Internationally-Tradable Permits Can Be Riskier for a Country than an Internally-Imposed Carbon Price

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Abstract

This paper compares internationally-tradeable permits with a uniform carbon price, as seen through the lens of an individual country. To ensure a level playing field, these two approaches are initially calibrated to be welfare-equivalent for the country in a deterministic setting. While both price and quantity instruments have identical consequences under perfect certainty, outcomes differ substantially when uncertainty is introduced. The uncertainty analyzed here takes the reduced form of idiosyncratic country-specific abatement-cost shocks. Then, because of cross-border revenue flows, internationally-tradable permits can expose a country to greater risk than the imposition of a uniform carbon price (whose revenue proceeds are domestically retained). This result is formalized in a very simple model that highlights the core essence of the argument. Some implications are discussed. I suggest that this relative-riskiness result may be a pertinent consideration in choosing between negotiated price-based approaches and negotiated quantity-based approaches for controlling worldwide carbon emissions.

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1 Introduction: Negotiating Prices vs. Negotiating Quantities

The world is currently mired in what has aptly been called *global warming gridlock*.[1] The core problem confronting the economics of climate change is an inability to overcome the obstacles associated with free riding on a very important international public good. The 'international' part is significant. Even within a nation, it can be difficult to resolve public goods problems. But at least there is a national government, with some governance structure, able to exert some control over externalities within its borders. With climate change there is no overarching international governance mechanism capable of coordinating the actions necessary to overcome the problem of free riding. Instead, instruments of control (like prices or quantities) must be *negotiated* among sovereign nation-states. Negotiators here are playing a game in which self-interested strategies are a crucial consideration. It turns out that negotiating rules define an important part of the game, and can thereby change self-interest, for better or for worse.

Two basic proposals for controlling carbon dioxide emissions have been the subject of a lively debate among economists. The first, price-based, approach promotes an internationally harmonized carbon price (or tax), the proceeds from which are nationally retained and internally distributed as lump-sum payments (or used domestically to offset other taxes). The second, quantity-based, approach promotes an international cap-and-trade regime where, for simplicity here, the initial permits are distributed for free.[2] The advantages and disadvantages of the two approaches have by this time been vetted and compared in a voluminous literature.[3]

It has often been noted in this literature that the revenues generated from an internationally harmonized cap-and-trade system flow as visible external transfer payments across national borders, which might be less easily tolerated by countries required to pay other

[1] *Global Warming Gridlock* is the title of a book by David Victor (2011), who popularized the phrase.

[2] If permits were auctioned, the distinction between a quantity-based system and a price-based system becomes blurrier, but a softened version of the basic point of this paper would remain.

[3] Rather than here listing scores of papers with varying viewpoints, for an elaborate recent overall summary review of carbon taxes vs. cap-and-trade see Goulder and Schein (2013) (and the many further references they cite). Their comprehensive survey indicates that, although the two options are equivalent over more dimensions than often are recognized, in the final analysis exogenous emissions pricing has a number of important attractions over pure cap and trade. They find it noteworthy that a carbon tax seems to score better along the dimensions where the advantages or disadvantages are unambiguous. On the other side, Gollier and Tirole (2015) make a recent case favoring a quantity-based approach. I personally have favored a price-based approach for several reasons: in large part because stability of carbon prices is very important for consumers and investors. However, in this paper I want to present a new argument based on a related but different idea that cap-and-trade is riskier for an individual nation-state than the corresponding price instrument even when the risk comes only from country-specific idiosyncratic shocks.

countries large sums of taxpayer-financed money to buy permits. Where it has been noted, this argument has typically been invoked verbally and informally (usually to the detriment of tradable permits relative to an internationally harmonized self-imposed price or tax). In a recent paper, Cramton, Ockenfels, and Stoft (2015) have provided a brief suggestive numerical example of the phenomenon.[4]

The purpose of this paper is to compare formally an internationally-tradeable permits system with its "twin" uniform carbon-price system. I am here making a "prices vs. quantities" type comparison[5] as it pertains to the welfare of an individual country (as opposed to the welfare of the entire world). It is important to bear in mind throughout the paper that the "prices vs. quantities" type welfare comparisons here are entirely from the perspective of an individual nation-state, and do not (necessarily) concern worldwide well being.

To ensure a level playing field, I initially calibrate the two twin price and quantity instruments to be welfare-equivalent for a country in a deterministic setting. While both price and quantity instruments then have identical consequences under perfect certainty, outcomes can differ substantially under uncertainty. In particular, when uncertainty takes the form of idiosyncratic country-specific abatement-cost shocks, then internationally tradable permits expose a country to greater risk than imposing a uniform carbon price whose tax proceeds are domestically retained. This result is shown formally in a very simple model that transparently exposes the core argument. Some suggestive implications are discussed. I argue that this relative-riskiness result may be a pertinent consideration in choosing between negotiated price-based approaches and negotiated quantity-based approaches for controlling worldwide carbon emissions.

2 The Model with Perfect Certainty

The unit of analysis here is some representative carbon-emitting nation. The model in this and the next section is completely deterministic. However, in order to be able to concentrate later on country-specific idiosyncratic uncertainty, I effectively assume that I can perform standard partial-equilibrium welfare analysis for this representative nation. I believe that the insights from the stochastic version of this simple core model survive many further complications, including the introduction of non-country-specific general uncertainty that affects all nations.

[4] While illuminating and inspiring, their example, in my opinion, does not constitute a formal model of what I think may be an important phenomenon in deciding which instruments are more easily negotiated among countries. Thus, I acknowledge the brief numerical-verbal example of Cramton, Ockenfels, and Stoft (2015) as an inspiration for the present paper.

[5] In the spirit of Weitzman (1974), but here at the level of an individual nation-state.

Let Q here stand for the "good" of carbon dioxide abatement of this representative nation from some initial position. (Note that the "good" of abatement is essentially the negative of the "bad" of emissions.)

The marginal cost of carbon abatement for this nation is given by the linear function

$$C'(Q) = a + bQ, \tag{1}$$

where a and b are given positive constants.

Let P be an exogenously-imposed price of carbon abatement (or emissions). When the country maximizes profits by setting marginal cost (1) equal to price, the resulting "abatement supply function" is

$$Q(P) = \frac{P - a}{b}. \tag{2}$$

This completes the sparse description here of the representative nation in the completely deterministic case.

3 Imposing a Level Playing Field

Continuing with the case of the completely deterministic model of the previous section, I assume that there are two alternative ways to attain some given level of abatement (or emissions). These two contrasting approaches correspond to a price instrument and a quantity instrument.

On the price-instrument side, suppose there is a worldwide harmonized price $\widehat{P}$ on carbon emissions that a nation imposes on itself, but the tax receipts from which are internally retained in the nation. The tax receipts are distributed within the nation as lump sum payments, or they could be used to relieve the burdens of other taxes. Either way, I assume that the self-imposed nationally-rebated tax of $\widehat{P}$ is revenue neutral and the tax-and-rebate payments constitute an internal transfer that does not represent by itself a net gain or net loss of real welfare for the nation.

On the quantity-instrument side I assume that the initially-assigned number of national permits in a cap-and-trade system (expressed in abatement units) is $\widehat{Q}$, which permits are freely distributed to the nation.

For comparability, the international equilibrium price of tradable carbon permits is also $\widehat{P}$. A level playing field for this country-based "prices vs. quantities" comparison is imposed by the condition that

$$\widehat{P} = a + b\widehat{Q} \tag{3}$$

or, equivalently,

$$\widehat{Q} = \frac{\widehat{P} - a}{b}. \tag{4}$$

Some reflection on this deterministic level-playing-field calibration (3), (4) reveals that, for a cap-and-trade regime, the nation's *net* purchase (or sale) of tradeable permits is zero. Thus, as might be expected here within a deterministic setting, the nation is completely indifferent whether the internally-imposed tax is $\widehat{P}$ in a price-based system or the initially-assigned free permits are $\widehat{Q}$ in a quantity-based system. We are encountering here an instance of the basic duality that in a comparable deterministic setup with full information there is no difference between the two instruments. Thus, the "prices vs. quantities" debate in this twin deterministic setup results in a draw. The above concept of a "level playing field" in terms of identical deterministic outcomes under the two instruments has heuristic or intuitive appeal (at least for me). Unfortunately, I cannot provide here, within this partial equilibrium framework, a more rigorous justification for using (3), (4) as a point of departure for what follows.

The next question to be addressed is what happens in the presence of uncertainty. In this case a major difference will emerge in risk-bearing under the two otherwise-twinned systems.

4 Idiosyncratic Country-Specific Uncertainty

Idiosyncratic country-specific abatement-cost uncertainty is modeled here as follows. Let X be a random variable representing an additive shock to the marginal cost function (1) with known distribution. Let x be a realization of the random variable X. Then the marginal cost function (given the realization x) is

$$C'(Q \mid x) = a + bQ + x. \tag{5}$$

Thus, "high" values of x are "bad" for the country, while "low" values of x are "good" for the country. The additive shock X is presumed to have a "neutral" effect on marginal cost in the sense that (without loss of generality) it is assumed that its expected value is zero:

$$\mathbb{E}[X] = 0. \tag{6}$$

Initially, during negotiations but before the uncertainty is resolved, the country accepts either the assigned price $\widehat{P}$ in the price system, or the initial quantity assignment $\widehat{Q}$ in the cap-and-trade quantity system, where (3), (4) hold.

Then, after the uncertainty is resolved, comes a longish reaction period of, say, 10 years or so. After the uncertainty is resolved (for analytical convenience at the beginning of the reaction period), then during the entire reaction period the country is stuck with the consequences of a quasi-fixed instrument until the next negotiating period. During the reaction period, the realized marginal cost has been shifted by amount x. Thus, the country must make a decision under uncertainty between choosing the price $\widehat{P}$ in the price system or choosing the initial quantity assignment $\widehat{Q}$ in the cap-and-trade quantity system while X is still a random variable, but thereafter the country must live with the consequences of its realization x of X throughout the reaction period.

For simplicity, I am assuming that after the idiosyncratic shock X has been realized to be x, the nation is stuck with its initial assignment of price $\widehat{P}$ throughout the reaction period. In the price system, this merely reflects the truism that the internally-assigned price remains $\widehat{P}$ throughout the reaction period. In the quantity system, I assume for simplicity here that the post-shock international equilibrium price of emissions permits remains $\widehat{P}$. I can make more complicated assumptions about the impacts of uncertainty, but the setup here focuses sharply on the main message in a form that the model can deliver most clearly.[6]

5 The Price-Instrument Reaction

In a price-instrument reaction to realization x, the nation will abate to the level where the post-shock marginal abatement cost (5) equals the imposed price $\widehat{P}$. This results in abatement quantity

$$Q(\widehat{P} \mid x) = \frac{\widehat{P} - a - x}{b} = \widehat{Q} - \frac{x}{b}. \tag{7}$$

From (7), the change in abatement level Q per unit change in x is $-1/b$. Therefore, the net *gain* of government revenue ΔR from taxing emissions at price $\widehat{P}$ for realization x (compared with $x = 0$) is

$$\Delta R(x) = \widehat{P} \times \left(\frac{x}{b}\right), \tag{8}$$

which also represents the net total *loss* of revenue to carbon emitters. However, the extra net revenues ΔR given by (8) do not constitute a genuine change of *real* welfare, because they are presumed to be recycled in a revenue-neutral fashion (via lump-sum transfers or

[6]For example, if the international equilibrium price of emissions permits increases with x (say because cost shocks are correlated across countries), a symbol- and algebra-intensive extension of the model might be used to show under reasonable assumptions that the quantity-based tradeable-permits system exposes the nation to even greater risk than occurs in the analysis of the current paper. Thus, an assumption of correlated cross-country abatement-cost shocks will tend to increase the risk-bearing differences in the country-level "prices vs. quantities" analysis of this paper. A rigorous treatment of this extension is more properly the subject of future research.

in relief of other equivalent taxes). Effectively, the nation is simultaneously collecting and rebating additional revenues of net amount ΔR, which is an internal transfer that leaves the real overall welfare level the same as before.

However, there is a real loss (or gain) from the increased (or decreased) cost of compliance. The real net cost loss from realization x (compared to $x = 0$) is

$$L_p(x) = \int_0^x C'(Q(\widehat{P} \mid X))\, dX. \tag{9}$$

Substituting from (5) and (7) into (9) gives the expression

$$L_p(x) = \int_0^x \left[a + b\left(\frac{\widehat{P} - a - X}{b} \right) + X \right] dX. \tag{10}$$

Cancelling redundant terms in (10) and carrying out the integration yields

$$L_p(x) = \widehat{P}\, x. \tag{11}$$

6 The Quantity-Instrument Reaction

Under cap-and-trade, the nation has been allocated allowance permits that cover only abatement of amount $\widehat{Q}$. Therefore, to be in compliance with the tradable-permits quantity mandate, the nation facing marginal cost shock realization x must purchase from (when $x > 0$, or sell to when $x < 0$) the outside world market $\left[\widehat{Q} - Q(\widehat{P} \mid x)\right]$ permits at the postulated post-shock world equilibrium price $\widehat{P}$. This amounts to a real *transfer* loss of national income in net amount

$$L_t(x) = \widehat{P} \times \left[\widehat{Q} - Q(\widehat{P} \mid x)\right], \tag{12}$$

consisting of real resources (in money terms) externally transferred abroad to buy permits. Using expression (7), the real national income transfer-loss (12) can be rewritten in the simpler reduced form

$$L_t(x) = \widehat{P} \times \frac{x}{b} \tag{13}$$

Additionally, there is a real loss (or gain) from the increased (or decreased) cost of compliance. The real net cost loss from realization x (compared to $x = 0$) is the same under the quantity system as it is under the price system, namely $L_p(x) = \widehat{P}\, x$ from equation (11).

The total real net loss of welfare under the quantity system is therefore

$$L_q(x) = L_p(x) + L_t(x), \tag{14}$$

which, making use of (11) and (13), can be rewritten in the reduced form

$$L_q(x) = \left(1 + \frac{1}{b}\right) \widehat{P}\, x. \tag{15}$$

7 The Basic Country-Level Welfare Comparison

Let us compare the price-based loss of welfare $L_p(x)$ in equation (11) with the quantity-based loss of welfare $L_q(x)$ in equation (15). Because $\mathbb{E}[X] = 0$, the *expected* net loss of welfare has the same value of zero in both systems, so that[7]

$$\mathbb{E}[L_q(X)] = \mathbb{E}[L_p(X)] = 0. \tag{16}$$

But, because of the extra term $\widehat{P}x/b$ in (15), the quantity-based loss of welfare $L_q(x)$ has greater *variability* than the price-based loss of welfare $L_p(x)$ given by (11). (Note that the probability distribution of $L_q(X)$ with variance $\mathbb{V}[L_q(X)] = (1 + 1/b)^2\, \widehat{P}^2\, \mathbb{V}[X]$ is a mean-preserving spread of the probability distribution of $L_p(X)$ with variance $\mathbb{V}[L_p(X)] = \widehat{P}^2\, \mathbb{V}[X]$). Thus,

$$\mathbb{V}[L_q(X)] = \mathbb{V}[L_p(X)] + \left(\frac{2}{b} + \frac{1}{b^2}\right) \widehat{P}^2\, \mathbb{V}[X] \tag{17}$$

From (16) and (17), it is fair to say that, while both systems have the same expected net loss (of zero), tradable permits expose a country to the additional external risk of a real loss (or gain) of $\widehat{P}x/b$, while under a price commitment to an internally-rebated carbon price (or tax) the nation merely keeps its price set to $\widehat{P}$, as if no foreign transfers occurred. This real-welfare comparison is the basis for the claim given by the title of this paper that "internationally-tradable permits can be riskier for a country than an internally-imposed carbon price." The reason here is just about as simple as an answer to the question: "Which of the following two alternatives would a risk-averse country prefer: to charge *itself* an additional carbon-tax revenue $\widehat{P}x/b$ that is internally rebated, or to be levied the same exact carbon-tax revenue $\widehat{P}x/b$ that is externally paid out to the rest of the world?". Thus, from the thicket of algebra emerges a very simple intuitive comparison.

Note that I am effectively resorting to an argument outside of the formal model of the

[7] If $P(Q)$ were convex, instead of linear, the expected welfare would be higher under the price system than under the quantity system.

paper to make the commonsense observation that the quantity instrument is riskier than the price instrument because $L_q(X)$ is more variable than $L_p(X)$, while having the same mean. I am thus not treating risk in a micro-foundational way that is fully integrated with the rest of the model of this paper. I also omit considerations of futures hedging markets, forward purchases and sales of permits, puts and calls on permit prices, and so forth, which, at least theoretically, might conceivably lessen (or, perhaps increase) variability.[8]

Suppose the world-equilibrium price of tradable permits is positively correlated with the bad country-specific outcomes. In other words, when the country wants to buy more permits to cover increased emissions (because $x > 0$), so do other countries, thereby raising the world-equilibrium price of permits. Exact results depend on how this aspect is modeled, but the commonsense conclusion would seem to favor an expression that is even more variable than (15). Thus, with an uncertain world price of tradable quotas the quantity instrument is likely to be riskier by an even larger margin (when compared with the the constant-price instrument $\widehat{P}$).[9] For purposes of the present paper, an exact investigation of this phenomenon remains an area of future research.

8 Concluding Remarks on the Value of Stability in Real-Revenue Transfers

If there were a single world government with the worldwide power to levy targets and redistribute taxes and transfers, then what, in this paper, constitutes external transfer payments across national boundaries (from a cap-and-trade system), would net out to zero worldwide. This is essentially the setup of my earlier paper "Prices vs. Quantities" (Weitzman (1974)), where there is a single overarching government that, in principle, might choose between the two instruments by using the formula in that article for the "comparative advantage of prices over quantities." However, in a world consisting of independent nation-states, prices and quantities are not *assigned* by an overarching (world) government; they must instead be *negotiated* among sovereign entities that are inclined to free ride on an international public good.

It is in the context of such international negotiations that the results of this paper might be most relevant. I believe that the idea that internationally tradeable permits can be riskier

[8] I am not sure but that derivatives markets for pollution permits might possibly backfire in practice, with bad consequences including public blaming of "speculators." Laffont and Tirole (1996) propose an imaginative mechanism where tradable permits have put options with various strike prices. They show that such a mechanism in principle deals effectively with the progressive resolution of uncertainty over time.

[9] McKibbin, Morris, and Wilcoxen (2009) compare numerically the performance of various instruments in the presence of unexpected macroeconomic shocks.

for a country than an internally-imposed carbon price translates, via risk aversion, into an argument that it may be easier for the world to negotiate a uniform quasi-fixed carbon price, which is internally retained, than to negotiate an initial assignment of tradeable permits.[10] It is not going to be easy to negotiate a uniform carbon price, but I believe that the main result of this paper might be informally interpreted as suggesting that lower side payments may be required of a "green fund" compensation mechanism to encourage a uniform carbon price than is required to induce compliance in a nationally riskier cap-and-trade system.

An internationally harmonized but domestically retained carbon price will require measurement, verification, and most importantly, serious sanctions for enforcement (as well as, most likely, some green fund transfers). One constructive idea is for a coalition of willing nations to form a "climate club" by agreeing to impose on themselves a uniform price of carbon. Any country willing to join the club must price carbon at the agreed-upon price. Nations choosing to remain outside the club are forced to pay some agreed-upon uniform ad-valorem border tax on goods and services that the club members import from non-club members.[11] Another possibility is to empower a "World Climate Assembly" where nations vote on the desired level of a uniform carbon price on the basis of one-person one-vote majority rule.[12] Where there is a will, there is a way. The purpose of this paper is merely to suggest that countries, because they are exposed to less risk, may find it *relatively* easier to comply with an internationally-harmonized but nationally-collected price than to comply with an analogous cap-and-trade system that is inherently riskier for them.

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[10] I have tried to argue previously, on different grounds of providing a focal point for a common commitment and lower transactions costs, that negotiating a uniform carbon price can help to internalize the global warming externality by empowering a "countervailing force" against free riding. See Weitzman (2014).

[11] This "climate club" idea is the brainchild of William Nordhaus, who shows numerically that an ad-valorem border tariff of 4% on imports from non-club members would be sufficient for all countries to want to join the climate club by agreeing to impose on themselves an internally-retained tax of $25 per ton of emitted carbon dioxide. See Nordhaus (2015).

[12] This voting idea is mooted in Weitzman (2014), who shows that voting on a harmonized carbon price gives voters incentives to employ countervailing force against free riding.

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