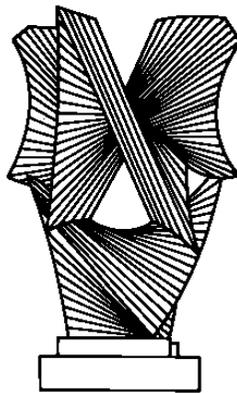


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## Instrument Choice Is Instrument Design

*David A. Weisbach*

**THE LAW SCHOOL  
THE UNIVERSITY OF CHICAGO**

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*David Weisbach*

The University of Chicago Law School

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### **ABSTRACT**

This paper analyzes the choice between taxes and cap and trade systems (also referred to here as a permit system or a quantity restriction) as methods of controlling greenhouse gas emissions. It argues that in the domestic context, with proper design, the two instruments are essentially the same. Commonly discussed differences in the two instruments are due to unjustified assumptions about design. In the climate change context and within a single country there is sufficient design flexibility that these differences can be substantially eliminated. To the extent that there are remaining differences, there should be a modest preference for taxes, but the benefits of taxes are swamped by the benefits of good design; even though the very best tax might be better than the very best quantity restriction, the first order of business is getting the design right.

In the international context, however, taxes dominate more strongly. The design flexibility available within a single country is reduced in the international context because of the problems of coordinating systems across countries and minimizing holdouts. Moreover, the incentives to cheat and the effects of cheating are not equivalent for the two instruments in the international setting. Because climate change will require a global system for emissions, these considerations mean we should favor taxes for controlling greenhouse gas emissions.

David Weisbach

The University of Chicago Law School

[d-weisbach@uchicago.edu](mailto:d-weisbach@uchicago.edu)

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In the international context, however, taxes dominate more strongly. The design flexibility available within a single country is reduced in the international context because of the problems of coordinating systems across countries and minimizing holdouts. Moreover, the incentives to cheat and the effects of cheating are not equivalent for the two instruments in the international setting. Because climate change will require a global system for emissions, these considerations mean we should favor taxes for controlling greenhouse gas emissions. Nevertheless, the preference should be modest; there remains substantial flexibility even internationally and taxes also have coordination and enforcement problems.

Part I provides basic definitions. Part II considers the arguments attributed to Weitzman (1974) that taxes and permit systems are different when the government is uncertain about the marginal costs of abatement. Weitzman's arguments rely on an assumption that taxes are flat, per-unit taxes, permits are a fixed quantity limitation, and neither taxes nor permits can be changed over time in response to new information. These assumptions are not correct in the climate context. Building on arguments advanced by Kaplow and Shavell (2002), Part II

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\* Walter J. Blum Professor, The University of Chicago Law School. I thank Louis Kaplow for extensive comments on an earlier draft.

shows that with flexible design, uncertainty does not affect the choice of instruments.

Part III discusses seven additional potential differences between taxes and permits. It considers, for example, whether the two instruments have different distributional or revenue consequences, whether tipping points and environmental certainty should alter the choice, whether permit price volatility is a problem, and whether framing effects matter in this context. It concludes that these and other claimed differences are most often a result of unjustified assumptions about design. With the flexibility, both systems will be substantially the same along these dimensions.

Part IV considers the implementation of carbon taxes or cap and trade systems internationally. Some of the design flexibility in the domestic context is lost once coordination across nations and hold-out problems are considered. In particular, in the international context, it might be hard to adjust the tax rate or the quantity of permits in response to new information, and taxes perform better in the absence of such adjustments. Moreover, the effects of cheating are different for taxes and permits and in general are worse for permits. Therefore, there should be a modest preference for taxes in the international context.

## **I. Basic Definitions and Terminology**

When individuals or firms emit carbon dioxide or other greenhouse gases, they impose harm on others.<sup>1</sup> Because the individuals or firms (together, polluters) do not have to consider these harms, they emit too much.

Harm from climate change is a result of the total stock of greenhouse gases in the atmosphere, not the flow. Emissions in a particular year do not matter except to the extent they add to the stock. Carbon dioxide also mixes in the atmosphere globally; it does not matter where emissions originate, the harm is the same. Pre-industrial concentrations of carbon dioxide were about 280 parts per million (ppm). Current concentrations are 380 ppm, increasing by around 2 ppm per year. Doubling pre-industrial concentrations would likely result in global average temperature increases of around 3.5°C, although the estimate has highly

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<sup>1</sup> There are a large number of gases which contribute to the greenhouse effect including carbon dioxide, methane, and nitrous oxide. Carbon dioxide is the most important. I will refer here to all greenhouse cases as carbon dioxide.

uncertain. Most analysts agree that high concentrations, such as 700 or higher, would result in severe harm, and typical targets for climate change proposals are between 400 to 500 ppm.

Control of environmental externalities was traditionally done through command and control regulations, under which the government specified particular technologies or firm-by-firm emissions limitations. Market-based instruments, however, are thought to be able to control externalities far more cheaply because the government does not have the ability to determine which particular technologies are best or which firms should use which technology. Market-based instruments utilize private information about firms' abatement costs to minimize total costs. The two chief market-based instruments are taxes and quantity restrictions.

A tax on greenhouse gases would simply be a charge on emissions. A polluter, considering whether to emit one more unit of pollution should face a cost equal to the harm imposed on others from that additional unit. Polluters, faced with a charge equal to the additional harm imposed on others from another unit of emissions would adjust their behavior appropriately.

If marginal harm is not flat – a fixed \$x per unit of pollution – the tax should vary with marginal harm. For example, if marginal harm increases as pollution increases, so should the optimal tax. Similarly, if the government learns that the marginal harm is different than it first believed, the tax should be changed to reflect the new information.

Metcalf and Weisbach (2009) consider the design of a carbon tax. They show that a carbon tax in the United States could cover 80% of total emissions by taxing less than 2,500 entities. The reason is that emissions from fossil fuels make up about 80% of U.S. emissions, and these can be taxed upstream on extraction or refining without a loss of accuracy. Globally, fossil fuel emissions are around 67% percent of total emissions, and a global carbon tax could similarly tax these emissions upstream.

Another 14% of global emissions are from agriculture. These emissions would be much more difficult to include in a tax system because they come from a wide variety of disparate sources, many of which are hard to observe. Taxes on inputs, such as nitrogen fertilizer or head of cattle might be the only way to

include these emissions in the tax base. Deforestation is the third largest source of emissions, making up about 12% of global emissions. A tax on deforestation would be complex because it would have to be based on deforestation relative to a baseline and because the effects of deforestation depend on many factors including location, use of the timber, and what replaces the forest. A decision to tax agricultural and forestry emissions will depend on the marginal abatement costs in these industries and whether there is a reasonably accurate and administrable method of including them in the base.

Design considerations can significantly affect the costs and benefits of a tax system. For example, rather than imposing the tax upstream on a small number of firms producing or distributing fossil fuels, the government could impose the tax downstream on emitters. There are almost 250 million automobiles in the United States and no easy way to measure emissions from each vehicle. There are also a large number of homes using natural gas for heating. Attempts to impose a tax downstream would significantly increase administrative costs, reduce the tax base, or both.

Quantity restrictions, also called permits or cap and trade systems (I will use these terms interchangeably here) limit the total quantity of emissions. The government issues permits (either by auctioning them or otherwise allocating them) equal to the total amount of emissions it decides is appropriate, usually over a given period. Polluters would be required to have a permit in order to pollute. Holders of the permits would be allowed to sell them, creating a market in permits. Anyone who could reduce emissions for less than the market permit price would do so and everyone else would buy a permit, thereby equalizing the marginal cost of abatement across all users. If the government issues a quantity of permits so that the permit trading price is equal to the marginal harm from emissions, polluters would, like in a tax, face a price equal to marginal harm and adjust behavior appropriately.

The number of permits does not have to remain fixed in a cap and trade system. The government can change the number of permits over time so that their price reflects marginal harm, for example, by buying permits to increase their price or selling additional permits to lower their price. Part II will discuss the reasons and mechanisms for doing this.

Stavins (2008) considers the design of a cap and trade system. Implementing a cap and trade system raises similar issues to a tax. Issues such as determining what emissions to cover and at what level to impose the permit requirement (e.g., upstream on fossil fuel production or downstream on emitters) are the same for permits as they are for taxes. Quantity restrictions also require a trading market and a method of making the initial allocation of permits.

Taxes and permit systems are equivalent if the government sets the tax rate or the number of permits correctly so that in either case the price faced by polluters is the marginal harm from emissions. They are, in a sense, duals. In a tax, the government sets the price and firms determine quantity subject to that price. In a permit system, the government sets the quantity and firms determine the price given that quantity. So long as the government has sufficient information, it can choose to regulate along either margin, and for every tax, there is an equivalent set of permits and vice versa. Moreover, the core implementation issues – what emissions to cover and at what level to regulate (e.g., upstream or downstream) are the same. For example, a decision to regulate upstream can be equivalently made for taxes and permits. The question in the next two sections is what happens when the assumption that the government correctly picks the price no longer holds or when we consider more subtle implementation issues.

## **II. Equivalence of Taxes and Permits with Uncertainty about Marginal Abatement Costs**

Weitzman (1974) argued that the equivalence between tax and quantity restrictions no longer holds when there is uncertainty about the marginal cost of abatement because the error costs will be different for taxes and quantity limitations.<sup>2</sup> Depending on the relative slopes of the marginal abatement cost curve and the marginal harm curve, either taxes or permits might be preferred. Virtually every analysis of instrument choice begins with this argument.

This section argues that Weitzman's arguments rely on assumptions about the design of the systems that are unlikely to hold in the climate change context. In particular, Weitzman assumes that taxes are flat, per-unit taxes and that quantity limits are fixed caps. In addition, Weitzman assumes that neither the tax

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<sup>2</sup> Similar arguments made contemporaneously by Adar and Griffin (1976), Rose-Ackerman (1973), and Fishelson (1976).

rate nor the quantity limit is adjusted in response to information showing that they were set in error. Weitzman is explicit about these assumptions and makes arguments that they are appropriate in the single-polluter context he was considering. Nevertheless, these assumptions are rarely mentioned in the literature on climate change that builds on Weitzman's arguments, and as far as I have been able to tell, never been defended in the climate context. I will argue that neither of these assumptions is appropriate in the climate context, and without both, taxes and quantity limits are equivalent.

The arguments here build on and extend to the climate change context arguments made in Kaplow and Shavell (2002). They directly address Weitzman's assumptions that taxes are flat, per-unit taxes, indefinitely fixed, and argue (1) that taxes can be and regularly are nonlinear,<sup>3</sup> and (2) that nonlinear taxes are second-best optimal; errors in estimating marginal abatement costs do not affect the efficiency of well-designed nonlinear taxes. As a result, they argue that nonlinear taxes dominate simple permit systems, such as non-traded permits or traded permits with hard caps. They also address flexible permit designs, focusing on flexibility designs such as those introduced by Roberts and Spence (1976). With sufficient design flexibility, the equivalence between taxes and permits is restored.

Section A briefly reviews Weitzman's argument, which is likely familiar to readers. Section B discusses the assumption of no updating in response to new information, arguing that sufficiently rapid updating would not be difficult in the climate change context. Section C discusses the assumption of flat-rate taxes and fixed quantity limits, arguing that more accurate schedules would not be difficult to implement. Section D considers the possibility of combining complex schedules and adjustments in response to new information.

#### A. Weitzman's argument

Recall that the optimal charge on emissions would be the marginal harm; if marginal harm is nonlinear, so is the optimal tax, and if marginal harm changes so does the tax. Weitzman makes two assumptions about the government's regulatory options that prevent the government from imposing the optimal charge.

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<sup>3</sup> Ireland (1976) makes a similar argument that contingent tax systems are possible and presents an example.

He assumes first that the government must impose either a fixed, per-unit tax or a fixed quantity limitation. The tax, for example, must be fixed at a given amount per unit of pollution. The quantity limit must specify the total emissions over time or in a given period.<sup>4</sup> Second, Weitzman assumes that the tax rate or quantity remains fixed; even if the government gains new information about the optimal tax or quantity, the original guess is not changed, at least for some unspecified time period.

Sections B and C below will discuss whether these assumptions are reasonable for climate change. To demonstrate Weitzman's argument, I will assume in this section that they are; the government must pick either a fixed, per unit tax or a fixed quantity of emissions.

If using a fixed-rate tax, the government should set the tax rate where it estimates the marginal cost of abatement equals the expected marginal harm from another unit of pollution. Firms, knowing their own marginal costs of abatement and faced with this tax will emit up to the point where the marginal costs of abatement equal the tax rate. If the government estimates marginal harm and marginal costs correctly, firms will emit the optimal amount. If using permits, the government should set the number of permits the same way it sets a tax: where it estimates the marginal cost of abatement equals the expected marginal harm from another unit of pollution. As discussed above, if set this way, permits they will trade at the same price as the tax and the result will be the same.

If the government incorrectly calculates the marginal abatement cost, taxes and permits will have different effects. When the government imposes a tax, the firm will set emissions so that the marginal cost of reductions equals the tax rate. The quantity of emissions will adjust. When the government fixes the quantity,

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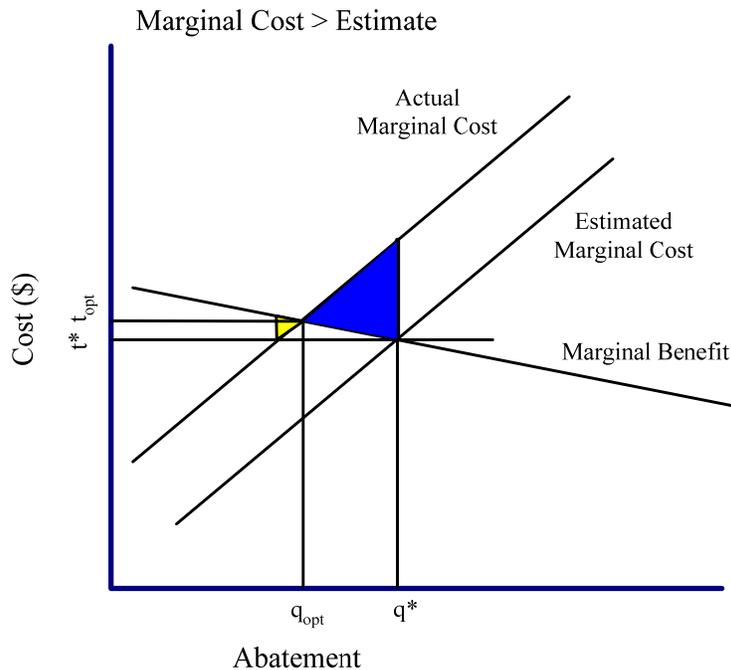
<sup>4</sup> Weitzman was considering a pollutant that cause harm in the period emitted – a flow pollutant. Carbon dioxide emitted in one period contributes to the stock of carbon dioxide in the atmosphere and it is stock concentrations that cause harm. Hoel and Karp (2002), Newell and Pizer (2003), and Karp and Zhang (2005) discuss how to translate Weitzman's arguments from flow to stock pollutants. These considerations do not change the arguments in the text.

Weitzman was also considering something closer to a command and control regulation than a modern, cap and trade system. It appears that the system he was considering involved the government imposing quantity restrictions on individual firms. His arguments, however, are now commonly applied to cap and trade systems and I will continue this tradition.

polluters will emit that amount and the price will adjust. The deadweight loss from the error will be different because of the different ways the error plays out.

To determine which instrument is preferred, we must compare quantity flexibility to price flexibility. If the marginal harm is relatively flat relative to the marginal cost of abatement, the costs of getting quantities wrong is low, making taxes preferable. Alternatively, if the marginal harm from changing quantities is steep relative to the marginal cost, the cost of getting the quantity wrong is very high. If an additional unit of pollution causes terrible harm, we may want to simply ban the emission of the additional unit rather than impose a tax on it. Quantity restrictions would be preferable. Weitzman demonstrates using a second-order approximation of the marginal cost and marginal harm curves, and develops a simple formula for instrument choice that relies on the relative slopes of these curves.

To remind readers of the analysis, I reproduce below the standard diagrams used to illustrate the issue. The x-axis represents abatement, the reduction in emissions; as we move to the right, emissions go down. The y-axis is dollars. The downward sloping curve is the marginal benefit from abatement (the inverse of marginal harm) and the upward sloping curve is the marginal cost of abatement. The (universal) assumption is that the marginal benefit of abatement goes down as we increase abatement; going from very high carbon dioxide concentrations to modest concentrations may yield huge benefits but going from low to very low concentrations may have small benefits. Similarly, marginal costs increase.



Given the government's best guess of the marginal abatement costs and marginal benefits of abatement, the optimal tax is equal to  $t^*$ , and the optimal quantity limit is  $q^*$ . If set correctly, a tax of  $t^*$  would result in a quantity  $q^*$  of emissions, and permits traded with quantity limit of  $q^*$  would sell for  $t^*$ . The two systems would be equivalent.

Suppose, however, that the actual marginal cost turns out to be higher than anticipated. If we use a tax, it will have been set too low. The optimal tax is where the actual marginal cost intersects the marginal benefit curve,  $t_{opt}$ . As can be seen, this is higher than  $t^*$ . Polluters will emit carbon up to the point where  $t^*$  intersects their actual marginal cost. At this level of emissions, the marginal benefit of additional abatement exceeds the marginal cost, creating a loss because of too little abatement. This is represented by the small, lightly-shaded triangle. If we use permits, polluters will emit up to the allowed amount,  $q^*$ . At this amount, the marginal cost of abating exceeds the marginal benefit and abatement should be reduced. The losses are represented by the large, dark triangle. The instrument that performs better is the one with the smaller loss triangle, in this diagram, the tax.

The relative size of the triangles depends only on the slopes of the marginal cost curve and the marginal benefit curve. If the slope of the marginal benefit curve is shallower than the slope of the marginal cost curve, taxes dominate. Permits dominate if the relative slopes are reversed. The intuition behind this result is that taxes allow quantities to vary while holding price constant while permits allow prices to vary while holding quantity constant. The question is where is it better to be wrong: the price or the quantity? A shallow marginal benefit curve indicates that getting the quantity wrong does not matter very much while a steep marginal cost curve indicates that getting the price wrong does matter. Similar, if the slopes of the curves were reversed.

Uncertainty over marginal harm (as opposed to the marginal costs of abatement) does not affect instrument choice. While estimates of marginal harm affect the level of taxes or quantities imposed, once they are chosen by the government, firms will optimize without regard to marginal harm; firms will make decisions based on their costs and the costs imposed by the regulatory regime. Therefore, uncertainty over marginal harm does not affect the choice of instruments. Kaplow and Shavell (2002) show that when there is uncertainty over marginal harm, the optimal schedule equals the expected marginal harm.

The centrality of these arguments can hardly be over-emphasized. They form the core of almost every analysis of instrument choice. Influential reports, such as the Stern Review adopt the Weitzman analysis wholesale. Stern (2007). Almost all of the scholarly literature on instrument choice elaborates on Weitzman's analysis; a Web of Knowledge Citation count lists around 400 citations to Weitzman's article, and this is likely substantially incomplete because it does not include many books and edited volumes. It is reproduced without criticism in graduate economics textbooks. Mas-Colell, Whinston et al. (1995). It is described in numerous Handbook chapters on instrument choice. Kolstad and Toman (2005), Bovenberg and Goulder (2002), Helfand, Berck et al. (2003). The Congressional Budget Office uses it to analyze Congressional proposals and to provide information to members considering legislation. Congressional Budget (2008). Research reports by think tanks and environmental non-governmental organizations, reports that are designed to inform and influence policy makers,

almost always start with this analysis.<sup>5</sup> It is the central analysis of instrument choice.

## B. Responding to new information, asymmetry in information

### 1. Weitzman's Assumption

Weitzman's argument is that firms will respond differently to government error when faced with taxes or permits. For this to be true, it has to be the case that firms have different estimates of marginal abatement costs than the government does. Even if wildly erroneous, if firms' estimates and the government's estimates are the same, the effects of taxes and permits will be the same.

Weitzman makes his assumption of different estimates of the marginal abatement costs by firms' and the government by assuming that the government initially makes an informed guess in the face of uncertainty but does not adjust as new information is revealed. He imagines a regulator engaging in the process of *tátonnement*, groping toward the optimal tax rate or quantity limit but eventually stopping the process and fixing a rate or quantity, at least for some period of time. He notes that:

[i]n an infinitely flexible control environment where the planners can continually adjust instruments to reflect current understanding of a fluid situation and producers instantaneously respond, the above considerations are irrelevant and the choice of control mode should be made to depend on other factors. p. 482

He argues, however, that at some point, the regulator has to stop gathering information and actually implement a plan based on current information. Therefore, he concludes, the right way to model the issue is as if the regulator has set a fixed tax or quantity limit. Laffont (1977) characterizes Weitzman this way: "suppose an iterative scheme is used but is stopped after a few iterations when a decision has to be taken." (p. 177)

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<sup>5</sup> For example, Aldy, Krupnick et al. (2009)

A more general version of the assumption is that there is asymmetric information about abatement costs. If the regulator does not have the same information about abatement costs as the firm, the regulator will set the tax or quantity limit in error and the firm, knowing its actual abatement costs, will respond differently to this error depending on whether the regulator uses taxes or quantity limits.

Weitzman's arguments can rely on either assumption: either there is asymmetric information about abatement costs or the regulator has good information but fails to update. In either case, the price or quantity limit will be set in error, and firms will respond differently to the different forms of regulation.

The assumptions of no updating and asymmetric information are rarely defended or even mentioned. Weitzman himself is careful to note that the regulator might subsequently adjust taxes or quantities and that his model only applies during the interim period. Newell and Pizer (2003) defend the assumption briefly, arguing that, "[a]lthough state-contingent policies could, in principle, be designed to maintain this proposition even under conditions of uncertainty, such policies would be of little if any practical use." p. 418. Sandmo (2000) argues that "in most cases of interest, a tax or quota has to be fixed *ex ante*, with uncertainty about the exact nature of costs and benefits." p. 53. Most often, the assumption is not mentioned. For example, there are at least recent three chapters in the Handbooks of Economics that discuss the Weitzman argument in some detail; none mention this restriction.<sup>6</sup> The relevant chapter in Mas-Colell, Whinston et al. (1995), a standard graduate text in microeconomics, does not mention these assumptions.

The question, then, is how rapidly and how well each system can adjust to new information about the marginal cost of abatement. If the adjustment is sufficiently rapid and accurate, the Weitzman-type differences between the systems will be small. If the systems are necessarily rigid, the analysis might have force (although it might not, as discussed in section C below). This is a question of design: how can each instrument be designed to respond to new information, and are there differences in their rates of adjustment.

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<sup>6</sup> Kolstad and Toman (2005), Bovenberg and Goulder (2002), Helfand, Berck et al. (2003). Karp and Zhang (2006) is the only paper I have found on learning and instrument choice. [discuss]

## 2. The extent of asymmetric information in the climate change context generally

Before examining how well taxes and quantities could be adjusted, we should first ask what would be needed in the climate context. Weitzman's model was of a single polluter. If the pollutant is from an individual firm or a modest number of firms, the assumption that the firm or firms have better information about their marginal cost of abatement than the regulator or that the marginal cost of abatement might change quickly may be justified. A single, closely-held invention by a firm might cause the regulator's estimate to have a large error.

Pizer (2002) provides an illustrative example of how the climate change literature incorporates assumptions about information. He calculates that taxes produce benefits that are five times larger than permits. The calculation is based on an assumption that the relevant policy (say, the choice to use a tax and the rate is it set at) remains fixed for 250 years (longer than the existence of the United States and longer than the entire industrial revolution). In an illustrative calculation for 2010, he assumes that the annual standard deviation in marginal abatement costs is 16.43 \$/ton C.<sup>7</sup> To get a sense of the magnitude of this assumption, he estimates that the marginal abatement costs at the optimum is \$7.50 per ton of carbon. In effect, he assumes that the government's best guess (\$7.50) is wildly off from the private sector's information, and notwithstanding that, the government's estimate remains fixed basically forever. Pizer's estimates have been repeated in information papers for Congress. See Congressional Budget (2008).

Assumptions of this sort are not appropriate for climate change. Climate change is a global problem, involving thousands (or perhaps millions) of firms and billions of individual polluters. Abatement will require massive changes to the economy. Because of the massive, public scale of the problem, firms are not likely to have a significant information advantage over governments, nor will the information about abatement costs change rapidly.

As noted, global carbon emissions come from three basic sources: about 67% are from burning fossil fuels, 14% are from agriculture, and 12% are from

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<sup>7</sup> Pizer is using carbon rather than carbon dioxide as his units. Carbon dioxide weights 44/12 of carbon, so the equivalent tax on carbon dioxide can be calculated using this ratio.

deforestation.<sup>8</sup> Estimating the marginal cost of reductions involves estimating the marginal cost of changing these systems. It will involve estimates of abatement technologies that spread across the entire economy, such as the installation economy-wide, new energy systems or the widespread use of new agricultural methods. Almost all of these abatement methods will be public; the technologies will be readily observable. To the extent there are some private technologies – say a proprietary, low emissions method of production – no single or even modest set of private technologies will change overall estimates of abatement costs very much. Firms are unlikely to have an information advantage over regulators in estimating overall marginal abatement costs.<sup>9</sup>

Moreover, estimates of the marginal abatement cost are unlikely to change very rapidly. The energy, forestry, and agriculture sectors are massive, global systems that will be difficult to change. Absent an invention like table-top cold fusion, changes to these systems are incremental. Even important inventions are likely to have only a modest effect on the marginal cost of abatement. For example, a new method of producing solar or wind power, or a new method of raising livestock to reduce methane emissions, will have only a modest effect on overall marginal cost. Moreover, current estimates of the marginal cost of abatement can include expected technological developments. Only surprises matter. It would likely take significant time before current estimates are far off previous estimates.

### 3. Taxes

The question is how likely is it that taxes would be set based on estimates of the marginal cost of abatement that are systematically different from firms' estimates because of information problems.<sup>10</sup> As noted, the government is unlikely in general to have an information disadvantage in estimating marginal abatement costs in the climate change context. The question is what type of information would taxes generate to improve the estimates and how often could taxes be adjusted to respond to new information. I address each in turn.

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<sup>8</sup> Herzog (2009)

<sup>9</sup> The government will not know any particular firm's abatement costs or the best technology to use, which is why market-based instruments should be preferred.

<sup>10</sup> The political system may, of course, produce suboptimal regulation, but claims about differential political outcomes for taxes and permits are separate from Weitzman-type claims.

Tax collections provide the government with information about private estimates of marginal abatement costs. In a tax system, the regulator would know the tax rate and quantity information. From this information, it can infer polluters' current estimate of marginal abatement costs. For example, suppose that the government set the tax rate at \$50 per unit of carbon dioxide and estimated that at this rate, 100 units should be emitted. If it observes 101 or 99, it can infer that it misestimated the marginal cost curve and adjust. If emissions are 101, marginal cost is higher than it expected and the tax rate should be adjusted downward, and vice versa for emissions of 99. That is, the quantity of emissions at a given tax rate reveals private information about marginal abatement costs and the government can use that information to adjust the rate.

Tax returns will necessarily provide this information because quantities are necessary for computing taxes; taxpaying entities would have to report quantity and multiply this by the tax rate to compute their tax. Tax returns could be required at relatively short intervals, at least for fossil fuel emissions because these taxes can be collected upstream on a small number of, large entities. Moreover, the regulator can also observe imports, exports, production, and storage of fossil fuels from data already being collected, and infer emissions. The U.S. Energy Information Agency, for example, collects this information on a weekly basis.<sup>11</sup> Similarly, satellites are being developed that can closely monitor forestry changes on short time scales.

It is apparent that by both observing technological and cost changes to the energy, agriculture, and forestry industries directly and by collecting emissions information through the tax or other information reporting systems, there would be little difference in the government's and polluters' information about marginal abatement costs.

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<sup>11</sup> The EIA publishes a weekly petroleum report, which has information on supply, imports, exports, total stocks of crude oil and petroleum products. Similarly, there is a [Weekly Natural Gas Storage Report](#) breaking down storage and production of national gas into the east and west regions of the lower 48 states. A separate report ([Natural Gas Monthly](#)), gives month-to-month import and export data for the entire country. As for coal, there is a [Weekly Coal Production Report](#) which provides estimates for U.S. coal production by state, weekly and cumulatively for the year. Additionally, EIA publishes the Monthly Energy Review, of which [Coal](#) has its own section, which reports monthly production, consumption and stocks by sector and imports, exports cumulatively for the U.S.

Given this information, the question is how often could the government adjust tax rates? It is possible to have very rapid adjustments simply through delegation to an expert agency with the authority to make these adjustments. Models in include U.S. system is the Federal Reserve, the EU Central Bank, or the Bank of England, in which the legislature delegated monetary policy decisions to an expert agency largely insulated from political interference. These agencies collect detailed information and are able to respond rapidly when new information dictates. When adjusting interest rates, they are not subject to the normal rule-making constraints, such as notice and comment, which slow down regulation. When new information indicates that there is a dramatic change in circumstances, there is essentially no delay in action. There is no *a priori* reason a carbon tax rate could not similarly be delegated.

This may be unrealistic – legislatures may be unwilling to delegate tax rates in this manner. But given that rate adjustments would not be needed very frequently, lesser delegations or other methods of adjusting rates, would suffice. Moreover, delegation and other methods of causing rates to adjust are design considerations, not “system-free” differences between taxes and quantity restrictions of the sort that are typically modeled. If there is a design limitation that would cause taxes to adjust to available information more slowly than is desirable, these need to be modeled and examined.

#### 4. Quantities

The analysis is similar for quantity restrictions. The government would still observe overall changes to the energy, agriculture, and forestry markets, and would likely have as good information as polluters about the overall marginal costs of abatement. Moreover, the permit system itself would generate information because permits are traded. The government, knowing the total quantity limitation, would only have to observe price, and it would know this by the second simply by observing the market.

It could also use this information to update the quantity limit. Like with taxes, we can imagine delegation to an expert agency like the Federal Reserve which could act rapidly to changes in information. Given the relatively slow pace of changes in the marginal cost of abatement, lesser delegations and slower changes in quantity limits would also suffice.

## 5. Conclusion

Weitzman's argument relies on an assumption of asymmetric information, either because the government does not have as good information as polluters about marginal abatement costs or because it has the information but fails to update the regulatory system because of some bureaucratic flaw. This assumption is untenable in the climate context. If the government has good information about the marginal cost of abatement and can update whenever that information is significantly out of date, there are no differences between taxes and permits.<sup>12</sup>

### C. Complex schedules

#### 1. Assumption of simple schedules

The second necessary assumption in Weitzman's argument is that the tax is a flat rate tax – \$x per unit of pollution – and that the quantity restriction is a simple, fixed quantity. As noted, the optimal system would impose a charge equal to the marginal harm from emissions, which is not likely to match either of these schedules. Weitzman defends this assumption by arguing that it should be “apparent that it is infeasible” to use more complex schedules and that analyzing these systems “is the best way to focus sharply and directly on the essential differences between prices and quantities as planning instruments.” p. 481. As noted above, Newell and Pizer (2003) argue that state-contingent schedules are infeasible.<sup>13</sup>

If the government imposes a charge equal to the marginal harm from emissions, it would not have to know marginal abatement costs. Whatever the private estimates of marginal abatement costs, the charge would be correct. Therefore, there would be no Weitzman-type differential error costs from taxes and permits. To illustrate, imagine that the government was unsure whether marginal abatement costs was either high or low. If it imposes a schedule equal to

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<sup>12</sup> [Comment about size of adjustments/learning assumed in Karp and Zhang (2006)]

<sup>13</sup> This could refer either to complex schedules or to simple schedules that are adjusted to new information. Pizer (2002) recommends a system with a complex schedule but assumes that policies stay in place for 250 years without adjusting to new information, implying that the quote refers to adjusting to new information.

estimated marginal harm, firms will face the correct charge regardless.<sup>14</sup> Asymmetric information about the marginal abatement cost or failure to update would, as a result, be irrelevant, and Weitzman's argument would not hold.

## 2. How complicated would the schedule have to be?

An initial question in determining whether the government could impose a charge equal to the marginal harm from emission is how complex would such a schedule be? It is likely extremely simple and relatively flat; the marginal harm of climate change is thought to change slowly with emissions

Marginal harm will increase over a broad range of concentrations – the harm from an increment of emissions will likely be higher at 750 parts per million than at 400. But these are changes in marginal harm over an enormous difference in concentrations. Even at current emissions rates, changes of this magnitude would take more than a century. Within any region, the changes are likely minimal. The difference in harm from an increment of emissions at 350, 450, and 550 is likely small enough to be difficult to measure. If the government merely estimated marginal harm over this range of concentrations, sufficient to cover decades of emissions, the marginal harm curve would likely be relatively simple (not simple to estimate, but simple in its shape).

To illustrate, right now, carbon dioxide is increasing at about two parts per million per year. A schedule that used a different marginal harm estimate for each one part per million change in concentrations would only mean a tax rate or quantity limitation that changes every six months. It is doubtful that there are measurable differences in marginal harm at this level of detail. If we could only measure changes in marginal harm for differences of, say, around 10 parts per million, a new tax rate or quantity would only have to apply once every five years. Tax rate schedules or quantity restrictions that mimic the marginal harm curve could be extremely simple.

One question is whether the possibility of a tipping point changes this conclusion. Environmental outcomes might be non-linear, so that we see very little change until carbon concentrations hit some level, at which point we see dramatic and fast changes. For example, as sea-ice melts, it exposes a darker

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<sup>14</sup> Figure 1 in Kaplow and Shavell (2002) illustrates.

ocean surface which absorbs more heat, amplifying the warming. If this effect is strong enough, sea-ice melting might be self-sustaining once it gets past a given point. Scientists looking at climate history going back millions of years see evidence for very fast changes, creating real concern about the possibility of a tipping point. Lenton (2008). If there is a tipping point, it would be very important to keep concentrations below that level.

The possibility of a tipping point does not change the conclusion that the expected marginal harm curve would likely look relatively smooth.<sup>15</sup> The optimal charge is equal to the expected marginal harm. We have little information about where such a tipping point might be or how steeply damages would increase at a tipping point. When we average over uncertain schedules, even if some of them have sharp kinks, the expected schedule will still be smooth.

To illustrate, suppose that the likelihood of a kink in the marginal harm curve at 550 ppm, 600 ppm, 650 ppm, and so forth, was some estimated percent, say 1% or 2%, (which if one thinks about the damages from surpassing a tipping point, is a large number). To determine expected marginal harm, we take the probability-weighted average over all possible marginal harm curves. At each level of concentration, there is only a small chance of a kink, and the expectation will be relatively flat. The overall expectation will be higher because of the possibility of tipping point, (because marginal harm is higher if there are tipping points), but the expectation will still rise smoothly. The possibility of tipping points would not make the schedule substantially more complex.

### 3. Taxes

It is clear that a tax schedule could be sufficiently complex to mimic the marginal harm curve. The schedule would only need to list a set of concentrations (or possibly flows of emissions) and the corresponding tax rate. Data on flows and concentrations are computed at least annually under the United Nations Framework Convention on Climate Change. Polluters could simply look up the tax rate applicable to the current concentration or flow of carbon dioxide and apply it. If rates change over time – for example, in some proposals they go up with the interest rate even absent changes in concentrations – taxpayers would also have to know the date.

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<sup>15</sup> Louis Kaplow pointed out this argument to me.

This is vastly simpler than type of schedule currently in use for income taxes around the world. Section 1 of the U.S Internal Revenue Code includes multiple nonlinear rate schedules. There are phase-outs, limitations and different rates that apply to specific items. There are uncertainties and judgment calls on how to report many items. Tax rates also change over time; as was done in the recent Bush tax cuts, Congress may apply one set of rates to one year and other to another year and do so differently for different items of income and different types of deductions. Other countries have similarly complex schedules.

In addition, income tax schedules apply to individuals. A carbon tax could be imposed at the firm level.<sup>16</sup> Firms would have a much easier time dealing with complex schedules than individuals. It is hard to think of a defense of the argument that carbon tax rates could not be sufficiently complex to mimic expected marginal harm.

#### 4. Quantities

It might be slightly more difficult for a quantity schedule to mimic the marginal harm curve because a simple, fixed quantity limit would not be as close to marginal harm as would simple, fixed-rate taxes; because the marginal harm from emissions is relatively flat, even the simplest tax schedule would be close to marginal harm. Nevertheless, it is apparent that it is feasible.

One widely discussed possibility is a set of price ceilings and floors: if the traded permit price in a quantity regime exceeds a limit, new permits could be issued automatically, creating a price ceiling. Similarly, if permit prices drop below a floor, the government could repurchase permits.<sup>17</sup>

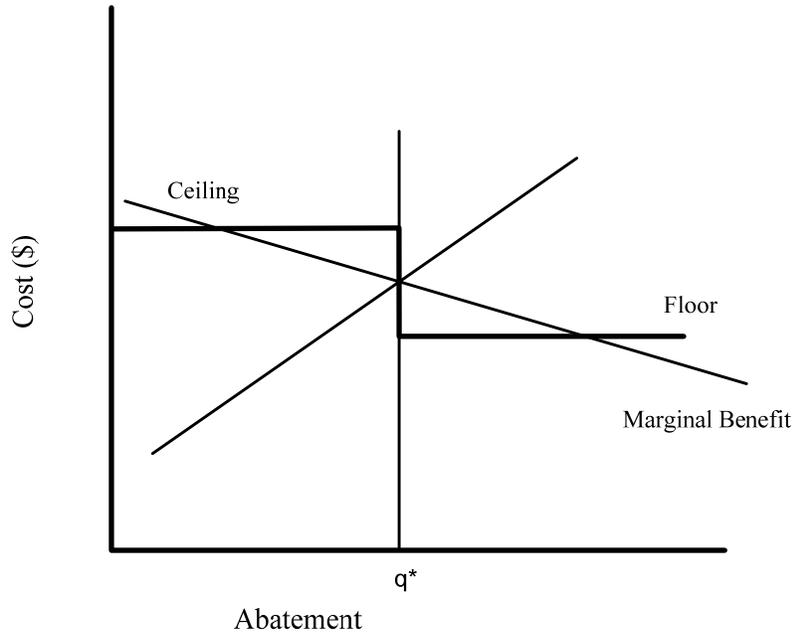
To illustrate, consider Figure x. In Figure x, the government imposes a quantity restriction where the estimated marginal harm from emission equals the estimated marginal cost – the vertical line at  $q^*$ . The government, however, also includes a price ceiling and floor. If the price goes above a set amount, the government will issue new permits at that price, effectively converting the system into a tax at the ceiling price. Similarly, if the price goes down below a set amount, the government will repurchase permits, ensuring that they do not go

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<sup>16</sup> Metcalf and Weisbach (2009).

<sup>17</sup> For a discussion of this system, see Jacoby and Ellerman (2004).

below that price. The heavy black line illustrates the net effect. As can be seen, the heavy black line closely matches the marginal benefit curve.



A related alternative, proposed by Roberts and Spence (1976) is having the regulator issuing permits with different exercise prices; permits at a given exercise price would allow holders to pay the exercise price for the right to emit a set amount. Once all of the permits at a given exercise price are used up, holders would have to use permits with higher exercise prices, and so forth, thereby creating a price schedule that mimics (as closely as desired), the marginal harm schedule. The system could have as many steps as is desirable.

Newell, Pizer et al. (2005) consider the possibility of a banking system where the number of permits issued in each period varies based on information learned in the prior period. They show that this system has the same cost flexibility as a price-based system. Depending on the degree of flexibility desired, various limits could be placed on the regulator, such as a limit on the number of permits it could sell. Pizer (2002), Murray, Newell et al. (2009) consider yet additional mechanisms.

## 5. Conclusion

It is clear that both taxes and permits can be structured to mimic the marginal harm curve. For taxes, we need merely to publish a schedule of rates. For permits, we need a slightly more elaborate mechanism in which additional permits are bought or sold over time. If the regulatory regime mimics the marginal harm curve, Weitzman's argument about asymmetric information in the marginal cost curve does not apply.

## 6. Combining complex schedules and adjustments

The two sections above argued that either (i) rate or quantity adjustments while maintaining Weitzman's assumption of flat rate taxes and simple quantity limits or (ii) more complex (yet still relatively simple) schedules would alone be sufficient to make Weitzman's arguments irrelevant in the climate context. The argument, however, is even stronger because complex schedules and adjustments to new information can be combined.

All that matters is that the price faced by polluters equals the best estimate of marginal harm. We can achieve this by dialing in how complex a schedule we want and how often we want to adjust the schedule in response to new information about the marginal abatement cost curve. A schedule that perfectly mimics marginal harm would eliminate the differences between taxes and permits.<sup>18</sup> A schedule that was adjusted to include all new information about the marginal abatement cost curve would also eliminate the differences. If there are concerns about schedule complexity or frequency of adjustments, systems could combine the two. A schedule of intermediate complexity would need less frequent adjustments than a simple schedule because it would already be closer to marginal harm; when marginal costs of abatement change, the intermediately complex schedule would have some built-in adjustments. Only when these built-in adjustments are not sufficient would the entire schedule have to be changed.

In the climate change context, it is likely that optimal schedules would be relatively simple and would need to be adjusted relatively infrequently. Nevertheless, we could have schedules that are as complex as need be and that

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<sup>18</sup> It would, of course, have to be adjusted as we learn new information about marginal harm, but these adjustments do not affect instrument choice.

adjust as frequently as need be. As noted, if a different tax or quantity limit were imposed for every single additional part per million of carbon dioxide concentrations, we would only need a new tax rate or quantity limit twice per year. Adjustments to the schedule, if necessary, could happen instantaneously as new information is revealed or on a regular basis, such as once every year or every five years. It is hard to imagine that between nonlinear price schedules and adjustments to those schedules that we cannot impose a price that is close to expected marginal harm.

7. Summary: the artificial distinction between prices and quantities and modeling strategies

Weitzman's arguments rely on two assumptions that are untenable in the climate change context: flat rate tax rates or fixed quantity limitations and no adjustment as new information about the optimal schedule is revealed. In the climate change context, it would be any more difficult than fixed-rate taxes and they could be adjusted at relevant intervals. Variable quantity limits, adjust them over time, could also be used. Weitzman's analysis, therefore, has little or no relevance to the choice of instruments for climate change.

Once we consider complex schedules and rate adjustments in response to new information, the difference between taxes and permits begins to dissolve. The goal of market-based climate policy is to force polluters to consider the harm they impose on others. They need to face a set of charges equal to the marginal harm they cause. Flat rate taxes and fixed quantity limits are just two possible schedules of prices that a regulator can use, and neither is likely to be optimal unless marginal harm happens to take a particular shape. Complex schedules fall between these extremes. A better debate to have than which simple instrument is better is how to best construct a more accurate instrument.

Recent proposals implicitly make this point. Indeed, they almost seemed designed to make fun of the artificial distinction between taxes and permits. One example is the "managed price allowance" approach to permits. Under this approach, put forth most prominently by the Congressional Budget Office, polluters would be required to purchase a permit, just like in an ordinary quantity restriction regime.<sup>19</sup> But permits would be purchased directly from the

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<sup>19</sup>U.S. Congressional Budget Office (2009).

government at a preset price and without a restriction in the amount that can be sold. It is simply a tax disguised as a permit system. Under another proposal put forth by Gilbert Metcalf, the government would impose a tax in which the rate would automatically adjust to meet a quantity target.<sup>20</sup> If in a given period, emissions are too high, the rate would go up in the next period and stay there until emissions are back on the preplanned path. This is a quantity restriction disguised as a tax (and with some features that often go along with taxes, such as no strict per-period emissions limit and flexibility across periods). It is also exactly the sort of state-contingent system that Weitzman (1974) and Newell and Pizer (2003) rule out as infeasible. Once we consider proposals of this sort, it should be clear that the simple end-points are meaningless.

It is clear that these sorts of complex schedules are feasible. In the climate change context, cap and trade proposals with price caps and floors are regularly discussed. Price ceilings have been included in numerous bills. At a minimum, given recent proposals, it is no longer possible to argue that only simple systems are realistic; the Waxman Markey bill is 1,200 pages long and is unbelievably complex.

Sometimes it is useful to examine endpoints as it helps inform us about the middle; models with extreme assumptions are often useful to illustrate the underlying structure. In this case, however, it is not clear how much, if anything, we learn by examining flat rate taxes or fixed quantity permits that remain fixed for centuries when both are dominated by feasible intermediate regimes. Doing so frames the debate in a way that causes commentators to focus on the wrong issues, such as which of the extreme systems is preferable rather than how to design a system that best causes polluters to internalize marginal harm.

### **III. Seven potential differences:**

There are a large number of other potential differences between taxes and permits that have been mentioned in the literature. Below are brief discussions of seven such potential differences.

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<sup>20</sup> Metcalf (2009).

#### A. Revenue/distribution/transition

One claimed difference between taxes and permits is that they might raise different amounts of revenue and consequently have different distributive effects and secondary effects on the income tax system. The reason is permits tend to be given away which means that they would not raise any revenue, unlike a tax.

Taxes and permits are, however, the same in this regard. Auctioned permits would raise the same revenue as a tax imposed at the auction price. Similarly, a tax system with grandfathering for existing emissions or offering refundable tax credits to the same individuals or firms that would have received free permits would have the same revenue and distributional effects as freely allocated permits.<sup>21</sup>

The basis of the claim that they are different is that as an historical matter, permits, with minor exceptions, have always been given away while new taxes sometimes have grandfathering but often do not. The claim that permits have always been given away is based on a list of environmental cap and trade systems, such as the U.S. sulfur dioxide system and the EU carbon dioxide system. If we look at cases where the government has created new property rights more broadly, however, there are examples of auctioning. The most significant example is the auctioning of electromagnetic spectrum rights in both the U.S. and the EU, in each case raising tens of billions of dollars. There are numerous other examples of government allocation of new property rights, such as the allocation of public lands or mineral leases and the distribution of newly public firms in the transition away from communism. Often these property rights are given away but not always. It is not clear that we can draw general lessons that apply across nations, time periods, and programs.

Suppose it is irresistible for the government to give away permits; the opportunity to pay off favored industries is simply too great. If this is the case, however, taxes will also likely be given way through grandfathering and the like. That is, the basic problem of building a coalition to pass a carbon pricing regime does not change with the label. If an adversely affected industry can block a bill,

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<sup>21</sup> Tax credits or similar tax benefits might have to be transferrable or refundable to be equivalent to transferrable but freely allocated permits.

they will have to be paid off regardless of which system is enacted. Both taxes and permits offer equal opportunities for graft.

If, notwithstanding these considerations, the two systems are different – permits likely to be given away, taxes not – we have to ask which approach is better, requiring polluters to pay for the initial rights to pollute through a non-grandfathered tax or given them the right for free through a permit allocation. A complete discussion of this issue would take us afield, but most commentators argue that it is better to collect the revenue – impose a tax or auction permits. The reasons vary, but the most important is that grandfathering existing emissions creates bad incentive effects; the more you polluted in the past, the more valuable emissions permits you will receive. The argument is similar to the arguments made about legal transitions in other contexts.<sup>22</sup> The result is a preference for taxes.

At a minimum, commentators should be clear about their rankings. Rather than basing rankings on the assumption that permits will be given away and taxes will not be grandfathered – and relying on the reader to have these same assumptions – commentators should distinguish four (or more) systems: auctioned permits, taxes, freely allocated permits, and grandfathered taxes (plus combinations, such as 50% auctioned permits). The ranking of these four systems will look different than a ranking of just pure flat rate taxes and fixed quantity restrictions with an implicit assumption about grandfathering.

## B. Complexity

An argument against cap and trade systems is that they are more complex to administer than a tax. There are three possible reasons. The first is that a cap and trade system needs a market, and markets may be costly to operate. Even in deep and liquid markets, trading costs can add up. A tax system does not need such a market; the regulator simply collects the tax. Note that in both systems, the regulator needs to monitor the quantity of emissions, so monitoring and enforcement costs should be similar. The difference is the costs of creating and operating the market.<sup>23</sup>

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<sup>22</sup> Kaplow (1986), Graetz (1977), Shaviro (2000).

<sup>23</sup> [insert estimates of costs of operating permit markets and discuss conclusions]

A second difference is that cap and trade systems tend to have time-stamped permits. Time-stamped permits are permits that can be used only in a specified time period. Time-stamped permits are the default assumption when commentators discuss permits. This is likely because for pollutants where the flow matters, time-stamped permits are necessary; the regulatory system must control emissions in each period because it is emissions per period that cause harm. In the case of a stock pollutant like carbon dioxide, flows do not matter, and we, therefore, need additional reasons to use time-stamped permits

One possible reason for using time-stamped permits is that periodic allocations allow the regulator to better control the number of permits issued (and thereby respond to new information). If the regulator is uncertain about the optimal number of permits to issue, it might be best to issue only a limited number in each period so that adjustments can be made more easily. Another reason might be that the government might want to prevent firms from unduly accelerating permit use. The government, for example, might not be able to credibly commit not to issue new permits in the future.<sup>24</sup>

If permits are issued only for fixed periods, however, then the economy loses the flexibility to determine when to reduce emissions.<sup>25</sup> Cap and trade systems would potentially create inefficiencies in the allocation of abatement efforts across time. The problem then becomes one of minimizing this inefficiency while not subjecting the government to whatever problems caused it to issue limited-time permits in the first place.

Mechanisms that do this – so-called banking and borrowing provisions – add complexity. Banking systems allow firms to use permits issued for one period in future periods. These are relatively uncontroversial and not very complex to administer. Borrowing systems allow firms to borrow permits from the future to use today. This is more difficult to administer because it requires commitments to future actions by the firms, the government, or both. For example, if permits are

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<sup>24</sup> A third reason might be that periodic allocations provide more opportunities for rent extraction by legislators. With a single permanent allocation, however, the stakes are larger. It is not clear whether legislators would be better off with a single, massive allocation or periodic smaller allocations. If legislators have limited terms in office, they would likely prefer giving away all of the permits relatively quickly. See Fischel and Sykes (1999).

<sup>25</sup> Individual firms could still purchase permits to pollute today in exchange for permits in the future, but in the aggregate, emissions would be fixed in each period.

freely allocated and firms could borrow, they could simply borrow permits from the future and then hope the government reneges in the future and issues additional permits. If firms depleted future years' permit supplies, the government would face significant pressure to issue more permits to prevent severe dislocations. Mechanisms to control borrowing, therefore, tend to be complex and limited.

The third difference is that cap and trade systems may need a larger number of caps, floors, adjustments, and the like than a tax system would. A simple, flat rate tax might be closer to the marginal harm curve than a simple fixed quantity restriction, so it would need less jury-rigging to improve its accuracy. Caps, floors, and similar adjustment mechanisms add complexity and costs.

While these arguments demonstrate that a cap and trade system is likely to have some additional costs, it is not clear how much. The costs of operating markets, having price ceilings and floors, and having banking and borrowing provisions, may be high but we do not yet have sufficient evidence to know.

### C. Information generation

A possible advantage of a cap and trade system is that the market for permits generates information. In particular, the set of future prices for permits is information about market participants' views of abatement costs in the future. To consider an extreme example to illustrate the point, imagine that industry but not the government knows that, five years from now, we will have a low carbon technology that will make it free to eliminate emissions (that is, the price of carbon-free energy will be below the price of fossil fuels). In a cap and trade system, industry would borrow permits from the future to use now. The government, not knowing about the technology, would observe low permit prices and high permit usage now. It would also observe low futures prices. The government could draw inferences from this information and could use it to set policy; it would be able to infer that industry expects abatement to be cheap in the future.

With taxes, the government would have a harder time making similar observations. Industry would anticipate very low taxes in the future but the government would not get any signal indicating this expectation. It would likely see little abatement now but would not know that this is because of anticipated

changes to abatement costs. Instead, it might be because abatement is more costly than expected. The government could observe forward prices in fossil fuels, however, which will give some indication of expected marginal costs. To the extent that permit markets convey better information than commodity markets, permit systems might convey some information to the government that taxes do not.

If the government issues time-stamped permits (and banking and borrowing are limited), however, this advantage for permits would disappear. The key informational advantage of permits in the above example was that by giving polluters price and quantity flexibility across years, the government could infer information about expectations for future years. If firms no longer have flexibility across years – and they would not in a time-stamped permit system – the government can no longer make these inferences. It would have no better information that it would get from a tax system.

The information available from the market, moreover, reflects the market's view of future government policy as well as abatement costs; the market in the example above might think that the government is going to issue more permits in the future. The government, therefore, would have a hard time getting clean interpretations from market data. The only way it could get clean information would be to not act on the information it learns.

Finally, if the information generated by a futures market is truly valuable in setting policy, we can set up an information market within a tax system. The market, for example, could allow participants to place bets on emissions at given dates.

#### D. Price volatility

One common concern with quantity restrictions is volatility in the price of traded permits. The history of existing cap and trade systems demonstrates that they tend to have significant price volatility. Nordhaus (2007), for example, computes the price volatility of the U.S. cap and trade system for sulfur dioxide, showing that it has volatility very close to that of oil and substantially greater than the S&P 500. The concern is that this sort of volatility will hurt investment, reducing the benefit of imposing a carbon price. In addition, Baldursson and von

der Fehr (2004) argue that if permit holders are risk averse, that volatility will reduce trading and might result in inefficient patterns of permit ownership.

To evaluate concerns about volatility, we need to ask why it arises. A central reason permit prices may change is new information about marginal abatement costs. If, for example, new information shows that abatement will be less expensive than thought, permit prices will go down, and vice versa if abatement will be more expensive. Price changes in response to new information should be encouraged. Markets are a method of aggregating information held by dispersed parties. They are one of the central advantages of a market system as opposed to centralized planning. Indeed, Section C above listed the information gained from the permits market as a *benefit* of permits. The last thing we should want to do is to suppress these sorts of price changes.

An analogy is to commodity markets. The earth has scarce resources of various minerals, fossil fuels, and atmosphere. Markets for these commodities serve as a method of conveying information about their relative scarcity, the price of substitutes and so forth. In fact, the same holds true for markets in almost any product. As a general matter, we do not want to suppress price changes.

A second reason for volatility might be what we might call noise trading effects. A long standing concern in the stock market, stemming from Shiller (1981), is that stock prices might be excessively volatile. Following Shiller, a number of papers, including Delong, Shleifer et al. (1990) developed models of stock trading by irrational “noise traders” that lead to excess volatility. It is possible that permit markets would exhibit similar effects. After more than 30 years of study, however, we do not know whether, and the extent to which, stock markets are excessively volatile. Researchers disagree. Shiller (2003), Malkiel (2003). Similarly, simply showing that permit markets have been volatile does not show that they are excessively volatile.

If permit markets are excessively volatile due to noise trading and similar effects, it is not clear what can be done that does not also suppress price changes that convey information. The problem is quite general – it applies to all markets that exhibit excessive volatility – and there are no widely accepted solutions. Stock markets take some measures to reduce volatility, such as circuit breaker rules, short sale restrictions, and the like. These measures are all controversial

because they inhibit price discovery and may do little to address the underlying problems of excess volatility. To the extent measures of this sort work, they might be incorporated into permit markets.

A final reason for permit market volatility is bad market design. In the climate context, even if we think we know optimal maximum concentration of carbon dioxide, nobody claims to know the year by year optimal flows. Time-stamped permits, however, impose year by year limits. Year-by-year limits, by preventing trading across periods, can create excess supply or too little supply of permits in a given period. Going back to the analogy of a commodity market, extraction of commodities can be accelerated or commodities can be stored. Time-stamped permit markets would not be like most commodity markets in this regard. They would look more like the market for raspberries – no storage and no ability to accelerate production once planting is done. The solution to this sort of volatility is good market design. If time stamping is the source of volatility, it will be desirable to reduce time stamping either by not doing it at all or by allowing banking/borrowing.

What about the claim that volatility will reduce investment or alter trading patterns? It is not clear why the effects of volatility in permits markets would be different than volatility in other markets. Individuals deal with volatility through diversification. Although firms, as a result, should be risk neutral, risk may affect firm behavior in adverse ways. For example, it may make it harder for owners to monitor managers, managers may be risk averse because they have overly concentrated exposure to the firm, and so forth. Firms can diversify to some extent to reduce this risk and can also use hedging techniques to transfer the risk to market participants who can diversify or otherwise bear the risk cheaply.

Note in addition, that firms will not suboptimally delay investment because of price volatility that is a result of changes to estimates of marginal costs.<sup>26</sup> So long as the trading price is a good estimate of marginal cost, firms will invest optimally, making decisions to delay or accelerate investment just like they do in general. Other than volatility caused by bad permit market design, it is hard to see why volatility is a particular problem of permit markets.

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<sup>26</sup> Kaplow and Shavell (2002) footnote 16 make a related point in the context of taxes.

Finally, note that in a tax system, firms must still face the problem of newly arriving information about marginal abatement costs. If the estimated marginal abatement cost shifts around constantly due to new studies and the like, firms will have to make investment decisions in the face of the same uncertainty they face with permits. Tax systems do not face the problem of market design or noise traders, but they do face the same problem of underlying uncertainty about abatement costs.

#### E. Framing

There are a number of potential differences between taxes and permits that fall under the rubric of perceptions or framing. Claims about these differences are invariably made casually, so it is difficult to evaluate them. Consider the following three.

One commonly made claim is that the United States Congress will not pass anything called a tax on emissions or energy. Many commentators making this claim say that this is one of the primary reasons they prefer a cap and trade system. Stavins (2008), Keohane (2009). But this is not a rationale for a cap and trade system. This is simply a statement that if a tax cannot be enacted, a cap and trade is next best. That the United States Congress will not do something is not an argument that it is not preferred; it is unrelated to the merits. Moreover, it is not clear why these commentators believe that Congress will not enact a carbon tax. It is difficult to predict outcomes of legislative negotiations. To the extent the views of these analysts matter, they hurt the chances of a tax being enacted when they support a cap and trade system for political rather than fundamental reasons; if all analysts had a true rank ordering of taxes over permits and if they gave their true rank ordering rather than modifying it to predict what the legislature will do, legislative outcomes might be different.

An example might be the history of permits. When economists first suggested the idea of tradable permits, the idea was not widely accepted. Environmentalists opposed the idea because it allowed people to pay for the right to behave badly. People called it “morally bankrupt” or “a license to kill.”<sup>27</sup> Over time, however, as analysts continued to argue the merits of the system, the ideas became acceptable and eventually, some environmental groups accepted it. Congress used the system

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<sup>27</sup> Conniff (2009).

in a major amendment to the Clean Air Act in 1990 and eventually the Europeans accepted the idea for carbon dioxide. It was only because analysts ignored the conventional wisdom that cap and trade systems were politically unacceptable that we can tell this history. We cannot know whether there will be a similar evolution for environmental taxes, but analysts can only help by making arguments on the merits rather than guesses about political acceptability.

A second claim, discussed above, is that the legislature is more likely to give away permits than to grandfather existing emissions in a tax. Somehow, the framing of forcing firms to purchase the right to do something they have always done in the past is different than imposing a tax on them for doing it. It is true that legislators in the U.S. and around the world have often given away permits, although, as mentioned, there are examples of very large auctions. It is, however, just as easy to grandfather existing emissions under a tax by offering “tax relief” to aggrieved taxpayers. If the politics require buying off powerful interests to pass a bill, it is hard to see how those interests go away when the framing is changed. Moreover, as noted, if it is true that permits will be given away and taxes will not be grandfathered, commentators should simply be clear about their ranking of the systems with all of their assumed attributed, as suggested above.

Finally, it may be more likely that we end up with a fixed quantity limit when we use permits than when we use taxes simply because of the language of permits as fixing quantities. Cap and trade systems tend to start with hard limits and then people debate about whether to have a price ceiling and floor. In the current U.S. debate, the price ceiling is referred to as a safety valve and is viewed as a deviation from the basic system rather than an inherent feature that makes the prices faced by polluters better reflect the marginal harm. Taxes tend to start with systems with variable quantities and then there is a debate about how to limit quantities if emissions do not decline fast enough. Perhaps starting at each end, the two meet in the middle at the optimal system, but it is not clear that this would happen. The framing might matter.

#### F. Environmental certainty, tipping points

The most commonly made argument that a quantity limit is preferable to a tax in the climate context is that a quantity limit provides certainty; it avoids the possibility of catastrophic outcomes. Section \_ argued that such a possibility

should have no effect on the choice of instrument, although it will increase the stringency of the system, whichever one is chosen. The basic idea was that even if some possible marginal harm schedules have tipping points, and tipping points might happen at various concentrations, the expected marginal harm will be higher than without this possibility but also smoothly increasing. A marginal increase in concentration at any given point will increase the probability of hitting the tipping point only by a small amount, so expected marginal harm increases only by a small amount. The optimal environmental charge would reflect this smoothly increasing schedule.<sup>28</sup> Both taxes and permits perform equally well in this context.

A related (perhaps the same) claim is that because taxes allow people to pollute as much as they want by paying the tax, taxes do not provide the necessary environmental certainty – they run the risk of carbon concentrations that are dangerously high. Only a fixed cap on emissions ensures that we keep concentrations at a safe level. As two well-known climate analysts put it, “a cap-and-trade system, coupled with adequate enforcement, assures that environmental goals actually would be achieved by a certain date. Given the potential for escalating damages and the urgent need to meet specific emission targets, such certainty is a major advantage.”<sup>29</sup> Or as another analyst put it, “one of the great advantages of tradable permit schemes (or at least cap-and-trade tradable permit schemes) is their environmental certainty. Relative to all other environmental policy instruments they provide – assuming perfect monitoring and complete enforcement – complete certainty with respect to the total level of emissions.”<sup>30</sup>

The environmental certainty claim has a number of problems. Suppose that there was a hard cap on global emissions with strong enforcement measures to ensure compliance so that we knew that carbon concentrations would be limited

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<sup>28</sup> The argument in the text is that Weitzman-type considerations do not apply in the climate context because, even with tipping points, there is sufficient design flexibility to make taxes and permits equivalent. Even if one were to adopt a Weitzman-type analysis, the result is similar. Pizer (2003) used a model based on Weitzman’s analysis to analyzing the problem of tipping points. He concluded that if we were near a tipping point, the differences between the two instruments are swamped by the sheer necessity of putting in place a stringent regime quickly. That is, if we were near a tipping point, it wouldn’t matter so much how we reduced emission as it would matter that we did so quickly. Moreover, there may be substantial harms from setting policy based on incorrect guesses about a tipping point.

<sup>29</sup> Chameides and Oppenheimer (2007).

<sup>30</sup> Johnstone (2003).

to a chosen amount. This would create emissions certainty but would not create environmental certainty. The reason is that we have very little understanding of the environmental outcomes for any given level of carbon concentration. The IPCC, for example, puts climate sensitivity (the equilibrium global average temperature increase for a doubling of carbon dioxide concentrations) between 2° and 4.5° Celsius, a range wide enough to include modest but easily manageable harms to severe disruption. That is, even if we knew for certain that carbon dioxide concentrations would at most double, we would have very little idea of the environmental outcome.

Moreover, modest changes in carbon dioxide concentrations do not substantially change our expectations for the environment. The International Energy Agency compared a hard emissions cap to policies that allowed some flexibility. Philibert (2008). The hard cap cut emissions in half by 2050; the flexible policy had the same goal but that put a ceiling and floor on permit prices, so that if, say, permit traded above some amount, polluters could purchase additional permits at that price, effectively converting the cap into a tax. In their model, the hard cap fixed concentrations at 462 parts per million (ppm) while the flexible policy produced a range of outcomes between 432 ppm and 506 ppm.<sup>31</sup> The environmental outcomes in the two cases were essentially identical: the median temperature increase was 2.49 for the hard cap and 2.53 for the flexible policy; the risk of avoiding a very bad outcome (5° C increase in global average surface temperatures) was 98.5% for the hard cap and 98.3% for the flexible policy. But the flexible policy cost less than 1/3 of the hard cap. It concluded, “achieving a given concentration level (such as 462 ppm ) exactly or on average does not make any real difference to the environmental outcome. The uncertainty introduced by price caps in concentration levels is entirely masked behind the uncertainty on climate sensitivity.”

The second problem with the environmental certainty claim is that it makes unrealistic assumptions about how taxes and permits would work. It assumes compliance with cap that remains fixed over time regardless of cost, and it assumes no adjustment to the tax rate if emissions exceed expectations. Once we relax the assumption of a compliance with cap that does not change, we lose the

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<sup>31</sup> Parts per million refers to the concentration of carbon dioxide in the atmosphere. Pre-industrial revolution concentrations were around 280 ppm and current concentrations are around 380. Commonly discussed goals tend to be around 450 ppm.

any benefit of certainty that a cap might offer. For example, if costs under a stringent cap turn out to be very high and we therefore loosen the cap, we no longer have certainty over final concentrations. Similarly, once we relax the assumption of a tax that is not adjusted to take its effect on behavior into account, taxes are able to achieve more certain carbon concentrations. Thus, if a given level of tax does not produce the predicted emissions reductions, we can increase the tax rate. Realistically, both caps and taxes will (and should) be adjusted over time as we learn more about climate science and the costs of reducing emissions.

#### G. Institutions

A final difference between quantity restrictions and taxes is that they may rely on different administrative apparatus and go through different legislative processes. In the United States, a tax is likely to be administered by the Internal Revenue Service, and the congressional committees with primary jurisdiction are the tax-writing committees. A quantity limit is likely to be administered by the Environmental Protection Agency or perhaps the Energy Department and the committees with primary jurisdiction are likely committees with responsibility for energy and the environment. These differences will change the results. It might, for example, be much simpler to have the Internal Revenue Service administer the program because of its regular contact with taxpayers and its experience in measuring quantities. Or it might be better to have the Environmental Protection Agency administer the program because of its expertise in climate matters or the Energy Department because of its expertise on fossil fuels and alternative energy.

This means is that individual nations might prefer one system or another because of local contingencies, such as a particularly competent agency, expert legislative committee, and so forth. It says nothing in general about the choice of instruments. Indeed, even with local knowledge, such as knowledge about how the U.S. system works, it is hard to say how these considerations change the balance.<sup>32</sup>

#### H. Conclusion for domestic systems:

The conclusion from the above analysis is that the major differences between quantity restrictions and taxes are all in the design of the systems rather than

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<sup>32</sup> See Weisbach and Nussim (2004) for a discussion of this issue.

anything inherent in one or the other system. If we insist on the simple design imagined by Weitzman (a flat-rate tax fixed forever or hard quantity limit, fixed forever), then there are real differences and taxes likely dominate in the climate context. But these assumptions are inappropriate in the climate context. With more sophisticated design, the two are substantially equivalent, with differences relating to subtle questions such as political economy and the like.

#### **IV. International systems**

The claim above was that within a single country, there are few differences between quantity restrictions and taxes because of design flexibility; claimed differences most often simply reflect unstated and incorrect assumptions about design. Climate change, however, is a global problem, and a solution will require all major emitting nations to reduce emissions. The analysis changes for international systems. An internationally harmonized system requires the cooperation of multiple governments raising costs of implementation. For example, compliance monitoring gets more expensive as more nations join an agreement. Similarly, hold-out problems in negotiating the agreement may limit the ability to make adjustments to the system later on, limiting flexibility. If the costs of implementation are higher and there is less flexibility in an international system, some of the conclusions above may not hold.

Section A discusses the benefits of having an international regime. Section B examines whether the design flexibility available in a domestic regime is equally possible internationally, arguing that there will be less flexibility in international systems. Section C considers the problem of monitoring and enforcement in an international system, arguing that the problem of cheating is worse with permits than with taxes. Section D considers whether distributive issues are more easily solved with a cap and trade system.

Before beginning the discussion, it is worth clarifying what internationally harmonized taxes and quantity limits might look like. In an internationally harmonized carbon tax, nations would have a tax with the same base and rate schedule, and the same or similar enforcement mechanisms. Rate adjustments would have to be coordinated. In an internationally harmonized cap and trade system, nations would have to agree to the same base and enforcement

mechanism.<sup>33</sup> To ensure a common price, we would need cross-country trading of permits or have some other similar mechanism to achieve price consistency. In addition, we would need an initial global allocation of quantities to nations or polluters.<sup>34</sup>

Another, perhaps more likely, possibility is a set of regional systems with coordination across regions. In such a system, regions would agree to harmonized systems within the region. Across regions, there might be coordination mechanisms, such as allowing credit in one region for reductions in other regions. VATs and income taxes might be examples, where there is substantial coordination across systems, but different rates and bases. The less coordination, the greater the potential will be for missing low-cost abatement opportunities. The discussion below considers the problem of instrument choice when there are a large number of participating nations; this can be taken to be either a global system or a regional system.

#### A. The Benefits of Coordination

While it is possible, and perhaps likely, that nations or regions will have separate systems with perhaps some coordination between them, there are likely significant benefits to a fully harmonized system. In a fully harmonized system, all nations, and all polluters in those nations would face the same set of prices. A uniform, global price for carbon dioxide means that the lowest cost abatement opportunities will be pursued regardless of location. If nations or regions have separate systems with differing prices, marginal abatement costs will not be equalized and some higher cost abatement options will be pursued at the expense of lower cost options. Depending on how different the prices are across regions and how different the abatement opportunities in each region are, the efficiency gains to harmonization may be substantial.

Analysts have estimated the cost of pursuing climate change using a subset of countries. Zhang (2003), for example, considered the costs of meeting the Kyoto

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<sup>33</sup> Generally, we refer to tax systems with the same rate, base, and other parameters as harmonized and quantity systems in which polluters can buy and sell permits in a single, international market as integrated. I will use the terms interchangeably.

<sup>34</sup> With taxes, the allocation is implicit – each nation keeps its own tax revenues. The allocation could be made explicit for taxes just like for quantity restrictions by having payments of tax revenue across nations that would mimic the effect of permit allocations.

targets with and without trading across, in various permutations (i.e., no trading, only trading within Annex I, trading across all countries, etc.). The costs fall dramatically as more nations are included in the trading regime, dropping by more than 93% from the “no-trading” case to the “trading across all countries” case. When considering the size of the global restructuring needed to reduce carbon emissions, these savings are large indeed. Other studies have found similar results.<sup>35</sup>

There are similar estimates of gains from allowing trading within a single country or region. Ellerman and Harrison (2003), for example, estimate the abatement cost savings from trading in the U.S. sulfur dioxide system as compared to a regulatory system without trading. Over the 13 year period from 1995 to 2007, they estimate that the total savings is 57% of the cost without trading – the trading system costs less than half. Similarly Burtraw and Mansur (1999) find health related benefits of \$124 million in 2005 (in 1995 dollars) from the trading of sulfur permits compared to a no-trading baseline, which is reasonably large given the size of the program.

#### B. Flexibility

The discussion above argued that the Weitzman analysis of the differences between quantity restrictions and taxes inappropriately relied on an assumption of limited flexibility both in adjusting to new information over time and in the complexity of the systems. There were two underlying claims. The first was that in the climate context, adjustments would need to be made relatively infrequently and the system would not have to be very different from a simple, linear tax. Weitzman’s assumptions that the regulatory system cannot track marginal harm are, in the climate context, very strong. The second was that both tax systems and permit systems, in the domestic context, could easily accommodate the needed flexibility; the assumptions are incorrect.

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<sup>35</sup> Markandya and Halsnaes (2004) looked at the results from 16 different models, all addressing this question. When trading across regions is not permitted, the costs of meeting the Kyoto requirements range from around \$200/ton for the US to \$400/ton for Japan, with the EU in the middle, at \$305/ton. When trading is allowed within the developed countries, the average drops to \$77/ton. If trading is allowed globally, the average drops to \$36/ton. Stevens and Rose (2002) have similar findings.

The first claim – that the flexibility needs in the climate context are modest, carries over in the international context. The only issue is whether taxes and regulatory regimes in the international context could meet these needs. I break the discussion into the same two pieces as Part I above: adjusting to new information and complexity of the schedules.

*1. Adjustments based on new information.*

*Taxes.* Achieving agreement in the international context is more difficult than in the domestic context because of the hold-out problem. It would be infeasible to renegotiate a climate treaty each time rates needed to be adjusted.

We can imagine an entity like the IMF, the World Bank, the WTO, or the International Panel on Climate Change being delegated task of adjusting tax rates. To avoid giving international bureaucrats too much discretion over national policies, the entity could be given a formula to use in making its decisions, so that they would be based on evidence rather than political views. Nations might have opt-out options or provisions to review the adjustments.

While possible, such a delegation would be an extraordinary change from the current environment. Nations have not regularly agreed to delegate tax rates to international bodies. Even within the EU nations have freedom regarding tax rates. An international body would inevitably have considerable discretion because of the complexity of the task. In addition, nations would have to agree to tax rate adjustments if emissions are higher or lower than expected, which means that they would have to agree that their domestic tax rate would go up if emissions in other countries were higher than expected. Nations may not readily agree to such a system, particularly if cheating is a problem. (Cheating is addressed in Section B.)

*Permits.* Permits present similar problems. Because of the difficulties of negotiation, adjusting the number of permits in response to new information would probably require delegation much like a tax would. It is not clear that the problems would be any different. Nations would still have to delegate fiscal policy to an international body with discretion to make adjustments.

*Summary.* There is likely to be less flexibility to adjust to new information in the international than in the domestic context. Nations would have to agree to

delegating tax rates or quantity restrictions to an international organization. There would be no way to force hold-outs to agree to such a delegation. If a major emitter did not want such a delegation, nothing could be done. In the domestic context, legislatures typically have majority rule voting procedures, so hold-outs have less power. This is at least one reason we see few examples of substantial delegation of authority in the international context and none like central banks, unlike in the domestic context where they are common. Therefore, it is likely that rate or quantity adjustments would be slower internationally than domestically.

## 2. *Complex Schedules.*

*Taxes.* In principle, there would be no problems with imposing a nonlinear tax in an international, harmonized system. Even if nations are unlikely to delegate the setting of tax rates for an international body, they might agree up front to a tax rate schedule that mimics the expected marginal harm from emissions. There is no reason to believe that the problem of holdouts means simpler schedules; the need to satisfy everyone in a negotiation may lead to more complex schedules or simpler schedules, and it hard to say in advance which way it cuts.

The only real issue would be same issue that arises for tax rate adjustments: whether nations would agree to allow their rate to increase because of excess emissions elsewhere. In the case of a pre-set, complex tax schedule, the rate increase would happen automatically under a formula, but the issue would be the same. Excess emissions by one nation force others to raise their rates.

*Permits.* Nations could just as easily agree to a complex system of quantity restrictions as they could to a complex tax schedule. The problem with complex quantity schedules comes at the implementation stage. Consider a quantity restriction with a cap and a floor on the trading price of the permits. If the permit prices get above a ceiling, new permits would be issued. If they were auctioned, nations would have to agree to the allocation of the revenue. If the permit prices were to go below a floor, the price would have to be supported through a purchase of permits. Nations would have to agree on who would pay for the purchase.

In principle, the allocation of these costs and benefits is no different from the allocation of other costs and benefits in a treaty generally. We can imagine a nation or group of nations setting up an international fund with the role of enforcing a price floor and having the right to sell permits to create a price ceiling.

Or, if we use a Roberts and Spence-type mechanism, the entity would buy and sell options on permits. This seems more plausible than an international body using its discretion to set tax rates or quantities based on new information. Nevertheless, caps and floors may be more difficult to implement than in the domestic context. For example, if the price of permits drops because of cheating by a nation or set of nations, other nations might be unwilling to pay to support a price floor.

*Summary.* Complex schedules are not as easy to implement in the international context as domestically. Nevertheless, complex schedules seem more feasible internationally than regular tax rate or quantity adjustments based on new information.

### 3. Conclusion

Flexibility will be somewhat more difficult in the international context than domestically. Delegation to an agency with discretion seems unlikely but complex rate or quantity schedules may be feasible. Nevertheless, the optimal schedule may be relatively simple and the optimal timing of adjustments infrequent. It is not clear that a well-designed international regime would not have sufficient flexibility to make the Weitzman-type differences between taxes and quantity restrictions second order.

#### C. Rogue regimes

Nordhaus (2007) argues that the problem of rogue countries is a strong reason for favoring taxes. The argument is that in a cap and trade regime, countries have an incentive cheat by not monitoring domestic emissions and selling their allocation of permits in the international markets. Nordhaus gives the example of Nigeria, which Nordhaus puts as having emissions of around 100 million tons per year.<sup>36</sup> If it were allocated permits equal to its recent emissions – 100 million tons – and could sell them for \$20 per ton, Nigeria would receive \$2 billion of foreign currency per year, which is more than three times the size of its non-oil exports. Taxes, Nordhaus argues, would create less of an incentive to cheat because

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<sup>36</sup> This estimate appears to be low. According to the World Resources Institute database of emissions, Nigeria has just under 300 million tons of emissions, making it the 25<sup>th</sup> highest emitting country. See [cait.wri.org](http://cait.wri.org). At \$20 per ton, Nigeria would receive \$6 billion per year in cash by selling the permits.

countries cheating on carbon taxes would be giving up revenue. This section compares the problem of cheating under taxes and permits.

As discussed by Hovi and Holtmark (2006), the sale of the permits by a rogue country would increase total emissions. The rogue country would have business as usual emissions instead of the capped amount. In addition, the rest of the world would have an increase in the number of permits equal to those allocated to the rogue country. The net would be an increase in global emissions (above the agreed cap) equal to the business as usual emissions in rogue country (there would be permits equal the agreed amount plus the additional business as usual emissions in the rogue country). So, in the case of Nigeria, there would be 100 million tons of additional emissions above whatever had been agreed to.

The problem of rogue countries is different in a tax regime. With permits, the rogue country exploits the rest of the world by failing to enforce. With taxes, if the rogue country does not enforce the rules, it loses tax revenue. To be sure, there is a net gain for failing to enforce a tax. Taxing emissions reduces the externality domestic polluters impose on the world; failing to enforce the tax allows domestic polluters to impose that externality, producing a local gain. But the gain is smaller than with permits because with permits, the rogue country gets hard currency in addition imposing an externality on the rest of the world.

Similarly, the increase in emissions is lower with rogue countries under a tax than under a quantity restriction. The increase will only be equal to the difference between emissions with a tax and without in the rogue country. Emissions in the rest of the world are unaffected (leaving aside the problem of carbon leakage).

The extent of the advantage for taxes because of this problem depends on the ability to monitor emissions and enforce agreed caps. We do not have experience with a similar system to know how well monitoring will work and to some extent it depends on technology. For nations that do not produce substantial amounts of fossil fuels, we may be able to monitor imports of fossil fuels and infer compliance. If states produce fossil fuels, we would have to be able to measure production (as well as imports and exports) to determine compliance. This may be possible but if permit prices were high, incentives to cheat would also be high.

Finally, satellites may soon be able to monitor local emissions, providing a method of monitoring that might be difficult to evade.<sup>37</sup>

We also would need to design an enforcement mechanism once a cheater is caught. For some countries, trade sanctions or similar measures may work, but for others this may not be sufficient or, because they export an important product, may be unlikely to be imposed. Victor (2001) and Keohane and Raustiala (2008) argue that buyer liability – a system in which buyers cannot use permits if the seller is found to be in violation – works because they create a market-based enforcement incentive. Such a system, however, would still ultimately rely on ex post political enforcement against rogue countries to declare the permits invalid. A related alternative is to prohibit the future use of rogue country permits, thereby limiting the effects of cheating to a single or perhaps small number of periods.

Taxes have their own monitoring problems. As Victor (2001) has argued, to determine compliance with an internationally harmonized tax system, we would have to be able to look at a country's entire set of taxes and subsidies to see whether the tax is offset elsewhere in the system with subsidies. That is, a country could have a nominal tax but elsewhere offer an offsetting subsidy so that there is no net tax. Reporting of all net taxes and subsidies to an international body would be required. Emissions monitoring through satellite technology – a potentially promising approach for quantity targets – would not be helpful.

Enforcement problems once a cheater is caught might be more difficult in a cap and trade system. With a cap and trade system, use of rogue country permits can be prohibited. There is no similar option for taxes.

To summarize, the incentives to cheat are greater and the effects of cheating worse in a cap and trade regime than in a tax regime. If good monitoring systems are available, such as accurate accounting for fossil fuel consumption or satellite tracking of emissions, the problems of cap and trade systems relative to taxes are reduced because enforcement might be easier in a cap and trade system than in a tax.

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<sup>37</sup> See [http://www.economist.com/sciencetechnology/displayStory.cfm?story\\_id=13097822](http://www.economist.com/sciencetechnology/displayStory.cfm?story_id=13097822)

#### D. Baselines, Distribution

Nordhaus (2007) also argues that a disadvantage of a cap and trade system is that it will likely require a set of baselines to determine targets, such as 20% of emissions in 1990 by 2050. Establishing baselines, he argues, will be complex and controversial. In a tax system, all we need is the rate structure, making a tax system easier to establish. It is not clear that this argument is correct.

Establishing baselines is the same as determining total emissions by each country:  $y\%$  of a given year emissions by a target date can be translated into  $x$  million tons of carbon dioxide by the same target date. So long as the percentages of the baseline can be varied, the baseline year itself does not matter, and vice versa. All that really matters is the total emissions allowed for each country in each year or over the set period. Because emissions permits would be traded internationally, the initial allocation does not have direct efficiency effects;<sup>38</sup> the allocation primarily determines the distributional effects of the system.

Tax systems, or at least tax systems in which each country keeps its own tax receipts, have an assumed distributional effect. It is equivalent to one where permits are allocated based on business as usual emissions. Tax systems do not avoid the distributional problems. If countries object to the implicit distribution in a tax system, they will demand side payments or the like necessary to agree a treaty. Whatever problems there are in determining who gets what in a cap and trade system will not go away because of a change in the method of regulating emissions.

The alternative view is that permits help with distributional issues because it will be easier to buy off nations with permits than to make the same side payments directly. Commentators such as Stewart and Wiener (2003) argue that a treaty is, therefore, more likely with permits than with taxes. The problem with this argument is the same as the problem with the Nordhaus argument in reverse. Whatever the distributional problems, they do not change because of the choice of instruments. Moreover, the massive distributional issues cannot be hidden through

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<sup>38</sup> There may be efficiency effects related to the transition between regimes. These transition issues should not be minimized. If permits are allocated based on business as usual projections, countries will have an incentive to increase emissions prior to the treaty. See Kaplow (2008) for a discussion.

the choice of instruments. Nations will easily be able to determine who is paying what regardless of which instrument is chosen.

One possibility, similar to the framing discussion above, is that the explicit allocation of permits will appear different to negotiators and their home country constituents than the implicit allocation in a tax. Many people have an intuition that emissions permits should be allocated to all individuals in the world on a per capita basis (based on the idea that all people have an equal right to the atmosphere) but at the same time have an intuition that countries would keep the taxes that they raise. These two intuitions are inconsistent. Because of these inconsistent intuitions, the end result distribution the extent of purely distributional bargaining might be different in the two systems. Framing might matter. Nevertheless, given the size of the issue, it seems unlikely that anyone would be fooled. At the end of the day, there are enormous distributional issues in a climate treaty, and they cannot be avoided through the choice of regulatory instruments.

## **V. Conclusion**

Discussions of instrument choice almost always have strong assumptions about design. Taxes are normally taken to be fixed, per-unit charges and cap and trade systems are taken to have annual, hard caps on emissions, perhaps sometimes with limited additional flexibility, such as banking and limited borrowing or a safety valve. These assumptions are not justified in the climate context. Other differences, such as distributional or revenue differences are also based on assumptions about design that are unlikely to hold in the domestic context.

Rather than focusing on instrument choice, a better focus is on the design of whichever instrument is chosen. A casual glance at existing or proposed climate change regimes indicates that much work needs to be done. The EU cap and trade system, for example, covers only a modest fraction of emissions, has freely allocated permits, and includes an unadministrable offset program. Most proposals seriously considered by the United States Congress have similar problems and in addition, embed within them massive command and control regulations. The gains from improving the design of these systems likely massively outweigh the gains from the choice of instruments.

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Readers with comments should address them to:

Professor David Weisbach  
University of Chicago Law School  
1111 East 60th Street  
Chicago, IL 60637  
d-weisbach@uchicago.edu

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