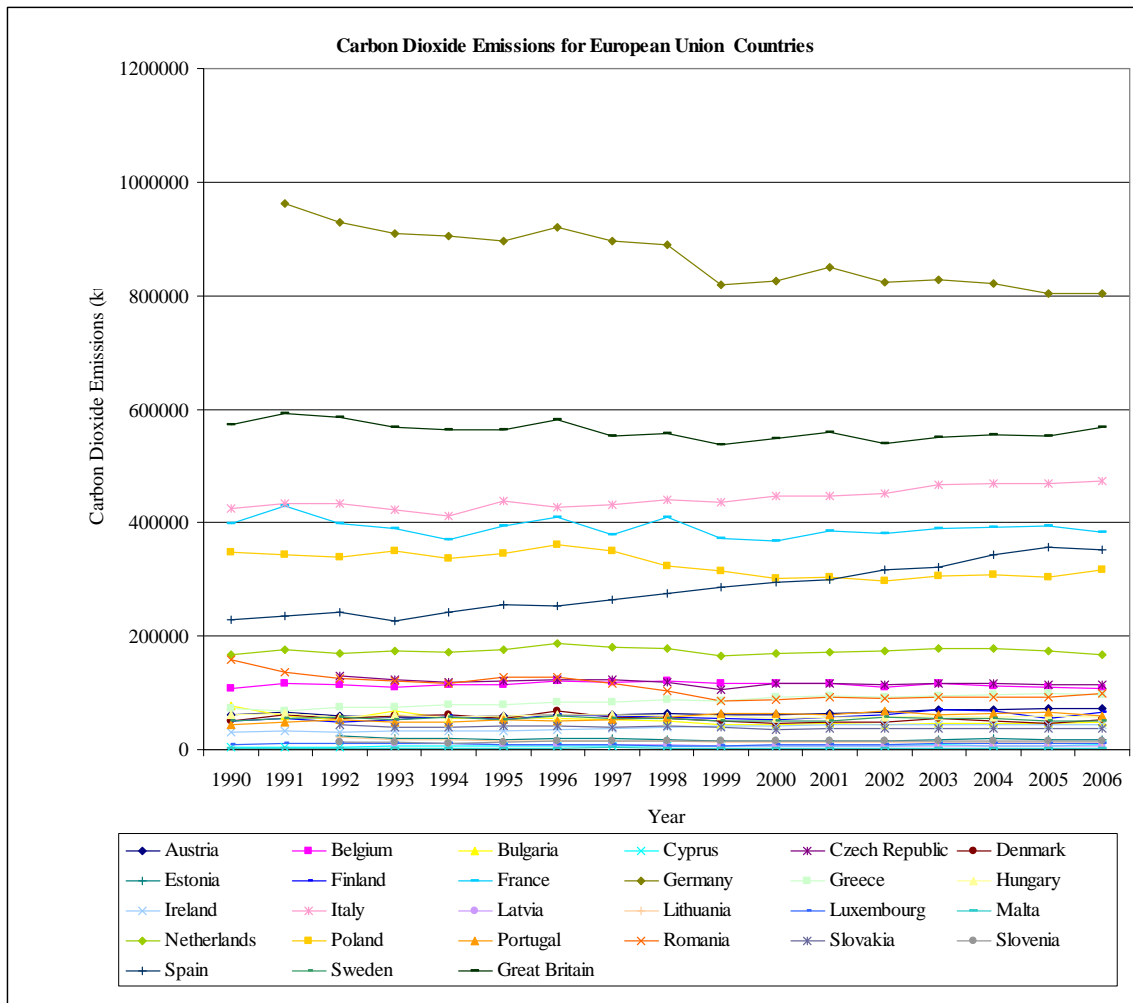


Source: Carbon Dioxide Emissions data obtained from the World Bank World Development Indicators.

Figure 4. CO₂ Emissions in Ireland, Hungary, and Lithuania 1990 - 2006

Phase II, which was instituted in 2008 required that no more than ten percent of the allowances be auctioned to firms. However, the policy of the other European Union member states of giving permits away has largely been a failure as CO₂ emissions has increased throughout the European Union. Therefore, the use of auctions will need to be expanded to create more incentives for firms to reduce their emissions level. Phase II is also the first time new European Union member countries, such as Romania, are included in the scheme. Phase III of the European Union ETS program, set to begin in 2013, calls for at least two-thirds of the permits to be auctioned (European Commission, 2008). A minimum of twenty percent of the revenues that are generated from the auctioning of the permits will be used for climate change mitigation and adaptation efforts (European Commission, 2008).

As shown in Figure 5, in the limited time that the European Union ETS has been in existence there has been little effect on carbon dioxide emissions. Some countries, such as Germany, have been experiencing decreasing emissions. However, most countries in the European Union have slightly increasing or relatively constant levels of CO₂ emissions.



Source: Carbon Dioxide Emissions data obtained from the World Bank World Development Indicators.

Figure 5. CO₂ Emissions for European Union Countries 1990-2006

As stated previously, the European system of reducing carbon emissions is complex with the various levels of regulation that are imposed. Not surprisingly, many are concerned about double-taxation. However, the ETS program, at least in theory, has

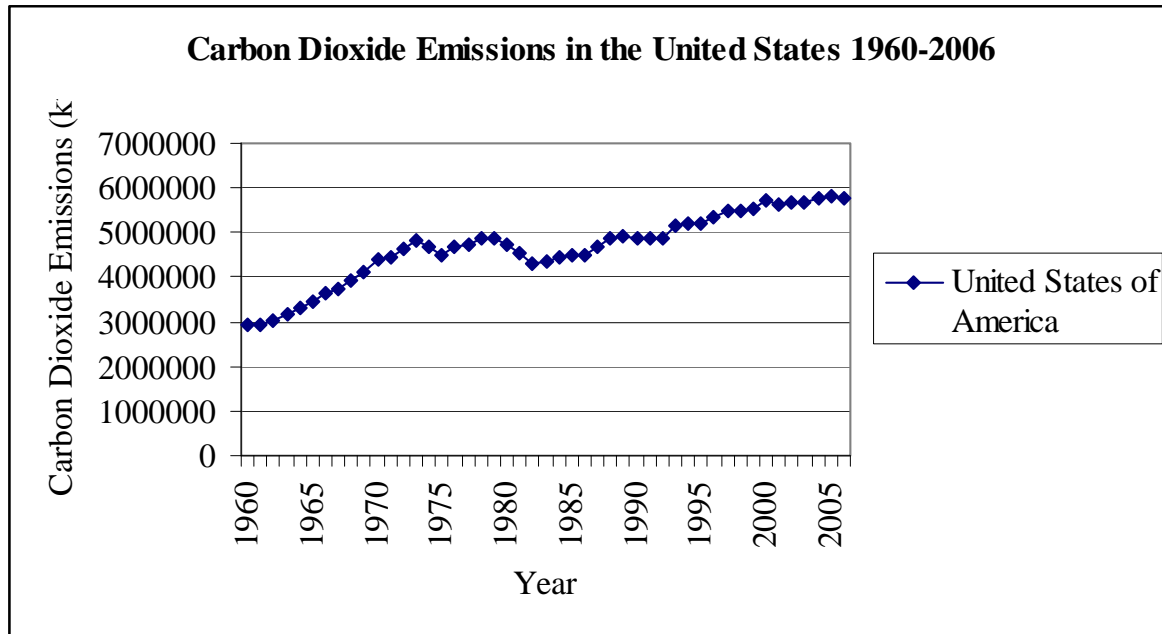
been developed to prevent double-taxation from occurring. The European Union ETS program creates two sectors of carbon emitters, the ETS and the non-ETS (Andersen, 1999). The carbon emitters designated as ETS are regulated under the European Union ETS program and, as such, are not eligible to have any additional tax levied on them. Furthermore, because the European Union ETS sets an emissions cap from the companies delegated to the ETS sector, if these companies wish to emit more carbon than they must purchase additional allowances on the market. Theoretically, this directive should prevent double-taxation of companies.

Since this directive has been developed to prevent double-taxation, a number of European Union countries have been considering eliminating their carbon and energy taxation programs in favor of the ETS provisions. However, for any individual European Union member-state to remove taxes selectively, as would be the case if the ETS sector was excluded, they would need approval from the European Commission (Andersen, 1999). The ETD, in contrast to the European Union ETS, was developed with a directive beyond carbon taxation; the ETD also attempts to equilibrate the energy supply with tax rates. However, by definition of the directive, the European Union ETS is heavily dependent upon the specific regional power markets (Andersen, 1999). Therefore, there can be no guarantee that the European Union ETS can synchronize energy tax rates across regions. As such, companies in different European Union countries can be at a competitive disadvantage with each other.

4. THE UNITED STATES

4.1 Comparison of Carbon Reduction Policies in the United States

Figure 6 presents the carbon dioxide emissions for the United States since 1960. As can be seen, CO₂ emissions have steadily trended upwards since 1960. In comparison to carbon emissions in Europe, the United States emits considerably more carbon into the atmosphere.



Source: Carbon Dioxide Emissions data obtained from the World Bank World Development Indicators.

Figure 6. CO₂ Emissions in the United States 1960-2006

Due to these high levels of emissions, many policies have either been used or proposed to reduce carbon dioxide emissions in the United States. As stated previously, market-based approaches to reduce CO₂ emissions such as taxes or cap-and-trade schemes are the preferred methods of economists. While carbon taxes are fairly straight-forward, there are a few different approaches to cap-and-trade programs. The Congressional Budget Office (2008) developed a chart, presented in Table 1, which summarizes the key aspects of each program for the United States.

Table 1. Comparison of CO₂ Emissions Policies

Comparison of Selected Policies for Cutting CO₂ Emissions

| Policy | Efficiency | | Implementation Considerations | International Consistency Considerations |
|---|------------|---|--|---|
| | Ranking | Considerations | | |
| Carbon Dioxide Tax | 1 | <p>A tax would avoid significant year-to-year fluctuations in costs. Setting the tax equal to the estimate of the marginal benefit of emission reductions would motivate reductions that cost less than their anticipated benefits but would not require reductions that cost more than those benefits.</p> <p>Research indicates that the net benefits of a tax could be roughly five times as high as the net benefits of an inflexible cap. Alternatively, a tax could achieve a long-term target at a fraction of the cost of an inflexible cap.</p> | <p>An upstream tax would not require monitoring emissions and could be relatively easy to implement. It could build on the administrative infrastructure for existing taxes, such as excise taxes on coal and petroleum.</p> | <p>A U.S. tax could be set at a rate consistent with carbon dioxide taxes in other countries. Consistency would require comparable verification and enforcement. If countries imposed taxes at different points in the carbon supply chain, special provisions could be needed to avoid double-taxing or exempting certain goods.</p> <p>Setting a U.S. tax that would be consistent with allowance prices under other countries' cap-and-trade systems would be somewhat more difficult because it would require predicting allowance prices in different countries.</p> |
| Cap With Safety Valve and Either Banking or a Price Floor | 2 | <p>A cap-and-trade program that included a safety valve and either banking or a price floor could have many of the efficiency advantages of a tax. The safety valve would prevent price spikes and could keep the costs of emission reductions from exceeding their expected benefits.</p> <p>Banking would help prevent the price of allowances from falling too low, provided that prices were expected to be higher in the future. A price floor, however, would be more effective at keeping the cost of emission reductions from falling below a target level.</p> | <p>An upstream cap would not require monitoring emissions. It would require a new administrative infrastructure to track allowance holdings and transfers.</p> <p>Implementing a safety valve would be straightforward: The government would offer an unlimited number of allowances at the safety-valve price.</p> <p>Banking has been successfully implemented in the U.S. Acid Rain Program.</p> <p>A price floor would be straightforward to implement only if the government chose to sell a significant fraction of emission allowances in an auction.</p> | <p>Either a safety valve or banking would become available to all sources of CO₂ emissions in a linked international cap-and-trade program. Some countries could object to linking with a U.S. program that included those features, because linked countries could not ensure that their emissions would be below a required level in a given year. Linking would also create concerns about inconsistent monitoring and enforcement among countries and international capital flows (as described below in the inflexible cap policy).</p> <p>Countries with different cap-and-trade programs could capture many of the efficiency gains that would be achieved by linking—while avoiding some of the complications—if they each included banking (or set a similar price floor) and agreed on a safety-valve price.</p> |

| Policy | Efficiency | | Implementation Considerations | International Consistency Considerations |
|--|------------|--|---|---|
| | Ranking | Considerations | | |
| Cap With Banking and Either a Circuit Breaker or Managed Borrowing | 3 | <p>Allowing firms to bank allowances would help prevent the price of allowances from falling too low, provided that prices were expected to be higher in the future.</p> <p>Including a circuit breaker—or increasing the ability of firms to borrow allowances—would help keep the price of allowances from climbing higher than desired, but would be significantly less effective at doing so than a price ceiling.</p> | <p>An upstream cap would not require monitoring emissions. It would require a new administrative infrastructure to track allowance holdings and transfers.</p> <p>Banking has been successfully implemented in the U.S. Acid Rain Program.</p> <p>Determining when to trigger a circuit breaker, or modify borrowing restrictions, would require judgment about current and future allowance prices. Such interventions could aggravate price fluctuations if those judgments were incorrect.</p> | <p>Including banking and either a circuit breaker or borrowing in the U.S. program could reduce the likelihood of linking because it would cause uncertainty about the stringency of the U.S. cap relative to other countries' caps and about the total supply of allowances in the global trading market.</p> |
| Inflexible Cap | 4 | <p>Allowance prices could be volatile. An inflexible cap could require too many emission reductions (relative to their benefits) if the cost of achieving them was higher than anticipated and could require too few reductions if the cost of meeting the cap was lower than policymakers had anticipated.</p> | <p>An upstream cap would not require monitoring emissions. It would require a new administrative infrastructure to track allowance holdings and transfers.</p> | <p>Linking an inflexible U.S. cap with other countries' cap-and-trade systems would create a consistent global incentive for reducing emissions. However, inconsistent monitoring and enforcement in any one country could undermine the entire linked trading system. Further, linking would alter allowance prices in participating countries, create capital flows between countries, and possibly encourage countries to set their caps so as to influence those flows.</p> |

Source: Congressional Budget Office.

Note: An "upstream" tax or cap would be imposed on suppliers of fossil fuel on the basis of the carbon dioxide (CO₂) emitted when the fuel was burned. A "safety valve" would set a ceiling on the price of allowances. "Banking" would allow firms to exceed their required emission reductions in one year and use their extra allowances in a later year. Under a "circuit breaker," the government would stop a declining cap from becoming more stringent if the price of allowances exceeded a specified level.

4.2 Carbon Taxes in the United States

The United States has a long history of using taxes to reduce pollution. In the 1970s, President Richard Nixon proposed two different taxes aimed at reducing pollution, a tax on lead additives in gasoline and a tax on sulfur dioxide emissions. Neither of these taxes was implemented. However, a tax on fuel inefficient cars was instituted in 1978, soon followed by the Superfund in 1980 which was developed to clean hazardous waste sites. The pollution tax that most Americans are familiar with is the gasoline tax, but this

regulatory action is not a widely applied energy tax because the levy is limited to gasoline.

Since that time, other forms of environmental taxation in the United States have been attempted. Soon after his election, President Bill Clinton proposed an energy tax aimed at reducing the deficit and pollution. At the time he stated, “it also combats pollution, promotes energy efficiency, promotes the independence economically of the country ...” (139th Congressional Record, 1993). However, the Clinton energy tax was never implemented, instead replaced by an increase in the gasoline tax.

Although the Clinton energy tax was never implemented, some important information can be obtained from examining that potential legislation. The proposed energy tax by President Clinton covered a wide range of energy products including fossil fuels, ethanol and methanol fuels, and nuclear and hydroelectric power. An interesting provision of the proposed energy tax was a supplemental tax on petroleum, without which natural gas would have actually had a higher percentage of market price than oil, which would likely have discouraged the shifting of consumption from petroleum to natural gas which is a lesser polluting fuel (United States Department of Treasury, Office of Tax Policy, 1993). Another important lesson that can be learned from is that the proposed tax was an energy tax, not a carbon tax which would have reduced CO₂ emissions much more than the energy tax. Why this distinction is important is because the differentiation illustrates the importance of politics in environmental policy. Had the proposal been a carbon tax instead of an energy tax then coal would have been taxed the highest, which would have impacted coal mining in West Virginia and other coal producing states and states that are heavily dependent on coal for energy or heat. The coal example further highlights the considerable regional differences that make the passing of any carbon tax extremely difficult in the United States. Besides the regional differences that must be addressed so would any differentiation among energy types. For example, in the Clinton energy tax proposal hydroelectric power would be taxed but not solar electricity. This certainly would have brought considerable objection from hydroelectricity proponents, claiming unfair practices and that solar electricity would be

receiving favored status. Questions of equity and potential impact on both the national and regional economies will have to be addressed with any carbon tax proposal. In addition to these two lessons, the Clinton energy tax proposal also underscores the need to treat imports the same as domestic products in regards to the tax in order to keep domestic products on equal competitive ground.

In the past several years, the United States has considered a few different regulatory actions aimed at creating a carbon tax. The bills that have been considered differ from the Clinton energy tax proposal in that they focus on fossil fuels while the Clinton energy tax proposal also included nuclear power and hydroelectric power. The first proposed legislation that will be examined is the “Save Our Climate Act of 2007,” which was legislation H.R. 2069 drafted and introduced by Congressmen Fortney Stark and Jim McDermott (110th Congressional Record, 2007). This bill proposed a \$10 per ton tax of carbon content on coal, petroleum, petroleum products, and natural gas. This \$10 per ton tax of carbon content would increase \$10 annually until CO₂ emissions in the United States were reduced to eighty percent below the 1990 level. The tax would be imposed on the manufacturer, importer, or producer of the fuel, but could be refunded if the fuel was used for carbon sequestration. In addition, exporters were exempt from the tax (110th Congressional Record, 2007). The bill also proposes that the tax be used to reduce taxes on low and middle class households and to fund alternative energy development. The bill also proposes that studies be done every five years to determine the environmental and economic impacts of the tax.

The second proposed legislative act is “America’s Energy Security Trust Fund Act of 2007,” which was legislation H.R. 3416 introduced by Congressman John Larson (110th Congressional Record, 2007). This bill is similar to the Stark-McDermott bill except the Larson bill proposes a tax levy of \$15 per ton increasing ten percent every year plus one per cent more than the annual cost of living adjustment (110th Congressional Record, 2007). There are other differences as well. Fuels used for exports and feedstock are exempt from the tax, and taxpayers that sequester greenhouse gases, perform carbon offset projects, or eliminate hydrofluorocarbons in the United States can qualify for a tax

credit or tax refund for taxes they paid (110th Congressional Record, 2007). In contrast to the Stark-McDermott bill the Larson bill would create a trust funded by the revenues from the tax to finance tax credits for clean energy technology, to assist industries negatively affected by the tax transition to less polluting production methods, and to provide an income tax credit for individual taxpayers. The income tax credit would be equal to the per capita share of the taxpayer's portion of the trust fund's revenue, but would be capped at the level of federal payroll taxes paid by that taxpayer or ten percent of the social security benefits the taxpayer may have received that year (110th Congressional Record, 2007).

Carbon taxes have been used by other levels of government in the United States. In 2006, Boulder, Colorado instituted the Climate Action Plan Tax that levied a tax on the end users of electricity. The energy tax is collected by the utility companies when consumers pay their bills. The revenue generated from the tax is used by the city to finance their climate action program. Their climate action program seeks to reduce local greenhouse gas emissions to seven percent below 1990 levels by the year 2012.

The Bay Area Air Quality Management District levies a fee that is very similar to a carbon tax. The tax that is imposed is based on the level of emissions but also covers other greenhouse gases beyond CO₂ (Bay Area Air Quality Management District, 2008). The tax is levied on industrial facilities and businesses that must abide by air quality permit requirements. The revenues generated from this tax are used by the Bay Area Air Quality Management District's climate programs.

A list of recent carbon tax initiatives that have either been instituted or suggested are listed in Table 2.

Table 2. Carbon Taxes Used in the United States

| Tax | Tax Base | Tax Rate | Taxpayer | Use of Revenue |
|--|---|---|--|---|
| Federal gas tax now in effect (not including taxes on diesel, aviation fuel) | Gasoline | 18.4 cents per gallon | Oil refiner; Position holder of fuel in terminal; Importer | Highway Trust Fund; Leaking Underground Storage Tank Trust Fund |
| Clinton Btu tax proposal in 1993 | Fossil fuels; Hydropower; Nuclear; Ethanol (in original proposal) | 25.7 cents per million Btus, with 34.2 cents per million Btus supplemental rate for oil | Oil refiner; End user of coal, electricity; Importer | Deficit reduction; Regressivity offsets in budget package |
| H.R. 2069 Save Our Climate Act of 2007 (Stark-McDermott) | Coal; Petroleum and petroleum products; Natural gas | \$10 per ton of carbon, increased by \$10 per year until emissions 80% below 1990 level | Manufacturer Producer Importer | Not mandated |
| H.R. 3416 America's Energy Security Trust Fund Act of 2007 (Larson) | Coal Petroleum and petroleum products; Natural gas | \$15 per ton of carbon dioxide, increased each year by 10% plus cost of living adjustment | Manufacturer Producer Importer | Dedicated to: Tax credit for clean energy technology; Transitional industry assistance; Carbon tax rebate |
| Boulder, Colorado, Climate Action Plan Tax | Electricity | Capped per kilowatt hour at: 0.49 cents (residential) 0.09 cents (commercial) 0.03 cent (industrial) | End user (collected by electric utility) | Climate action program |
| San Francisco, Bay Area Air Quality Management District Fee | Greenhouse gas emissions | 4.4 cents per ton of greenhouse gas emissions | Industry, businesses subject to air quality permits | Climate protection programs |

5. CAP-AND-TRADE IN THE UNITED STATES

The United States was the first to implement a cap-and-trade scheme, first in the 1980s to regulate lead in gasoline and ozone depleting chemicals, and then again in 1990 to reduce

sulfur dioxide (Harrison, Jr., 1999). The most recent carbon reducing policies discussed in the United States have been of the cap-and-trade variety.

Table 3. Cap-and-Trade Proposals in the United States

| Cap-and-Trade | Covered Emissions | Cost per Permit | Regulated Entity | Use of Revenue |
|--|---|---|---|--|
| S. 3036 Lieberman-Warner Climate Security Act of 2008 (Amendment 4825) | Carbon dioxide Methane Nitrous oxide Sulfur hexafluoride Perfluorocarbons Hydrofluorocarbons | Unknown; ability to provide relief if economy subject to harm | Coal user; Importer or producer of natural gas, petroleum, coal-based fuel, or certain greenhouse gases; Producers of HCFCs | Broad range of purposes including: worker assistance; consumer relief; greenhouse gas reduction programs; deficit reduction |
| Regional Greenhouse Gas Initiative (RGGI) | Carbon dioxide from electricity generation | Unknown; potential for liberalized offset provisions if price above \$7/ton | Electricity generator | Extent of auctioning and use of revenue varies with state |
| Western Climate Initiative (proposed) | Carbon dioxide Methane Nitrous oxide Sulfur hexafluoride Perfluorocarbons Hydrofluorocarbons | Unknown; anticipates rigorous offset program to reduce cost | Broad range of sectors for facilities, starting with electricity sector in 2012 and expanding to other sectors in 2015 | Minimum of 10% allowances auctioned in 2012, 25% in 2020, possibly higher thereafter; within guidelines, use of proceeds can vary by jurisdiction |

Starting in 2007, the momentum for a national cap-and-trade policy for the United States really started to take hold. The most relevant legislation introduced in 2007 was the Lieberman-Warner Climate Security Act of 2008, S. 3036 by Senators Joseph Lieberman and John Warner. This legislation proposed a national cap-and-trade program that sought to reduce greenhouse gas emissions to 19% below 2005 levels by 2020 and 71% below 2005 levels by 2050 (Pew Center on Global Climate Change, 2008; Eilperin, 2008). The bill would have imposed carbon caps on upstream producers or users. The proposed cap-and-trade bill would have applied to firms that use more than 5,000 tons of coal per year, process or import petroleum or coal-based liquid or gaseous fuels, methane,

nitrous oxide, sulfur hexafluoride, manufacture or import more than 10,000 tons of CO₂ or equivalent, or manufacture hydrochlorofluorocarbons (110th Congressional Record, 2007). The Lieberman-Warner bill states that for each ton of CO₂ or downstream emissions potential that a firm will need one allowance starting in 2012 (110th Congressional Record, 2007). The bill also institutes a decreasing number of allowances between 2012 and 2050, which would significantly reduce the amount of CO₂ emissions. Additionally, there are provisions in the bill that significantly restricts the use of domestic offset projects from foreign trading programs and allows firms to have limited borrowing capabilities against future years' allowances (110th Congressional Record, 2007). In order to try to maintain competitive equilibrium, the Lieberman-Warner bill has a provision that requires importers of products that produce high levels of greenhouse gas emissions during the manufacturing process to purchase emission allowances if the country where the product was produced does not have similar climate change regulations (110th Congressional Record, 2007).

As the number of allowances decrease over time, how these allowances will be distributed also changes. The bill calls for an ever increasing number of the available allowances to be auctioned off to firms with the revenues used to fund a variety of programs such as: tax relief for low income families impacted by the cap-and-trade program, energy efficiency programs, mass transit infrastructure development, research and development, greenhouse gas emission reductions not covered by the bill, international funding initiatives, and for deficit reduction among others (110th Congressional Record, 2007). Additionally the bill will provide allowances for free to industries that are dependent on fossil fuels, such as petroleum refiners and electricity generators that use fossil fuels, and to firms that would use the allowances to encourage the transition to an economy with fewer emissions, provide relief to consumers, reward early action, and attend to adaptation on an continuing basis (110th Congressional Record, 2007). The Lieberman-Warner bill also creates a separate cap-and-trade program for hydrofluorocarbon emissions.

Although the Lieberman-Warner bill was never passed and to date no federal cap-and-trade program exists, there are a couple regional cap-and-trade programs in the United States. One such initiative is the Regional Greenhouse Gas Initiative created by ten Northeast and Mid-Atlantic States. The states involved in the Regional Greenhouse Gas Initiative are Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont. This regional cap-and-trade program targets electricity generating firms that produce at least twenty-five megawatts of electricity. The objective of this Regional Initiative is to stabilize current level emissions by 2014 and reduce emissions to ten percent below 2009 levels by the year 2018 (Regional Greenhouse Gas Initiative, 2005). Each state in the Initiative has some autonomy over the implementation details. However, the Initiative permits offset projects for up to 3.3% of the emissions and allows for more moderate offsets if the price of the permits reaches seven dollars per ton or higher (Regional Greenhouse Gas Initiative, 2005). The distribution of the permits is primarily by auction, with the first auction of the Initiative taking place in September of 2008.

A different regional cap-and-trade program takes place in the western United States. The Western Climate Initiative is composed of seven western states, Arizona, California, Montana, New Mexico, Oregon, Utah, and Washington and four Canadian provinces, British Columbia, Manitoba, Ontario, and Quebec. The objective of the Western Climate Initiative is to reduce greenhouse gas emissions fifteen percent below 2005 levels by the year 2020 (Western Climate Initiative, 2007). The Initiative recommends a broad range of ideas to reduce greenhouse gas emissions covering electricity generation, industrial and commercial facilities, upstream residential, commercial, and industrial fuels, and gasoline and diesel-based transportation (Western Climate Initiative, 2007). The Western Climate Initiative is designed to work in conjunction with carbon taxes. This is an important distinction from other programs because British Columbia, Canada uses carbon taxes. The Initiative enables each of the states and provinces in the Initiative how to decide how to incorporate the carbon tax used in British Columbia with the cap-and-trade program (Western Climate Initiative, 2007). The Initiative is continuously changing to match California's commitment to

decrease greenhouse gas emission levels to 1990 levels by the year 2020 (California Health and Safety Code, 2007).

The regional cap-and-trade initiatives described above, as well as the Lieberman-Warner proposal, have paved the way and created momentum for the current bill in Congress, the Waxman-Markey Climate Change Bill, H.R. 2454, the American Clean Energy and Security Act of 2009. This bill was introduced by Representative Henry Waxman and Representative Edward Markey and is far more comprehensive than any previous cap-and-trade initiative. The bill was passed by the United States House of Representatives on May 21, 2009 and is currently under consideration in the United States Senate.

The American Clean Energy and Security Act of 2009 would create a renewable electricity program that would require large utilities to increase their production levels of renewable sources of electricity, such as solar, wind, biogas, biomass, biofuels, geothermal, and marine and hydrokinetic energy (111th Congressional Record, 2009). Specifically the Act would require that six percent of electricity come from renewable sources by 2012 and that twenty percent of electricity come from renewable sources by 2020, of which up to five percent of these targets can be met through energy efficiency measures. The Act does provide states some leeway in meeting these requirements. If an individual state does not think that these requirements can be met by the utilities in their state, the percentage of renewable energy sources can be reduced to twelve percent and the energy efficiency measures can be increased to eight percent (110th Congressional Record, 2007). The Act will allocate 85% of pollution permits to industry for free and will hold an auction for the remaining 15%. Furthermore, the Act requires a seventeen percent of the level of carbon emissions in 2005 by 2020.

Since this legislation has been passed in the House of Representatives, the bill has stalled in the United States Senate. So, as a refreshed effort at getting climate legislation passed, Senator Maria Cantwell and Senator Susan Collins introduced the Carbon Limits and Energy for America's Renewal (CLEAR) Act, S. 2877 (111th Congressional Record,

2009). The proposed bill calls for the President to set an initial target amount of fossil fuels that can be emitted starting in 2012, remaining at that level for three years, and then decreasing the amount of carbon emissions by a quarter of a percent each year thereafter (111th Congressional Record, 2009; Cantwell, 2009). The legislation is aimed at producers and importers of coal, natural gas, and oil; in other words an upstream regulatory action. The objectives of the bill is to reduce emissions to twenty percent less the 2005 carbon emissions by 2020, to thirty percent less the 2005 carbon emissions by 2025, to forty-two percent less the 2005 carbon emissions by 2030, and eighty-three percent less the 2005 carbon emissions by 2050 (111th Congressional Record, 2009; Cantwell, 2009). The carbon permits would be distributed among fossil fuel companies through monthly auctions. Seventy-five percent of the revenues generated from the auction would be distributed to consumers every month on an equal per capita basis to offset increases in energy costs (111th Congressional Record, 2009; Cantwell, 2009). Cantwell and Collins estimate that the transfer of the revenues of the cap-and-trade program will result in eighty percent of the American public incurring no net costs from the higher energy prices with low income households receive positive net benefits and high income households experiencing a 0.3% decrease in income (111th Congressional Record, 2009; Cantwell, 2009). The other twenty-five percent of the revenues from the permit auctions would go to a Clean Energy Reinvestment Trust Fund that would be used to further reduce greenhouse gas emissions, climate change adaptation, low-carbon energy investment, and regional economic development adjustment projects (111th Congressional Record, 2009; Cantwell, 2009).

6. POTENTIAL ECONOMIC RENT FROM CO₂ PERMIT AUCTIONS

The mere mention of the American Clean Energy and Security Act of 2009 causes great debate. The Act will allocate 85% of pollution permits to industry for free and will hold an auction for the remaining 15%. However, by auctioning-off only 15% of the permits, the bill fails to capture the maximum potential economic rent. This section seeks to

measure the amount of economic rent that could potentially be captured if 100% of the permits were auctioned off.

Calculating the economic rent from any cap-and-trade program requires knowledge of the elasticity of demand for each firm. However, the elasticity of demand for every firm cannot be known. On the other hand, an approximate elasticity of demand for individual sectors is known. Therefore, the elasticity of demand for the most important sectors in the United States with regard to carbon emissions (electricity, gasoline, aviation, and other) will be used to calculate the potential economic rent. Additionally, the number of permits that would initially be auctioned to firms would need to be known, as would how much of a decrease in CO₂ emissions would be required annually. This information is also unknown.

Therefore, since the necessary information to calculate the potential economic rent that can be generated from auctioning CO₂ emissions permits is unavailable a spreadsheet developed by the Carbon Tax Center¹ to illustrate the decrease in carbon emissions from a carbon tax will be used. Although this spreadsheet was developed for a carbon tax, the calculations were made based upon carbon emitted instead of the carbon content of the energy. Therefore, in this particular case, the spreadsheet can be used to approximate the potential economic rent from auctioning pollution permits. Various assumptions are built into the model and the reader should follow his or her own curiosity to the Carbon Tax Center for complete information. In addition to the assumptions built into the model, other assumptions have been made for the purpose of this project.

The most important assumption made is about the price of the pollution allowance permit. First, each permit sold in auction is assumed to be an allowance for one ton of CO₂ emitted. Second, for the purposes of this paper the price of the permit will be assumed to be the average price of a permit sold in an auction. As stated previously to calculate the economic rent that could be generated from an auction would require the elasticity, marginal abatement costs, and marginal benefits for each individual firm.

¹ Carbon Tax Center. <http://www.carbontax.org>

The other assumptions made are related to the amount of economic rent generated. First, the average amount the permits sell for will be assumed to be between the ranges of \$5 per permit to \$1,600 per permit. The \$5 per ton figure was chosen because that price is below the amount of the initial tax in the proposed Save Our Climate Bill by Stark and McDermott of \$10 per ton. The assumption is that the United States Congress would propose an initial value that would allow firms an opportunity to adjust to new carbon regulations without being harmed. Additionally, the \$5 per ton assumption is below the range that allowance permits have been trading for in Europe (€10 to €33) in the past year (European Climate Exchange and Point Carbon). The price of European Union ETS permits have ranged from a low of €0.29 in May of 2007 to a high of €31.50 (Point Carbon; Shapiro, 2007; Shrum, 2007). The \$1,600 upper limit for CO₂ allowance permits was based on the upper range of SO₂ and NO_x permits (Shapiro, 2007). Second, the average auction price is assumed to increase over time as their supply decreases. Third, the increase of the auction price is assumed to increase between the ranges of 2% and 6%. These values were chosen because they represent the typical historical inflation rates in the United States since 1990. During this time period, the inflation rate has never been more than 6%, either on an annual or monthly basis, and has rarely gone below 2% during this time-frame. Lastly, to calculate the potential economic rent from a CO₂ permit auction, the number of permits available in the first year of the abatement program and the annual decrease in the number of permits would need to be known, which as previously discussed is unavailable. Therefore, the number of permits available is assumed to be a constant number with the annual increase in permits serving as a proxy for the decrease in permits. The price increase will cause a decrease in the amount of CO₂ emissions, which in effect is equivalent to a reduction in the number of permits available. Furthermore, the annual price increase would be consistent with higher auction prices which would likely result from a decrease in the permits available.

Since a more exact figure cannot be calculated for the potential economic rent generated from CO₂ allowance permit auctions, sensitivity analysis is performed to get a range of the potential economic rent generated. Several variables will be altered to make

these calculations. Those variables which sensitivity analysis will be performed with are the initial average auction price for an emissions permit and the annual increase in price of the allowance permits.

The results are shown in Tables 4, 5, and 6. Table 4 corresponds to an annual increase in permit prices of 2%, Table 5 with a 4% annual increase in permit prices, and Table 6 with a 6% increase in permit prices. As shown in Tables 4, 5, and 6 the potential economic rent that could be generated from auctioning CO₂ permits to firms is very large. The rent generated from these auctions could be redistributed back to the populace, used to fund a variety of projects, or used to reduce the budget deficit. In either case, the proposals currently being debated in Congress do not capture the potential economic rent that is available and belongs to the populace because the atmosphere is common to each of us.

Table 4. Potential Economic Rent From Permit Auctions Assuming a 2% Annual Price Increase

| 2% Annual Increase in Permit Price | | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 |
|------------------------------------|---|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| \$5 | CO ₂ emissions, millions of metric tons | 5727.48 | 5799.09 | 5871.45 | 5944.54 | 6018.39 | 6092.98 | 6168.32 | 6244.42 | 6321.26 | 6398.86 | 6487.77 | 6577.91 | 6669.31 | 6762.25 | 6856.76 | 6952.87 |
| | Reduction in CO ₂ relative to moving trajectory, million metric tons | 115.587 | 129.007 | 143.006 | 157.604 | 172.823 | 188.683 | 205.207 | 222.419 | 240.343 | 259.002 | 267.865 | 277.028 | 286.503 | 296.034 | 305.617 | 315.245 |
| | Economic Rent, \$ millions (rounded to nearest hundred million) | 30600 | 31600 | 32600 | 33700 | 34800 | 35900 | 37100 | 38300 | 39500 | 40800 | 42200 | 43700 | 45200 | 46700 | 48300 | 50000 |
| \$10 | CO ₂ emissions, millions of metric tons | 5718.45 | 5780.64 | 5843.19 | 5906.06 | 5969.27 | 6032.8 | 6096.63 | 6160.75 | 6225.16 | 6289.84 | 6375.16 | 6461.61 | 6549.19 | 6638.43 | 6729.35 | 6822.02 |
| | Reduction in CO ₂ relative to moving trajectory, million metric tons | 124.619 | 147.455 | 171.266 | 196.083 | 221.938 | 248.867 | 276.903 | 306.083 | 336.442 | 368.019 | 380.468 | 393.333 | 406.625 | 419.861 | 433.024 | 446.099 |
| | Economic Rent, \$ millions (rounded to nearest hundred million) | 61000 | 62900 | 64900 | 66900 | 69000 | 71100 | 73300 | 75600 | 77900 | 80300 | 83000 | 85800 | 88800 | 91800 | 94900 | 98100 |
| \$25 | CO ₂ emissions, millions of metric tons | 5692.92 | 5728.7 | 5763.94 | 5798.6 | 5832.67 | 5866.12 | 5898.93 | 5931.06 | 5962.49 | 5993.21 | 6069.3 | 6146.24 | 6224.05 | 6303.79 | 6385.53 | 6469.34 |
| | Reduction in CO ₂ relative to moving trajectory, million metric tons | 150.151 | 199.398 | 250.514 | 303.544 | 358.537 | 415.541 | 474.605 | 535.777 | 599.109 | 664.65 | 686.332 | 708.696 | 731.764 | 754.493 | 776.845 | 798.781 |
| | Economic Rent, \$ millions (rounded to nearest hundred million) | 151900 | 155900 | 160000 | 164300 | 168600 | 173000 | 177400 | 182000 | 186700 | 191400 | 197800 | 204300 | 211000 | 218000 | 225300 | 232800 |
| \$50 | CO ₂ emissions, millions of metric tons | 5654.78 | 5651.67 | 5647.27 | 5641.57 | 5634.56 | 5626.23 | 5616.57 | 5605.57 | 5593.24 | 5579.55 | 5644 | 5709.01 | 5774.59 | 5842.43 | 5912.62 | 5985.23 |
| | Reduction in CO ₂ relative to moving trajectory, million metric tons | 188.288 | 276.428 | 367.18 | 460.577 | 556.651 | 655.436 | 756.963 | 861.264 | 968.368 | 1078.31 | 1111.63 | 1145.93 | 1181.22 | 1215.85 | 1249.76 | 1282.89 |
| | Economic Rent, \$ millions (rounded to nearest hundred million) | 301800 | 307700 | 313700 | 319800 | 325800 | 332000 | 338100 | 344300 | 350500 | 356800 | 368200 | 379900 | 392000 | 404600 | 417700 | 431300 |
| \$100 | CO ₂ emissions, millions of metric tons | 5590.87 | 5524.02 | 5456.14 | 5387.26 | 5317.43 | 5246.71 | 5175.16 | 5102.82 | 5029.74 | 4955.99 | 5005.37 | 5055.03 | 5104.99 | 5157.53 | 5212.76 | 5270.78 |
| | Reduction in CO ₂ relative to moving trajectory, million metric tons | 252.203 | 404.075 | 558.313 | 714.89 | 873.778 | 1034.95 | 1198.37 | 1364.02 | 1531.86 | 1701.87 | 1750.26 | 1799.91 | 1850.83 | 1900.75 | 1949.62 | 1997.34 |
| | Economic Rent, \$ millions (rounded to nearest hundred million) | 596800 | 601700 | 606500 | 611100 | 615500 | 619700 | 623800 | 627700 | 631400 | 634800 | 654100 | 673900 | 694200 | 715500 | 737700 | 760900 |
| \$250 | CO ₂ emissions, millions of metric tons | 5455.95 | 5260.25 | 5069.53 | 4883.77 | 4702.96 | 4527.06 | 4356.06 | 4189.91 | 4028.57 | 3872 | 3901.41 | 3930.9 | 3960.46 | 3992.75 | 4027.86 | 4065.89 |
| | Reduction in CO ₂ relative to moving trajectory, million metric tons | 387.123 | 667.847 | 944.921 | 1218.38 | 1488.25 | 1754.6 | 2017.47 | 2276.92 | 2533.03 | 2785.86 | 2854.22 | 2924.04 | 2995.36 | 3065.54 | 3134.51 | 3202.23 |
| | Economic Rent, \$ millions (rounded to nearest hundred million) | 1456400 | 1433300 | 1410100 | 1386600 | 1363000 | 1339300 | 1315500 | 1291600 | 1267700 | 1243700 | 1278400 | 1314100 | 1350600 | 1389100 | 1429500 | 1472000 |

| 2% Annual Increase in Permit Price | | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 |
|------------------------------------|---|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| \$500 | CO ₂ emissions, millions of metric tons | 5317.03 | 4996.31 | 4693.56 | 4407.89 | 4138.49 | 3884.53 | 3645.23 | 3419.85 | 3207.67 | 3007.97 | 3026.21 | 3044.47 | 3062.75 | 3083.53 | 3106.86 | 3132.81 |
| | Reduction in CO ₂ relative to moving trajectory, million metric tons | 526.034 | 931.785 | 1320.9 | 1694.26 | 2052.72 | 2397.14 | 2728.3 | 3046.98 | 3353.94 | 3649.89 | 3729.42 | 3810.47 | 3893.06 | 3974.75 | 4055.51 | 4135.3 |
| | Economic Rent, \$ millions (rounded to nearest hundred million) | 2839500 | 2724500 | 2613300 | 2505900 | 2402300 | 2302300 | 2206000 | 2113100 | 2023700 | 1937600 | 1988700 | 2041000 | 2094600 | 2151300 | 2211200 | 2274600 |
| \$750 | CO ₂ emissions, millions of metric tons | 5224.67 | 4824.94 | 4455.14 | 4113.15 | 3796.97 | 3504.75 | 3234.73 | 2985.29 | 2754.91 | 2542.17 | 2555.81 | 2569.48 | 2583.16 | 2599.09 | 2617.31 | 2637.87 |
| | Reduction in CO ₂ relative to moving trajectory, million metric tons | 618.396 | 1103.16 | 1559.31 | 1989 | 2394.24 | 2776.92 | 3138.8 | 3481.55 | 3806.7 | 4115.69 | 4199.82 | 4285.46 | 4372.66 | 4459.2 | 4545.07 | 4630.25 |
| | Economic Rent, \$ millions (rounded to nearest hundred million) | 4186100 | 3948000 | 3722800 | 3510000 | 3309000 | 3119100 | 2939900 | 2770700 | 2611000 | 2460400 | 2523400 | 2588000 | 2654200 | 2724400 | 2798700 | 2877500 |
| \$1,000 | CO ₂ emissions, millions of metric tons | 5155.67 | 4699.01 | 4282.79 | 3903.52 | 3557.96 | 3243.16 | 2956.4 | 2695.22 | 2457.34 | 2240.68 | 2251.81 | 2262.96 | 2274.13 | 2287.34 | 2302.64 | 2320.07 |
| | Reduction in CO ₂ relative to moving trajectory, million metric tons | 687.396 | 1229.09 | 1731.66 | 2198.63 | 2633.25 | 3038.51 | 3417.13 | 3771.61 | 4104.27 | 4417.18 | 4503.82 | 4591.98 | 4681.69 | 4770.94 | 4859.73 | 4948.04 |
| | Economic Rent, \$ millions (rounded to nearest hundred million) | 5508500 | 5128000 | 4773600 | 4443800 | 4136900 | 3851300 | 3585600 | 3338500 | 3108600 | 2894700 | 2967700 | 3042500 | 3119100 | 3200400 | 3286700 | 3378200 |
| \$1,250 | CO ₂ emissions, millions of metric tons | 5100.72 | 4599.98 | 4148.96 | 3742.75 | 3376.9 | 3047.39 | 2750.6 | 2483.27 | 2242.43 | 2025.44 | 2034.97 | 2044.52 | 2054.1 | 2065.56 | 2078.94 | 2094.29 |
| | Reduction in CO ₂ relative to moving trajectory, million metric tons | 742.349 | 1328.12 | 1865.49 | 2359.4 | 2814.31 | 3234.27 | 3622.93 | 3983.57 | 4319.17 | 4632.42 | 4720.66 | 4810.41 | 4901.72 | 4992.73 | 5083.43 | 5173.83 |
| | Economic Rent, \$ millions (rounded to nearest hundred million) | 6813000 | 6276200 | 5782400 | 5328200 | 4910500 | 4526200 | 4172800 | 3847800 | 3548800 | 3273700 | 3355300 | 3439000 | 3524700 | 3615700 | 3712400 | 3815000 |
| \$1,500 | CO ₂ emissions, millions of metric tons | 5055.13 | 4518.68 | 4040.21 | 3613.42 | 3232.69 | 2893 | 2589.87 | 2319.3 | 2077.73 | 1862.01 | 1870.43 | 1878.87 | 1887.34 | 1897.56 | 1909.57 | 1923.41 |
| | Reduction in CO ₂ relative to moving trajectory, million metric tons | 787.934 | 1409.42 | 1974.24 | 2488.72 | 2958.52 | 3388.66 | 3783.66 | 4147.54 | 4483.87 | 4795.85 | 4885.2 | 4976.07 | 5068.48 | 5160.73 | 5252.81 | 5344.71 |
| | Economic Rent, \$ millions (rounded to nearest hundred million) | 8103300 | 7399600 | 6758700 | 6175000 | 5643200 | 5158800 | 4717300 | 4315000 | 3948300 | 3613900 | 3703400 | 3795000 | 3888900 | 3988700 | 4094700 | 4207400 |
| \$1,600 | CO ₂ emissions, millions of metric tons | 5038.88 | 4489.88 | 4001.93 | 3568.18 | 3182.56 | 2839.65 | 2534.65 | 2263.3 | 2021.82 | 1806.84 | 1814.9 | 1822.99 | 1831.1 | 1840.92 | 1852.48 | 1865.82 |
| | Reduction in CO ₂ relative to moving trajectory, million metric tons | 804.186 | 1438.21 | 2012.52 | 2533.96 | 3008.65 | 3442.02 | 3838.88 | 4203.53 | 4539.79 | 4851.02 | 4940.73 | 5031.95 | 5124.72 | 5217.37 | 5309.89 | 5402.29 |
| | Economic Rent, \$ millions (rounded to nearest hundred million) | 8616000 | 7843100 | 7141700 | 6504900 | 5926900 | 5402100 | 4925500 | 4492500 | 4099100 | 3741500 | 3833900 | 3928600 | 4025500 | 4128600 | 4238100 | 4354500 |

Table 5. Potential Economic Rent From Permit Auctions Assuming a 4% Annual Price Increase

| 4% Annual Increase in Permit Price | | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 |
|------------------------------------|---|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| \$5 | CO ₂ emissions, millions of metric tons | 5727.48 | 5796.79 | 5866.46 | 5936.48 | 6006.8 | 6077.41 | 6148.26 | 6219.33 | 6290.57 | 6361.95 | 6443.9 | 6526.57 | 6609.94 | 6694.64 | 6780.69 | 6868.14 |
| | Reduction in CO ₂ relative to moving trajectory, million metric tons | 115.587 | 131.309 | 147.987 | 165.67 | 184.408 | 204.256 | 225.271 | 247.51 | 271.035 | 295.91 | 311.726 | 328.367 | 345.874 | 363.647 | 381.683 | 399.979 |
| | Economic Rent, \$ millions (rounded to nearest hundred million) | 30600 | 32200 | 33900 | 35600 | 37500 | 39500 | 41500 | 43700 | 46000 | 48400 | 50900 | 53700 | 56500 | 59600 | 62700 | 66100 |
| \$10 | CO ₂ emissions, millions of metric tons | 5718.45 | 5778.18 | 5837.71 | 5896.98 | 5955.95 | 6014.56 | 6072.74 | 6130.45 | 6187.62 | 6244.17 | 6320.24 | 6396.75 | 6473.68 | 6552.2 | 6632.38 | 6714.27 |
| | Reduction in CO ₂ relative to moving trajectory, million metric tons | 124.619 | 149.919 | 176.744 | 205.165 | 235.26 | 267.107 | 300.787 | 336.384 | 373.987 | 413.686 | 435.39 | 458.19 | 482.136 | 506.082 | 529.997 | 553.852 |
| | Economic Rent, \$ millions (rounded to nearest hundred million) | 61000 | 64100 | 67400 | 70800 | 74400 | 78100 | 82100 | 86200 | 90500 | 95000 | 100000 | 105200 | 110800 | 116600 | 122800 | 129300 |
| \$25 | CO ₂ emissions, millions of metric tons | 5692.92 | 5725.81 | 5757.17 | 5786.9 | 5814.92 | 5841.15 | 5865.51 | 5887.9 | 5908.24 | 5926.45 | 5987.85 | 6049.13 | 6110.24 | 6173.62 | 6239.38 | 6307.64 |
| | Reduction in CO ₂ relative to moving trajectory, million metric tons | 150.151 | 202.287 | 257.285 | 315.25 | 376.289 | 440.51 | 508.022 | 578.937 | 653.363 | 731.412 | 767.777 | 805.81 | 845.577 | 884.665 | 922.995 | 960.48 |
| | Economic Rent, \$ millions (rounded to nearest hundred million) | 151900 | 158900 | 166200 | 173800 | 181600 | 189800 | 198300 | 207000 | 216100 | 225500 | 237000 | 249000 | 261600 | 275000 | 289000 | 303900 |
| \$50 | CO ₂ emissions, millions of metric tons | 5654.78 | 5648.23 | 5638.84 | 5626.57 | 5611.35 | 5593.14 | 5571.89 | 5547.56 | 5520.13 | 5489.57 | 5533.57 | 5576.96 | 5619.7 | 5665.52 | 5714.57 | 5766.99 |
| | Reduction in CO ₂ relative to moving trajectory, million metric tons | 188.288 | 279.872 | 375.609 | 475.58 | 579.862 | 688.527 | 801.643 | 919.273 | 1041.47 | 1168.29 | 1222.06 | 1277.98 | 1336.12 | 1392.77 | 1447.81 | 1501.13 |
| | Economic Rent, \$ millions (rounded to nearest hundred million) | 301800 | 313600 | 325700 | 338100 | 350700 | 363700 | 376900 | 390400 | 404200 | 418200 | 438500 | 459700 | 481800 | 505200 | 530100 | 556400 |
| \$100 | CO ₂ emissions, millions of metric tons | 5590.87 | 5519.83 | 5445.54 | 5368.09 | 5287.57 | 5204.08 | 5117.75 | 5028.71 | 4937.09 | 4843.04 | 4866.62 | 4889.32 | 4911.12 | 4936.9 | 4966.8 | 5000.99 |
| | Reduction in CO ₂ relative to moving trajectory, million metric tons | 252.203 | 408.266 | 568.906 | 734.057 | 903.644 | 1077.58 | 1255.78 | 1438.12 | 1624.51 | 1814.82 | 1889.01 | 1965.62 | 2044.7 | 2121.39 | 2195.57 | 2267.13 |
| | Economic Rent, \$ millions (rounded to nearest hundred million) | 596800 | 613100 | 629300 | 645500 | 661500 | 677500 | 693200 | 708800 | 724100 | 739100 | 772600 | 807400 | 843600 | 882100 | 923100 | 966900 |
| \$250 | CO ₂ emissions, millions of metric tons | 5455.95 | 5255.05 | 5056.21 | 4859.77 | 4666.02 | 4475.27 | 4287.79 | 4103.84 | 3923.66 | 3747.45 | 3748.91 | 3749.66 | 3749.72 | 3754.4 | 3763.77 | 3777.92 |
| | Reduction in CO ₂ relative to moving trajectory, million metric tons | 387.123 | 673.052 | 958.24 | 1242.38 | 1525.19 | 1806.39 | 2085.74 | 2362.99 | 2637.95 | 2910.41 | 3006.72 | 3105.28 | 3206.09 | 3303.89 | 3398.61 | 3490.2 |
| | Economic Rent, \$ millions (rounded to nearest hundred million) | 1456400 | 1460000 | 1462100 | 1462700 | 1461700 | 1459200 | 1455200 | 1449700 | 1442700 | 1434200 | 1492500 | 1552900 | 1615400 | 1682500 | 1754500 | 1831900 |

| 4% Annual Increase in Permit Price | | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 |
|------------------------------------|---|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| \$500 | CO ₂ emissions, millions of metric tons | 5317.03 | 4990.6 | 4679.11 | 4382.35 | 4100.06 | 3831.95 | 3577.69 | 3336.93 | 3109.28 | 2894.32 | 2887.46 | 2880.21 | 2872.59 | 2869.32 | 2870.4 | 2875.87 |
| | Reduction in CO ₂ relative to moving trajectory, million metric tons | 526.034 | 937.495 | 1335.34 | 1719.8 | 2091.15 | 2449.71 | 2795.84 | 3129.9 | 3452.33 | 3763.54 | 3868.17 | 3974.73 | 4083.22 | 4188.97 | 4291.98 | 4392.24 |
| | Economic Rent, \$ millions (rounded to nearest hundred million) | 2839500 | 2774800 | 2708500 | 2641000 | 2572500 | 2503200 | 2433200 | 2362800 | 2292100 | 2221400 | 2305300 | 2392100 | 2481800 | 2578700 | 2683400 | 2796600 |
| \$750 | CO ₂ emissions, millions of metric tons | 5224.67 | 4819.09 | 4440.53 | 4087.7 | 3759.32 | 3454.1 | 3170.8 | 2908.16 | 2665 | 2440.13 | 2431.42 | 2422.48 | 2413.31 | 2408.1 | 2406.83 | 2409.52 |
| | Reduction in CO ₂ relative to moving trajectory, million metric tons | 618.396 | 1109.01 | 1573.92 | 2014.44 | 2431.89 | 2827.56 | 3202.73 | 3558.67 | 3896.6 | 4217.73 | 4324.21 | 4432.46 | 4542.51 | 4650.19 | 4755.55 | 4858.6 |
| | Economic Rent, \$ millions (rounded to nearest hundred million) | 4186100 | 4020600 | 3857700 | 3697900 | 3541200 | 3388100 | 3238600 | 3093000 | 2951300 | 2813800 | 2916500 | 3022700 | 3132400 | 3251400 | 3380400 | 3520200 |
| \$1,000 | CO ₂ emissions, millions of metric tons | 5155.67 | 4693.13 | 4268.26 | 3878.51 | 3521.42 | 3194.65 | 2895.97 | 2623.26 | 2374.53 | 2147.9 | 2138.81 | 2129.56 | 2120.16 | 2114.39 | 2112.23 | 2113.66 |
| | Reduction in CO ₂ relative to moving trajectory, million metric tons | 687.396 | 1234.97 | 1746.19 | 2223.63 | 2669.79 | 3087.01 | 3477.56 | 3843.57 | 4187.07 | 4509.96 | 4616.82 | 4725.38 | 4835.65 | 4943.89 | 5050.15 | 5154.46 |
| | Economic Rent, \$ millions (rounded to nearest hundred million) | 5508500 | 5222100 | 4946100 | 4680600 | 4425700 | 4181300 | 3947200 | 3723500 | 3509900 | 3306100 | 3424600 | 3546900 | 3673300 | 3810700 | 3959800 | 4121800 |
| \$1,250 | CO ₂ emissions, millions of metric tons | 5100.72 | 4594.11 | 4134.58 | 3718.25 | 3341.48 | 3000.85 | 2693.22 | 2415.64 | 2165.41 | 1940.01 | 1930.98 | 1921.84 | 1912.61 | 1906.72 | 1904.17 | 1904.94 |
| | Reduction in CO ₂ relative to moving trajectory, million metric tons | 742.349 | 1333.99 | 1879.87 | 2383.89 | 2849.73 | 3280.81 | 3680.31 | 4051.2 | 4396.2 | 4717.85 | 4824.65 | 4933.1 | 5043.21 | 5151.56 | 5258.21 | 5363.18 |
| | Economic Rent, \$ millions (rounded to nearest hundred million) | 6813000 | 6391200 | 5990800 | 5611300 | 5252000 | 4912400 | 4591700 | 4289100 | 4004100 | 3735900 | 3868000 | 4004600 | 4145700 | 4299100 | 4465900 | 4647300 |
| \$1,500 | CO ₂ emissions, millions of metric tons | 5055.13 | 4512.83 | 4026.01 | 3589.43 | 3198.29 | 2848.2 | 2535.09 | 2255.3 | 2005.47 | 1782.53 | 1773.71 | 1764.82 | 1755.87 | 1750.04 | 1747.32 | 1747.69 |
| | Reduction in CO ₂ relative to moving trajectory, million metric tons | 787.934 | 1415.26 | 1988.44 | 2512.72 | 2992.92 | 3433.47 | 3838.44 | 4211.53 | 4556.14 | 4875.33 | 4981.92 | 5090.12 | 5199.95 | 5308.24 | 5415.06 | 5520.43 |
| | Economic Rent, \$ millions (rounded to nearest hundred million) | 8103300 | 7535100 | 7002000 | 6502400 | 6034800 | 5597600 | 5189300 | 4808200 | 4452900 | 4121900 | 4266500 | 4415900 | 4570200 | 4738200 | 4921000 | 5119800 |
| \$1,600 | CO ₂ emissions, millions of metric tons | 5038.88 | 4484.05 | 3987.8 | 3544.38 | 3148.54 | 2795.48 | 2480.82 | 2200.6 | 1951.22 | 1729.43 | 1720.72 | 1711.94 | 1703.11 | 1697.33 | 1694.58 | 1694.83 |
| | Reduction in CO ₂ relative to moving trajectory, million metric tons | 804.186 | 1444.05 | 2026.65 | 2557.77 | 3042.67 | 3486.18 | 3892.71 | 4266.23 | 4610.38 | 4928.43 | 5034.91 | 5143 | 5252.7 | 5360.96 | 5467.8 | 5573.28 |
| | Economic Rent, \$ millions (rounded to nearest hundred million) | 8616000 | 7986700 | 7398600 | 6849700 | 6337900 | 5861300 | 5417800 | 5005400 | 4622400 | 4266800 | 4416000 | 4570200 | 4729500 | 4903000 | 5091700 | 5297200 |

Table 6. Potential Economic Rent From Permit Auctions Assuming a 6% Annual Price Increase

| 6% Annual Increase in Permit Price | | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 |
|------------------------------------|---|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| \$5 | CO ₂ emissions, millions of metric tons | 5727.48 | 5794.49 | 5861.4 | 5928.13 | 5994.61 | 6060.74 | 6126.45 | 6191.62 | 6256.15 | 6319.93 | 6393.23 | 6466.36 | 6539.23 | 6612.92 | 6687.43 | 6762.76 |
| | Reduction in CO ₂ relative to moving trajectory, million metric tons | 115.587 | 133.61 | 153.055 | 174.018 | 196.603 | 220.92 | 247.085 | 275.22 | 305.456 | 337.929 | 362.401 | 388.582 | 416.585 | 445.365 | 474.948 | 505.362 |
| | Economic Rent, \$ millions (rounded to nearest hundred million) | 30600 | 32800 | 35100 | 37700 | 40400 | 43300 | 46400 | 49700 | 53300 | 57000 | 61200 | 65600 | 70300 | 75400 | 80800 | 86700 |
| \$10 | CO ₂ emissions, millions of metric tons | 5718.45 | 5775.72 | 5832.14 | 5887.6 | 5941.98 | 5995.14 | 6046.95 | 6097.27 | 6145.94 | 6192.82 | 6257.7 | 6321.91 | 6385.36 | 6450.08 | 6516.1 | 6583.5 |
| | Reduction in CO ₂ relative to moving trajectory, million metric tons | 124.619 | 152.381 | 182.311 | 214.546 | 249.234 | 286.525 | 326.581 | 369.568 | 415.659 | 465.036 | 497.933 | 533.029 | 570.453 | 608.209 | 646.273 | 684.621 |
| | Economic Rent, \$ millions (rounded to nearest hundred million) | 61000 | 65300 | 69900 | 74900 | 80100 | 85700 | 91600 | 97900 | 104700 | 111800 | 119800 | 128300 | 137400 | 147100 | 157600 | 168800 |
| \$25 | CO ₂ emissions, millions of metric tons | 5692.92 | 5722.93 | 5750.3 | 5774.87 | 5796.45 | 5814.86 | 5829.92 | 5841.45 | 5849.26 | 5853.18 | 5897.67 | 5940.56 | 5981.73 | 6025.32 | 6071.46 | 6120.3 |
| | Reduction in CO ₂ relative to moving trajectory, million metric tons | 150.151 | 205.171 | 264.148 | 327.278 | 394.762 | 466.805 | 543.612 | 625.389 | 712.344 | 804.681 | 857.959 | 914.38 | 974.085 | 1032.97 | 1090.92 | 1147.82 |
| | Economic Rent, \$ millions (rounded to nearest hundred million) | 151900 | 161900 | 172400 | 183600 | 195400 | 207800 | 220900 | 234700 | 249200 | 264400 | 282500 | 301600 | 322000 | 343900 | 367400 | 392700 |
| \$50 | CO ₂ emissions, millions of metric tons | 5654.78 | 5644.79 | 5630.33 | 5611.25 | 5587.41 | 5558.7 | 5525.01 | 5486.25 | 5442.35 | 5393.25 | 5414.76 | 5434.04 | 5451.01 | 5471.81 | 5496.61 | 5525.6 |
| | Reduction in CO ₂ relative to moving trajectory, million metric tons | 188.288 | 283.306 | 384.122 | 490.901 | 603.799 | 722.961 | 848.517 | 980.582 | 1119.25 | 1264.61 | 1340.87 | 1420.9 | 1504.8 | 1586.48 | 1665.77 | 1742.52 |
| | Economic Rent, \$ millions (rounded to nearest hundred million) | 301800 | 319400 | 337800 | 357000 | 376900 | 397600 | 419100 | 441300 | 464200 | 487800 | 519300 | 552500 | 587700 | 625400 | 666100 | 710000 |
| \$100 | CO ₂ emissions, millions of metric tons | 5590.87 | 5515.66 | 5434.9 | 5348.68 | 5257.11 | 5160.37 | 5058.62 | 4952.08 | 4841 | 4725.64 | 4722.26 | 4716.62 | 4708.71 | 4706.21 | 4709.24 | 4717.96 |
| | Reduction in CO ₂ relative to moving trajectory, million metric tons | 252.203 | 412.437 | 579.55 | 753.47 | 934.096 | 1121.3 | 1314.91 | 1514.75 | 1720.6 | 1932.22 | 2033.37 | 2138.32 | 2247.1 | 2352.08 | 2453.14 | 2550.15 |
| | Economic Rent, \$ millions (rounded to nearest hundred million) | 596800 | 624400 | 652500 | 681000 | 709900 | 739000 | 768300 | 797700 | 827100 | 856400 | 907400 | 960900 | 1017200 | 1077900 | 1143700 | 1214800 |
| \$250 | CO ₂ emissions, millions of metric tons | 5455.95 | 5249.89 | 5042.93 | 4835.74 | 4628.96 | 4423.23 | 4219.17 | 4017.39 | 3818.45 | 3622.9 | 3596.98 | 3569.74 | 3541.25 | 3519.32 | 3503.94 | 3495.11 |
| | Reduction in CO ₂ relative to moving trajectory, million metric tons | 387.123 | 678.212 | 971.52 | 1266.41 | 1562.25 | 1858.44 | 2154.36 | 2449.44 | 2743.15 | 3034.96 | 3158.65 | 3285.2 | 3414.57 | 3538.96 | 3658.43 | 3773.01 |
| | Economic Rent, \$ millions (rounded to nearest hundred million) | 1456400 | 1486700 | 1515000 | 1541100 | 1565100 | 1586600 | 1605600 | 1622000 | 1635700 | 1646500 | 1733400 | 1824000 | 1918700 | 2021800 | 2134400 | 2257400 |

| 6% Annual Increase in Permit Price | | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 |
|------------------------------------|---|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| \$500 | CO ₂ emissions, millions of metric tons | 5317.03 | 4984.96 | 4664.79 | 4356.97 | 4061.88 | 3779.77 | 3510.81 | 3255.08 | 3012.57 | 2783.19 | 2752.68 | 2721.66 | 2690.17 | 2664.93 | 2645.82 | 2632.73 |
| | Reduction in CO ₂ relative to moving trajectory, million metric tons | 526.034 | 943.139 | 1349.67 | 1745.18 | 2129.33 | 2501.9 | 2862.72 | 3211.76 | 3549.03 | 3874.67 | 4002.95 | 4133.28 | 4265.64 | 4393.35 | 4516.56 | 4635.39 |
| | Economic Rent, \$ millions (rounded to nearest hundred million) | 2839500 | 2825000 | 2805200 | 2780400 | 2750700 | 2716300 | 2677400 | 2634300 | 2587300 | 2536700 | 2660300 | 2789000 | 2923000 | 3070300 | 3232100 | 3410000 |
| \$750 | CO ₂ emissions, millions of metric tons | 5224.67 | 4813.32 | 4426.07 | 4062.51 | 3722.07 | 3404.12 | 3107.9 | 2832.62 | 2577.39 | 2341.32 | 2311.88 | 2282.26 | 2252.48 | 2228.4 | 2209.86 | 2196.74 |
| | Reduction in CO ₂ relative to moving trajectory, million metric tons | 618.396 | 1114.78 | 1588.38 | 2039.64 | 2469.14 | 2877.55 | 3265.63 | 3634.22 | 3984.21 | 4316.54 | 4443.75 | 4572.68 | 4703.34 | 4829.89 | 4952.52 | 5071.37 |
| | Economic Rent, \$ millions (rounded to nearest hundred million) | 4186100 | 4093100 | 3994700 | 3891500 | 3784200 | 3673300 | 3559500 | 3443300 | 3325300 | 3206100 | 3356700 | 3513600 | 3677000 | 3857100 | 4055600 | 4274500 |
| \$1,000 | CO ₂ emissions, millions of metric tons | 5155.67 | 4687.32 | 4253.9 | 3853.8 | 3485.37 | 3146.93 | 2836.73 | 2553.07 | 2294.24 | 2058.55 | 2030.86 | 2003.15 | 1975.42 | 1952.91 | 1935.47 | 1922.96 |
| | Reduction in CO ₂ relative to moving trajectory, million metric tons | 687.396 | 1240.78 | 1760.55 | 2248.35 | 2705.84 | 3134.74 | 3536.8 | 3913.76 | 4267.37 | 4599.31 | 4724.77 | 4851.79 | 4980.4 | 5105.37 | 5226.91 | 5345.16 |
| | Economic Rent, \$ millions (rounded to nearest hundred million) | 5508500 | 5316000 | 5121100 | 4924700 | 4727800 | 4531100 | 4335600 | 4141900 | 3950800 | 3762700 | 3936000 | 4116400 | 4304300 | 4511900 | 4741100 | 4994300 |
| \$1,250 | CO ₂ emissions, millions of metric tons | 5100.72 | 4588.32 | 4120.38 | 3694.07 | 3306.58 | 2955.14 | 2637.1 | 2349.85 | 2090.95 | 1858.02 | 1832.02 | 1806.07 | 1780.18 | 1759.13 | 1742.76 | 1730.92 |
| | Reduction in CO ₂ relative to moving trajectory, million metric tons | 742.349 | 1339.78 | 1894.07 | 2408.07 | 2884.63 | 3326.52 | 3736.43 | 4116.98 | 4470.66 | 4799.84 | 4923.61 | 5048.87 | 5175.63 | 5299.15 | 5419.62 | 5537.19 |
| | Economic Rent, \$ millions (rounded to nearest hundred million) | 6813000 | 6506000 | 6202400 | 5903100 | 5609300 | 5321900 | 5041500 | 4768800 | 4504400 | 4248800 | 4442000 | 4643100 | 4852600 | 5084400 | 5340600 | 5624000 |
| \$1,500 | CO ₂ emissions, millions of metric tons | 5055.13 | 4507.07 | 4011.98 | 3565.76 | 3164.44 | 2804.26 | 2481.62 | 2193.18 | 1935.76 | 1706.42 | 1681.91 | 1657.51 | 1633.21 | 1613.43 | 1598 | 1586.8 |
| | Reduction in CO ₂ relative to moving trajectory, million metric tons | 787.934 | 1421.03 | 2002.47 | 2536.38 | 3026.77 | 3477.41 | 3891.91 | 4273.66 | 4625.85 | 4951.44 | 5073.72 | 5197.43 | 5322.61 | 5444.86 | 5564.38 | 5681.32 |
| | Economic Rent, \$ millions (rounded to nearest hundred million) | 8103300 | 7670300 | 7248900 | 6840000 | 6444500 | 6063000 | 5696100 | 5344200 | 5007300 | 4685700 | 4896900 | 5116900 | 5345900 | 5599500 | 5880200 | 6190800 |
| \$1,600 | CO ₂ emissions, millions of metric tons | 5038.88 | 4478.29 | 3973.85 | 3520.91 | 3115.08 | 2752.18 | 2428.3 | 2139.77 | 1883.18 | 1655.36 | 1631.4 | 1607.55 | 1583.82 | 1564.49 | 1549.41 | 1538.45 |
| | Reduction in CO ₂ relative to moving trajectory, million metric tons | 804.186 | 1449.81 | 2040.6 | 2581.24 | 3076.13 | 3529.48 | 3945.23 | 4327.07 | 4678.43 | 5002.5 | 5124.23 | 5247.39 | 5372 | 5493.79 | 5612.97 | 5729.67 |
| | Economic Rent, \$ millions (rounded to nearest hundred million) | 8616000 | 8129900 | 7659300 | 7205100 | 6767800 | 6348200 | 5946400 | 5562800 | 5197200 | 4849700 | 5067700 | 5294700 | 5531100 | 5793000 | 6082900 | 6403800 |

7. Discussion

While the exact calculations are difficult to obtain because of a lack of specific information, such as the individual firm elasticities of demand, the potential economic rent from carbon abatement policies, specifically cap-and-trade and carbon taxes, are substantial. However, the economic rent figures in the tables above are not net of taxes. For an overview of the Georgist perspective on taxes and rent the reader is encouraged to follow his or her curiosity to examine the work of Foldvary (2010). Despite these shortcomings, the findings presented in this paper are meaningful and robust. The results of the scenario analyses show that the potential economic rent that could be captured from carbon abatement programs is in the order of billions of dollars, and in some scenarios trillions of dollars.

Three different scenarios, a 2% annual permit price increase from the starting permit price, a 4% annual permit price increase, and a 6% annual permit price increase, illustrate how much economic rent is available from CO₂ abatement programs. Not surprisingly, economic rent increases with each annual price increase. However, an interesting result is the corresponding decrease in CO₂ emissions. As shown in the tables, the decrease in CO₂ as a result of the increase in the price of permits initially increases. At some permit price level, however, the reduction of CO₂ emissions reaches an apex and then starts to decrease. This result could be due to a few reasons. First, and the most likely reason, is that firms have shifted to new technologies that reduce their CO₂ emissions. As the price of permits increase, the cost of investment in new technology to reduce CO₂ emissions is cheaper than the cost of the permits. The new technologies will result in fewer emissions. However, at some point there will be a flood of new technology and additional investment will not be feasible preventing additional reductions in CO₂ emissions. Second, the permits will reduce emissions to a point where further increases in reductions are not possible. Therefore, additional reductions will occur but at a diminishing rate.

As shown in this paper, the two main schemes for CO₂ abatement are carbon taxes and cap-and-trade. Furthermore, the economic rent that can be captured with the two schemes is nearly identical if the calculations are made based upon carbon emitted instead of the carbon content of the energy. The economic rent would be similar if the calculations were made on the carbon content of the energy, although the rent would likely be higher. Thus, a cap-and-trade program that auctions all of the abatement permits can obtain the economic rent levels estimated in Tables 4, 5, and 6. Despite the benefits of a cap-and-trade program, many people favor carbon taxes over a cap-and-trade program. The reasons for this preference are that taxes are predictable and the increased prices would be expected by firms and consumers, while cap-and-trade auctions are volatile in their price ranges and cannot be anticipated by actors in the market place. Furthermore, cap-and-trade auctions could potentially be manipulated by firms to keep the prices of the permits low, whereas carbon taxes are set per ton of CO₂ by a regulatory agency.

Despite some drawbacks, the results presented in this paper suggest that either carbon taxation or a cap-and-trade scheme that auctions all the abatement permits can work. Furthermore, the findings indicate that applying Georgist principles to environmental problems, such as those that affect the commons like air and water, can be an effective method for reducing environmental degradation while capturing the economic rent that rightfully belongs to society. The rent captured can then be redistributed back to society to ensure that the abatement policies are, at worst, tax neutral and not regressive. As Barnes (2001) argues, treating environmental assets as commons and making those that pollute pay, the redistribution of the captured economic rent is an equitable method of reducing environmental degradation.

References:

Aldy, J.E. and Stavins, R.N. (2008). "The Role of Technology Policies in an International Climate Agreement." Issue Paper Prepared for *The Climate Dialogue*, September 2-3, Copenhagen, Denmark.

Andersen, M.S. (1999). "Governance by Green Taxes: Implementing Clean Water Policies in Europe." *Environmental Economics and Policy Studies*, 39: 39-63.

- Barnes, P. (2001). *Who Owns the Sky?: Our Common Assets and the Future of Capitalism*. Island Press: Washington, D.C.
- Baumol, William J. (1972). "On Taxation and the Control of Externalities." *American Economic Review*, 62(3): 307-322.
- Bay Area Quality Management District. (2008). Regulation 3, Schedule T, May 21.
- Benkovic, S. and Kruger, J. (2001). "To Trade or Not to Trade? Criteria for Applying Cap and Trade." In: *Optimizing Nitrogen Management in Food and Energy Production and Environmental Protection: Proceedings of the 2nd International Nitrogen Conference on Science and Policy*. *The Scientific World*, 1:
- Boulder Revised Code. <http://www.colocode.com/boulder2/chapter3-12.htm>
- Brouillard, C. and Van Pelt, S. (2007). "A Community Takes Charge: Boulder's Carbon Tax." http://www.bouldercolorado.gov/files/Environmental%20Affairs/climate%20and%20energy/boulders_carbon_tax.pdf
- California Health and Safety Code. (2007). <http://www.arb.ca.gov/cc/ab32/ab32.htm>
- Cantwell, M. (2009). "How the CLEAR Act Works." <http://cantwell.senate.gov/issues/CLEAR%20Act%20how%20it%20works.pdf>
- Congressional Budget Office. (2008). "Policy Options for Reducing CO₂ Emissions." *Congress of the United States Congressional Budget Office*, February.
- Eilperin, J. (2008). "Senate Leaders Pull Measure on Climate." *Washington Post*, June 7.
- Environmental Protection Agency. (2008). "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006." http://www.epa.gov/climatechange/emissions/downloads/08_CR.pdf
- European Climate Exchange. <http://www.ecx.eu/>
- Foldvary, F. (2010). "Taxes and Rent: A Georgist View." *Project Prepared for The Robert Schalkenbach Foundation*.
- Galbraith, K. (2009). "Buffett: Cap-and-Trade is a 'Regressive' Tax." *New York Times*, March 9.
- Harrison, Jr., D. (1999). "Tradable Permits for Air Pollution Control: The U.S. Experience." In: OECD, *Implementing Domestic Tradable Permits for Environmental Protection*, 28-37.

Hasselknippe, H. and Christiansen, A.C. (2003). "Energy Taxation in Europe: Current Status – Drivers and Barriers – Future Prospects." Fridtjof Nansen Institute, FNI Report 14.

Johansson, B. (2000). "Economic Instruments in Practice 1: Carbon Tax in Sweden." Swedish Environmental Protection Agency.
<http://www.oecd.org/dataoecd/25/0/2108273.pdf>

110th Congressional Record. (2007). H.R. 2069.

110th Congressional Record. (2007). H.R. 3416.

110th Congressional Record. (2007). S. 3036, Amendment 4825.

111th Congressional Record. (2009). H.R. 2454.

111th Congressional Record. (2009). S. 2877.

139th Congressional Record. (1993). "State of the Union Address by President Bill Clinton." H674, H678, February 17.

Pew Center on Global Climate Change. (2008). "Summary of the Boxer Substitute Amendment to the Lieberman-Warner Climate Security Act."
<http://www.pewclimate.org/docUploads/L-WFullSummary.doc>

Pigou, Arthur C. (1920). *The Economics of Welfare*. Macmillan: London.

Point Carbon. <http://www.pointcarbon.com/>

Regional Greenhouse Gas Initiative. (2005). <http://www.rggi.org/about>

Shapiro, R. (2007). "Addressing the Risks of Climate Change: The Environmental Effectiveness and Economic Efficiency of Emissions Caps and Tradable Permits, Compared to Carbon Taxes." *The American Consumer Institute*,
<http://www.theamericanconsumer.org/Shapiro.pdf>

Shrum, T. (2007). "Greenhouse Gas Emissions: Policy and Economics." *A Report Prepared for the Kansas Energy Council Goals Committee*,
http://kec.kansas.gov/reports/GHG_Review_FINAL.pdf

Speck, S. (2008). "The Design of Carbon and Broad-based Energy Taxes in European Countries." *Vermont Journal of Environmental Law*, 10: 31-59.

United States Department of Treasury, Office of Tax Policy. (1993). "Frequently Asked Questions Regarding the Administration's Proposed Modified BTU Tax 2."