The Design of a Carbon Tax

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ABSTRACT

We consider the design of a tax on greenhouse gas emissions for a developed country such as the United States. We consider three sets of issues: the optimal tax base, issues relating to the rate (including the use of the revenues and rate changes over time) and trade. We show that a well-designed carbon tax can capture about 80% of U.S. emissions by taxing fewer than 3,000 taxpayers and up to almost 90% with a modest additional cost. We recommend full or partial delegation of rate setting authority to an agency to ensure that rates reflect new information about the costs of carbon emissions and of abatement. Adjustments should be made to the income tax to ensure that a carbon tax is revenue neutral and distributionally neutral. Finally, a carbon tax should include a system of border tax adjustments. We suggest a system that imposes presumptive border tax adjustments with the ability of an individual firm to prove that a different rate should apply. The presumptive tax could be based either on average emissions for production of the item by the exporting country or by the importing country.

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This paper considers the design of a tax on greenhouse gases. The purpose of such a tax, which we will generally refer to as a carbon tax, is to internalize externalities associated with anthropogenic climate change.[1] Without a carbon tax, individuals face a distorted set of prices. Activities that result in carbon emissions are relatively too cheap because individuals will not consider the costs the emissions impose on others, including on future generations. A tax forces individuals to consider the full set of consequences from emissions.

The theory behind these sorts of taxes dates back to writings by Pigou, 70 years ago, but there is little experience with the design of these taxes and almost none with a Pigouvian tax that covers a substantial portion of the economy, as would a carbon tax.[2] There are several existing carbon taxes but all are comparatively narrow or are otherwise badly designed. There have also been several proposed carbon taxes introduced into legislation in the U.S., but only in bare bones form. Although we can learn from these examples, they do not serve as adequate models for the best possible design of a carbon tax.

We consider three central design issues: the tax base (including possible offsets or credits), the tax rate (including distributional issues, the use of the revenues, and tax rate changes), and trade. With respect to the base, we show that by collecting the tax upstream, we can accurately and cheaply cover 80 percent of U.S. emissions by taxing fewer than 3,000 taxpayers, and that we can cover close to 90 percent of U.S. emissions at a modest additional cost. As the base gets broader, the accuracy of the tax and the collection costs correspondingly increase, and this tradeoff determines the optimal tax base. The main problem presented by upstream collection is that a tax credit or offset must be given for fossil fuels that are not combusted. For example, if a tax is imposed at

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[1] As we will discuss below, there are a wide variety of greenhouse gases other than carbon. See Intergovernmental Panel on Climate Change (2007a) p. 33 for a list of greenhouse gases. We refer to the tax generically as a carbon tax with the understanding that it will likely cover a wide variety of greenhouse gases. We will not discuss the science behind anthropogenic climate change. See Intergovernmental Panel on Climate Change (2007a) for a review of the science.

[2] Pigou (1938) For a review of the theory behind these taxes, see Bovenberg and Goulder (2002) There are a number of papers that consider design issues from a general perspective, such as how to set the tax when there are administrative costs of collection. See, for example, Polinsky and Shavell (1982).

the refinery and some distillates are sequestered into products such as asphalt, the tax will be too broad. We discuss how such an credit system would be designed.

Although the theory behind setting the rate is well known – it should equal the marginal harm from emissions -- there are a number of difficult design issues.[3] The most difficult issue with respect to rates is the design of a system for ensuring that the rate changes over time as we learn new information about the costs and benefits of reducing emissions. In particular, a central problem with climate change is uncertainty about the effects and uncertainty about the costs of abatement. The best that can be done now is a crude estimate of the optimal rate. As we learn new information, the tax rate will have to change to reflect this. We suggest a delegation or partial delegation of rate setting authority to an expert agency to ensure that rate changes at appropriate intervals are on the agenda and expertise in the relevant parameters for setting the rate. Given the size of the tax and the potential winners and losers from rate changes, full delegation may not be possible, in which case we recommend a number of intermediate regimes. We also discuss the use of the revenues, recommending a revenue neutral and distributionally neutral adjustment to the income tax.

The third design issue relates to trade in carbon intensive goods. We argue that border tax adjustments for a carbon tax are necessary and appropriate. There is, however, no simple and clearly legal method of implementing a system of border tax adjustments to prevent so-called carbon leakage, the shifting of production to countries without a carbon pricing mechanism. The key problem is that to set the border tax adjustment, we need information about the particular production technology and sources of energy used to produce an item, unlike with a VAT, where price is all that is needed. The necessary information may be difficult to obtain. We consider a number of possible options and their legality, recommending a system of presumptive border tax adjustments that allow individual firms to provide evidence of lower emissions. The presumptive border tax can be based on either average emissions from the production of like products in the exporting country or in the importing country. Using information from the exporting country is preferable but obtaining that information may be more difficult and using it raises additional trade-related legal issues.

3 The optimal tax rate in a second-best world is a bit more complicated. We discuss this further below.

Cap and trade systems are currently the favored carbon-pricing mechanism. The EU uses a cap and trade system for compliance with the Kyoto Protocol and cap and trade systems are prominently under consideration in the U.S. Congress. Although there are many reasons for preferring a tax,[4] if a cap and trade system is ultimately adopted, most of the design issues for the tax will be relevant for a cap and trade system. For example, it is likely that we will want to use the same point in production for remittance of a tax and for the imposition of a permit requirement. Similarly, carbon leakage raises similar issues under a cap and trade regime and under a tax. Thus, a detailed consideration of how to implement a carbon tax can inform the discussion of how best to implement a cap and trade system should a cap and trade system end up being chosen as the carbon pricing mechanism.[5]

Our focus here is on a tax implemented in a developed country. We have the U.S. in mind, and use U.S. data, but the considerations may be similar in other developed countries even if some particulars change. Other issues may arise in developing countries, where, for example, tax enforcement is not as robust and where the sources of emissions are likely to be very different (for example, agriculture and deforestation will play a larger role and energy a smaller role in developing countries).

Part I provides background on greenhouse gas emissions and the various regulatory regimes used currently to control them. Part II discusses principles related

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[4] The literature is large. For a small sample, see Weitzman (1974), Roberts and Spence (1976), Hoel and Karp (2002), Karp and Zhang (2005), Nordhaus (2007). Most of these discussions focus on theoretical issues such as the deadweight loss from error. We note that from an administrative perspective a carbon tax can be more quickly implemented than a cap and trade system. Coal producers already pay an excise tax to fund the Black Lung Trust Fund and oil producers pay a tax to fund the Oil Spill Trust Fund (see Metcalf (2007a) for a description of these funds). We also have precedents for refundable credits for sequestration activities in federal fuels tax credits. In contrast, we have no administrative structure in place for running a carbon cap-and-trade program. The Acid Rain Program is a helpful precedent but the value of permits is an order of magnitude smaller than the potential value of carbon emission permits. It also was highly concentrated among a small set of electric utilities.

[5] Some issues will be different. For example, a cap and trade system will likely need a so-called safety value or price ceiling as well as a price floor, and there are a number of design issues in setting the ceiling and flow that are not present in a carbon tax. Burtraw and Palmer (2006)

to setting the rate, including also the use of the tax revenues and adjusting for the distributive effects of the tax. Part III considers the tax base. It begins with a discussion of the theory of setting the optimal base and then turns to the detail the various production systems and discusses how best to collect a tax on various types of emissions. Part IV considers sequestration and other carbon-reducing activities that should receive tax credits. Part V considers the interaction of a carbon tax and the trade rules. Part VI considers interactions with other domestic regulations and taxes that affect carbon emissions. Part VII concludes.

I. Emissions and current control mechanisms

As background to understanding how best to design a carbon tax regime in the United States, we begin with a review of greenhouse gas emissions in the United States. We also briefly review carbon pricing policies in other countries.

A. Emissions

The U.S. emitted 7.0 billion metric tons of CO_2 equivalents in 2006, roughly 20 percent of worldwide emissions.[6] This amount consists of emissions of CO_2 (more than 80% of the total) and emissions of other gases such as methane and nitrous oxide that also contribute to the greenhouse effect. It is conventional to convert the emissions of other gases to CO_2 equivalent amounts (CO_2e) by determining how much CO_2 would have to be emitted to have the same effect on the climate. The conversion factors are known as global warming potentials.[7] Methane, for example, has a 100 year global

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[6] Net emissions in the United States– gross emissions less carbon sinks – were 6.2 billion metric tons (U. S. Environmental Protection Agency (2008) Carbon sinks are measured in the EPA report as those arising from land use, land use changes, and forestry activities.

[7] Calculation of global warming potentials is not straightforward. The problem is that different gases have different lifetimes in the atmosphere, so determining the global warming potential involves aggregating over time. Current inventories of greenhouse gas emissions use the 100 year global warming potentials calculated by the IPCC Second Assessment Report 1996 and are listed in the most recent IPCC Report, Intergovernmental Panel on Climate Change (2007a) Table TS.2, page 33. To avoid some of the problems with discounting, the IPCC also reports the global warming potentials over various time periods. The following is a selection of 100 global warming potentials for important gases along with their associated U.S. emissions in carbon equivalents in million metric ton units:

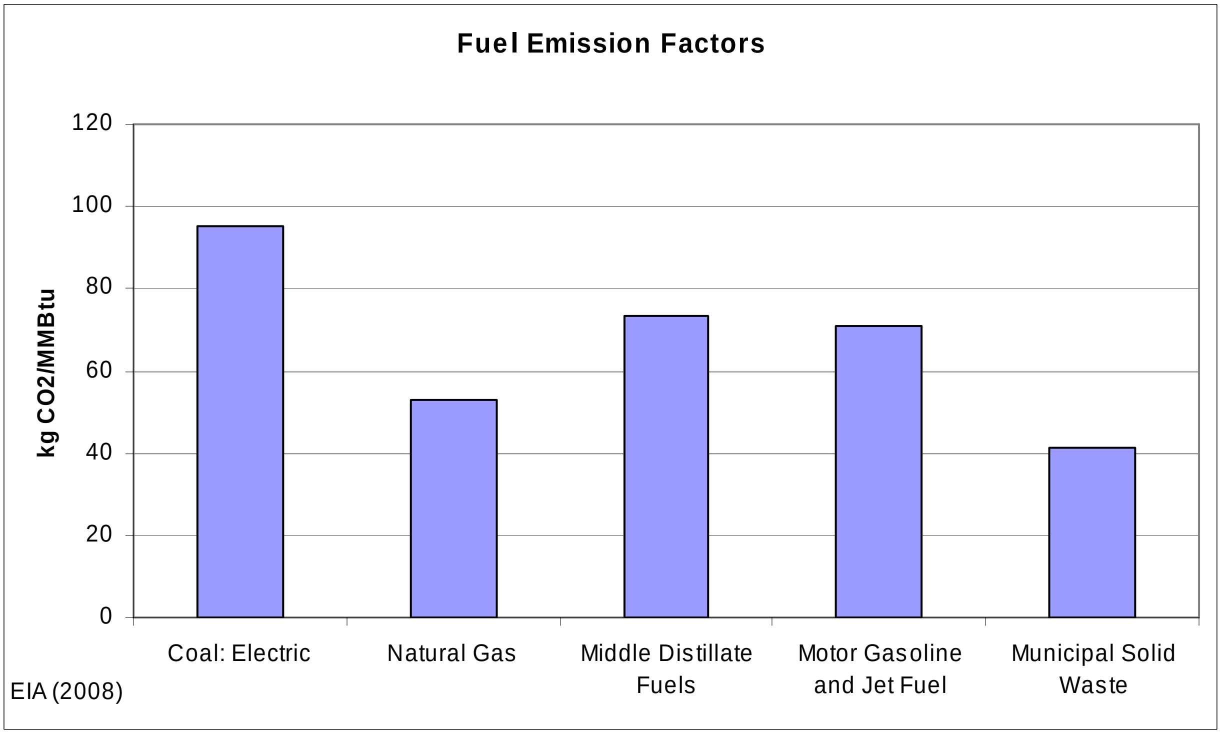
warming potential of 21, which means that a ton of methane has the same climate forcing impact as 21 tons of CO_2.

Parties to the UN Framework Convention for Climate Change (UNFCCC) must provide inventories of their carbon emissions. The U.S. inventory is done by the Environmental Protection Agency following guidelines set by the International Panel on Climate Change pursuant to the UNFCCC. The most recent data is for 2006. U. S. Environmental Protection Agency (2008), and our data is based on this source.

About 80 percent of U.S. emissions in 2006 were from the combustion of fossil fuel. Petroleum use makes up about 43 percent of this total, coal makes up 37 percent, and natural gas makes up the remaining 20 percent. Non-energy uses of fossil fuel as well as other miscellaneous uses (such as for international bunkers to supply fuel for shipping) add a modest amount of additional emissions. Of the three fossil fuels, coal has the highest carbon content per unit of energy (with the amount varying by type of coal), then petroleum, and then natural gas. See Figure X.[8]

Table X. GWP's and 2006 Greenhouse Gas Emissions		
	CO2e (MMT)	GWP
Carbon Dioxide	5,983.1	1
Methane	555.3	21
Nitrous Oxide	367.9	310
HFCs	124.5	140 to 11,700
PFCs	6.0	6,500 to 9,200
Sulfur Hexaflouride	17.3	23,900
Total	7,054.2	
Source: EPA (2008), Tables ES-1 and ES-2		

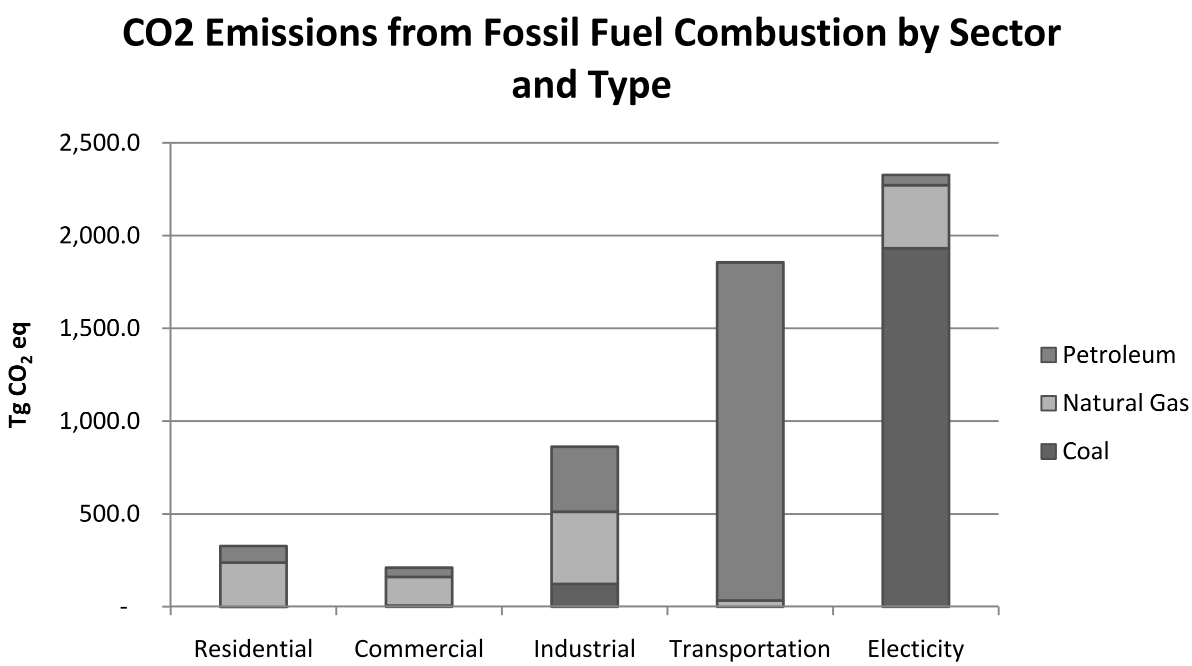
[8] Data from EIA Voluntary Reporting of Greenhouse Gases website at http://www.eia.doe.gov/oiaf/1605/techassist.html and accessed on May 27, 2008.



The four major end uses of fossil fuels are industrial, transportation, residential, and commercial. Transportation makes up the largest category of emissions, making up about 33 percent of fossil fuel emissions (and 26 percent of all U.S. emissions). Transportation emissions come almost exclusively from petroleum. Over 60 percent of transportation emissions are from personal vehicle use with most of the rest from heavy-duty vehicles and jet fuel.

Industrial uses of fossil fuels make up 27 percent of emissions from fossil fuels (22 percent of the total emissions). About half of these come from direct combustion of fossil fuels to produce steam or heat for industrial processes and the other half from electricity use by industry. Residential and commercial end-use make up the rest of emissions from fossil fuel combustion, relying heavily on electricity, with the remaining amount natural gas or petroleum for heating and cooking.

Electricity acts as an intermediate source of emissions – emissions result from the generation of electricity which is then used by consumers in the various categories listed above (industrial, commercial, residential, and transportation). Emissions from the generation of electricity were included in the end-use numbers reported above. Looking at electricity as a separate category, it accounts for 36 percent of the energy from fossil fuels in the U.S. and 41 percent of CO_2 emissions from fossil fuel combustion. The type of fuel used for electricity generation has a significant effect on emissions. Electricity can be generated through non-emitting methods such as hydroelectric, nuclear, or geothermal energy, as well as through combustion of natural gas and coal. Almost all coal used in the U.S. (93 percent) is used for electricity generation. Conventional use of coal to generate electricity is by far the highest emitting method of generating electricity. The following graphic summarizes U.S. fossil fuel emissions, keeping electricity as a separate category. Environmental Protection Agency (2008) Table 3.1



By comparison to emissions from fossil fuels, emissions from other sources are small. The table below gives a list of the major sources in the U.S. Once we move away from fossil fuels, the various sources of emissions quickly become, as a relative matter, very small. The top non-fossil-fuel-combustion item, agricultural soils management, produced 265 million metric tons of CO_2 equivalents in 2005 while fossil fuel combustion produced 5,637 million metric tons, more than 21 times the amount. Cement production caused direct emissions of 45 million metric tons of CO_2 (i.e., emissions associated with the production process itself, not from the fossil fuel energy used in the process), which is less than one one-hundredth of fossil fuel emissions. Nevertheless, these sources together make up about 20 percent of U.S. emissions.

GHG Sources above 20 MMT CO2e in 2006

Source: 2008 EPA GHG Inventory

Rank	Source	Gas	MMT CO_2e	% of Total	Cumulative %
1.	Fossil Fuels	CO_2	5,637.0	79.9%	79.9%
2.	Agricultural Soil Management	N_2O	265.0	3.8%	83.7%
3.	Nonenergy Use of Fuels	CO_2	138.0	2.0%	85.6%
4.	Landfills	Methane	132.0	1.9%	87.5%
5.	Enteric Fermentation	Methane	126.2	1.8%	89.3%
6.	ODS Substitutes	HFC	110.4	1.6%	90.8%
7.	Natural Gas Systems (methane)	Methane	102.4	1.5%	92.3%
8.	Coal Mining	Methane	58.5	0.8%	93.1%
9.	Iron and Steel Production	CO_2	49.1	0.7%	93.8%
10.	Cement Manufacturing	CO_2	45.7	0.6%	94.5%
11.	Manure Management	Methane	41.4	0.6%	95.1%
12.	Mobile Combustion	N_2O	33.1	0.5%	95.5%
13.	Petroleum Systems	Methane	28.4	0.4%	95.9%
14.	Natural Gas Systems (CO2)	CO_2	28.2	0.4%	96.3%
15.	Forest land remaining forest	Methane	24.6	0.3%	96.7%
16.	Municipal Wastewater Treatment	Methane	23.9	0.3%	97.0%
17.	Solid Waste Combustion	CO_2	20.9	0.3%	97.3%
		Total	6,864.8		
		U.S. Total	7,054.2		

While emissions from each of these sources are relatively small, some of these sources are good candidates for inclusion in the tax base. As we will discuss below, in determining what should be taxed, we care about marginal abatement costs – how much emissions can be reduced if an additional dollar were spent trying to do so – rather than the total size of emissions from a given source. The reason is that to minimize the total cost of abatement, the tax base must include low marginal abatement cost items even if their total contribution to emissions is small. For example, if it is extremely easy to reduce methane emissions from landfills, it may be important to include them in the tax base notwithstanding the modest amount of these emissions. Many items with low marginal abatement costs will be unrelated to fossil fuels. Reilly, Jacoby and Prinn (2003)

Worldwide emissions of greenhouse gases were 42 million metric tons of CO_2 equivalents in 2000. Stern (2007) p 195; World Resources Institute (2006). Energy use is a relatively smaller component of the worldwide total than it is for the U.S., comprising just over 60 percent of worldwide emissions (compared to 80 percent of U.S. emissions). Land use change, particularly deforestation is a larger contributor worldwide than it is in the U.S., contributing 18.2 percent of emissions worldwide and a negligible amount for the U.S. Preventing deforestation in Indonesia and Brazil in particular are likely low-cost methods of abatement and, therefore, important to include in a global climate policy. Similarly, emissions from agriculture make up about 13.5 percent of worldwide emissions but only 6.2 percent of U.S. emissions.

B Existing Carbon Control Regimes

Neither the U.S. nor the rest of the world makes any significant use of taxes explicitly on carbon. There are currently seven taxes explicitly on carbon (five Scandinavian countries, the UK, and Italy). There are, however, a wide variety of taxes on, and subsidies for, energy (as well as a wide variety of regulatory regimes for other greenhouse gases). These taxes and subsidies will affect carbon emissions, although because they are on energy rather than carbon, they will not be designed to set a uniform price for carbon across different types of energy. Baranzini, Goldemberg and Speck (2000) survey energy taxes in 12 countries as of 2000, finding that the vast majority of energy taxes are on gasoline and diesel fuel, with very few taxes on coal and natural gas.

All of the Scandinavian countries adopted carbon taxes in the 1990s. These taxes have narrow bases and do not impose a uniform tax on emissions from the sources that they do cover. Instead, they provide a wide variety of different rates. Bruvoll and Larsen (2004) The Norwegian carbon tax covers about 60 percent of energy-related CO_2 emissions and 46 percent of total emissions.[9] Stern (2007) (Box 15.4, p. 386) and Ekins and Barker (2001) According to Stern, the impact of the tax was weakened because of numerous exemptions related to competitive concerns. Moreover, the tax did not accurately reflect emissions from various fuels. Finally, notwithstanding that all of the

[9] Norway's emissions from energy in 2000 were 41.1 million metric tons and total emissions were 53.8 million metric tons of CO_2 equivalents. See Bjotveit (2005) for the Norwegian greenhouse gas inventory.

Scandinavian countries adopted carbon taxes and that, compared to differences around the globe, the Scandinavian countries are relatively similar, they were unable to harmonize their taxes.

The U.K. imposed a climate tax (known as the climate change levy or CCL) in 2001. The levy is on industrial and commercial use of energy. Transportation and domestic use of energy are excluded. The rate is currently modest. For example, electricity is charged as £4.41 per megawatt hour. Gas is taxed at £1.54 per megawatt hour. Moreover, taxpayers can enter into agreements with the government to reduce emissions in exchange for a significantly reduced rate of tax, effectively converting the climate change levy into a command and control regulation. Total collections from the levy are around £1 billion annually.

If the United States were to adopt a carbon tax, an important design issue would be how it interacted with other carbon pricing and energy policies both domestically and abroad. Internationally, the major program with which a domestic tax would have to interact is the European Union Emissions Trading Scheme (ETS). The ETS is a cap and trade program on EU emissions from the energy industry plus energy-intensive industries. Phase I of the ETS ran from 2005 through 2007 and was viewed as a trial run to develop the market mechanisms to support permit trading. Phase II running from 2008 through 2012 is designed to help the EU meet its Kyoto obligation of an eight percent reduction below the base year levels (generally 1990). The burden sharing allocation within the EU is complex and Ellerman, Buchner and Carraro (2007) describe it in detail.

We do not discuss the merits of the ETS in this paper but do wish to comment on two aspects of its design. First, the EU system was implemented at the electric utility and industry level. This significantly multiplies the number of covered installations and makes a comprehensive system difficult to implement. Second, the ETS only covers a relatively small portion of greenhouse gas emissions in the EU. According to Convery and Redmond (2007) the European Commission estimates that less than half of CO_2 emissions and less than one-third of all greenhouse gas emissions will be subject to the ETS caps in 2010. In particular, the transportation sector is excluded. It has been argued that the transport sector was excluded from the ETS because it was already subject to high taxes on motor fuels (see Metcalf (2008a) for a comparison of US and EU gasoline tax rates). These taxes on motor fuels, however, were presumably motivated by other externalities associated with driving. Therefore, these taxes need to be imposed in addition to rather than as a replacement for, a carbon tax. Moreover, to the extent that an element of these taxes relates to carbon emissions, nothing precluded the EU from including transport and encouraging EU countries to lower their gasoline tax rates to offset the carbon permit price impact.[10] To the extent EU motor fuels taxes are to be thought of as part of their carbon pricing regime, the EU has a hybrid cap and trade, tax regime rather than a pure cap and trade regime.

None of these carbon pricing regimes services as a good model for the design of a carbon tax. All have comparatively narrow bases, and are none are imposed so as to minimize compliance and administrative costs.

II. Rates

A. Setting the Rates

At the most basic level, the principles for setting the correct tax rate were established long ago by Pigou: the tax rate should equal the social marginal damages from an additional unit of emissions. If social marginal damages change with emissions, the tax rate would change as well; the tax rate schedule is simply the marginal damages curve. Under such a tax, the government would only need the information required to estimate marginal damages and would not need information about the costs of abatement or the private benefits of emissions. Emitters facing this tax schedule would internalize the cost and set emissions at a level that equalizes the cost to their marginal benefit from emitting. Equivalently, we can think of emitters as facing a marginal cost of abatement (reducing emissions) and the tax equal to the

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[10] One obstacle to this swap is that the permits were given away and so national governments would lose revenue. But the amounts in question are small. Average gasoline tax rates in OECD countries other than the United States averaged $2.30 per gallon as of January 2007 according to the OECD database on environmental taxes at http://www2.oecd.org/ecoinst/queries/ (accessed on May 8, 2008). At the current price for ETS permits in the neighborhood of €26, this would raise the price of gasoline by about 35¢ per gallon. A modest amount of auctioning would allow countries to recoup revenue lost by a gasoline tax offset to transport fuel permit price increases.

marginal benefit of abatement. Emitters would set the marginal cost of abatement equal to the marginal tax rate.

If the tax has to be set at a fixed rate, say, $x per metric ton of CO_2, the government will also need to estimate the marginal cost of abatement, and set the tax where the marginal abatement cost and marginal damage curves intersect. This is a more difficult task because the government needs information about both the marginal damages and marginal costs of abatement.

There are a wide range of estimates of the optimal tax rate. The calculation is difficult, perhaps even heroic, because it involves combining uncertain science, such as the predicting the local effects of climate change, with predictions of economic and technological developments far in the future, and discounting those values to the present. The IPCC's Working Group II surveys 100 different studies of the optimal tax rate and estimates a mean for 2005 of $12 per metric ton of CO_2, but notes that estimates range from $3 to $95 per ton. (Intergovernmental Panel on Climate Change (2007b), p. 16). The report goes on to note that these estimates are likely to underestimate the costs of carbon emissions because of the difficulty in quantifying many impacts. The revenue raised from such a tax would depend on the coverage and on the elasticity of emissions to taxation, but rough and ready figures suggest a modest tax would likely raise between $75 and $100 billion per year.[11]

Because of the difficulties in computing the optimal tax rate, an alternative taken by some analysts is to determine a set of taxes over time that result in meeting a target for emissions reductions or total carbon concentrations in the atmosphere. This approach separates the analysis into two components: an overall social decision about what level of greenhouse gas concentrations we are willing to tolerate and a technical

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[11]Metcalf et al. (2008a), Table 9, provides revenue estimates for several carbon tax bills. Their estimates for revenue raised in 2015 from relatively narrow taxes range from $69 billion to $126 billion. To put this in context, a carbon tax of $25 per metric ton CO_2 would raise the price of gasoline by about 22¢ per gallon and the price of coal fired electricity by roughly 2.5¢ per kWh. A carbon tax would also increase the price of other commodities that use energy as an intermediate good. Hassett, Mathur and Metcalf (2009) estimate that a $25 per ton tax would raise the purchase price of a new automobile by about 1.5 percent.

solution to how best achieve that goal. When analysts take this approach and use likely targets, the ranges of tax rates they produce are similar to those from trying to find the social cost of carbon.[12]

There is a longstanding debate about whether the tax rate should be adjusted because of interactions with the labor tax. Bovenberg and de Mooij (1994), Goulder, Parry and Burtraw (1997), Fullerton and Metcalf (1998). The original view was that environmental taxes create a "double dividend" because they internalize environmental externalities and allow the distorting income tax to be reduced by the revenue that they raise. The most recent view is that the extent to which, and even the direction of an adjustment to environmental taxes, depends on subtle factors, such as whether there are pre-existing regulatory regimes and the use of the revenues, rather than a priori economic reasoning. For example, environmental taxes themselves may reduce labor supply much the same way as a labor tax and, therefore, substituting an environmental tax for a labor tax may not reduce such distortions. Regardless of the details of this debate, given the heroic assumptions needed to compute the optimal carbon tax rate, the double dividend hypothesis is to a large extent second order – determining the carbon tax rate at this point involves guessing about orders of magnitude and not about potentially subtle adjustments.

B. Revenue and Redistribution

Depending on one's frame of reference, a carbon tax is likely to be modest to highly regressive. Table X shows the distributional burden of a $15 per ton carbon tax across households using data from 2003.[13]

Table X. Carbon Tax Burden Across Income Groups

[12] For a comparison of economic models of climate change using similar emissions scenarios, see Clark et al. (2007)

[13] Hassett, et al. (2009) use both annual income and two measures of lifetime income to distribute the tax across households. Using a lifetime income measure reduces the regressivity of the tax considerably. Metcalf et al. (2008b) show that over time more of the carbon tax is passed back to resource owners and owners of capital also mitigating the regressivity somewhat.

Income Decile	Direct	Indirect	Total
Bottom	2.12	1.60	3.74
Second	1.74	1.31	3.06
Third	1.36	0.99	2.36
Fourth	1.19	0.88	2.06
Fifth	0.97	0.78	1.76
Sixth	0.85	0.68	1.53
Seventh	0.69	0.61	1.30
Eighth	0.61	0.63	1.23
Ninth	0.53	0.49	1.01
Top	0.36	0.45	0.81

Source: Hassett, Mathur, and Metcalf (2009). The table reports the within decile average carbon tax burdens as a percentage of income. Direct burden refers to fuel consumption. Indirect burden refers to higher prices of goods due to use of energy as an input.

Based on the practice in European VAT systems of zero rating and exemptions, one might ask whether similar exemptions should be built into the carbon tax to reduce its regressivity. The answer is no. Instead, the distributive effects of a carbon tax should be offset through adjustments to the overall tax system (and in particular, the income tax) rather than through the design of the carbon tax itself. The reason is that attempts to redistribute through adjustments to a commodity tax are in general less efficient than adjustments to direct taxes. Atkinson and Stiglitz (1976), Kaplow (2006) In particular, adjusting the carbon tax for distributive effects produces the same types of distortions that adjustments to labor income taxes do. For example, progressive taxes reduce work incentives. In addition, adjusting the carbon tax for distributive effects would reduce the environmental benefits of the tax: carbon emissions would not be priced equal to their marginal damages. Therefore, the better approach is to design the carbon tax to best internalize the effects of emissions and to adjust the income tax for any distributive effects.

We note in passing that concerns about geographic disparities in the burden of a carbon tax are likely overblown. Table X from Hassett, et al. (2009) show that the geographic variation in tax burdens is quite modest.

Table X. Carbon Tax Burden Across Regions

Region	Direct	Indirect	Total
New England	0.73	0.76	1.47
Mid Atlantic	0.75	0.76	1.50
South Atlantic	0.87	0.77	1.62
East South Central	1.19	0.75	1.92
East North Central	1.05	0.76	1.79
West North Central	0.84	0.77	1.59
West South Central	1.08	0.78	1.84
Mountain	0.85	0.91	1.73
Pacific	0.74	0.81	1.54

Source: Hassett, Mathur, and Metcalf (2009). The table reports the within region average carbon tax burdens as a percentage of income.

To a large extent, the design of a carbon tax is separable from the issue of how to spend the money. Moreover, as noted, the potentially regressive distributive effects of a carbon tax should be offset through adjustments to the income tax rather than through adjustments in the design of the carbon tax, so distributive issues are also separable. Nevertheless, because the revenue and distributive effects are significant, it is worth a few words on these issues. We consider two alternatives.

Our first and preferred option is to maintain revenue and distributional neutrality. The reason would be that whatever the decision is on proper size of government and proper deficit, the enactment of carbon tax does not change it. So if the current judgment, right or wrong, is that the federal government should be 19 percent of the economy, the enactment of a carbon tax should not change this. Similarly, whatever our decision is on proper degree of progressivity of the tax system, the enactment of a carbon tax does not change these views. Under this argument, carbon tax revenues should be used to reduce other taxes in a way that maintains progressivity. Metcalf (2007b) provides an example of such a proposal.

A second option is to spend the resources to help shift toward a low-carbon economy. It is certainly the case that an increase in federal research funding for basic energy-related research and development would be beneficial. A number of studies suggest that a doubling of such funding over a five to seven year period could be spent productively (e.g. Furman et al. (2007)). This would require funds in the range of $3 billion per year in addition to what is currently spent. This amount could be funded by removing subsidies to energy production which are either unproductive or unnecessary in the presence of a carbon tax. By no means would it be sensible to spend *all* the carbon tax revenue on basic R&D.

Some funding will also be needed to move to advanced technologies at scale such as carbon capture and storage. The recent setback in funding for Future Gen is unfortunate and speaks to the large financial risks facing firms if they try to undertake such investments on their own. Carbon capture and storage (CCS) illustrates another set of issues requiring government action. A national CCS system will require a network of pipelines to move carbon from generators to storage sites. This may require some funding by the government.[14]

In addition, enhanced support for energy efficiency investments contributes to a reduction in energy consumption and carbon emissions. Increasing energy prices through a carbon tax will contribute to increased efficiency investments to be sure but two factors suggest benefits from more generous tax credits for efficiency investments: First, certain sectors of the economy may not respond to energy price increases arising from a carbon policy. Commercial real estate and rental housing are sectors where the economic agent who makes efficiency investments (developer or homeowner) is not the

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[14] While funding will be required to build this network, as important will be a review and potential overhaul of state and federal regulatory systems to remove obstacles to the development of this network. Important questions include at what level in our federal system will regulatory oversight of this network take place? What is the right balance between national interests in a CCS system and local property rights? Who will bear the liability if stored carbon leaks in the near or long term? What insurance mechanisms will be necessary to cover that liability?

person who benefits from the energy savings (tenant). Second, the hidden nature of many efficiency improvements makes it difficult to recapture the energy savings through their capitalization into building prices or rents. In addition, empirical work suggests that efficiency investment tax credits have a substantial impact on efficiency investments (see Hassett and Metcalf (1995)).

In summary, we believe that in large measure funds from a carbon tax should be used as part of a carbon tax swap that is revenue and distributionally neutral. A small portion of the funds might be directed to basic energy R&D, to providing support to solve vexing issues associated with bringing CCS to scale, and perhaps to encourage conservation activities that market imperfections might otherwise block. But we reiterate that the decision on how to spend carbon tax revenues is separate from the decision to enact a carbon tax.

C. Initial enactment and grandfathering

There are a number of choices regarding how to impose a carbon tax in its initial period, the most important being a slow ramp-up of the tax, grandfathering existing emissions, or a cold-turkey introduction. A slow ramp up would gradually introduce the tax over time, perhaps by starting with low initial rates or a narrow initial base and then increasing the rates or base at a preannounced schedule to reach the desired system. Grandfathering would exempt from taxation a baseline level of emissions, such as an amount equal to emissions in a reference year. Cold turkey would simply introduce the tax without any special provision for transition.

While cold turkey is likely the least politically feasible approach, it is our preferred approach. There are two reasons. First, cold-turkey introduction maximizes what we might call the "anticipation effect." If businesses understand today that the eventual carbon tax will be imposed without special relief for existing investments, they will start adjusting their behavior now, anticipating the future effects of the tax. For example, a utility constructing a power plant now is more likely to use gas instead of coal if it will be subject to a future tax on carbon emissions (gas being much less carbon intensive than coal). We can, in effect, think of this as pushing some of the effects of the policy earlier in time, which in this case is a good thing. Kaplow (1986), Shaviro (2000).

The usual argument against this sort of anticipation effect is that individuals act or should be allowed to act without trying to guess future government policy – they should be allowed to rely on current law. The government by passing current law has, in effect, told people what their compliance obligations are, and it is unfair to change that midstream.

This argument, however, is circular. Individuals or industries only know they can rely on unchanging rules (or grandfathering if the rules do change) if there is some external reason why that should be the case. For example, the Sixth Amendment to the Constitution allows property owners to rely on their rights to prevent government takings. Taxes, however, change all the time and there is no fairness reason why people should be able to rely on them not changing. This is particularly true with respect to a carbon tax as carbon pricing policies have been widely discussed for a long time.

Second, the revenues raised by a carbon tax are likely to be significant – in the range of $100 billion per year – and those revenues can likely be spent in better ways than grandfathering carbon emissions. For example, the taxes could be used to reduce the income or payroll taxes. Alternatively, shifting to a low carbon economy may take significant changes in infrastructure and some of the tax revenues could be used to pay for those changes. As implied in our discussion of the use of revenues, it is hard to imagine that there are not better ways to spend the money than giving it to industries that currently emit carbon. Metcalf (2007b) shows that grandfathering the energy sector also has perverse distributional consequences. The value of grandfathered permits accrues to owners of capital thereby exacerbating the undesirable distributional consequences of carbon pricing.

A slow ramp up can be seen simply as an intermediate solution between grandfathering and cold turkey. It is like grandfathering that is phased out over time. Therefore, the same arguments apply to the extent the phase in is like grandfathering.

Note that the possibility of grandfathering a carbon tax based on business as usual emissions allows a carbon tax to have the same effect as a cap and trade system with free allocation of permits, if such a system were to be desired. In particular, one claim that a cap and trade system is more efficient than a tax is if blocking industries must be bought off to allow legislation to pass, a cap and trade system can do so relatively efficiently through the free allocation of allowances. This is relatively efficient because the blocking industry would still face the right price at the margin – it would benefit from any increase or decrease in emissions by an amount equal to the price of the permits. A tax, it is claimed, must exempt the industry to buy it off, which is less efficient. This, however, is not true. An identical economic outcome can be obtained in a carbon tax by taxing emissions above some floor. This preserves the impact at the margin while exempting initial emissions in a lump sum fashion.[15]

D. Anticipated Rate Schedule

The optimal schedule of tax rates will depend on how the target is being set. In a welfare maximizing framework where the benefits and costs of carbon abatement are both taken into account the tax rate should match social marginal damages across time.[16] Nordhaus (2008) undertakes an explicit welfare-maximizing analysis and finds that tax rates grow over time at a pattern that is similar to but not exactly exponential. His model includes population growth, technology changes, and non-constant discount rates. If there are technological surprises, the optimal tax rate will also adjust to take these into account. In general, in broad-based general equilibrium models we would expect the optimal tax rate to grow at an underlying exponential growth rate that is modified by other forces at work in the model.

Where the goal is to cap emissions at some fixed amount over a set time period, the tax rate should grow at the rate of return on capital.[17] Metcalf, et al. (2008a) develop the argument as follows. They start by imagining that we issued permits instead of taxes, issuing today the set of permits that can be used over time. The permits would be an asset. Holders would save that asset for later use if its value went up faster than the rate of return on other assets and use it sooner if its value when up slower. In equilibrium, therefore permits will increase at the same rate as the return on other

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[15] An interesting issue we have yet fully resolved is why the EU Emissions Trading System required participating countries to freely allocate permits instead of giving each local country the choice. This is particularly puzzling in light of the inefficiency of free allocation.

[16] This abstracts from the second-best considerations discussed above.

[17] This abstracts away from risk or multiple forms of capital with different return characteristics.

forms of capital. Taxes and permits, however, are merely substitute methods of imposing the Pigouvian price on emissions in the absence of uncertainty. Therefore, if permits optimally have this price pattern, taxes must as well.

The real world is significantly more complicated than even the most complex computable general equilibrium model. Multiple forms of capital exist with different rates of return based on their risk characteristics. What is the right capital return to benchmark the growth of the carbon tax rate? The logic of Metcalf et al. suggests that the appropriate capital return to use is that with similar risk characteristics to the hypothetical permit program that is equivalent to the carbon tax. But immediately the logic breaks down since taxes and permit systems are no longer equivalent in a world with uncertainty.

In practice the best we may be able to do is set out a given real growth rate for the tax rate (say, 4 or 5 percent real) in carbon tax legislation and anticipate the need to adjust the rate as more information becomes available. We turn next to this issue.

E. Rate changes

Tax rates must be adjusted to reflect new information about the marginal cost and marginal benefit of abatement. We are likely to get new information about these all the time as the science of climate change progresses and as abatement technologies are discovered and developed. The question is how often to change the tax rate.

Many commentators have expressed concerns over the price volatility associated with cap and trade systems because of worries that price volatility will reduce or delay long-term investment. It is not clear, however, why carbon prices are different than any other sort of price. The price of a barrel of oil changes all the time, and yet markets function and investment takes place. Those who need price stability use futures markets or other hedging techniques. On the other hand, there is a belief in the value of stability in law, expressed in the judicial doctrine of stare decisis. We do not know in general how important stability in the law is. The costs and benefits of rapid changes to carbon prices, therefore, remain unknown.

We need not resolve the issue of the optimal pace of change for laws – there is surprisingly little literature addressing this point – because most significant abatement opportunities involve long-term investments, such as the structure of the power industry. This means that there will be little benefit from adjusting rates in the short run. Thus, if a utility is considering the design of a power plant that has a 50 year life, it probably would matter little whether the carbon tax were to adjust every year or every five years. If there is any cost to frequent changes, therefore, less frequent changes would be preferred.

The question for the design of a carbon tax is whether there is some mechanism for causing intelligent rate changes to happen at regular intervals. One possibility is to delegate the responsibility to set the rate to an expert agency. An agency would have the advantage of being able to revisit the rate at regular intervals and the advantage of experts who are able to distill the complex information needed to determine the correct rate. Agencies commonly set prices for significant items when they set electricity, airfares, and railroad rates. Agencies have also been used to set tariffs. Although many of these pricing decisions are now made in the private market, the government must set the tax rate and these examples illustrate the feasibility of delegation of similar decisions.[18]

If Congress is unwilling to delegate tax rate decisions of this scope to an agency – the revenue numbers are large and many important industries or regions can be hurt – intermediate solutions are available in which an agency recommends a rate and then various procedural rules force consideration of the recommendation by Congress or even perhaps even give procedural protection to the recommendation. For example, the agency-recommended rate could take effect absent a supermajority vote to change it. An even more mild form of delegation is to require a commission to meet on a regular basis to recommend rates. Although most commissions have little effect, there have been some that have worked, notably the Greenspan social security commission.

If an intermediate delegation system of this sort is not feasible, we recommend a system that forces consideration of the rate by Congress at regular intervals. The two

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[18] Various ways of framing the tax may change perceptions of whether delegation is appropriate. For example, if the tax is seen as a user fee, delegation may seem more appropriate.. Similarly, if carbon tax revenues are dedicated to a particular source, the entire system looks more like traditional agency action as compared to the setting of a tax rate that raises general revenues.

obvious possibilities are a pre-scheduled rate that either goes up quickly, forcing Congress to act to reduce it as necessary, or a rate that goes down quickly (i.e., the tax expires), forcing Congress to increase it. The fast-increasing rate would be more difficult to pass initially but later reductions in the rate would be easy. The expiring tax would be easier to pass initially but would require regular pain when it has to be reenacted.

III. The Tax Base

We begin the discussion of the carbon tax base with a review of the theory of how to set the base when there are measurement and collection costs. We then turn to a discussion of particular sources of emissions, focusing first on fossil fuels and then on other sources of emissions.

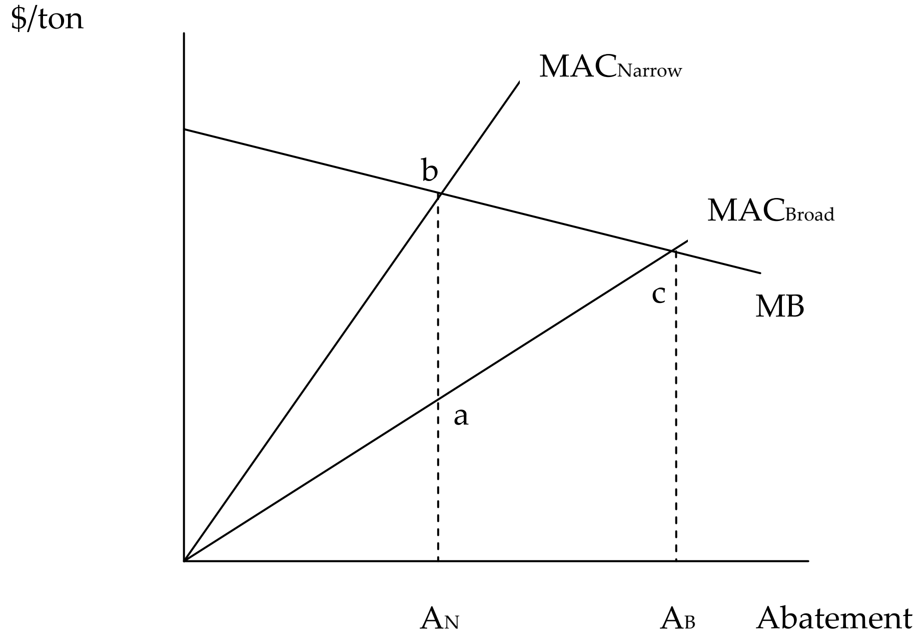
A. Theory

1. The Optimal Base

Absent administrative, enforcement, and political costs, an ideal tax system would include all activities that produce climate externalities. This includes emissions of all greenhouse gases from any activity, including not only energy usage but also agriculture, forestry, and industrial emissions. Moreover, absent administrative costs, the tax would include not only emissions of gases but any climate forcing including, for example, changes to albedo caused by forestry activities. (Trees at certain latitudes absorb sunlight, reducing albedo and causing warming.)

There are, however, hundreds of sources of greenhouse gases in the U.S. and other countries, most very small contributors. Moreover many sources of emissions may be hard to measure and tax. To determine the optimal tax base, we must compare the administrative savings of a narrow base with the efficiency benefits of a broad base. In particular, the tax base should be set so that the benefit of a small expansion in the base is equal to the increase in administrative or compliance costs.

We can think of broadening the tax base as rotating the marginal abatement cost curve downward – a broader base will include more sources of abatement and therefore, reduce the cost for any given amount of abatement. In figure X below, the steeper marginal abatement cost curve reflects a narrow tax base. Broadening the base



rotates the curve to the right and optimal abatement increases from A_N to A_B given the marginal benefit of abatement curve MB. The marginal benefit from broadening the tax base is equal to triangle abc in the diagram.[19]

To determine whether it is desirable to add any particular item to the tax base, we have to determine the size of the relevant triangle and the administrative cost of taxing the item. In general, items, with large opportunities for low-cost abatement and that are easy to monitor are obvious candidates for inclusion in the tax base.

There are a large number of studies of abatement opportunities in particular sectors. Working Group III of the IPCC is, to a large extent, devoted to summarizing these opportunities. Nevertheless, aggregate data of the sort that would allow us to create the marginal abatement cost curves depicted above is not generally available.[20]

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[19] This abstracts from interactions with other tax distortions. In a second-best world with pre-existing distortions, lowering the environmental tax rate will have first-order efficiency gains not reflected in the diagram.

[20] Marginal abatement cost curves have been produced in a number of studies. See, for example, Ellerman and Decaux (1998) and Klepper and Peterson (2006) among others.

Instead, making these determinations requires a detailed examination of each particular source of emissions. We will discuss particular items in more detail below, but the problem will be where there are large sources of emissions that can potentially be reduced at a reasonable cost but that are hard to measure. Emissions from agricultural practices are an example, where there may be many low-cost abatement opportunities but emissions depend on very particular and localized factors that are hard to observe.

We also note that there is also a set of complicated political considerations. Adding items to the tax base increases the number of special interests that will oppose the tax. At the same time broadening the base allows the tax rate to be lower overall, thereby possibly reducing opposition from those already in the base. In addition the lower tax rate reduces deadweight loss in the overall tax system.

2. Upstream Remittance

There are two principles, one physical and one economic, that allow us to substantially reduce the collection and enforcement costs of a tax on greenhouse gases. The first is that a unit of fossil fuel will emit the same amount of carbon regardless of when or where it is burned. For carbon emissions from fossil fuel combustion, there is a perfect correspondence between input and output. Therefore, we can tax the input – the fossil fuel – rather than the output – the emission. (The exception to this rule is for fossil fuel permanently sequestered, such as fuel used for tar or carbon that is captured and stored. This issue is discussed in section _ below.) This principle holds more generally for other greenhouse gases for the most part. Certain sources of greenhouse gases, however do not have a fixed relationship between inputs and emissions (e.g. agricultural nitrogen emissions as noted above). For these gases, a balance will have to be struck between the precision with which emissions are measured (or correlated with observable practices that can be built into the tax code) and administrative costs. We will note these situations as they arise in our discussion below.

The second principle is that the incidence of a tax (and its efficiency effects) is unrelated to the statutory obligation to remit the tax. This means that we can impose the tax (choose the remitting entity) to minimize collection and monitoring costs and to ensure maximum coverage. In general, imposing the tax upstream (i.e., at the earliest point in the production process) will achieve these goals as there are (1) far fewer upstream producers than there are downstream consumers and (2) because of economies of scale in tax administration, the cost will be lower per unit of tax.

To illustrate, there are approximately 149 petroleum refineries in the U.S. but there are 247 million drivers as well as millions of users of other petroleum distillates. Imposing the tax at the refinery level on petroleum products will be far less expensive than, say, trying to monitor emissions at the tailpipe. Similar principles apply to other fossil fuels. The issues become more complex when we expand beyond energy, however.

Arguments for downstream imposition of the tax tend to be based on a claim that a downstream tax is more visible and, therefore will have a greater effect. The claim would be that consumers' response depends on visibility.[21] It is doubtful that this effect could be very large in the case of a carbon tax for two reasons. First, firms are likely to advertise the embedded tax in, say, gasoline, so that drivers would be aware that part of the cost of the gasoline is the tax. Second, key energy consumers – electric utilities and industrial energy users – are unlikely to be affected by this behavioral phenomenon.[22]

B. Fossil Fuels

Fossil fuels made up approximately 80 percent of U.S. emissions in 2006. Energy Information Administration (2007c) Most developed countries have a similar profile. Developing countries will tend to have higher emissions from agricultural and

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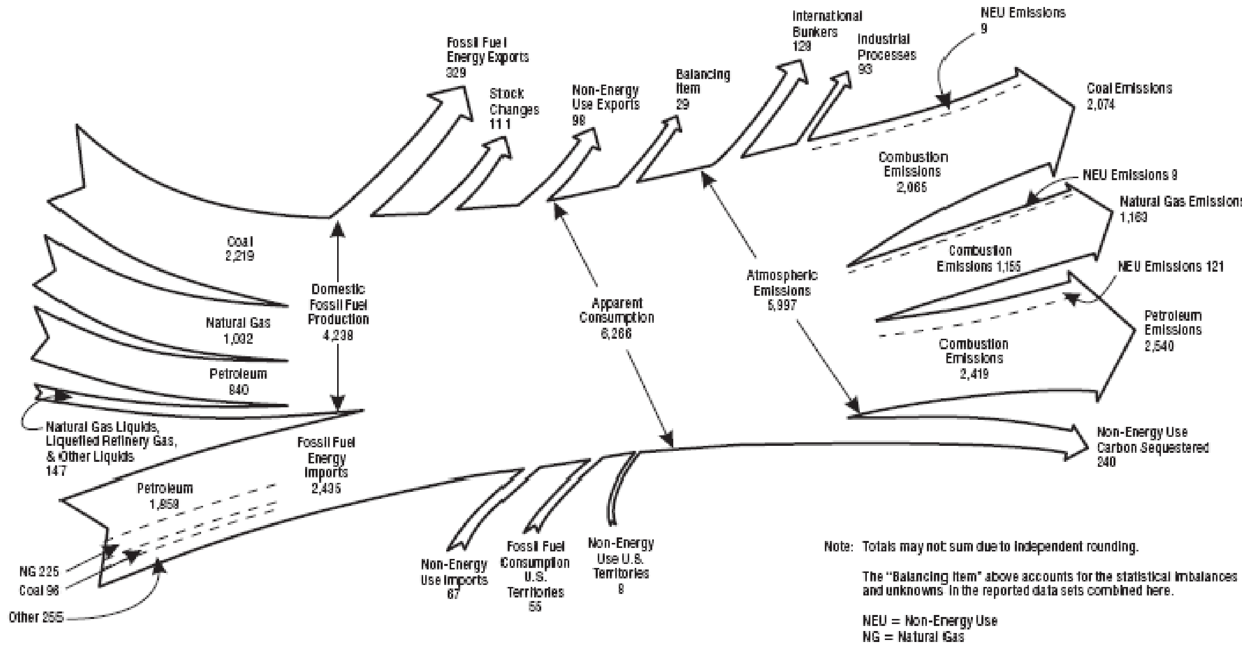
[21] Chetty, Looney and Kroft (2007) and Finkelstein (2007) present evidence that the saliency of a tax increases the elasticity of demand among consumers (Chetty et al) and among commuters on a toll road (Finkelstein).

[22] None of the existing carbon pricing schemes are imposed upstream. Instead, they tend to be imposed midstream, on large industrial point sources of emissions, such as power plants and industrial users of fuel. For example, the EU emissions trading regime is imposed midstream. The reason appears to be that countries in the EU wanted to exclude transportation from their system. An upstream tax would have a harder time excluding transportation, so the compromise was a more expensive downstream tax. A related issue is the allocation of free permits. If there are short-term price rigidities (such as through electricity price regulation, for example), it may matter which entities receive the free allocation. Midstream allocation of the permits may allow politicians to buy off potentially blocking interests.

deforestation, so considerations of how to include those activities in the tax base will be more important for developing countries. Figure X shows the fossil fuels flows in the U.S. economy. Environmental Protection Agency (2008) figure 2-6.



1. Natural Gas

Natural gas was responsible for 1,163 million metric tons of CO_2 emissions in the U.S. in 2006. Energy Information Administration (2007c) (p. 11, Table 4) (this is burned natural gas that produces CO_2 as opposed to release of natural gas or methane into the atmosphere). It is used largely for heating in the industrial and residential sectors and to produce electric power. Energy Information Administration (2006a) It is a very efficient fuel in the sense that it produces a large amount of energy for a given emission of CO_2.

A convenient tax collection point for natural gas is the natural gas processor. Natural gas, when extracted is "wet" and must be converted to "dry" gas before it is put into the pipeline system. There are only around 530 natural gas processors in the lower 48 states and these process virtually 100 percent of the natural gas used.[23] Energy

[23] A modest amount of natural gas enters the pipeline network without processing. Energy Information Administration (2006b) p. 3. We would propose that all sources of natural gas entering the pipeline

Information Administration (2006b). There were almost 450,000 natural gas wells in the U.S. in 2006, and we would need to tax about 100,000 of them to get 90 percent coverage of U.S. production. In addition, by taxing at the processor, we avoid the problem of different wells producing natural gas of differing carbon content (i.e., differing amounts of containments).

Most natural gas used in the U.S. is produced here, but some is imported through pipelines from Canada and through liquefied natural gas facilities from other places. There are right now only 55 locations where natural gas (or liquefied natural gas) can be imported or exported, consisting of five liquefied natural gas facilities and 50 pipelines. Energy Information Administration (2007a) These are all regulated by the FERC. All of these facilities would need to be added to the tax base, bringing the total up to 585 taxpayers to cover virtually 100 percent of natural gas emissions.

2. Coal

Coal can be taxed at the mine or by consumers of coal. We recommend the former. There were 1,438 operating mines in the U.S. in 2006. Energy Information Administration (2007b) Almost all coal used in the U.S. is produced here and there are very few exports. Taxing at the mine would capture virtually 100 percent of U.S. coal production. Moreover, coal mines are potential sources of methane, either captured and put into the pipeline system or released into the air. If it is captured, this sort of methane may not need to be processed Therefore, having mines as taxpayers may create synergy – they can pay the tax on this source of natural gas or methane as well. If it is not captured, coal mines should pay a tax on any release. Coal-bed methane emissions were around 58.5 million metric tons of CO_2 equivalents, so imposing this tax will be important.

As noted an alternative is to tax coal downstream. Almost 93 percent of coal is used in electricity generation and the rest is used by industry. There are 1,493 coal generated power plants in the U.S., so taxing the power plants would not be more difficult than taxing at the mine and would have only a slightly smaller base. Taxing at

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network be made subject to the tax. This would include all processors, the 55 import points and the few producers that do not need to process gas before entering the pipeline.

the utility, however, would mean losing the synergy created by taxing at the mine discussed above. As there does not appear to be any advantage to taxing at the utility and some disadvantage, taxing at the mine seems to be preferable.[24]

In the U.S., coal is sorted into four types: anthracite, bituminous, subbituminous, and lignite. Each of these grades has a different energy content and different carbon content and, therefore, would need to face a different tax rate.[25] If the carbon content is within any one of the U.S. grades is relatively uniform, there would be little reason to consider a more fine-grained approach. If, however, there is significant variation within a grade, finer gradations may be worth considering. Existing cap and trade bills in Congress generally delegate this decision so the relevant agency, and a similar delegation would probably be sensible for a carbon tax.

3. Petroleum

The two potential places to tax petroleum products are at the well (or at import) or at the refinery. Taxing petroleum downstream is impractical – there are over two hundred million drivers plus many users of distillates other than gasoline. There were only 149 operating refineries in the US in 2007, making the refineries a logical place to impose the tax. Refineries could pay a separate tax on each distillate depending on the carbon content. Distillates, such as tar, that will not be burned would not be subject to tax. Imports of crude would be subject to the tax at the refinery without any special provision and exports of crude would similarly be exempt from tax without any special rules such as a rebate of tax at the border. Imports of refined products (about 3.5

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[24] If a large percentage of utilities are in eventually the tax system because of credits for carbon capture and storage activities, there may be little difference in the number of taxpayers. Mines will be taxpayers because of coal-bed methane and coal-burning utilities will be taxpayers because of CCS. Moreover, unless CCS credits were refundable or tradable, having utilities being taxpayers may reduce problems with unusable credits. On the other hand, CCS does not right now exist in the U.S. and it is not clear how long it will be before it is in widespread use. Taxing utilities may also be more complex because some plants can use more than one type of fuel, so the tax would have to vary depending on the fuel being used. In addition, taxing utilities would require industrial users of coal to be subject to tax separately, a step that is not necessary if the mines are taxed.

[25] Germany apparently uses eight grades, with the carbon content varying by grade.

million barrels/day), however, would need to be taxed and exports of refined, given a tax rebate.[26]

Refineries often engage in inventory exchanges with other refineries. Although normally, the sale of inventory would be the event that triggers the carbon tax, inventory exchanges should not be taxed because doing so would cascade the tax: the inventory would be taxed when refinery 1 exchanges it with refinery 2 and once again when refinery 2 sells it into the market.

4. Other issues with the taxation of fossil fuels

We approached carbon emissions from fossil fuels by looking at each fuel. It is worth pausing to look at whether the structure of particular industries will affect how the tax works. We examine here permanently sequestered carbon, regulated power, and transportation (road, air, and sea).

The most important issue with respect to the regulated power industry is to ensure that the tax is part of the rate base so that it is passed on to customers. If it is not, users will not see the appropriate price, defeating part of the reason for the tax. (Investors would see the effect, potentially leading to beneficial diversion of investment into low carbon technology.) This should not be an issue with a tax on the fuel purchased by the utility: if the tax is imposed upstream, it would simply be embedded in the price and naturally flow into the rate base. This presumes that state regulators allow utilities to flow through fuel cost increases into higher prices. It is not obvious that this will always occur. Regulatory reluctance to flow permit costs through to higher prices will likely be higher for a cap and trade system where permits are given away; there is an opportunity cost to using a permit, even if received for free but it is very unlikely that the opportunity cost would be in the rate base. Similar issues may arise with respect to tax credits intended to act similarly to freely allocated permits.

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[26] An advantage of taxing at the refinery is that we would be setting rates for refined products that could then be used for taxing imports of refined products.

Note that we need to ensure that any fuel used by refineries would be taxed under this system. That is, we have to ensure the tax on refined products is not only on the sale of refined products but also in the refinery's own use of any petroleum.

The major issue with respect to road transportation is the interaction with existing tax and regulatory regimes. There are gas taxes under current law as well as regulatory regimes, such as CAFE, designed to alter gasoline usage. The question is whether the carbon tax goes on top of these regimes or replaces some or all of them.

There are numerous externalities from driving, including (noncarbon) pollution, accidents, and congestion. Parry and Small (2005) find that the optimal gas tax is roughly twice as high as the current U.S. tax. The major component of the tax is congestion externalities, and carbon emissions are a relatively small element. Therefore, the imposition of a tax on petroleum and hence gasoline to internalize externalities from carbon emissions should not result in a reduction in the existing gasoline tax.

The appropriate treatment of aviation and other bunker fuels is part of the larger issue of carbon leakage and optimal border tax treatment. We discuss this in greater detail below. But we make some preliminary comments here. Taxing emissions from aviation on purely domestic flights would be straightforward – jet fuel would be taxed at the refinery. There are, however, two problems with taxing emissions from international aviation. The first is that there is an existing treaty under the International Civil Aviation Organisation (ICAO) that prohibits imposing taxes on fuel carried on international services. Second, because of the possibility of fueling or refueling in countries without a tax, leakage would be a significant problem. Moreover, if we cannot know when fuel is taxed at the refinery whether it will be used for international or domestic flights, taxing fuel at the refinery may not be feasible.

There are several options. First, we could impose a tax on international aviation by making several adjustments. The ICAO treaty could be renegotiated (or we could simply breach it). In addition, to prevent leakage, we could impose a surcharge for any fuel taken on in a non-taxing country. The second alternative is to forgo taxing fuel used in international aviation. The problem with this alternative is that it would leave out a significant source of emissions – globally international aviation emissions are about twice as great as domestic aviation emissions. Stern (2007) p. 549. Moreover, it would be administratively difficult to tax domestic aviation and not international aviation. The reason is that if jet fuel continues to be taxed at the refinery, we would need to allow a credit or refund of fuel when taken on for an international flight.

The economic issues are similar for bunker fuels in shipping. While there is no treaty preventing the taxation of bunker fuels, the problem of leakage is serious – ships would have incentives to refuel in locations where there is no tax. Moreover, it might be more difficult to track fuel use on ships that on aircraft, making it more difficult to impose a surcharge for such refueling.

C. Other sources of emissions

In addition to fossil fuel combustion, greenhouse gas emissions arise from 1) non-combustion CO_2 emissions; 2) other greenhouse gas emissions; and 3) forestry and land use activities; and 4) non-energy use of fuels. We will address the issue of non-energy use of fuels in the section below on carbon tax credits as an upstream carbon tax would include these in the base. The issue for this category of emissions is that some of CO_2 is permanently captured in products and so should not be subject to the tax. We discuss the other emission sources here.

1. Non-Combustion CO_2 emissions

Non-combustion carbon dioxide emissions account for less than 4 percent of CO_2 emissions in 2006. Cement manufacturing and steel and iron production account for nearly half the emissions in this category. It may be reasonable to include their emissions (as well as emissions from a few other industries in this category) in the tax base.

Cement manufacturing produces about 46 million metric tons of CO_2 per year separate from the energy used during production. The emissions stem from the production of clinker, an intermediate product, which is a combination of lime and silica-containing materials. According to the U. S. Environmental Protection Agency (2008), the quantity of CO_2 emitted during production is directly proportional to the lime content of the clinker (p. 4-5). The tax would be imposed at the source of clinker production. There are 118 cement plants in the United States owned by 39 companies. These are large, stationary sources of emissions and, therefore, should be relatively easy to tax.

Steel and iron production produced 49.1 MMT of CO_2 in 2006 and 0.9 MMT of CO_2e of methane. The emissions, separate from emissions associated with the energy used to produce iron and steel, come from the production of metallurgical coke, pig iron, and steel itself. The emissions can be measured indirectly by the amount of coke, pig iron, and steel production. The tax can be applied at the point of production. There are only 23 steel mills in the U.S. Therefore, like cement manufacturing, steel and iron production should be relatively easy to include in the tax base.

2. Other Greenhouse Gas Emissions

In addition to carbon dioxide, a number of other gases contribute to global warming. The most important include methane, nitrous oxide, fluorinated gases, and sulfur hexaflouride. Gases other than carbon dioxide account for 15 percent of total emissions with methane being the most important. We discuss each of the gases in turn. Note the high global warming potential of some of the gases. Sulfur hexaflouride, for example, has a 100 year global warming potential of 23,900. Using this conversion, a \$25 per ton CO_2e carbon tax would be equal to \$597,500 per ton SF_6. While non-CO_2 emissions are not a large share of total emissions, studies suggest that they will provide a relatively low-cost source of emission reductions under a carbon tax or other form of carbon pricing. Paltsev et al. (forthcoming), for example, estimate that nearly half the initial emission reductions from carbon pricing would come from reductions in non-CO_2 emissions.

Two-thirds of all methane emissions come from three sources: enteric fermentation (126.2 million metric tons of CO_2e), landfills (125.7) and natural gas systems (102.4). Coal mining and manure management add about another 100 million metric tons.

Enteric fermentation comes primarily from the digestive process in ruminants, in the U.S., largely cattle, which produces methane. The feed quality and feed intake affect emissions. The U.S. inventory system measures emissions from enteric fermentation through detailed calculations that separate cattle by region, age, sub-type (dairy cows, beef cows, dairy replacements, beef replacements, steer stockers, heifer stockers, steer feedlot animals, and heifer feedlot animals), and production (e.g., pregnant, lactating). They use estimates of the digestible energy from various diets to determine emissions from the various categories. One could imagine levying a head tax on cattle based on average emissions. Given the variations among cattle type as well as variations in emissions arising from modifications to diet, simple tax formulas would be imprecise. It may be difficult to bring this into the carbon tax base.

According to the EPA Inventory, roughly 1,800 operating landfills exist in the United States. Municipal landfills account for nearly 90 percent of methane landfill emissions with industrial landfills making up the rest. Methane recovery has grown over time since 1990 federal regulations required large landfills to capture and combust landfill methane (thereby converting it to less potent CO_2). Whereas only 20 percent of landfill methane was burned for gas, flared, or oxidized in 1990, over half of the methane emissions were in 2006 (Table 8-3). Requiring monitoring of all landfills and including their emissions in the tax base should be relatively straightforward.

Methane emissions from natural gas systems arise in field production (27%), processing (12%), transmission and storage (37%) and distribution (24%).[27] Implementing the carbon tax on processers will ensure that nearly three-quarters of these emissions are brought into the carbon tax base and thereby provide the appropriate incentives to producers to implement improvements to reduce accidental releases. Scope appears available for improvement. Despite the growth in natural gas consumption between 1990 and 2006, emissions in the processing, transmission and storage, and distribution stages fell by nearly twenty percent.

Bringing emissions in the field into the tax system is probably not realistic. Instead, mandates for certain processes or technologies may be useful here. The rising price of natural gas over time will also provide an incentive to reduce emissions (as they reflect natural gas that cannot be sold).

Methane emissions from other sources can be considered for inclusion in the tax base on a case-by-case basis. Emissions from coal mines, for example, are easily monitored and collected in some but not all cases. Nearly two-thirds of these emissions come from underground mines (Table 3-26, EPA (2008)) where methane is removed through ventilation systems for safety reasons and so can be collected, measured, and

[27] Shares of emissions from U. S. Environmental Protection Agency (2008).

made subject to the tax.[28] Emissions from surface mines, on the other hand, are more difficult to capture as they are released as the overburden is removed. These emissions are much lower in amount, however.

Nitrous oxide has a high global warming potential. Nearly three-quarters of the 368 million metric tons CO_2e of emissions come from agricultural management activities. These emissions are a prime example of a case where there are large emissions (almost 4% of the US total) but where it will be difficult to include them in the tax base. The reason is that the emissions stem from a wide variety of hard to observe sources. The particular extent of emissions depends on the precise nature and location of the activity, making it difficult to set tax rates. A full exploration of emissions from agricultural soil management would need a separate study. We make only a few initial observations here.

Nitrous oxide is produced naturally in soils through nitrification and denitrification. Various agricultural activities increase mineral nitrogen availability in soils, increasing the amount of nitrous oxide emitted. These include application of synthetic nitrogen fertilizers, organic amendments to soil (such as manure, compost, and sludge), urine and dung from grazing animals, and crop residues.[29] Various soil management activities, such as irrigation, drainage, tillage, and fallowing of land influences nitrogen mineralization. See U. S. Environmental Protection Agency (2008).

The precise emissions from any given activity depend on many factors. For example, the granularity of the soil affects the process of denitrification. Environmental Protection Agency (2007) p 6-16. This means that the tax rate can only be correct on average. Actual emissions from any particular activity cannot be measured. Instead a tax will have to rely on rough proxies, such as the total amount of fertilizer applied, or the total number of livestock grazing during the year. It is worth noting, however that EPA (2008) estimates that roughly twenty percent of N_2O emissions arise from the use

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[28] Prior to 2002, coalbed methane was eligible for the section 29 non-conventional fuels tax credit of $3 per barrel of oil equivalent (see Carlson and Metcalf (2008)). The credit could be reinstated or methane flaring could be allowed as an offset activity to provide a financial incentive to capture these emissions.

[29] Figure 6-2 in U. S. Environmental Protection Agency (2008) provides a picture of agricultural sources of nitrogen that result in N_2O emissions.

of artificial fertilizers. A fertilizer tax would likely lead to less fertilizer use but could lead to other practices that in turn release nitrogen. For example, if fertilizer is taxed but manure is not, there would be incentives to substitute toward manure (thereby making livestock relatively less expensive as an output would become more valuable and, therefore, possibly increasing emissions from livestock).

The second largest source of nitrous oxide is mobile combustion emissions (33.1 million metric tons). Mandating annual vehicle emissions tests would provide a way to include these in the tax base.[30] The remaining nitrous oxide emissions can be added to the tax base on a case by case basis.

There are a large number of manmade gases (generically, fluorinated gases) used throughout the economy with high global warming potentials.[31] Chlorofluorocarbons (CFCs) and related chemicals were in wide use prior to the Montreal Protocol but were banned because of their effect on ozone. Hydrofluorocarbons (HFCs) were developed as alternatives to these ozone-depleting substances for industrial, commercial, and consumer products. The global warming potentials of these gases range from around 140 (HFC-152a) to 11,700 (HFC-23).[32] They have varying atmospheric lives, with some very short and some ranging up to tens of thousands of years. If treated as a single category, they make up about 123 million metric tons of carbon dioxide equivalent emissions in the US each year. This would make them one of the top five sources of emissions.

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[30] Annual emissions are the product of emissions per gallon gasoline, miles per gallon, and miles driven. The first and third components of this can be measured at the inspection (assuming mileage records are kept as part of the inspection). Assumptions about fuel efficiency can be built into the tax based on year and model of the vehicle.

[31] Information for this section of the paper comes from Intergovernmental Panel on Climate Change (2005).

[32] The global warming potential of these gases is very sensitive to the period of measurement as they have a wide range of atmospheric lifetimes. See table TS.2, p. 33-34 in Intergovernmental Panel on Climate Change (2007a) for a completely list of these chemicals and their global warming potentials over various periods.

Because they have a very high global warming potential, the tax on these chemicals will be many times the market price. The price signal from taxation, therefore, may be very important for these chemicals. Nevertheless, they may not be easy to tax through a direct mechanism. The reason is that emissions from fluorinated gases are largely fugitive emissions, gases that inadvertently escape through leakage or inappropriate disposal. For example, a significant source of HFC's is leakage from air conditioning for cars and trucks. Similarly, certain types of foam contain significant HFC's and improper disposal can lead to the eventual release of the gases. This means that there is no observable transaction on which to base the tax.

A promising method of taxing emissions of these gases is a deposit-refund system. In a deposit refund system, an initial presumptive tax on the manufacture or purchase of an item is levied and a refund provided upon proof of proper disposal. To illustrate, consider an automobile with an air conditioner that uses HFCs. Imagine that it uses an amount that if emitted to the atmosphere would trigger a tax of $1,000. Any HFCs that have not leaked out of the car can be recovered upon scrapping of the car and reused thereby avoiding any release to the atmosphere. Rather than try to tax the leakage, we can impose a tax of $1,000 per unit when purchased and a refund of the tax for all HFCs that are recycled upon retirement of the automobile. Even though disposition of the automobile may not be easily monitored, an incentive exists to capture and recycle the HFCs. The tax is then paid only on the HFCs that have leaked out of the car over its lifetime.[33]

A deposit refund system potentially works in the fluorinated gas context because there are a relatively few manufacturers, making collection of the upfront tax easy. For example, there are only five producers of HFC's in the U.S. right now. Intergovernmental Panel on Climate Change (2005) In addition, in many places, there are well-developed recycling, reuse, or disposal requirements for these chemicals, which means that tracking disposal would not be expensive. In addition, given the refund upon proper disposal, there would be an incentive to reveal information about

[33] Deposit-refund systems are discussed extensively Fullerton and Wolverton (2005). It might be necessary to create tightness quality standards for automobile air conditioners since it is difficult for the consumer to monitor the quality of the air conditioner.

disposal to be eligible for refunds. For example, HFC's are currently used in vehicle air conditioning systems. When a vehicle is junked, there would be an incentive to remove the system with the HFC's intact to obtain the refund.

A deposit refund system faces many of the same design issues as does a tax. For example imports would have to be carefully monitored and taxed. If the gases can be imported without tax, businesses could earn profits by manufacturing the chemicals abroad for the sole reason of obtaining the refund in the U.S. Since most of the HFCs are used in refrigeration and air conditioners, it is likely that imposing a tax on import should not be overly difficult.

In a related vein, some of these gases are used in the production of other goods, such as the use of perfluorocarbons in semiconductor manufacturing. Unless imports of goods manufactured with these chemicals are subject to tax, taxing domestic production would create an incentive to shift production abroad, particularly because the tax would be many times the cost of the chemical (due to the high global warming potential). Moreover, an accurate tax on imports might be difficult to assess because the tax should be on the emission of these gases and emissions from manufacturing abroad would not be observable. Therefore, depending on how easy it is to shift manufacturing using these gases abroad, a lower tax rate may be appropriate. This is simply another example of the border tax problem that we discuss below.

A major source of emissions of fluorinated gases comes from existing banks of these gases rather than new production. According to the IPCC, there are almost 21 million metric tons of CO_2 equivalents in banked fluorinated gases. Intergovernmental Panel on Climate Change (2005) For example, because of the Montreal Protocol, production of CFC's has ceased in the developed world. Nevertheless, emissions from CFC's continue because they remaining in existing refrigeration and other systems. Banked gases will not have been subject to the tax on production, so the question is whether they should be subject to the refund on proper disposal. Our view is that they should: the refund on proper disposal creates an incentive not to emit these gases. Given the size of existing banks, proper disposal is important. This is analogous to an offset provision for greenhouse gas emissions that are not included in the tax base.

Finally sulfur hexaflouride is a potent greenhouse gas. It is used on electrical transmission and distribution equipment with most emissions arising from leakage. Emissions of SF_6 fell by fifty percent between 1990 and 2006 (EPA (2008)) reflecting the higher price of the product. A deposit-refund mechanism here would be a relatively simple way to bring this gas into the carbon tax base.

3. Forestry and Land Use Activities

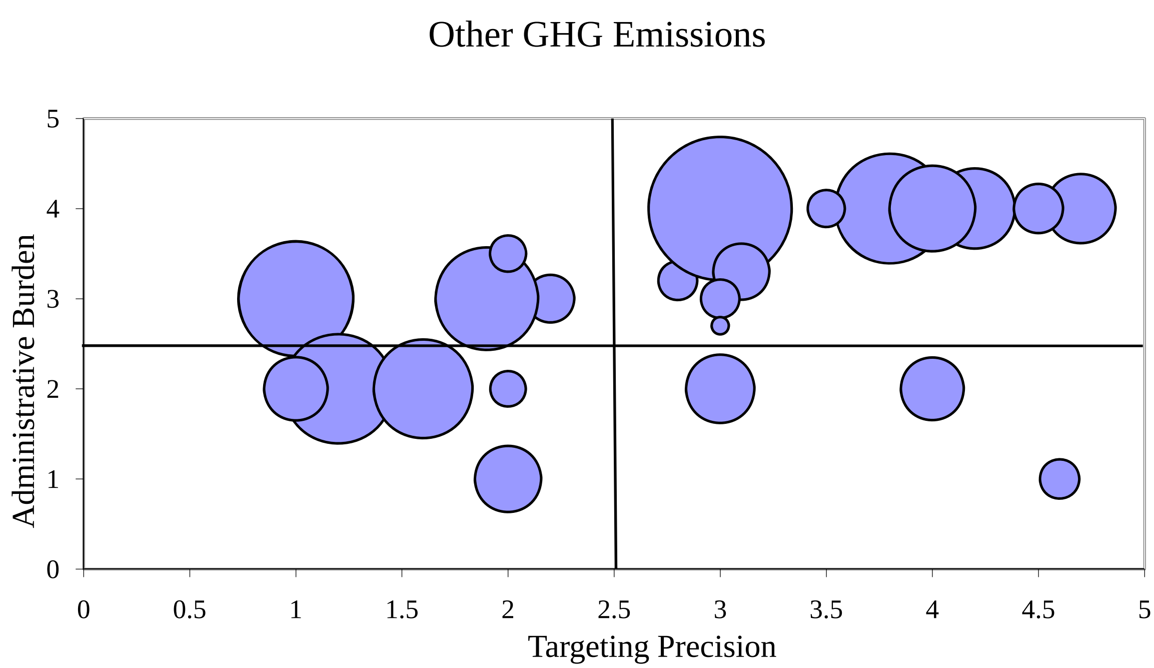
Forestry and land use serves as a net sink, removing some 900 million metric tons of CO_2e in 2006 from the atmosphere. Changes in land and forest use can add or remove carbon on balance. Adding these activities to the tax base would require establishing a base line. To see the complexity of this, consider a forest that currently sequesters 100 tons of carbon dioxide per year. Should an owner of that property receive a tax credit for the 100 tons of sequestered CO_2? Or perhaps the owner should be subjected to a tax on 50 tons of CO_2 because an "undisturbed" forest would sequester 150 tons of CO_2. One way to proceed would be to set as a baseline emissions/sequestration as of the first year of the carbon tax. If the tax is anticipated, this creates an incentive to cut down the forest prior to the first year of the tax so as to obtain large amounts of credits in early years (young forests absorb more carbon than do mature forests).

Once a baseline is set, a forestry carbon assessment could be undertaken periodically (say every ten years) and the tax applied retrospectively. Continuing with the example above, assume the forest in question is an immature forest and over a ten year period sequestration falls to 80. With 100 established as the baseline, the annual emissions would be estimated to rise from zero to 20 by year ten. The retrospective tax would be equal to 2 tons in year 1 times the tax rate in that year plus 4 tons in year 2 times the tax rate in that year and so on to year 10 when the tax rate is 20 times the tax rate in that year. Landowners could be required to make estimated payments over the decade in anticipation of the retrospective liability. See Reilly and Asadoorian (2007) and Metcalf and Reilly (2008) for further discussion of this point.

One can imagine any number of complications with such a system. It may be preferable to leave forestry and land use out of the tax system but provide the opportunity for them to opt in through offsets. This might be limited to major land owners to limit administrative costs. Considering forest ownership, we might limit offsets to the major paper and forest product companies and require that they consider offsets on their entire stock of land rather than individual parcels. This reduces problems of non-additional projects (projects that lead to local reductions in greenhouse gas emissions but not to global reductions).

We have listed a number of additional sources of greenhouse gas emissions that range in their forcing impact, their share in overall emissions, and in the ease with which they can be included in the carbon tax base. We conclude with a summary of our results to aid the reader.

Figure X below illustrates the range of possibilities for including non-CO_2 gases in a carbon tax base. The chart measures various non-CO_2 emission sources charted by the precision with which emissions can be measured and the administrative burden of the tax. The ranking runs from 1 (easiest) to 5 (hardest). The size of the bubble indicates the amount of emissions from this source. The rankings are intentionally rough and intended to be merely illustrative given the lack of data, but the chart indicates that emissions vary considerably in how easily we could include them in the carbon tax base.



The chart indicates that roughly one-quarter of emissions would be easy to include in the tax base with low administrative burden (the lower left quadrant of the graph) while nearly one-half would be both difficult to include in the base and difficult to administer (upper right quadrant). If we focus on our ability to measure and target emissions, nearly half the non-CO_2 emissions would be relatively easy to include in the tax base.

IV. Carbon Sequestration Credits

We have noted above in several places the need to provide credits for activities that permanently sequester carbon. Carbon capture and storage, for example, is a much discussed technology to capture CO_2 emissions from coal combustion in electricity generators. The CO_2 is compressed, liquefied, and transported to a geologically desirable location where it is permanently stored underground. The technology for CCS is well understood and CO_2 is injected underground now as part of enhanced oil recovery (EOR) methods. StatoilHydro has a CCS program in place at its Sleipner natural gas field. It captures one million metric tons of CO_2 annually and stores it 800 meters below the seabed. Gas from the Snovhit field is converted to liquefied natural gas and the CO_2 frozen and removed. The CO_2 is transported back to the field and stored in a porous sandstone structure below the gas field. A third CCS project in the Saleh gas field in Algeria currently captures and reinjects roughly 700,000 metric tons of CO_2 into the gas field.[34] The Weyburn-Midale fields in Saskatchewan, Canada are oil fields where CO_2 is used for EOR on a large-scale. The CO_2 is purchased from the Dakota Gasification Company synfuels plant in North Dakota and shipped by pipeline to the Canadian fields. It currently sequesters nearly 9000 metric tons of CO_2 per day in the field making it the largest sequestration project in operation today.[35]

While it is clear that CCS works in single applications, little is known about the potential to scale this up to levels that will be required given our current or projected

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[34] Information about these projects comes from StatoilHydro's website at http://www.statoilhydro.com/en/EnvironmentSociety/Sustainability/2007/Environment/Climate/CarbonCapture/Pages/CarbonCaptureAndStorage.aspx, accessed on May 31, 2008.

[35] Information taken from http://www.ptrc.ca/weyburn_overview.php accessed on May 31, 2008.

coal consumption. It is noteworthy that none of the existing projects are associated with coal production. Deutch and Moniz (2007) address the obstacles that the United States faces in developing a major CCS program for coal. They estimate that a price in the neighborhood of $30 per ton CO_2 begins to make CCS economically viable. This assumes the various technical, regulatory, and political obstacles can be overcome.

Regardless of the feasibility of CCS, the carbon tax will only provide an incentive for sequestration if the tax base excludes fossil fuel use for which emissions are captured and stored. This can be done either by explicitly excluding such fuels (and other gases for which sequestration occurs) from the tax base or by levying the tax and providing a credit for approved sequestration activities. We advocate the latter as being easier to administer. Credits could be applied against carbon tax liability. Because firms engaging in CCS and other approved sequestration activities may not be the same firms that pay the carbon tax, we recommend that the credits be made tradable as is effectively done with other tax credits such as the low income housing tax credit. Making the credits tradable ensures that their full value is realized by firms engaging in sequestration activities.[36]

Tax credits are also an issue for fossil fuels that are used as feedstocks, asphalt, lubricants, waxes, and other uses. Table X breaks down emissions for these uses as well as carbon storage.

Table X. 2006 Carbon Dioxide Emissions and Storage from Non-Energy Fuel Use

Source	**Emissions**	**Stored**	**Percentage Stored**
Feedstocks	83.0	132.4	62%
Asphalt	0.0	92.8	100%
Lubricants	19.1	1.8	9%
Waxes	0.8	1.1	58%
Other	35.2	11.4	24%
Total	138.0	239.4	63%

[36] The final incidence of the credits will depend on the relative supply and demand elasticities for these credits. We anticipate that the demand elasticity would be significantly greater than the supply elasticity so that most of the value of credits will go to firms engaging in approved sequestration activities.

Source: Tables 3-14 and 3-15 in U. S. Environmental Protection Agency (2008).

Emissions from non-energy use accounted for 2 percent of total emissions in 2006. Feedstocks are the main source of these emissions. An upstream carbon tax will incorporate these emission sources in the tax base. The more salient issue for non-energy fuel use is to ensure that we only tax emissions and not the carbon that is captured and permanently sequestered. As Table X above indicates, the percentage of carbon stored ranges from very little (lubricants) to all (asphalt). A simple tax credit works well where 100 percent of carbon is captured (as is the case with carbon capture and storage or the use of fuels in asphalt). For intermediate fuels used as feedstocks, the 2008 EPA greenhouse gas report assumes that 62 percent of all carbon is stored regardless of the feedstock source. Thus one approach would allow a credit for fuels sold as feedstocks to receive a partial credit (62 percent of a $CO2_2e$ ton per credit) with periodic updating of the storage factor as needed. For the other category in Table X above, storage factors range from 10 percent for industrial coking coal to 50 percent for petroleum coke and distillate fuel oil. It may be that providing a credit for asphalt and feedstock use is sufficient given the small amounts of stored carbon in the other categories.

Credits can be combined with offsets for non-covered activities. As noted above, we see a role for qualified offsets that pass the additionality test (they are activities that lead to a net reduction in emissions and would not have taken place in the absence of the offset funds). The difficulty of course is in assessing additionality. Offsets would be provided to entities that demonstrate to the government's satisfaction that their non-tax base activities are reducing greenhouse gas emissions. The offsets could be traded like the tax credits and used to reduce the carbon tax liability. An open question is whether offsets should be limited to activities within the United States or available for activities undertaken elsewhere. For example, offsets might be allowed for projects that satisfy CDM criteria.[37] The experience with CDMs is instructive here. Progress has been very slow in certifying and accepting CDM projects. This occurs on a case-by-case basis.

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[37] Of course, projects that are used as offsets under a U.S. carbon tax should not be allowed as offsets under the EU Emissions Trading Scheme.

Some have argued for sector-based CDM eligibility. All the issues that arise with assessing CDM projects would also arise with domestic offset programs.

V. International Issues

Because carbon emissions are a global externality – emissions anywhere affect everyone – and because of the large volume of trade in fossil fuels and in goods produced with fossil fuels, carbon taxes must always be designed with international considerations in mind. In an ideal, and imaginary, world, all countries would impose a harmonized carbon tax so that emissions anywhere in the world faced the same price. Realistically, some major emitting countries either will refuse to impose any price on carbon at all or do so in a narrow or perfunctory way. Even countries that impose carbon pricing regimes may not harmonize their regimes creating problems when goods that are priced differently are traded.

The result, as we will argue in this section, is that a carbon tax needs a system of border tax adjustments that impose a tax on imports and rebate the tax on exports. The border tax adjustments must apply to trade in both carbon itself (i.e., fossil fuels) and trade in carbon intensive goods, such as steel. Border tax adjustments put products produced in the home country (with a carbon tax) and in the exporting country (without a carbon tax) on the same basis. For example, suppose that a unit of steel can be produced for $x in both the U.S. and a country seeking to export to the U.S. If the U.S. were to impose a carbon tax and the exporting country did not, the cost of production in the U.S. would go up. The exporting country would have an advantage solely because it is willing to impose emissions externalities on the rest of the world. A border tax on the product equal to the tax that would have been imposed had it been produced in the U.S. corrects this imbalance.

Such a border tax is not inconsistent with, and in fact is required by, the principles of free trade. Free trade relies on the principle of comparative advantage. In a free market, everyone is better off if those who can produce a good at lowest cost do so. A carbon tax is necessary to ensure that the conditions for market prices to be efficient are met. That is, the principles behind free trade require rather than prohibit border tax adjustments.[38]

Tax adjustments for fossil the carbon content of fuels shipped across borders should be relatively uncontroversial under existing trade law and would also be relatively easy to implement. Border tax adjustments for trade in carbon intensive goods where the trade is in the good itself but not the carbon emitted during its production, however, is likely raise significant legal and implementation issues. Because the carbon created in the production of the good is not itself imported or exported, the border tax adjustment must be based on the so-called production or process method used to create the traded good. The trade law on such adjustments is uncertain and conflicting. Moreover, the information necessary to make accurate adjustments may be difficult to obtain. Nevertheless, it will be important for the design of greenhouse gas taxes to allow such adjustments.

Although a complete discussion of the legal issues applicable to border tax adjustments for carbon taxes requires a separate paper, we provide a short discussion of the issues here.

A. *Trade in Carbon-Intensive Goods*

Before discussing the economic and legal issues related to border tax adjustments, it is worth having a sense of the extent of trade in carbon-intensive goods and the sources of imports. To start, the six most energy-intensive U.S. manufacturing industries are petroleum refining, paper, mineral products (such as lime and cement), chemicals, ferrous metals (iron and steel), and nonferrous metals (largely aluminum). Energy Information Administration (2002). Border tax adjustments for imports of crude oil for petroleum refining should be relatively uncontroversial, so the major issues relate to the remaining five industries.[39]

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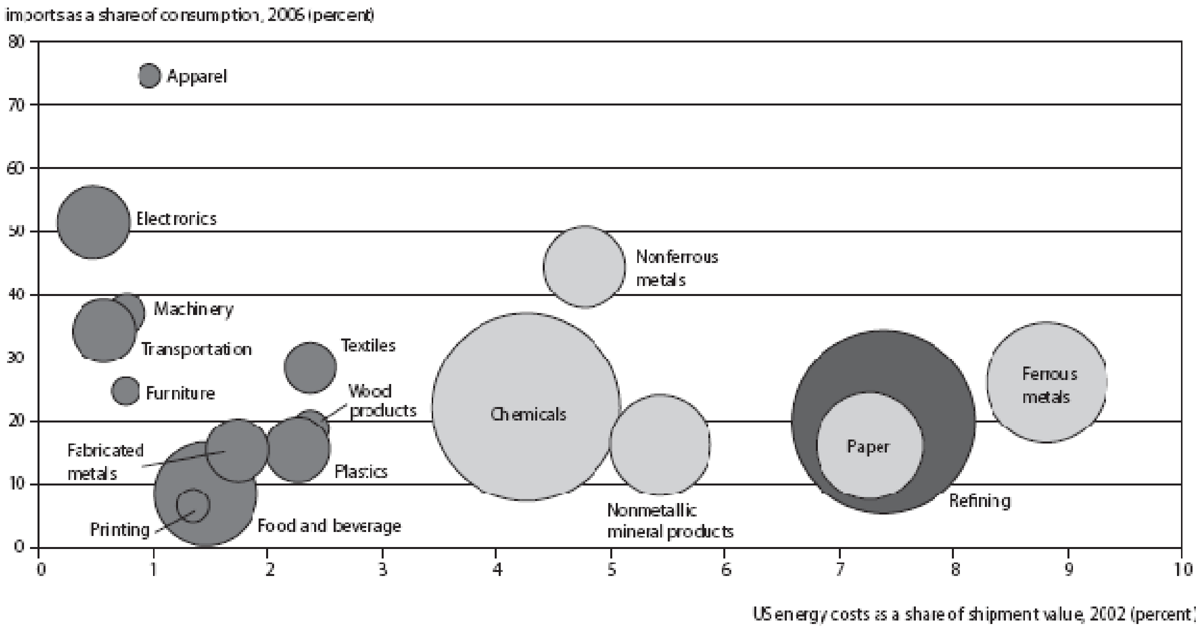
[38] If there were an internationally harmonized carbon tax, border tax adjustments would not be necessary but may still be desirable.

[39] We focus here on energy intensive goods. Note, however, that there may be goods that have high associated emissions because they are produced using high global warming potential gases.

These products vary in their exposure to trade. We import more than 40 percent of our aluminum and copper, but only 13-15 percent of our paper. Surprisingly, the United States imports 25 percent of the cement it consumes notwithstanding its weight. Houser et al. (2008). The most energy-intensive goods tend to be less exposed to trade than non-energy intensive goods. To illustrate this relationship, we reproduce below a table from Houser, et al. (2008) that charts energy intensiveness relative to share of imports. The size of the bubbles represents emissions (which can vary with energy intensity based on the source of energy):

Figure 1.3 US industry exposure to climate costs based on energy intensity and imports as a share of consumption



Note: The size of the bubbles indicates the total CO_2 emissions from the industry in 2002.

Sources: US Department of Commerce, Bureau of Economic Analysis, Industry Economic Accounts, 2007; US Department of Energy, Energy Information Administration, Manufacturing Energy Consumption Survey 2002.

Although trade discussions often explicitly or implicitly focus on China because of its increasing share of imports into the United States, China is a relatively small exporter of carbon-intensive goods. Canada is instead the dominant exporter of such goods to the U.S. Below we reproduce data from Houser, et al. (2008) on imports by origin for steel, aluminum, chemicals, paper, and cement. As can be seen, China is significant only with respect to cement and Canada dominates all categories except for chemical imports, where it is second.

U.S. Imports by Origin, 2005

	Steel		Aluminum		Chemicals		Paper		Cement	
Rank	*Source*	*Share*	*Source*	*Share*	*Source*	*Share*	*Source*	*Share*	*Source*	*Share*
1	Canada	18.6	Canada	51.0	Trinidad	41.6	Canada	66.9	Canada	16.1
2	EU	17.3	Russia	17.1	Canada	19.3	EU	16.8	China	14.0
3	Mexico	13.1	EU	6.2	Ukraine	7.3	China	3.5	EU	13.9
4	Brazil	8.2	OPEC	5.1	OPEC	6.6	S. Korea	2.2	OPEC	10.0
5	China	7.1	Brazil	3.8	EU	4.5	Mexico	2.2	Thailand	8.6

It is worth making several comments on this table. First, it does not include finished products such as automobiles. These products may be very carbon intensive and their sources may be different than the sources listed above. Second, the manufacture of many of these items has been shifting toward developing nations, so the 2005 data presented by not reflect long term trends. Finally, as discussed below, even a large majority of our imports of carbon intensive goods comes from developed countries that are likely to enact or have already enacted carbon pricing regimes, border tax adjustments can still be important because they will have net revenue effects (unlike in the typical case of border tax adjustments under a VAT). We discuss this latter point below.

B. The Benefits and Need for Border Tax Adjustments

1. The effect of border tax adjustments for a specific excise tax.

Border tax adjustments provide a rebate for any taxes paid when a good is exported and impose a tax when a good is imported. They are standard in VAT's around the world. VAT's with border tax adjustments are known as destination-basis VAT's. A VAT without border tax adjustments is known as an origin-basis VAT. Virtually all VATs are destination basis.

As is well-known, border tax adjustments under a broad-based VAT have no net present value effect. The reason is that the present value of exports has to be equal to the present value of imports. Therefore, the present value of the rebate on exports has to equal the present value of the tax on imports.[40] There are timing differences in the

[40] The key assumption is that the VAT covers all exports and imports.

flow of revenues to the government – imports and exports with the same present value can happen at different times – but the long-term effect has a net present value of zero.

Because origin and destination-based systems have the same net effect, it does not matter which system is used, apart from tax administrative cost and compliance issues. Moreover, it does not matter whether countries imposing a VAT harmonize with one another with respect to border tax adjustments (again, apart from administrative or compliance issues).

These results do not hold for a specific excise tax like a carbon tax. We consider four effects. First, border tax adjustments will have present value revenue effects. The reason is that the present value of imports and exports of embedded carbon may not be the same. Carbon intensive products can be imported in exchange, say, for services or exported for non-carbon intensive goods. The taxes or rebates on carbon products will not be offset by the taxes or rebate on the services or non-carbon intensive goods.

Second, border tax adjustments and the location of tax remittance interact. Once we are in a world with cross-border trade in taxed products, it is no longer true that the location of tax remittance matters only with respect to administrative and compliance costs. Instead, countries that import carbon-intensive goods benefit with a destination-based system while countries that export carbon-intensive goods benefit with an origin-based system.

To illustrate, suppose that a carbon-intensive good, say petroleum, is produced in three stages: extraction, refining, and consumption. Suppose also, as is often the case, that extraction takes place in a different country than refining and consumption. In particular, suppose that C_1 extracts oil and sells it to C_2 in exchange for untaxed items. C_2 then refines and consumes the oil.

If C_1 collects the tax at the wellhead and there are no border adjustments, C_1 keeps the revenue and, depending on the incidence of the tax, some combination of individuals in C_1 and C_2 bear the tax. If there are border tax adjustments in both countries, C_1 would rebate the taxes when the oil is exported and C_2 would impose a tax when the oil is imported. In effect, the border tax adjustment acts as an indirect transfer of the tax revenues from the extracting country to the consuming country. If, on the other hand, the tax is collected at the refinery or on consumption, border tax adjustments have no effect because the tax is imposed in the same country as the consumption. There is no occasion for border tax adjustments to operate.

In general, if the good is produced in one country and consumed in another, it matters if tax is remitted by the producer or the consumer of the good and whether there are border tax adjustments. To foreshadow the discussion below, if we conclude that border tax adjustments for a carbon tax imposed upstream are illegal under current trade law but a carbon tax imposed directly on consumers would not be illegal (because there would be no border tax adjustments), we are effectively saying that the legal rules care about the technical issue of which entity is responsible for tax remittance rather than the economic effects of border tax adjustments. This seems inappropriate.

Third, when there is trade between two countries with carbon taxes, the system of border tax adjustments has to be harmonized. Either both countries need to impose border tax adjustments or neither. The reason is that without harmonization, products can either be subject to double taxation or no taxation, depending on the direction of trade. To illustrate, suppose that both C_1 and C_2 have carbon taxes, and that C_1 has no border tax adjustments and C_2 has them. If a product is produced in C_1 and is subject to a carbon tax in C_1 and then is exported to C_2, there will be no rebate by C_1 as there are no border tax adjustments. C_2, however will impose a tax at the border, resulting in a double tax on the product. If a product is produced in C_2 and exported to C_1, however, there would be no tax because C_1 would rebate the tax at the border and C_2 would not impose a border tax adjustment. Thus, harmonization is needed.

Note that the same effect can occur in a world entirely without border tax adjustments but where countries do not harmonize on the location of tax collection. For example, if C_1 imposes a tax upstream on producers and C_2 imposes a tax downstream on consumers, we get exactly the same result, two taxes on the same emission, even if neither C_1 nor C_2 has border tax adjustments. Border tax adjustments eliminate this problem because they ensure that the consuming country ends up with the tax. In this sense, we can view border tax adjustments as simply a mechanism for allowing the location of tax remittance to be determined on purely administrative cost grounds. (As we will see, however, there is a trade-off because border tax adjustments themselves are complex.)

Finally, and most centrally, border tax adjustments ensure that the terms of trade are consistent with the principle of comparative advantage. As noted above, if two countries produce a good at the same cost but one imposes a carbon tax on production and the other does not, it is not correct to say that the country without the tax has a comparative advantage and, therefore, is the efficient producer of the good. The sole advantage of the non-taxing country is simply its willingness to impose an externality on the rest of the world. This is not an advantage that the free trade laws should protect.

Another way to say this is that the logic behind free trade relies on well-functioning markets to allocate production of goods. When there is a massive externality such as the emission of carbon, a Pigouvian tax on the externality is entirely consistent with free trade as the tax ensures that prices are correct. Border tax adjustments are necessary to impose a Pigouvian tax where there is an export from a non-taxing country.

One of the arguments made against border tax adjustments for carbon taxes is a slippery slope argument: if border tax adjustments are allowed in this case, they would be allowed for a wide variety of measures with protectionist intent or effect. Any "trade plus" problem (trade plus labor, trade plus environment, etc.) can be recast as an externality. For example, low-wage or child labor in a trading partner can be thought of as creating externalities in the form of empathy for the workers. A border tax would be necessary to internalize this harm. Because almost anything can be cast as an externality, there appears to be no limits to this logic.

Slippery slope arguments rely on an institutional inability to distinguish cases. The argument is that if we take action x, we inevitably will take action y, and action y is undesirable. This logic seems spurious in the context of climate change. Legal and tax systems around the world regularly must decide which types of harms to recognize. For example, tort systems must decide when an action by one party creates a compensable obligation. Harms such as that expected from climate change – measurable and large harms – are easily distinguished from other types of harm.

2. Border tax adjustments and renegade countries

Carbon tax design and implementation will likely take place in a world where at least some major producing countries do not agree to impose a tax (or other carbon pricing regime) or do so only at minimal levels. Thus, China or the United States, or some other major producing country, may not find it in its interest to impose a carbon pricing regime when other major countries do. Border tax adjustments can play a central role in such a world. There are two effects: preventing "leakage" and encouraging renegade countries to put a price on carbon.

Leakage in the carbon pricing context refers to the shifting of production to countries that do not impose a price or otherwise regulate carbon. A producer in a country with a carbon tax might move the location of production to a country without the tax and thereby avoid the tax.[41]

With a border tax adjustment, the tax cannot be avoided by altering the location of production. Suppose that production was originally taking place in C_1 and some consumption was taking place in each of C_1 and C_2. If C_1 imposes a carbon tax without border adjustments and C_2 does not impose a carbon tax, shifting production to C_2 avoids the tax entirely. If C_1 imposes border tax adjustments, there is no advantage to shifting the location of production. Consumption in C_1 will be taxed and consumption

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[41] A second reason why carbon leakage will occur in these circumstances is that if the demand for energy goes down in the taxing countries because of the carbon tax, it will be cheaper for production in non-taxing countries to use energy intensive production processes. If the U.S. reduces its demand for oil, China may simply increase its demand, offsetting the conservation efforts made in the U.S.

The extent of carbon leakage is uncertain and is the subject of a number of studies. Modeling the problem is complex because it requires modeling production location decisions. Technological change also plays a role. Thus, Babiker (2005) argues that carbon leakage from the Kyoto Protocol may actually be substantially more than 100 percent – Kyoto would actually increase total carbon emissions. Di Maria and van der Weft (2008), however, argue that induced technological change may counterbalance the effect of carbon prices on the terms of trade. The idea is that high carbon prices in countries that impose a tax or quota change the relative profitability of investing in clean technology. There are numerous other studies of the issue. Regardless of the extent of leakage, however, it is clear that any leakage is inefficient and that border tax adjustments prevent leakage through the location of production decisions.

in C_2 will not be taxed regardless of where production takes place. Thus, border tax adjustments reduce this form of leakage.

The second, closely related, reason for having border tax adjustments is to reduce the incentive for countries to be renegades. The focus in this second argument is on the incentives on countries themselves as opposed to the incentives on industries. Border tax adjustments reduce the benefit to renegade countries of remaining renegades because they would no longer be able to attract production through their lack of a carbon tax.

A mixed regime of border tax adjustments for renegades and no adjustments (an origin-based system) for countries with harmonized taxes could be used to actually create an incentive for renegades to price carbon. In particular, suppose that border tax adjustments were only applied to imports and exports from countries without a carbon pricing mechanism. Goods from a country without carbon pricing exporting to a country with a carbon tax would face a border tax adjustment and the revenues would go to the consuming country. There would be no tax revenues and no advantage for the non-pricing country. If the country prices carbon, however, it would get to keep the revenues – there would be no border adjustment – but not face any additional disadvantage with respect to trade. (Its own citizens, of course, would now be subject to a tax on carbon consumption, but the tax could be made revenue neutral through reductions in other taxes.) As will be discussed below, however, a mixed regime of this sort would be more suspect legally.

C. Legal Issues with Border Tax Adjustments

The economic case for border tax adjustments is straightforward. The difficult issues relate primarily to their legality and implementation. The problem with their legality relates to the detailed rules under the GATT and WTO governing border tax adjustments in general and the scope of the so-called environmental exception. The problem with implementation is that it is difficult to determine the carbon content of many goods. Energy sources and methods of production can vary across countries and knowledge of the emissions from the production of a particular item may be imperfect. Moreover, given the wide variety of products that are imported and exported, accurate adjustments would require extensive categorization of products and schedules of tax adjustments, creating a significant administrative burden.

A detailed discussion of the legal issues related to border tax adjustments for carbon taxes is well beyond the scope of this paper.[42] Briefly, a tax on import can only be imposed if there is an equivalent tax on like products in the home country. There are two key phrases: "likeness" and "on the product."

"Likeness" does not include how a product is produced. Thus, a widget produced using coal as the source of energy and an identical widget produced using hydroelectric power are considered like products if the widgets themselves are alike. If a product is produced in a foreign country using a different method than that used in the importing country, the importing country may not be able to impose a border tax based on the emissions created by the production of the good.

Conceivably, the likeness restriction would not be fatal as we could impose a tax on imports equal to the tax imposed on domestic production of the good. This would be imperfect – foreign producers with high emissions would face too low a tax and foreign products with low emissions too high a tax. Nevertheless, if the variance in emissions from production of the good is not too great, it may be a reasonable approach.

The second phrase in the rule, however, may make this approach illegal. We cannot impose a border tax adjustment equivalent to the domestic tax unless the domestic tax is "on the product," and it is unclear whether a carbon tax is a tax "on the

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[42] For a discussion, see Goh (2004), de Cendra (2006), Ismer and Neuhoff (2007), de Cendra (2006, Goh (2004, Ismer and Neuhoff (2007)de Cendra (2006, Goh (2004, Ismer and Neuhoff (2007)de Cendra (2006, Goh (2004, Ismer and Neuhoff (2007)de Cendra (2006, Goh (2004, Ismer and Neuhoff (2007)de Cendra (2006, Goh (2004, Ismer and Neuhoff (2007)de Cendra (2006, Goh (2004, Ismer and Neuhoff (2007)de Cendra (2006, Goh (2004, Ismer and Neuhoff (2007)Goh, G. (2004). "The World Trade Organization, Kyoto and Energy Tax Adjustment at the Border." Journal of World Trade **38**(3): 395-423, de Cendra, J. (2006). "Can Emissions Trading Schemes be Coupled with Border Tax Adjustments? An Analysis vis-a-vis WTO Law." Reciel **15**(2): 131-145, Ismer, R. and K. Neuhoff (2007). "Border tax adjustment: a feasible way to support stringent emission trading." European Journal of Law and Economics **24**: 137-164.Goh (2004; de Cendra (2006; Ismer and Neuhoff (2007)Goh (2004; de Cendra (2006; Ismer and Neuhoff (2007)

product.” A tax on profits from production of the product is not a tax on the product – it is a tax on profits. Because the same product can face different taxes based on the production mechanism (and under the reasoning behind the “likeness” rule, production methods are not part of the product), the tax is arguably not on the product at all. Therefore, even a tax on imports based on domestic emissions when the product is produced may not be legal.

Tax rebates on exports are covered under a different set of provisions governing illegal export subsidies. Rebates are allowed for “prior stage cumulative taxes” borne by a like product when destined for local consumption. The definition of this phrase, prior stage cumulative taxes, is obscure but under existing interpretations, there are serious concerns that a carbon tax would not fit the definition.

Finally, mixing origin and destination-based systems to create an incentive for renegade countries to impose a pricing regime would arguably fail the most favored nations rule, which is a fundamental tenet of trade law. In particular, renegade nations subject to a border tax would argue that they are treated worse than other nations, contrary to the most favored nations clause principles.

An entirely separate and possibly more promising legal approach is to claim that border tax adjustments are allowed under the so-called environmental exception to the normal GATT rules. Under these rules, trade restrictions are allowed if needed to protect “human, animal, or plant life or health” or if they relate “to the conservation of exhaustible natural resources” and “such measures are made effective in conjunction with restrictions on domestic production or consumption.” Any such trade restriction under these rules must not be applied “in a manner which would constitute a means of arbitrary or unjustifiable discrimination between countries where the same conditions prevail, or a disguised restriction on international trade.”

Interpretation of these various conditions has been controversial. There have been many attempts to prevent trading partners from engaging in various practices viewed by the importing nation as inappropriate. Thus, the U.S. attempted to impose rules to protect dolphins when tuna are harvested or and rules to product turtles were affected by shrimp farming. Most of these restrictions have been struck down, although the U.S. turtle/shrimp rules were allowed. The reasoning behind these cases is obscure – it is difficult to differentiate dolphin-safe tuna and turtle-safe shrimp.

It is difficult to see why the legal rules should be interpreted to prevent border tax adjustments. As noted above, direct taxation of the consumer would have the same effect as taxation of production plus border tax adjustment, and there is no argument that direct taxation of consumers would be an illegal trade barrier. Border tax adjustments are also consistent with, indeed mandated by, the principles behind free trade. On the other hand, GATT rules are often formalistic, drawing distinctions that do not seem to make sense. Border tax adjustments are allowed for indirect taxes like the VAT but not for economic equivalents, like wage taxes.

As noted above, a concern with border tax adjustments for carbon is the problem of slippery slopes. Although carbon emissions are a very serious international problem, allowing taxes on imports under an environmental or human health argument would allow all kinds of less justified border taxes. Without a clear set of principles delineated when border taxes for externalities will be allowed, trade courts might be reluctant to allow any. We do not think that this concern should prevent necessary border tax adjustments for a problem as serious as climate change.

D. Border Tax Adjustment Design

The design of border tax adjustments must take into account the legal uncertainty, the economic reasons for border tax adjustments, and, a factor we have not yet mentioned, the information available when a good is imported or exported and the resulting administrative costs.

A real problem with border tax adjustments is that it will be difficult to determine the carbon content of a good when it is imported. This problem is especially salient for so-called non-Annex I countries under the UNFCCC. These countries do not submit regular, detailed carbon inventories, making it difficult to determine the carbon content of their exports. Moreover, these countries may not agree to impose a price on carbon.[43]

[43] For example, a number of studies have measured the carbon content of U.S. produced goods relying on input-output accounts. Hassett, et al. (2009) Comparable quality data that covers multiple years in an up

One suggestion that has been made is that the border tax be imposed based on the carbon that that would have been emitted had the product been produced in the U.S.[44] This proposal gets around the "likeness" problem with a tax on imports (although there remains the problem of whether a carbon tax is a tax on the product). It also reduces the information problem both by using domestic information and by limiting the class of goods it applies to.

The major problem with this tax is that it will often be very inaccurate because foreign production of a good often results in very different emissions that U.S. production. To illustrate, we reproduce below a table from Houser, et al. (2008) that estimates the carbon intensity of steel production in major producing countries. As can be seen, there are dramatic differences. The U.S. tax on steel would be significantly too low for imports of steel from Russia, for example.

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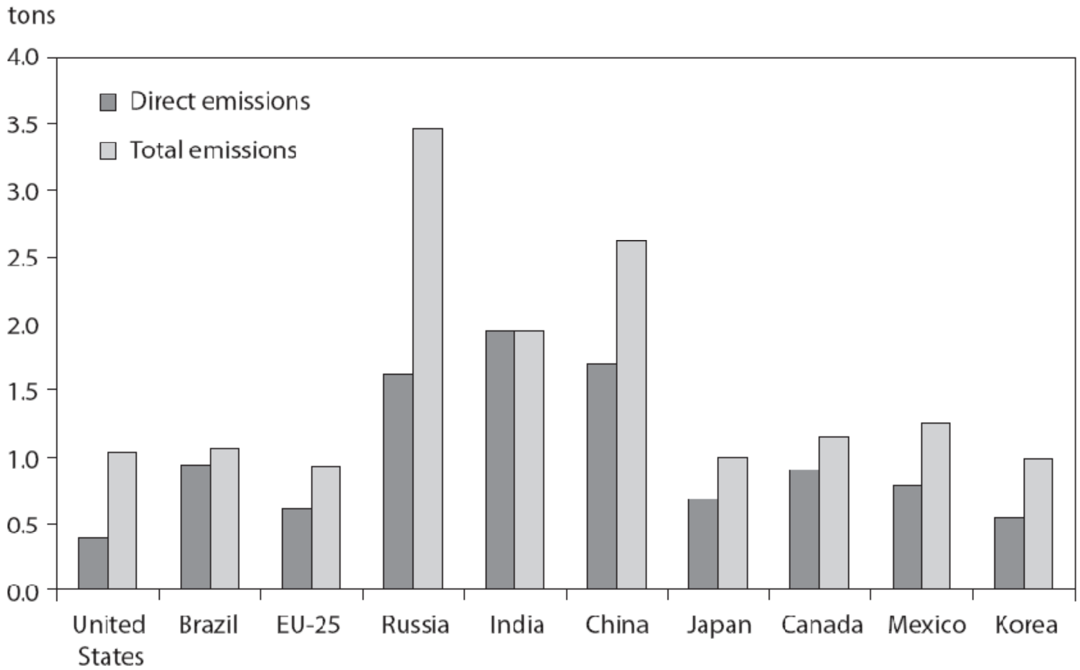
to date fashion simply do not exist, for example, for China and other major exporting developing countries.

[44]For example, this proposal has been suggested jointly by American Electric Power and the International Brotherhood of Electrical Workers (see description and discussion in Committee on Energy and Commerce (2008))

Figure 3.4 Carbon intensity of steel, 2005
(tons of CO_2 emissions per ton of steel)



Sources: International Iron and Steel Institute, *Steel Statistical Yearbook,* 2006; IEA (2007c); authors' estimates.

Similarly, U.S. carbon intensity for chemicals is different from the intensity in other countries and, in this case, often higher, producing too high a border tax.

On a related matter, a tax based on U.S. emissions would not create any incentive for foreign producers to substitute toward low-emission production techniques. The tax would remain the same, so if a low emission production technique is otherwise less desirable, the tax will not induce the needed switching.[45]

An alternative system would be to base border tax adjustments on estimates of average emissions in the exporting nation from production of a given good. This would require information about production techniques and energy systems abroad at the national level but not the firm level. While possibly more information intensive than basing the tax on the importing country's emissions, it is potentially more accurate.

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[45] An additional problem might arise if emissions from production of a good vary widely in the U.S. It would then be difficult to determine which production system to base the border tax on.

Thus, the border taxes for steel would reflect the national differences illustrated in the table above. The main question will be the availability and reliability of national-level data for developing countries. In addition, this approach runs directly into the legal problem with basing taxes on production techniques.

Yet another refinement would be to allow individual exporting firms to provide information proving that they are below their national averages. A particularly efficient firm, therefore, could get a lower border tax, creating an incentive to shift to more efficient technologies.

Any border tax adjustment, whether based on importing country information, exporting country information, or firm-level information, will require significant information gathering, documentation, categorization, and recordkeeping. Without border tax adjustments, a carbon tax could cover 80 percent of U.S. emissions by taxing around 3,000 companies and could cover an even larger fraction without imposing a significant additional burden. Once we have border tax adjustments, we would need records of carbon emissions from a wide variety of activities. Dispute resolution mechanisms would be needed. Because technology changes all the time, disputes would continue.

By way of analogy, consider how hard carbon footprint labeling has been. The problem for determining proper border tax adjustments is essentially the same. The tax, which looked so simple, suddenly becomes a very difficult administrative exercise.

In light of these problems and the potential legal issues, border tax adjustments should be made only if there is evidence of a significant problem from leakage. Babiker (2005), for example, finds that leakage is substantially more than 100 percent under the Kyoto Protocol – the shifting induced by the treaty actually increased emissions, substantially! Thus, if the problem is of this magnitude, the implementation costs are clearly worthwhile. If there is little leakage, they would not be. Moreover, limiting border tax adjustments to the most carbon intensive goods and goods where the production is particularly mobile might help reduce the administrative cost (although it would increase the rent seeking costs as industries lobbied for border tax adjustments for their industry). Alternately, we could limit border tax adjustments to a smaller group of carbon intensive commodities.

VI. Interaction with Existing Domestic Taxes and Regulations

There are a large number of regimes in the U.S. that affect carbon emissions, from various command and control regulations to incentives and taxes. An important question in implementing a carbon tax is how it interacts with existing rules. In this section, we offer a brief review of the relevant existing regimes and a discussion of whether and how they would need to be modified if the United States had a broad-based carbon tax.

We have already noted that the U.S. imposes a gas tax. We argued that this should remain in place if a carbon tax is enacted on the basis that the gas tax corrects for nonclimate change related externalities from driving.

The major form of support for renewable energy production in the United States is the system of production tax credits for renewable power enacted in the Energy Policy Act of 1992 (P.L. 102-486). Production tax credits (PTCs) are provided for qualifying facilities (wind power, biomass, and geothermal among other sources) for ten years at a rate of 1.5¢ per kWh.[46] PTCs have generally been viewed as successful except for the uncertainty surrounding their Congressional renewal every two years. Congressional delays have twice led to their temporary expiration with a consequent fall in investment in the following year (see discussion in Wiser (2007)).

The role of production tax credits is to reduce the price of renewably generated electricity relative to that of fossil or nuclear fueled electricity. A carbon tax would also lower the price of non-fossil fuel generated electricity relative to fossil-fuel generated electricity by raising the cost of the latter rather than the PTC's subsidy to the former. A tax based approach has two advantages over the PTC approach. First, the carbon tax raises the cost of electricity on average while the PTC lowers it on average. The tax then provides an additional mechanism to reduce carbon emissions by reducing overall demand for electricity rather than stimulating it as the subsidy does. Second, the carbon tax creates a price differential among fossil fuels based on their carbon content.

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[46] Metcalf (2007a) describes federal energy tax policies in detail and provides a levelized cost analysis of the benefit of these subsidies. Carlson and Metcalf (2008) discuss the interaction between energy credits and the corporate alternative minimum tax.

Studies such as Metcalf, et al. (2008a) show that an early response to carbon pricing is fuel substitution in the electric utility industry to shift away from coal towards natural gas. These considerations all suggest that the appropriate policy would be to eliminate production tax credits if a carbon tax were enacted.

A second regulatory approach at the federal level is the mandating of minimum fuel efficiency standards through the Corporate Average Fuel Efficiency (CAFE) program. CAFE mandates fleet standards for automobiles and light trucks. CAFE standards were significantly tightened in the Energy Independence and Security Act of 2007 (P.L. 110-140) which will raise the fleet average from the current level of 26.7 mpg in 2007 to 35 mpg by 2020.[47]

Ellerman, Jacoby and Zimmerman (2006) consider how Corporate Average Fuel Efficiency (CAFE) standards could be integrated into a cap and trade system and estimate that the cost of carbon emission reductions through CAFE is in the neighborhood of $350 per ton of CO_2 equivalent, considerably higher than estimates of permit prices under the Lieberman-Warner Climate Security Act (S. 2191) (see Appendix D to Paltsev et al. (2007)). This estimate helps make two points. First, sector-based regulatory policies that are not integrated more broadly into a carbon reduction scheme can be very expensive. Second, the early reductions in carbon emissions are likely to occur in industry and the electric utility industry rather than in the transport sector. Since the source of emissions has no bearing on damages associated with climate change, sector based approaches are likely to be quite inefficient.[48]

At the sub-federal level, the number of state-level programs to control greenhouse gas emissions or to encourage renewable energy programs is growing. Thirty-two states have some form of renewable portfolio standard (RPS) mandating a given percentage of electricity be provided by renewable sources. DSIRE (2008)

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[47] Prior to the 2007 act, separate standards existed for automobiles and light trucks. In 2007 the standards were 27.5 mpg and 22.2 mpg respectively with a realized fleet average of 26.7 mpg. See U.S. Department of Transportation (2008) for fleet efficiency data and CAFE standards.

[48] Other pollutants or market failures may provide a rationale for reducing oil consumption or tailpipe emissions. This simply reflects the fact that multiple instruments are generally needed to address multiple market failures.

RPS programs generally mandate that electricity distributors or retailers must provide Renewable Energy Credits (RECs) for a given percentage or amount of electricity sold by the facility. A qualifying renewable facility is provided a number of RECs based on its electricity production that the facility may then sell in a REC market to distributors or retailers needing RECs to match their power sales. The sale of RECs provides a subsidy to renewable electricity generation financed by utility customers and/or shareholders.

A slightly different approach to supporting renewable electricity generation is through a Feed-in Tariff. A feed-in tariff requires utilities to purchase power from qualifying facilities at a fixed rate (or premium) for a given number of years. Feed-in tariffs differ from renewable portfolio standards in setting a price for renewable electricity rather than a fixed amount of new supply.[49] They differ from production tax credits in two important ways. First they can be designed to provide a price guarantee rather than a fixed premium.[50] This has two benefits. If the generation price of competing fossil fuel generators falls, the FIT subsidy rises to maintain a fixed purchase price. This provides price stability to investors. On the other hand, if competing generation prices rise, the FIT phases out and so reduces the cost to rate payers. FITs differ from production tax credits in a second important way. While PTCs are subsidized by the federal government and subject to reauthorization every two years, FITs are subsidized by rate payers. This may reduce politically motivated price volatility as has occurred with PTCs in recent years.

RPS and FIT programs serve support renewable electricity generation. Unlike the production tax credits, they raise the average price of electricity thereby providing a demand side reduction in emissions. Unlike a carbon tax, however, they are sectoral based policies and thus will not necessarily lead to the equalization of marginal abatement costs across different sources of carbon, a necessary condition for efficiency

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[49] In this sense the two instruments correspond to subsidy versions of price versus quantity controls.

[50] Feed in tarrifs (FITs) have been constructed to provide a price premium or a fixed price. European FITs have generally been of the fixed price rather than premium type. See Metcalf (2008b) for a discussion of European FITs and Rickerson, Bennhold and Bradbury (2008) for a discussion of their possible use in the United States..

in carbon emission policy. An important federalism policy arises with the adoption of a federal carbon tax. Should the tax supplant these state-level policies or co-exist with them? For the RPS program, a national carbon tax would reduce the value of RECs by the magnitude of the carbon tax.[51] As we discussed above with respect to the transition to a carbon tax, governments should not engage in compensations for takings of this sort. For the FIT program, the carbon tax would simply replace a portion (or all) of the FIT subsidy. To see this, imagine that a natural gas power plant is the marginal fuel source and costs 6¢ per kWh. A wind generator in contrast costs 9¢ per kWh. The feed in tarrif would be 3¢ per kWh for the wind facility funded by ratepayers of the utility purchasing the wind power. Now consider a carbon tax that raises the cost of gas from 6¢ per kWh to 8.5¢ per kWh. The FIT automatically drops to 0.5¢ per kWh on the wind generated electricity.

A third regulatory regime of importance is the emerging carbon cap and trade programs at the state or regional level. The two most significant to date are the Northeast states' Regional Greenhouse Gas Initiative (RGGI) and California's Global Warming Solution Act of 2006 (AB 32) which establishes a statewide emissions cap in 2020 equal to 1990 levels. While the California Air Resources Board (CARB), the agency tasked with implementing this law, has not yet determined what instruments it will use to meet this goal, it is widely expected that it will recommend a cap and trade system. The RGGI initiative builds on state-level initiatives to cap emissions from the electric power sector in their state. RGGI establishes a regional trading system to reduce costs among participating states. In the first phase, it caps emissions at "current levels," by 2009. Current emissions are defined as 188 million short tons of CO_2, roughly 4 percent above average regional emissions in 2000 to 2004. It would then reduce emissions gradually to achieve a ten percent reduction from current levels by 2018.[52]

In addition to RGGI, the Midwestern Regional Greenhouse Gas Reduction Accord was established in November 2007 with six states and one Canadian province

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[51] If the RPS program were abolished upon enactment of a carbon tax, the value of RECs would go to zero.

[52] See "Overview of RGGI CO_2 Budget Trading Program" available at http://www.rggi.org/docs/program_summary_10_07.pdf, accessed on May 27, 2008.

participating. A separate Western Climate Initiative has recently set a goal of a fifteen percent reduction below 2005 levels by 2020.[53]

A similar issue arises with regional or state-level cap and trade programs as with RPS programs upon enactment of a carbon tax. If a federal tax must be paid on emissions for which a state or regional permit is required, the value of the permit will fall by the amount of the tax (or to zero, whichever is less). States might argue that the carbon tax should not apply to emissions subject to state or regional permits. This would be equivalent to carbon tax revenues being levied on all emissions and rebated to holders of state or regional cap and trade permits. This would be a mistake.

VII. Conclusion

Most carbon pricing regimes around the world today are imposed on relatively narrow bases and are imposed midstream, on industrial users of energy. Moreover, the trend seems to be in the direction of a cap and trade system. We propose a different approach here. For reasons long established in the literature, a carbon tax is preferable to a cap and trade system. We show that a well-implemented carbon tax imposed upstream can easily cover 80 percent of U.S. emissions and can likely cover almost 90 percent with a modest additional cost. The benefits of the broad base and lower compliance costs are likely to be significant.

[53] These regional initiatives are described at http://www.pewclimate.org/what_s_being_done/in_the_states/regional_initiatives.cfm, accessed on May 27, 2008.

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