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CARBON TAXES VERSUS CAP AND TRADE: A CRITICAL REVIEW

LAWRENCE H. GOULDER*

Stanford University, Resources for the Future and NBER
Department of Economics, Landau Economics Building
Stanford University, Stanford CA, 94305, USA

ANDREW R. SCHEIN

Department of Economics, Landau Economics Building
Stanford University, Stanford CA, 94305, USA

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We examine the relative attractions of a carbon tax, a "pure" cap-and-trade system, and a "hybrid" option (a cap-and-trade system with a price ceiling and/or price floor). We show that the various options are equivalent along more dimensions than often are recognized. In addition, we bring out important dimensions along which the approaches have very different impacts, including some dimensions that have received little attention in prior literature. Although no option dominates the others, a key finding is that exogenous emissions pricing (whether through a carbon tax or through the hybrid option) has a number of important attractions over pure cap and trade. Beyond helping prevent price volatility and reducing expected policy errors in the face of uncertainties, exogenous pricing helps avoid problematic interactions with other climate policies and helps avoid potential wealth transfers to oil-exporting countries.

Keywords: Carbon tax; cap and trade; climate change policy; emissions pricing.

1. Introduction

In response to mounting scientific evidence that human activities are contributing significantly to global climate change,[1] decision makers are devoting considerable attention to public policies to reduce greenhouse gas emissions and thereby prevent or reduce such change. In the U.S., there currently is little action on climate change policy at the Congressional level, but such policy is being actively conducted by the Executive Branch — by the U.S. Environmental Protection Agency under the auspices of the Clean Air Act.[2] In addition, climate change policy is being pursued through various

*Corresponding author.

[1]For a compilation of current scientific evidence, see Intergovernmental Panel on Climate Change (Intergovernmental Panel on Climate Change, 2007).

[2]EPA action is called for as a result of the 2006 U.S. Supreme Court decision in *Massachusetts versus EPA*, the Obama administration's subsequent "endangerment finding" that carbon dioxide (and other greenhouse gases) endanger public health and welfare, and the consequent designation in 2010 of carbon dioxide as a pollutant for regulatory purposes under the Clean Air Act both for stationary and mobile sources.

initiatives by several U.S. states. In other countries, significant efforts include the national cap-and-trade systems of Australia and New Zealand, carbon tax programs in various European and Scandinavian countries, a carbon tax introduced in the Canadian province of British Columbia, the cap-and-trade program to reduce greenhouse gas emissions by the nations involved in the European Union's Emissions Trading Scheme (EU ETS), a pilot cap-and-trade scheme in seven cities in China, and a range of efforts undertaken by nations that have signed on to the Kyoto Protocol.

The policies span a range of regulatory approaches, including technology mandates, performance standards, and emissions pricing. A main theoretical attraction of emissions pricing — which includes carbon taxes and "cap and trade" (a system of tradable emissions allowances) — is its potential to achieve emissions reductions at lower cost than is possible under direct regulations such as mandated technologies or performance standards.

While there is wide agreement among economists as to the potential advantages of emissions pricing, there is much debate as to which particular form — carbon taxes or cap and trade — is the better climate policy option. Academic researchers offer varying perspectives. For example, Keohane (2009) and Stavins (2007) favor cap and trade, while Metcalf (2007) and the "Pigou Club" formed by Harvard's Greg Mankiw[3] prefer a carbon tax. Disagreements as to the relative merits of the two options can hamper efforts to introduce any form of greenhouse gas emissions pricing in the U.S.

Until recently, cap and trade commanded most of the attention in policy circles. But interest in the carbon tax seems to be on the rise, in the U.S. at least. Many U.S. policy makers, discouraged with the inability to pass federal cap-and-trade legislation, are now setting their sights on the carbon tax. In addition, decision makers are attracted to the possibility of introducing a carbon tax as part of broader tax reform or as a source of new revenue to reduce budget deficits (for example, see Morris, 2011; Resources for the Future, 2011).

This paper takes stock of the relative attractions and disadvantages of these policy alternatives. It reviews and interprets previous findings and offers some new insights as well. Several analyses have claimed that a carbon tax is superior to cap and trade in terms of the ability to achieve a fair distribution of the policy burden between polluters (firms) and consumers, to preserve international competitiveness, or to avoid problems associated with the verification of "emissions offsets." This paper indicates that these arguments are unfounded: that if properly designed, the two approaches have equivalent potential along each of these dimensions.[4] The performance of the two approaches depends critically on specifics of design. Indeed, the design of the instrument may be as important as the choice between the two instruments.

Along other dimensions, however, the alternatives have different impacts. Cap and trade has advantages along some dimensions, carbon taxes along others. Yet despite the many dimensions involved and variety of impacts, some general findings emerge. One is that

[3]The Pigou Club is named after the renowned early 20th century tax and welfare economist Alfred Pigou. It includes a large number of eminent economists, including three Nobel prize winners. See http://gregmankiw.blogspot.com/2006/09/rogoff-joins-pigou-club.html.

[4]Weisbach's (2009) analysis yields similar conclusions.

policies that specify emissions prices exogenously have several attractions relative to policies that do not. Emissions prices are exogenous under the carbon tax: the specified carbon tax rate is the emissions price. A hybrid system — that is, a cap-and-trade system that establishes a ceiling and/or floor price — also has exogenous prices when the floor or ceiling price is in effect. Exogenously specified prices confer several attractions. One is that they prevent emissions price volatility. Another is that they are likely to minimize expected policy errors in the face of uncertainties about benefits and costs. These attractions have already gained some recognition. Two additional and important attractions — which have received relatively little attention — are that exogenous prices help avoid problematic interactions with other climate policies, and avoid large wealth transfers to oil exporting countries. We consider these and other important dimensions below.

An alternative to both the carbon tax and the pure form of cap and trade is a hybrid policy — a cap-and-trade program accompanied by a price floor, price ceiling, or both. We show that most of the attractions of pure cap and trade are also enjoyed in large part by the hybrid and that, given the hybrid's additional attractions, it is easier to make the case for the hybrid than for pure cap and trade. Many of the hybrid's attractions stem from the exogeneity of allowance prices that arises when its price ceiling or floor is engaged.

The rest of this paper is organized as follows. The next section presents dimensions along which carbon taxes and cap-and-trade systems, if well designed, are equivalent. Section 3 concentrates on dimensions along which the two options perform differently. The final section integrates the information from the previous two sections to arrive at an overall assessment of the relative attractions of the different policy instruments.

2. Dimensions Along Which the Options are Equivalent (Despite Suggestions to the Contrary)

By establishing a price for emissions of carbon dioxide, carbon taxes and cap-and-trade systems (as well as the hybrid) encourage firms to alter their production processes so as to reduce emissions per unit of output.[5] These policies also affect consumers' decisions by causing the prices of carbon-intensive goods (for example, electricity, aluminum, and gasoline) to rise relative to those of other goods. They thereby encourage shifts in consumption patterns toward less carbon-intensive goods, which implies lower output by carbon-intensive industries and further emissions reductions.

The different instruments establish the prices in different ways, however. Under a carbon tax, the price of carbon (or of CO_2 emissions) is set directly by the regulatory authority — this is the tax rate. In contrast, under a (pure) cap-and-trade system, the price of carbon or CO_2 emissions is established indirectly: the regulatory authority stipulates the allowable overall quantity of emissions; this then yields a price of carbon or CO_2 emissions through the market for allowances. The provision for allowance

[5]Emissions pricing programs such as a carbon tax or cap and trade can be applied not only to CO_2 but also to other greenhouse gases such as methane, nitrous oxide, fluorinated gases, and sulfur hexafluoride. Here we focus on policies that impose prices only on CO_2 emissions. The conclusions drawn tend to apply equally to policies that price the other greenhouse gases.

trading is a critical element of cap and trade, as it promotes the emergence of a single market price for emissions faced by all market participants at any given time.

Thus, under both the carbon tax and cap and trade, the covered firms — those that are subject to the carbon tax or that are required to submit emissions allowances — face the same price of emissions. If covered firms are cost-minimizing, they will reduce emissions up to the point where, at the margin, the cost of emissions abatement equals the common emissions price. The two policies thus tend to bring about equality of marginal abatement costs across emitters, a condition for cost-minimization. The ability to bring marginal abatement costs to equality is the central advantage of the two market-based approaches over direct regulations such as mandated technologies or plant- or firm-level emissions quotas. In general, regulators do not have sufficient information about individual firms' marginal abatement cost schedules to specify a set of emissions quotas or technologies that lead to equality of marginal abatement costs.[6]

Although they have much in common, carbon taxes and cap and trade differ in important ways. Yet several of the perceived differences are not real. Here, we point out four dimensions along which, contrary to frequently made claims, the two approaches are equivalent.

2.1. *Incentives to reduce emissions: Carbon taxes versus freely allocated allowances*

Under cap and trade, the allowances can be introduced into the system either by auction or through free allocation. A concern sometimes leveled against cap and trade is that free allocation eliminates the recipient's incentive to reduce emissions. But theory suggests otherwise. Even when allowances are received for free, each additional unit of emissions carries an opportunity cost: one more unit of pollution either reduces the number of allowances the covered firm can sell, or it raises the number of allowances the firm must purchase to remain in compliance. The carbon tax and cap and trade thus offer equivalent incentives to reduce emissions, regardless of whether the allowances are introduced through auction or free provision. Table 1 records this conclusion.

2.2. *Flexibility in compensating for uneven distributional impacts*

The distribution of the regulatory burden is obviously an important policy consideration, for reasons of fairness and political feasibility. Emissions pricing can lead to a very

[6]Prior studies indicate that under direct regulation, marginal abatement cost can differ substantially, so that market approaches can have a large cost advantage. The South Coast Air Quality Management District estimated, for example, that the RECLAIM cap-and-trade program in Los Angeles would reduce costs by 46% relative to the costs of achieving the same aggregate reductions under the prior air quality management program, which involved fixed emissions caps (no trades). Carlson *et al.* (2000) estimated that the sulfur dioxide allowance trading under Title IV of the Clean Air Act offered potential cost savings of $700–$800 million per year compared to an "enlightened" command-and-control program characterized by a uniform emissions rate standard. A review by Chan *et al.* (2012) of various analyses indicates that sulfur dioxide allowance trading under the Clean Air Act yielded cost savings in the range of 15% to 90% relative to the costs under various conventional forms of regulation. Still, direct regulation sometimes can have advantages. In situations where emissions are difficult to monitor, for example, it may be less costly to control emissions by requiring the installation of a particular type of equipment and monitoring its use than by aiming to monitor emissions directly.

Table 1. Equivalences between carbon taxes and cap and trade.

Issue	Comment
Incentives to Reduce Emissions	Marginal incentives are the same. This applies even in the case where allowances are freely allocated under cap and trade.
Distribution of Burden across Industries and across Household Groups	Depends on: (1) extent of free emissions (2) disposition of policy revenues Cap and trade and carbon tax have the same options along these dimensions.
International Competitiveness	Depends on: (1) opportunities for border adjustments (2) mechanisms for subsidizing carbon-intensive trade-exposed industries. Cap and trade and carbon tax have similar opportunities along these dimensions.
Connection with Offsets	Under a carbon tax or a cap-and-trade program, provisions for offsets may be added or left out.

uneven distribution of costs across producing sectors, or between producers and consumers. Some analysts have suggested that the ability to allocate allowances for free is an especially useful device for achieving desired distributional outcomes (or avoiding undesirable ones), and that a carbon tax has no comparable feature. Since allowances are valuable, free allocation can indeed alter the distributional impact. However, in principle any distributional outcome under cap and trade can be matched via a carbon tax. As we show below, the same redistribution brought about through free allocation of allowances can be produced through the granting of partial or full exemptions to the carbon tax.

Figure 1 illustrates the idea. The figure indicates the impacts of the two forms of emissions pricing on producer surplus for a polluting industry in a setting of pure competition. In the absence of emissions pricing, the output price and quantity produced are p_0 and Q_0, respectively. Consider first the impacts of a cap-and-trade program

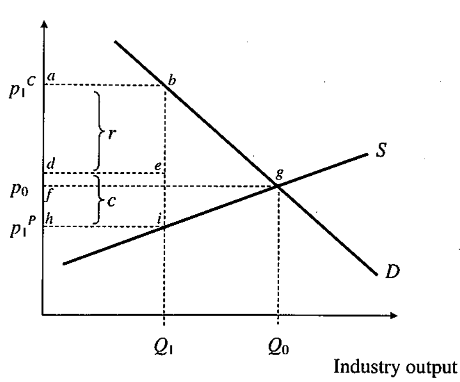

Figure 1. Impacts of cap and trade and carbon tax on producer and consumer surplus.

covering this industry. Firms in this industry will incur costs of c per unit of output from induced changes in their input mix and/or adoption of end-of-pipe treatment. The cost per unit of remaining emissions — the allowance price multiplied by emissions per unit of output — is r. Thus, the policy drives a wedge of $c + r$ between the resulting consumer price p_1^C and producer price p_1^P, and reduces output to Q_1.

The distribution of the burden between firms and the taxpaying public depends on how the allowances are introduced. If they are introduced through a competitive auction, the policy will generate no rents: rents are bid away through competitive bidding for allowances. In this case, the loss of producer surplus is trapezoid *fgih*, while the loss of consumer surplus is *abgf*. The rectangular area *abed* represents the revenue that the government would receive from the allowance auction. This revenue benefits the general public, since it can be used either to finance cuts in other taxes or to pay for additional public goods and services.

The impacts of cap and trade differ when the allowances are introduced via free provision. In this case, the rectangle *abed* represents rents to producers rather than revenues to the government. Freely allocated allowances mitigate the burden of reducing emissions.[7]

Now consider the impacts of a carbon tax of equivalent stringency, that is, a carbon tax at a rate equal to the market price of allowances under the cap-and-trade program. This tax's impact on producer and consumer surplus is identical to those in the case of cap and trade with auctioning: again firms pay the price of emissions (the carbon tax rate in this case) for every unit of pollution generated (or carbon supplied), and the loss of producer surplus given by the trapezoid *fgih*.

A point less recognized is that the carbon tax can also mimic the outcome when the cap-and-trade program involves free allocation of allowances. This is a carbon tax system that grants a tradable tax exemption for a certain amount of emissions — that is, the tax applies only to emissions in excess of a certain quantity.[8] For a given emitting firm, this carbon tax policy has an impact identical to a cap-and-trade system in which the firm is freely granted emissions allowances authorizing emissions of that same quantity.

Thus we conclude that there is no inherent difference in distributional impacts of the two approaches. We indicate that conclusion in Table 1. Still, carbon taxes are generally perceived to be more burdensome to firms. Most likely this is because there has

[7]Studies of NO_x allowance trading under the U.S. Clean Air Act (Bovenberg *et al.*, 2005) and of potential carbon dioxide allowance trading in the United States (Bovenberg and Goulder, 2001; Smith and Ross, 2002; Goulder *et al.*, 2010), suggest that the rents from 100% free allocation would substantially overcompensate firms for the costs they would otherwise face under these programs. In fact, these studies show that a fairly small share of the allowances — generally less than 30% — need to be freely allocated in order to provide sufficient rents to prevent an overall decline in firm equity values. In the first phase of the EU ETS, over 95% of the allowances were given away for free. In keeping with the analysis above, this generated windfall profits to many of the regulated firms. Partly in reaction to this result, there has been a distinct shift towards greater emphasis on the auctioning of allowances in the recently established Regional Greenhouse Gas Initiative in the northeast U.S. and in various climate bills recently introduced in the U.S. Congress. It should be noted, however, that both cases involve relatively modest emission reductions. Phase III of the EU ETS will allocate a much greater percentage of allowances through auctioning (Harrison *et al.*, 2011).

[8]This would allow entities that receive more exemptions than they wish to use to sell the exemptions to other entities, whose allowable emissions would be expanded according to the number of exemptions purchased.

been little consideration of the possibility of using tax exemptions under a carbon tax policy to cushion or eliminate adverse profit impacts.

It is worth noting that both cap and trade and the carbon tax can address distributional issues through another channel — the recycling of policy-generated revenues. Revenues from auctioned allowances or from the carbon tax can be used to finance tax cuts or lump-sum transfers to firms or households that otherwise would suffer disproportional losses from emissions pricing.[9]

2.3. *Safeguarding international competitiveness*

A region or nation that moves ahead of its neighbors on climate policy can potentially put its own carbon-intensive firms at a disadvantage. This is a major policy concern. California policy makers continue to contemplate how the state's climate policies will affect the ability of in-state firms to maintain market share with competitors elsewhere. Likewise, decision makers at the federal level in the U.S. are concerned with the impact of a national policy on the international competitiveness of U.S. firms. Border adjustments can offset potential adverse impacts on international competitiveness. Such adjustments would serve to offset the price advantage that goods imported to the U.S. might otherwise enjoy, or the price handicap that U.S. exports might otherwise suffer. Border adjustments can include taxes or allowance requirements applied to imports of fuels and carbon-intensive products, and exemptions for exported fuels or goods.[10]

Border adjustments pose huge implementation challenges. No regulator will have sufficient information to identify the border tax or allowance requirements that would perfectly prevent any tilting of the playing field. And border adjustments can easily become administratively very complex.[11]

[9]Work by Dinan and Rogers (2002), Parry (2004), and Metcalf (2007) indicates that a U.S. cap-and-trade system with freely allocated allowances would impose a disproportionately large economic burden on low-income individuals. For this reason a number of citizens' groups prefer cap and trade with auctioning (which allows for revenue-recycling) to cap and trade with free allocation. Hoerner and Robinson (2008) endorse a "cap and dividend" policy involving auctioned allowances, with all auction revenues recycled to households on a per capita basis, and a "climate asset plan," in which revenues are targeted for relief to low and moderate income households, the financing of investments in energy efficiency and renewable energy, and other tax reductions.

[10]The instrument chosen for the border adjustment need not match the instrument applied to domestic firms. That is, one could accompany a domestic carbon tax with either a tax on carbon-intensive imports or limits on the quantities of such imports, based on their carbon content. Similarly, if an upstream cap-and-trade system were introduced, one could address imports either by including imported carbon within the system (that is, requiring importers to submit allowances in keeping with the carbon content of the imports) or by taxing imports.

[11]Consider in particular the difficulties of determining the needed border adjustments related to U.S. imports. To prevent any adverse competitiveness effect, border adjustments would need to undo the price advantages that imported goods would otherwise enjoy as a result of a domestic climate policy. It is impossible to eliminate this advantage perfectly. Nations that export goods to the U.S. differ dramatically in the stringency of their climate policies. Moreover, the technologies employed to produce goods for export to the U.S. differ across countries and differ from U.S. production methods. To discern the price advantage, one would need to know the production technologies employed at each stage of production, since these technologies affect the ultimate direct and indirect carbon associated with production. No U.S. regulator will have the information to determine the necessary adjustment applicable to each good arriving at the U.S. border. Moreover, beyond the information problem, any "perfect" border adjustments would be extremely complex, distinguishing imports by type of good and country of origin. Recognizing these administrative constraints, proposed policies have involved far simpler border adjustment schemes that involve imposing border taxes or applying emissions allowances only for imported fossil fuels and, in some cases, for some refined fuels and highly carbon-intensive products like steel and aluminum.

Does one policy have an advantage over the other in terms of either the need for border adjustments, or the ease of introducing such adjustments, assuming they are needed? It has been argued that a cap-and-trade system can be introduced downstream, and that this implies less need for border adjustments. A downstream cap-and-trade system is one in which the points of regulation (the entities that must submit carbon allowances) are at the point of combustion. Under such a system, domestic producers of fuel would not be at a competitive disadvantage relative to foreign suppliers of fuels. The allowance price would lead to reductions in demand for both the domestic and foreign fuels earlier in the supply chain. In contrast, under an upstream systems (where the entities that must submit allowances are at or nearer to the point of supply of carbon-based fuels), domestic producers would face a disadvantage since (absent border adjustments) purchases of imported fuels would not carry an obligation to purchase emissions allowances associated with the carbon content of those fuels. In the absence of border adjustments, an upstream system would likely cause users of carbon-based fuels to shift their demands toward imports. This would imply emissions leakage: higher CO_2 emissions from the increased imports would offset the reduced domestic emissions.[12] Preserving environmental effectiveness and international competitiveness would require border adjustments.

The argument that a downstream system reduces the need for border adjustments is valid. However, the potential for downstream implementation is not exclusively enjoyed by cap and trade: A carbon tax system can also be introduced downstream. Although downstream implementation might have some attractions in terms of reducing the need for border adjustments, it does not favor cap and trade over a carbon tax.

A further tool to safeguard international competitiveness is the use of output-based updating, a particular form of allowance allocation in cap-and-trade systems. The potential success of output-based updating has been viewed as a distinct attraction of cap and trade. Output-based updating is equivalent to the combination of an emissions tax and subsidy to the recipient firm's production or output. This combination can avoid an adverse competitiveness impact, since the subsidy helps reduce or avoid the emission pricing system's impact on firms' output prices. At the same time, it preserves firms' incentives to reduce emissions per unit output, since the marginal cost of emitting continues to be the allowance price. However, as shown by Fowlie (2012), output-based updating can reduce the cost-effectiveness of a cap-and-trade program because it effectively mandates additional emissions reductions by sources deemed ineligible for the extra allowances. (Put differently, updating may lead to inequality of marginal abatement costs across emitters.)

Output-based updating is a feature of California's AB 32 and was an important component of the American Clean Energy and Security Act, which was passed by the

[12]See Bushnell and Mansur (2011) for further discussion of the interaction between leakage and the upstream/downstream issue.

U.S. House of Representatives in 2009.[13] In both of these efforts, firms in industries deemed especially carbon-intensive and trade-exposed enjoyed output-based allocations of allowances.

Output-based updating has some significant attractions.[14] However, it does not imply an advantage of cap and trade over a carbon tax. Although seldom recognized, a carbon tax could similarly protect domestic firms in industries that are especially carbon-intensive and trade-exposed. It could do this by conferring to these firms tradable exemptions for a certain amount of emissions, with the scale of the exemptions to a firm based on the firm's level of output. This is functionally identical to output-based updating under cap and trade.

Based on these considerations, we find that a carbon tax and cap and trade have similar options for addressing international competitiveness, and that the ease of implementing those options is similar under both types of policies. This conclusion is recorded in Table 1.

2.4. *The connection with offsets*

An offset is a credit for emissions reductions achieved by an entity in a sector that is not covered by a given cap-and-trade system. By encouraging emissions reductions in areas or sectors outside the cap-and-trade program, offsets broaden the reach of the program and help promote the achievement of overall emissions-reduction goals at lower cost.

Many policy analysts are critical of offsets because of the problem of "additionality": It is difficult to discern whether a credited reduction truly constitutes a reduction relative to what would have been the case under business as usual, that is, relative to what would have occurred if provisions for offsets had not been in place (for example, see Wara and Victor, 2008).

Some analysts claim that cap and trade is a faulty system because of the potential difficulties with offsets (for example, see Hansen, 2009). However, these difficulties do not constitute a weakness of cap and trade relative to the carbon tax alternative. Offsets are not an inherent feature of cap and trade: one can include or exclude offsets from cap-and-trade systems.[15] Moreover, just as with cap and trade, it is possible to include or exclude offsets as part of a carbon tax program.[16] Thus as acknowledged in Table 1, considerations relating to offsets have no bearing on the choice between cap and trade and the carbon tax.

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[13]The ACES act never came up for a vote in the U.S. Senate and thus never became law.

[14]See Fischer and Fox (2007) for conditions under which output-based updating is an efficient policy tool.

[15]For example, South Korea's proposed cap-and-trade program bans the use of international offsets, while New Zealand's cap-and-trade program allows unlimited use of offsets.

[16]For example, Australia's emissions pricing program allows the use of some offsets even during its "fixed price period" from 2012 to 2014 (during which the program is essentially a carbon tax).

3. Where the Choice between the Instruments Makes a Difference

We now consider dimensions along which the carbon tax and cap and trade (and the hybrid) produce different outcomes, even when comparably designed. We contrast the approaches according to their ability to: minimize administrative costs, address uncertainties about damages from emissions and costs of emissions abatement, control volatility of emissions prices, avoid "emissions leakage," avoid large international wealth transfers, achieve budget discipline, achieve useful linkages across jurisdictions, achieve broad sector coverage (and related cost-effectiveness), and gain political support.

3.1. *Administrative ease*

The costs of administering an emissions pricing policy depend on the number of sources that must be evaluated and monitored. Some analysts have criticized the cap and trade system as being far more costly to administer than a carbon tax. But several of these claims stem from the assumption that a carbon tax would be introduced "upstream" (at our near the point where carbon first enters the economy) while the cap-and-trade program would be applied further downstream (at or near the ultimate point of combustion of the carbon-based fuels) (for example, see Sachs, 2009). As indicated in Table 2, an upstream program involves far fewer covered entities. The table, adapted from Cambridge Energy Research Associates (2006) and Stavins (2007), indicates that an upstream system might involve some 2000 energy supply companies as points of regulation. In contrast, a fully downstream system — one that considered only the ultimate emitters of CO_2 — would involve millions of points of regulation since it would need to include furnaces and automobile emissions of every household. Thus,

Table 2. Alternative points of regulation for a U.S. carbon tax or cap and trade system.

Point of Regulation	— Fossil Fuel Category —		
	Coal	Oil	Natural Gas
Upstream	Mining and imports (500 companies	Production wells and imports (750 companies)	Production wells and imports (750 companies)
Midstream	Rail, barge, and trucking operations (numbers not estimated)	Refining (200 refineries)	Pipelines and processing (200 pipelines, or 1,250 local distribution companies and 500 liquified natural gas plants)
Downstream	Electric power plants (500 plants)	Mobile sources, industrial boilers, and electric power plants (millions of sources)	Industrial boilers, commercial and residential furnaces, and electric power plants (millions of sources)

Source: Adopted from Cambridge Energy Research Associates (2006).

Table 3. Relative advantages of carbon tax, hybrid, and cap and trade.

Issue	Carbon Tax	Hybrid	(Pure) Cap and Trade
Minimize Administrative Costs	✓		
Avoid Price Volatility	✓	✓*	
Address Uncertainty			
Weitzman issue (price vs. emissions uncertainty)	✓	✓	
Murray-Newell-Pizer issue (flexibiity to respond to new information)		✓	✓
Avoid Leakage from "Nested" Regulation	✓	✓*	
Avoid Wealth Transfers to Oil-Exporting Countries	✓	✓*	
Achieve Revenue-Neutrality, Promote Broader Tax Reform	✓		
Achieve Linkages across Jurisdictions	?	?	?
Achieve Benefits from Broad Sectoral Coverage	?	?	?
Achieve Greater Political Support	?	?	?

* applicable when the price ceiling or floor is engaged

Notes: Check marks indicate relative advantage; question marks indicate that the relative advantage is uncertain.

the administrative costs associated with monitoring emissions can be considerably lower under an upstream system.[17] However, both a carbon tax and a cap-and-trade program can be implemented upstream or further downstream.[18,19] Hence this particular claim as to the greater administrative ease of a carbon tax is not valid.

Still, the overall costs of administration might be somewhat higher under cap and trade. The reason is that cap and trade imposes an additional administrative responsibility: the regulator must not only monitor emissions but also establish a registry for allowances and keep track of allowance trades and the associated changes in ownership of allowances. Table 3 records the idea that cap and trade might involve higher costs of administration.

[17]Bushnell and Mansur (2011) note that the upstream-downstream question is related to the issue of leakage, where emissions pricing policy (either carbon tax or cap and trade) causes an increase in emissions elsewhere, such as by foreign firms. In measuring cost-effectiveness of a downstream versus upstream system, it is thus not only the number of covered sources that matters but also the extent to which the point of regulation influences leakage.

[18]For non-CO_2 greenhouse gases, downstream approaches mainly apply, since for these gases there is no simple proportionality between the chemical composition of the fuel and ultimate emissions. For these gases the ratio of emissions per unit of fuel depends on the production process involved. Metcalf and Weisbach (2008) discuss potential methods for incorporating some of these other gases in a U.S. carbon tax system.

[19]Given that administrative costs are smallest under an upstream approach, one might expect wide support for such an approach, regardless of whether the policy involved is a carbon tax or cap and trade. This is not the case. Many proponents of cap and trade favor the (practical) downstream approach, claiming that it produces greater incentives by downstream entities to reduce emissions. However, an upstream approach still generates incentives for emissions reductions downstream, as upstream producers pass through the policy-induced increases in cost. Some interested parties are skeptical as to whether this would yield comparable reductions, however. To illustrate: In 2006 the California EPA set up a 14-member Market Advisory Committee of outside experts to arrive at recommendations for the design of a cap-and-trade system for the state. Most members of the Committee favored the downstream approach, claiming that it would make the constraints on emissions and consequently lead to more effective emissions-reductions that would compensate for potentially higher administrative costs. All of the economists on the committee, however, favored an upstream approach.

3.2. *Volatility of emissions prices*

Emissions price volatility is not a problem for a carbon tax. Under that policy, the emissions price is the tax rate, and presumably the time-profile of tax rates imposed by policy makers involves relatively smooth changes rather than sudden jumps or ups and downs. But volatility is an issue for a cap-and-trade system, where the emissions price is the allowance price. Under cap and trade, the supply of allowances is perfectly inelastic. Hence shifts in demand can cause significant price changes — and irregular shifts in demand can produce price volatility. Nordhaus (2007) notes that demand for allowances is also likely to be highly inelastic in the short run, leading to even greater potential for high price volatility. He argues that allowance trading programs' price volatility represents a reason to favor carbon taxes over cap and trade.[20]

Some existing cap-and-trade systems have in fact displayed considerable allowance price volatility. The energy supply crisis in California in the summer of 2000 gave power companies incentives to bring online some older power generators in the Los Angeles region. This led to a significant increase in the demand for NOx emissions allowances under the Regional Clean Air Incentives Market (RECLAIM) program, since allowances were needed to validate the emissions produced by these generators. As a consequence, NOx allowance prices rose from about $400 per ton to an average in the year 2000 of over $40,000 per ton (with the average allowance price reaching $70,000 in the peak month of 2000) (Ellerman and Joskow, 2008).

Prices were volatile as well in the first phase of cap and trade under the EU ETS. About a year after its implementation, emissions allowance prices dropped dramatically with the release of information that indicated that the ETS Phase I permit allocations were very generous in the sense that they did not much constrain the covered sources. The December 2008 futures prices fell from €32.25 to €17.80 between April 19 and May 12, 2006. There was even greater volatility for the Phase I permit prices contained in December 2007 contracts. These prices dropped from €31.65 on April 19, 2006 to €11.95 on May 3, 2006. In the year 2008, the December 2009 futures prices ranged from €13 per ton (January) to €30 per ton (June).

Phase II of the ETS began in 2008, and while price instability has still been a problem, the swings have been less frequent and intense, including a stretch of almost two years (roughly mid-2009 to mid-2011) with very stable prices hovering between about €15 and €20. Since then, a surplus of permits equivalent to 1.5 billion to 2 billion tons of carbon has led to steady drop in prices, falling as low as €5 a tonne in early 2013 (*The Economist*, April 20, 2013).

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[20] A few analysts have suggested that the endogeneity of emissions prices under cap and trade may have a virtue: namely the ability to respond positively to business-cycle changes. In particular, during economic downturns, the demand for allowances may fall. The associated decline in allowance prices could ease the burden on producers during these more difficult economic periods.

One way to reduce potential price volatility is to allow for intertemporal banking and borrowing of allowances. With intertemporal borrowing, firms can apply toward present emissions the allowances allocated to them for future time periods. Similarly, with intertemporal banking, firms can apply to future periods the allowances they do not use in the current period. Such intertemporal flexibility makes the current supply of allowances more elastic and thereby can damp price volatility.

Stavins (2007) and Ellerman *et al.* (2003) point out that much of the allowance price volatility experienced by RECLAIM was due to the absence of provisions for banking. And volatility in allowance prices for Phase I of the EU ETS has been attributed in part to the fact that the program prevented banking of allowances from the first phase to the second (Market Advisory Committee to the California Air Resources Board, 2007). Nearly unlimited banking in the SO_2 Trading Program is generally agreed to have been a successful design feature of that program, as it mitigated issues of price volatility and led firms to achieve SO_2 reductions faster than they would have without banking (Ellerman and Buchner, 2008).

Still, allowing intertermporal banking is not a panacea. Nordhaus (2007) finds that SO_2 allowance prices between 1995 and 2006 were about as volatile as oil prices and more volatile than prices of stocks, other assets such as houses, and most consumer goods. SO_2 allowance prices were particularly volatile in the late-2000s, as a series of court and regulatory decisions changed expectations about the future stringency of the cap (Palmer and Evans, 2009; Bravender, 2009).

Another way to address volatility is to incorporate within a cap-and-trade system an allowance price floor, allowance price ceiling, or both.[21] The "hybrid" referred above is a cap-and-trade system with one or both of these features. The hybrid was a feature of several significant climate policy bills introduced in the 110th Congress.[22] Many economists endorse the hybrid approach, believing that it reduces potential price volatility while retaining several attractions (discussed below) that are not enjoyed by pure cap and trade. Table 3 records as an attraction of the hybrid its ability to reduce potential price volatility.

To impose a ceiling on allowance prices, the regulator may (1) introduce into circulation additional allowances whenever the stipulated ceiling price is reached so as to prevent allowance prices from rising further, or (2) allow firms to pay a set fee to emit instead of submitting allowances, if allowance prices reach a threshold (usually set at the same price as the fee itself).[23] To enforce a price floor, the regulator may (1) buy up (remove from circulation) allowances whenever the floor price is reached,

[21]For a detailed discussion, see Pizer (2002), Jacoby and Ellerman (2004), Burtraw and Palmer (2006), and Wood and Jotzo (2011).
[22]Senate Bill 1766, sponsored by Jeff Bingaman (D-NM) and Arlen Specter (R-PA), and Senate Bill 2191, sponsored by Joseph Lieberman (I-CT) and John Warner (R-VA) — contained a price ceiling. The Carbon Limits and Energy for America's Renewal, or CLEAR, Act of 2009 (S. 2877), had both a price ceiling and floor. The American Clean Energy and Security Act of 2009 (H.R. 2454), the Clean Energy Jobs and American Power Act (S. 1733), and the American Power Act of 2010 (APA) would have established a price floor by withholding allowances from auction if their price fell below a given amount.
[23]RECLAIM regulators improvised a set-fee "price ceiling" in the California energy crisis in the summer of 2001.

thereby preventing prices from falling further,[24] or (2) set a fee that purchasers must pay in addition to the allowance price when allowance prices drop below the stipulated floor level.[25] Various cap-and-trade programs, such as the one recently set up in California, use an auction reserve price.[26]

Burtraw *et al.* (2006) assert that having both a floor and ceiling is superior to a ceiling alone. Their numerical simulations suggest that the implementation of a price ceiling without a corresponding price floor will have the unintended consequence of lowering the expected allowance price and the overall expected return on low-emissions technology. This is true whether or not the price ceiling is binding. In the absence of a price ceiling, investors take risks on low-carbon investments given expectations over a distribution of potential payoffs for their investment. A price ceiling truncates that distribution, limiting the upside of low-emissions investments. A price floor makes the truncation two-sided, limiting the downside of these same investments.[27]

3.3. *Addressing uncertainty*

As discussed above, a carbon tax and a cap-and-trade program address uncertainty differently. The carbon tax stipulates the price of emissions, while leaving uncertain the aggregate emissions level. Cap and trade stipulates aggregate emissions, leaving the price uncertain.

For some environmental groups, the fact that a carbon tax does not guarantee that emissions will be kept within a given limit is a crucial liability. Under a carbon tax it remains possible that emissions will significantly exceed the levels these groups prefer. At the same time, some business groups abhor the fact that cap and trade leaves prices uncertain. They emphasize that uncertainty about emissions prices (under cap and trade) constrains the business community's ability to respond to climate policy: changing the input mix (for, example, engaging in fuel substitution) and investing in research toward new technologies is more risky when future allowance prices are uncertain.

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[24]Many analysts, including EU climate commissioner Connie Hedegaard, regard the EU ETS permit prices as problematically low (Carrington, 2013a). The EU ETS has temporarily dealt with this issue by issuing plans to delay the release of permits for 900 m tonnes of carbon (Carrington, 2013b), a step akin to removing permits from circulation. European Parliament members are still in the process of discussing longer-term structural reforms, including the possible inclusion of a permanent price floor (*The Economist*, April 20, 2013).

[25]Wood and Jotzo (2011) note that the fee-based approach to enforcing a price floor might be viewed more favorably by those concerned about "budget discipline," since this approach yields government revenue while buying up allowances requires government outlays.

[26]Auction reserve prices set initial price floors. Subsequent trading may lead to allowance prices below the auction reserve price. California's auction reserve price was $10 in the first auction (November 2012) and is stipulated to rise each year by the rate of inflation plus 5% (for 2013, the auction reserve price is $10.71).

[27]Price floors and price ceilings have potentially problematic interactions with the other set of price stabilization measure discussed in this section, namely allowing firms to bank and borrow allowances. See Elmendorf (2009), Dinan (2010), and Stocking (2012) for examples. Their analyses suggest that in light of these problematic interactions, it would be prudent to allow banking and borrowing in pure cap-and-trade programs but not in hybrid ones.

At least two arguments underlie environmental groups' opposition to emissions uncertainty and their support of fixed quantity limits under cap and trade. One is that specifying a given quantity limit on emissions is consistent with the intent of many types of climate legislation, which stipulate given emissions targets. Imposing cap and trade (with no price ceiling) helps assure adherence to this goal. California's Global Climate Solutions Act of 2006 (AB 32) commits the state to reducing greenhouse gases to 1990 levels by the year 2020. Environmental groups argue that a cap-and-trade system best assures that this target is not exceeded.[28]

A second argument is that leaving the emissions level uncertain risks greater harm to society than allowing uncertainty about emissions prices. If the relationship between emissions and environmental damage is highly nonlinear, then allowing emissions to exceed given levels might pose significant risks. This tends to favor setting a limit on emissions quantities. On the other hand, setting such a limit would compel firms to reduce emissions to a given level no matter what their costs of abatement turn out to be. If abatement costs are highly nonlinear, rising sharply with the amount of abatement, there's a risk that abatement costs could become very large. The important contribution of Weitzman (1974) provides insights relevant to this issue. It compared the expected efficiency gains under uncertainty of a price-based approach (as with carbon taxes) and a quantity-based approach (as with cap and trade). The relative advantage depends on the slopes of the functions that express marginal environmental damages and marginal costs as functions of emissions. The quantity-based approach emerges as superior when the marginal damage function is relatively steep; otherwise the price-based approach is more attractive. Several recent studies apply a Weitzman-type framework to climate policy.[29] These analyses tend to suggest that a relevant marginal abatement cost function is steeper than the relevant marginal environmental damage function. Hence they tend to support the carbon tax.

The Weitzman framework is most relevant to situations where the policy objective is *net benefit maximization*: Achieving the level of emissions reductions that maximize the benefits from the reductions minus the costs of achieving those reductions. For many climate policy efforts — particularly those at the state or regional levels — the objective is instead *cost-effectiveness*: The achievement of some previously established level of emissions reductions at minimum cost. When the objective is achieving a given emissions target, cap and trade gains favor, since the target is given by the aggregate cap.

[28]It is worth noting that a California cap-and-trade system would not embrace all emitting sources in the state. Hence the state's adoption of cap and trade would not guarantee that *statewide* emissions stay within the stipulated target: it would only assure that, with proper enforcement, emissions from sources covered by the system are constrained to the level given by the system's aggregate cap.

[29]See Pizer (2002), Hoel and Karp (2002), Newell and Pizer (2003), and Karp and Zhang (2005). The finding that, as a function of emissions, the marginal damage schedule is relatively flat reflects the facts that marginal damages depend directly on atmospheric concentrations and that changes in emissions in a given period do not substantially alter the atmospheric concentrations.

The hybrid policy also introduces uncertainty about emissions levels: Enforcing the ceiling implies the introduction of extra allowances, while enforcing the floor can imply removal of some allowances that were in circulation.[30] Stavins (2008) dismisses concerns about the emissions uncertainty arising under the hybrid. He notes that the uncertainty about emissions quantities under the hybrid can be reduced or eliminated if policy makers pledge to invest in other, offset projects to compensate for whatever increase in emissions would otherwise occur as a result of enforcing the price ceiling. Revenues from emissions allowances sold could be used to finance some or all of these offset projects.[31]

Murray *et al.* (2008) address a different aspect of the uncertainty issue. They argue that a cap-and-trade system (or the hybrid) with intertemporal banking of allowances has more ability to adjust to new information in the presence of uncertainty than does the carbon tax. Their argument relies on the fact that under a carbon tax, current marginal abatement costs are largely determined by the carbon tax rate in place today. In contrast, under a pure or hybrid cap-and-trade system with intertemporal borrowing and banking, the current cap on allowances does not fully determine current marginal abatement costs: Changes in expectations about future policy will lead to adjustments in current abatement decisions. This greater ability to respond to changing expectations gives cap and trade an advantage over the carbon tax in smoothing emissions prices over time.

These considerations suggest that the uncertainty dimension does not clearly favor any single emissions pricing approach. When the objective is net benefit maximization, the carbon tax or hybrid seem to have an advantage, given the implications of the Weitzman framework when the marginal damage function is relatively flat. On the other hand, the hybrid or pure cap and trade program could have an edge over the carbon tax along the lines considered by Murray, Newell, and Pizer — attaining flexibility to adjust to new information — as long as the price ceiling is not binding. These points are recorded in Table 3.[32]

3.4. *Interactions with other climate policies*

Relatively recently some analysts have pointed out a potentially important advantage of a carbon tax over cap and trade. Burtraw and Shobe (2012), Fischer and Preonas (2010), and Goulder and Stavins (2012) have shown that, in the presence of a cap-and-trade program, introducing an additional GHG-reducing policy such as a performance standard might yield no further reductions in overall emissions. The reason is that

[30]As mentioned above, the price floor can be enforced through a supplemental fee rather than the removal of allowances. Regardless of how the price floor is implemented, a binding price floor will lead to more extensive emissions reductions than originally implied by the cap.

[31]Stavins makes this point in reference to the hybrid, but it applies equally to concerns about uncertain emissions from a carbon tax.

[32]It is possible to design a more complex hybrid that addresses both price and emissions uncertainty. See Murray *et al.* (2008).

overall emissions are determined by the overall cap or number of allowances in circulation. To the extent that the additional policy yields reductions in emissions by some facilities, the demand for emissions allowances falls. This causes the price of allowances to fall until all the allowances in circulation are again demanded.[33] Overall emissions do not change.[34]

In contrast, introducing an additional GHG-reducing policy in the presence of a carbon tax *can* lead to a reduction in overall emissions. In this case, the price of emissions — tax — does not change when the supplementary policy causes a reduction in emissions. For this reason the reduction caused by the supplemental policy does not lead to "emissions leakage," that is, an offsetting increase in emissions elsewhere. Overall emissions fall. Thus, as recorded in Table 3, carbon taxes (or, more generally, policies with exogenous emission prices (including the hybrid if the floor is engaged) have an advantage over cap-and-trade (policies with exogenous emissions quantities) in that they allow supplementary policies to generate larger reductions in emissions.

This issue came to life when the United Kingdom recently decided to impose a tax on CO_2 emissions by electric power generators in the country. For each unit of emissions, these generators would need to pay this tax in addition to the price that they paid for EU ETS emissions allowances. Although the tax will likely cause greater abatement by generators within the UK, it would not cause greater overall abatement in Europe, since overall European abatement is determined by the Europe-wide cap under the EU ETS. The UK initiative will reduce the UK's demands for emissions allowances from the EU ETS, putting downward pressure on allowance prices and prompting increased emissions in the rest of Europe.

3.5. *Wealth transfers to oil exporting countries*

Under cap and trade, the intended economic rents to domestic firms or households can be lost to energy-exporting countries. This can occur when a cartel or government in an energy-exporting country responds strategically to the domestic cap-and trade policy. This transfer of wealth does not arise under a carbon tax.

Perhaps the first analysis of this issue was provided by Berger *et al.* (1992). They showed that when the supply side of fossil fuel markets is imperfectly competitive, cap and trade could lead to the transfer of policy-generated rents from the domestic economy to fossil-fuel-exporting countries. More specifically, they indicated that, when treating fossil fuels as a single good (such as oil) produced by a single

[33]In the extreme, allowance prices could fall to zero, so that the cap no longer binds. This result was approximated at one time under the U.S. SO_2 trading program. Federal regulations mandated reductions in SO_2 emissions beyond the cap in place, and SO_2 allowances prices settled near zero (Chan *et al.*, 2012).

[34]The sequencing of regulatory efforts is relevant here. If a cap-and-trade program is already in place, then adding additional regulations within the sectors already covered by cap and trade might not lead to additional reductions. In contrast, if certain sectors are currently regulated, then introducing cap and trade may well cause a further reduction in emissions.

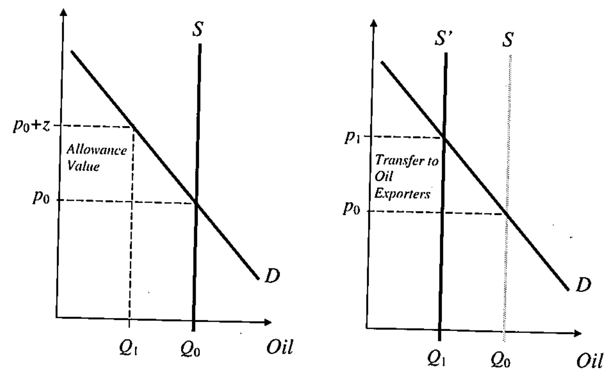

Figure 2. Potential for wealth transfers to oil exporting countries under cap and trade.

monopolist or cartel (such as OPEC), the cartel could exploit a system of cap and trade by reducing oil quantity and raising oil prices until allowance prices were zero. Subsequent analyses by Judd (2008), Strand (2011, 2013), Wirl (2012), and Karp *et al.* (2013) offer broadly similar results.

Judd illustrates the wealth-transfer issue in a simplified setting where the only carbon-based fuel is oil. Suppose that in the absence of cap and trade, the equilibrium price of oil on the world market, given by the (fixed) world supply and the world demand is p_0. Now suppose a cap-and-trade program is introduced. The price of oil now rises to consumers, since oil users must now face an allowance price. Let z represent the cost of allowances needed per unit of oil.[35] The new equilibrium is established where the quantity of oil demanded is Q1 and the price of oil inclusive of the allowance cost is $p0 + z$, as in the left-hand portion of Fig. 2. The rectangular area between p_0 and $p0 + z$ and extending up to the quantity Q_1 is the value of the allowances. This value accrues either as rents to domestic firms or as revenue to the Treasury and the public, as discussed in subsection 2.2.

As Judd's analysis indicates, oil exporters could exploit this situation: they could reduce supply and cause world oil prices to rise to p_1 (or the original $p_0 + z$) without suffering any loss of revenue. In fact, the exporters would *gain* revenue from doing so! How is this possible? If the oil exporters reduced supply to S' while the cap and trade system was in place, as long as the allowance price z remained positive the quantity of oil demanded would be less than Q_1. For in this case the price to consumers would be $p_1 + z$, above the price that yields a quantity demanded of Q_1. This would not be a sustainable equilibrium, however. So long as the quantity of oil consumed fell short of Q_1, emissions would be below the amount "targeted" by the supply of allowances. (Recall that the supply of allowances was such as to bring oil demand down to Q_1 when the oil supply was S.) So now the demand for allowances would fall short of the supply, and the price of allowances would fall. Indeed, the price of allowances would

[35]This cost is positive whether or not the firm obtains the allowances free, since there is an opportunity cost from using an allowance rather than selling it.

continue to fall until the overall price of oil to consumers (including the component due to the allowance price) was p_1. But given that the oil exporters have reduced the supply to S', this requires that the allowance price z fall to zero. Any positive price of allowances would imply a price of oil to consumers above p_1, a quantity demand of oil below Q_1, and a demand for allowances below supply. Hence the reduction in the world supply of oil brings oil demand (and emissions) down by exactly the amount otherwise reduced through scarce allowances. Hence the new equilibrium is as on the right-hand portion of Fig. 2. The allowances are no longer necessary: their price goes to zero. Importantly, what was rent or revenue to domestic firms or the domestic Treasury now becomes revenue to the oil exporters. In this analysis, the cap-and-trade program becomes considerably more costly than the comparable carbon tax, whose revenues are retained domestically.

Two qualifications to these results are in order. First, the wealth transfer is muted once one accounts for the fact that oil is not the only fuel that would be covered by cap and trade. The CO_2 allowance price is determined not simply by the demand for oil but by the demands for other carbon-based fuels (coal and natural gas) as well.[36] As a result, if oil exporters raised the world price, CO_2 emissions would fall less than in proportion to the reduction in oil quantity demanded, since higher oil prices would induce substitutions to other carbon based fuels and associated increases in emissions from these other fuels. This means that the allowance price would not fall one-for-one with the increase in the world oil price. This in turn reduces the extent of the international wealth transfer. In this more realistic setting, by increasing world oil prices the oil exporting countries transfer wealth to owners of competing fuels as well as to themselves.[37] The more competitive fossil fuel markets are, the more muted is the vulnerability of a cap and trade program to manipulation by fossil fuel exporters. Fossil fuel markets are not, in fact, characterized by totally monopolistic production.

Second, the result depends on the extent of market power by the oil-exporting nations. The oil market comprises not only a cartel but also a competitive fringe of price-taking suppliers. The presence of the competitive fringe reduces the market power of the cartel and thereby lowers the magnitude of the wealth transfer induced by the cartel's strategic behavior.[38]

These qualifications soften but do not refute the ability of oil-exporting nations to capture the rents generated by cap and trade remains. Under a carbon tax, the wealth transfer does not occur since the price of emissions is exogenous. Hence the carbon tax has an advantage in this dimension. This is recorded in Table 3. This is another case

[36]In 2003, oil accounted for about 43% of the carbon in U.S. fossil fuels consumed. It might account for a roughly similar percentage of emissions under a climate policy.

[37]Judd suggests that the main result from his analysis is that cap and trade makes consumer demand for oil inelastic. The present paper suggests that in fact the crucial finding is that cap and trade gives oil exporters the ability to convert allowance revenues or rents into revenues for the oil-exporting countries. Also, it might be noted that Judd's result does not apply in the case of a hybrid cap-and-trade program in which the price floor is binding; in this case, the program is analogous to a carbon tax, and the strategic behavior by oil exporters outlined above would not work.

[38]See Berger *et al.* (1992) for an analysis of this issue.

where the exogeneity of emissions prices under a carbon tax confers some advantages over the endogenous prices under cap and trade.

3.6. *Budget discipline and tax reform*

Several studies have shown that the costs of emissions pricing policies can be kept to a minimum if the policies yield government revenue and the revenue is used to finance reductions in the marginal rates of pre-existing distortionary taxes such as income and sales taxes (for example, see Goulder, 1995; Parry, 1995; Parry and Williams, 2013). In particular, the costs of a carbon tax are lower when its revenues are devoted to financing marginal rate cuts, as opposed to lump-sum transfers (as would be the case if the revenues finance rebate checks to households. Similarly, a cap-and-trade program in which allowances are auctioned and the revenues finance marginal rate cuts will involve lower economy-wide costs than a program in which allowances are given out free (and thus no revenue is raised) or in which the auction revenues are recycled as lump-sum payments to citizens. In the U.S., the idea of financing broader tax reforms with revenues from an emissions pricing policy has gained considerable support.

However, Metcalf (2007) suggests that in the U.S. it might be more difficult to achieve the revenue-recycling benefit under cap and trade than under a carbon tax. He points out that the revenues from a carbon tax would fall under the domain of the House Ways and Means Committee and Senate Finance Committee, and that coordination across these two tax committees has a long history; and he indicates, in contrast, that disbursement of revenues from auctioned allowances under a cap-and-trade system would likely involve not only these committees but also the House Energy and Commerce and Senate Energy and Natural Resources committees. Metcalf suggests that the latter committees might be predisposed toward using the revenues to finance environmental projects and be less inclined toward recycling the revenues. Thus, to the extent that revenue-neutrality is considered a critical feature of climate policy, this can be seen as a potential disadvantage of a cap-and-trade program (and of a hybrid program as well)in the United States.[39] Table 3 records this idea.

3.7. *Potential for linkages across jurisdictions*

Initially separate cap-and-trade systems can be linked, and previously distinct carbon tax systems can be harmonized (that is, the rates can be set equal). Linkage and harmonization can yield cost savings. Linking separate emissions pricing programs yields greater abatement effort in the region with the initially lower emissions price and less abatement effort in the region with the initially higher emissions price, thus spurring equal abatement at overall lower costs. Linking once-separate cap-and-trade

[39]In the U.S., there has been considerable discussion of using revenue from a carbon tax to help finance broader tax reform. There has been much less discussion of using revenue from auctioned emissions allowances under cap and trade for this purpose. These differences might reflect recognition of the greater institutional difficulties of coordinating cap and trade with tax reform.

programs allows for further (cross-jurisdictional) reallocations of abatement effort and thereby yields further cost reductions beyond those generated by separate programs.

Linkage can be difficult when the programs being linked have design differences. For example, linking an upstream program with a downstream one is problematic. This can lead to the double-counting or the absence of counting of emissions.[40]

How do these considerations affect the choice between carbon taxes and cap-and-trade? The fact that other nations have already committed to cap and trade might seem to weigh in favor of a U.S. cap-and-trade system over a U.S. carbon tax, since opportunities exist for linking a U.S. cap-and-trade program with such programs elsewhere, whereas there seems to be less room, at present at least, for tax harmonization.[41]

A second consideration is the magnitude of international revenue flows and associated macroeconomic impacts. A potential difficulty associated with internationally linked cap-and-trade programs is the potential for very large revenue flows from the nations purchasing allowances to the nations selling them. The potential for large international revenue flows under cap and trade raises concerns about exchange rate and other macroeconomic effects (for example, see McKibbin and Wilcoxen, 1997). In contrast, an internationally harmonized carbon tax does not directly produce any international revenue flows. However, experience to date with the EU ETS yields no evidence of adverse exchange rate or macroeconomic consequences from trade-induced revenue flows.

The potential for large international revenue flows is especially pronounced when one of the nations employs a hybrid policy involving a (relatively low) ceiling price for allowances. If the ceiling price is low relative to initial marginal abatement costs in other countries, covered firms in other countries will want to purchase allowances from the country with the ceiling price. However, since the ceiling price is fixed, the magnitude of these purchases will not be stemmed by increases in the allowance price. Hence the potential for large international revenue flows is significant. As pointed out by Stavins (2007), other nations may be unwilling to link with a nation that utilizes a ceiling price, given the possibility of very significant revenue outflows. This suggests a

[40]To illustrate, consider an example adapted from Metcalf and Weisbach (2008). Suppose that Country 1 (C_1) and Country 2 (C_2) have linked their cap-and-trade systems, but that C_1 has an upstream program, while C_2 has a downstream one. If a fossil fuel is produced in C_1, it will require submission of allowances there; if it is then exported to C_2, it will again be subjected to C_2's cap-and-trade program when it is consumed there. This will lead to double-counting of emissions. Alternatively, if the same fuel is produced in C_2 and exported to C_1, it will not require allowances for its production or its consumption. This will lead to noncounting of emissions. The same argument applies to harmonizing carbon taxes, where firms pay taxes for emissions instead of submitting allowances for them.

[41]While advocates of cap and trade point out this advantage, carbon tax proponents argue that current (and possibly transitory) international commitments toward cap and trade should not carry great weight in a U.S. decision about a long-term climate policy. Moreover, analysis by Metcalf and Weisbach (2012) suggests that it is possible to link effectively a new carbon tax system with existing cap-and-trade systems, so commitment history need not influence what new system is introduce. Successful linkage of differing systems could be accomplished by both systems accepting "credits" from some source, with the credits serving as allowances under one jurisdiction's cap-and-trade program *or* as a method of tax payment in the other jurisdiction's carbon tax program.

tension between the goals of price stability (addressed through a price ceiling) and cost-effectiveness (addressed through international linkages).

At the same time, arriving at a uniform international carbon tax raises practical difficulties. Various nations may claim that they already tax carbon through existing taxes on individual fossil fuels or on refined fuels (gasoline, home heating oil, etc.). Arriving at a uniform international tax on carbon would in theory require knowledge of the incidence of a wide range of existing energy taxes — in practice this can only be approximated. Individual nations might well manipulate the calculations so as to suggest they are already paying significant taxes on carbon and thereby avoid much of an increase as part of an international effort to obtain a uniform international tax rate.

Thus, there are significant challenges involved in linking systems internationally, no matter whether the systems involved involve cap and trade or carbon taxes. The discussion above suggests that some considerations favor cap and trade while others favor the carbon tax. Thus, as acknowledged by the question marks in Table 3, it is not clear that the linkage issue significantly works in favor of one system or the other.

3.8. *Potential for greater cost-effectiveness from broad sectoral coverage*

Stavins (2007) claims that the political dynamics surrounding a carbon tax and cap and trade are likely to be very different, carrying important implications for cost-effectiveness. Pointing to historical experience, he argues that as a carbon tax moves from initial proposal toward implementation, various industries will seek, and some will win, exclusions from the tax. This would make the carbon tax less cost-effective: any given target for emissions reductions will be reached at a higher cost, the narrower the set covered pollution sources.

He contrasts this result with what has occurred historically as the details of a cap-and-trade system get defined prior to implementation. He points out that stakeholders struggle less for outright exclusions than for a larger share of the stock of freely allocated emissions allowances. Stavins concludes that, in light of political considerations, cap and trade has a greater ability to achieve broad sectoral coverage and the cost-effectiveness associated with it.

It is important to recognize, however, that gaining broader coverage through free allocation can also involve an offsetting element that *sacrifices* of cost-effectiveness. To the extent that the government auctions the allowances, it brings in revenues and thereby reduces its reliance on other revenue sources for financing given expenditures. As a result, the government's budgetary needs can be met with lower marginal tax rates for existing taxes such as income, sales, or payroll taxes. As mentioned in subsection 3.6, lower marginal rates imply lower efficiency losses (or excess burden) from these taxes. Thus, even if cap and trade has an advantage over a carbon tax in terms of the potential for broad sector coverage, it is not clear whether this implies an overall benefit in terms of cost-effectiveness. The method of achieving the broader coverage — free allocation — could imply a significant loss of cost-effectiveness.

Thus, while cap and trade might have greater potential for broad coverage, the benefits of the broader coverage in terms of cost-effectiveness are ambiguous. The question marks in Table 3 attest to this ambiguity.

It is also important to recognize that a carbon tax also has its own version of (partial or full) free allocation in the form of tradable tax exemptions for a certain amount of emissions. Historically, inframarginal exemptions are more common under cap and trade (and the hybrid) than under the carbon tax, but the reasons are not related to inherent constraints or features of the three policies. We do not regard any of the three policies as clearly having a greater ability to reduce costs through broader sectoral coverage. This conclusion is reflected in Table 3.

3.9. *Perceptions and political feasibility*

Political winds can change suddenly and unexpectedly. In the U.S., until recently cap and trade seemed to have more political support than a carbon tax. The major state-level climate change efforts — the Regional Greenhouse Gas Initiative in the Northeast and California's AB 32 — selected cap and trade as the major instrument for achieving emissions reductions. The various climate-policy bills introduced in the U.S. Congress featured cap and trade as the principal vehicle for reducing emissions. This includes the American Clean Energy and Security Act (or Waxman-Markey bill), the only recent proposal to gain a majority of votes in the U.S. House of Representatives.

Recently, however, cap and trade seems to have lost political ground. The fact that the Waxman–Markey bill never attained a vote by the Senate might have caused some legislators to focus more on alternatives. In addition, to many U.S. politicians, cap and trade's appeal stemmed from the fact that it was viewed as something quite different from a tax, and supporting cap and trade seemed as politically safer than showing support for a tax. Over time, politicians increasingly have recognized (correctly) that cap and trade functions much like a tax. Indeed, as mentioned earlier, a cap-and-trade policy involving auctioned allowances has the same impact as a carbon tax, assuming the revenues from the two policies are used in the same way. This recognition may have eroded some of the support for cap and trade. Furthermore, as discussed in subsection 3.6, there is increasing attention to using revenues from a carbon tax — but not from a cap-and-trade system — to help finance a broader tax reform effort. In the U.S. neither market-based approach has a clear political advantage at present.

In other nations, the relative popularity of the two approaches seems to vary by country or region. Cap and trade has been implemented in the EU ETS and in New Zealand and Australia. South Korea plans to implement such a program, and China has initiated test programs in seven cities. Carbon taxes are in effect in Sweden, Norway, Finland, Denmark, the UK, and in the Canadian province of British Columbia.

If cap and trade once had a political advantage, this advantage is no longer so clear. This ambiguity is acknowledged in Table 3.

4. How It Adds Up

In debates about the relative attractiveness of carbon taxes, a cap-and-trade system, or a hybrid of the two, some commentators have supported one option or another based on claimed differences in their incentives for reducing emissions, capabilities for addressing distributional impacts, options for employing or avoiding offsets, and potential for safeguarding international competitiveness. We show that these dimensions do not discriminate between the options. When comparably designed, a carbon tax, cap-and-trade system, and hybrid policy yield very similar incentives to reduce emissions. Comparably designed systems imply the same distribution of policy costs (or policy-generated windfalls) across households or firms; the relevant design features are the extent to which firms are allowed inframarginal emissions without charge and the way that revenues from auctioned emissions allowances or a carbon tax are spent. In addition, each of the policy tools may include or exclude offsets. And the different policy tools have similar capabilities for mitigating potential adverse impacts on the international competitiveness of carbon-intensive domestic firms. This depends on whether the policies are introduced upstream or downstream, and the extent to which provisions for border adjustments or output-based subsidies are included; the three policies have equal potential along these lines. Thus, the incentives for emissions abatement, the distributional impacts, the connection with offsets, and the ability to safeguard international competitiveness depend primarily on the specifics of design, not on the general instrument type.

On other important dimensions, however, the alternatives perform quite differently. The check marks in Table 3 indicate that no approach dominates. One's overall ranking of the different options will depend on the weights one applies to the different dimensions — weights that are inherently subjective. Still, it is noteworthy that the carbon tax or hybrid seems to score better along the dimensions where the advantages or disadvantages are unambiguous.

Many of the attractions of the carbon tax and the hybrid (when the hybrid's floor or ceiling is engaged) stem from the exogeneity of the allowance prices. Exogenously specified prices confer several attractions. They prevent emissions price volatility (assuming that the specified prices themselves do not display a volatile pattern). In addition, they may imply smaller expected policy errors in the face of uncertainties about the marginal benefits and marginal costs of emissions reductions. These attractions are fairly well known. There are other, less obvious, attractions as well: as discussed above, they help avoid an important form of emissions leakage and they avoid potential wealth transfers to oil-exporting countries.

Although debates are likely to continue as to the relative virtues of the carbon tax, cap-and-trade, and hybrid approaches, it is worth recognizing a virtue shared by all three. Each approach is a form of emissions pricing and, as such, each provides flexible and permanent incentives for emissions abatement that are absent in other forms of regulation. All three approaches have the potential to bring about greenhouse gas

emissions reductions in a way that is cost-effective and equitable as well as environmentally successful.

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